Overview
Before beginning this section review with your students the objectives listed in the Student Edition. This lesson describes Darwin's experiences as a naturalist, how his curiosity about the things he saw prompted him to conclude that evolution occurs, and how he developed an explanation for the mechanism of evolution. Students will also learn how Darwin's theory of evolution by natural selection has been modified by other scientists with regard to formation of new species.

Objectives
- Identify several observations that led Darwin to conclude that species evolve. 3C 3F
- Relate the process of natural selection to its outcome. 7B TAKS 3
- Summarize the main points of Darwin's theory of evolution by natural selection as it is stated today. 2A TAKS 1
- Contrast the gradualism and punctuated equilibrium models of evolution. 3E

Key Terms
- population
- natural selection
- adaptation
- reproductive isolation
- gradualism
- punctuated equilibrium

Bellringer
Write the following headings on the board: Long life span; Short life span. Have students write a few sentences in which they relate an organism's life span to the potential rate of evolution of a species. (Species with shorter life spans can potentially undergo evolutionary change much faster than species with longer life spans.)

Motivate
Demonstration —— BASIC
Show students pictures of several different varieties (breeds) of a commercially important plant or animal. Ask students how these varieties originated. (All originated through selective breeding by humans.) If possible, show students pictures of the wild ancestors of the organisms. Tell students that observations of change in domesticated animals and plants helped people recognize that species can change over time.

Figure 1  Charles Darwin.
Darwin was born in England in 1809 and died in 1882.

Chapter Resource File
- Lesson Plan  GENERAL
- Directed Reading  BASIC
- Active Reading  GENERAL
- Data Sheet for Quick Lab  GENERAL

One-Step Planner CD-ROM
- Reading Organizers  BASIC
- Reading Strategies  BASIC

Transparencies
- TT Bellringer
- TT Darwin’s Finches
- TT Two Rates of Progression

Darwin Proposed a Mechanism for Evolution
The idea that life evolves may have been first proposed by Lucretius, a Roman philosopher who lived nearly 2,000 years ago before the modern theory of evolution was proposed. Then, in 1859, the English naturalist Charles Darwin, shown in Figure 1, published convincing evidence that species evolve, and he proposed a reasonable mechanism explaining how evolution occurs.

Like all scientific theories, the theory of evolution has developed through decades of scientific observation and experimentation. The modern theory of evolution began to take shape as a result of Darwin's work. Today almost all scientists accept that evolution is the basis for the diversity of life on Earth.

As a youth, Darwin struggled in school. His father was a wealthy doctor who wanted him to become either a doctor or a minister. Not interested in the subjects his father urged him to study, Darwin frequently spent more time outdoors than in class. At the age of 16, Darwin was sent to Edinburgh, Scotland, to study medicine. Repelled by surgery, which at the time was done without anesthetics, Darwin repeatedly skipped lectures to collect biological specimens. In 1827, Darwin's father sent him to Cambridge University, in England, to become a minister. Although he completed a degree in theology, Darwin spent much of his time with friends who were also interested in natural science.

In 1831, one of Darwin's professors at Cambridge recommended him for a position as a naturalist on a voyage of HMS Beagle. Although the ship had an official naturalist, the Beagle's captain preferred to have someone aboard who was of his own social class. At the age of 22, Darwin set off on a journey that would both change his life and forever change how we think of ourselves. The ship and its route are shown in Figure 2.
Science Before Darwin’s Voyage
In Darwin’s time, most people—including scientists—held the view that each species is a divine creation that exists, unchanging, as it was originally created. But scientists had begun to seek to explain the origins of fossils. Some scientists tried to explain their observations by altering traditional explanations of creation. Others (including Darwin’s own grandfather) proposed various mechanisms to explain how living things change over time.

In 1809, the French scientist Jean Baptiste Lamarck (1744–1829) proposed a hypothesis for how organisms change over generations. Lamarck believed that over the lifetime of an individual, physical features increase in size because of use or reduce in size because of disuse. Further, according to Lamarck, these changes are then passed on to offspring. This part of Lamarck’s hypothesis is now known to be incorrect. However, Lamarack correctly pointed out that change in species is linked to the “physical conditions of life,” referring to an organism’s environmental conditions.

Darwin’s Observations
During his voyage on the Beagle, Darwin found evidence that challenged the traditional belief that species are unchanging. During the voyage, Darwin read Charles Lyell’s book Principles of Geology. Lyell proposed that the surface of Earth changed slowly over many years. As Darwin visited different places, he also saw things that he thought could be explained only by a process of gradual change. For example, in South America, Darwin found fossils of extinct armadillos. These fossilized animals closely resembled, but were not identical to, the armadillos living in the area. 1 2

Teaching Tip
Galapagos Giant Tortoises
Tell students that the Galapagos Islands were named for the large tortoises that inhabit this archipelago. When Spanish explorers arrived, they found so many giant tortoises they called the islands “Galapagos,” Spanish for tortoise. The scientific name for the tortoises is Geochelone elephantopus. Galapagos tortoises can weigh up to 227 kg (550 lb) and measure 150 cm (5 ft) across the carapace (the upper shell). Galapagos tortoises metabolize fat stored in their tissues and, therefore, can survive without food or water for long periods of time. Because of this characteristic, they became a convenient source of fresh meat for early explorers. The explorers caught the tortoises on land and stored them live in ship holds for up to a year. When the Spanish arrived, there were an estimated 250,000 tortoises. Today, approximately 15,000 remain. Bio 3F

Teaching Tip
Law of Use and Disuse
Point out to students that Lamarck recognized that the environment played an important role in evolution. He theorized that when an organism uses a part of its body, that part becomes more developed as a result of its use. He reasoned that the modified part is then passed on to the organism’s offspring. For example, he might have argued that a bird that eats tough seeds will develop a thicker beak and will in turn have offspring with thicker beaks. Tell students that if Lamarack were correct, the offspring of bodybuilders would be born with enormously developed muscles. TAKS 1 IPC 2A

IPC Benchmark Mini Lesson
Biology/IPC Skills TAKS 1 IPC 1A: Demonstrate safe practices during field and laboratory investigations. Activity Take students on a field trip to a local park or wildlife area to conduct a bird survey. Have students try to write down as many different types of birds as they can. Then, have them group them using physical similarities and create their own classification system.

IPC Benchmark Fact
Have students design a simple and hypothetical experiment in which Lamarack’s theory of evolution—the inheritance of acquired characteristics—could be tested. They should ask questions, formulate a testable hypothesis, and suggest how they would conduct the experiment. If time permits and the experiment is doable, have students carry out their investigations. TAKS 1 Bio/IPC 2A
Darwin visited the Galápagos Islands, located about 1,000 km (620 mi) off the coast of Ecuador. Darwin was struck by the fact that many of the plants and animals of the Galápagos Islands resembled those of the nearby coast of South America. Darwin later suggested that the simplest explanation for this was that the ancestors of Galápagos species such as those shown in Figure 3, migrated to the islands from South America long ago and changed after they arrived. Darwin later called such a change “descent with modification”—evolution.

When Darwin returned from his voyage at the age of 27, he continued his lifelong study of plants, animals, and geology. However, he did not report his ideas about evolution until many years later. During those years, Darwin studied the data from his voyage. As Darwin studied his data, his confidence that organisms had evolved grew even stronger. But he was still deeply puzzled about how evolution occurs.

**Growth of Populations**
The key that unlocked Darwin’s thinking about how evolution takes place was an essay written in 1798 by the English economist Thomas Malthus. Malthus wrote that human populations are able to increase faster than the food supply can. Malthus pointed out that unchecked populations grow by geometric progression, as shown in Figure 4. Food supplies, however, increase by an arithmetic progression at best, also shown in Figure 4. He suggested that human populations do not grow unchecked because death caused by disease, war, and famine slows population growth.

The term population, as it is used in biology, does not only refer to the human population. In the study of biology, a population consists of all the individuals of a species that live in a specific geographical area and that can interbreed.

**Trends in Field Biology**
**Role of Naturalist** Most scientists today must specialize in one field. However, many of the great scientists of the past were called naturalists—people who studied nature from a variety of different perspectives. Darwin’s role on the Beagle was not just to study the native plants and animals encountered at the ship’s many stops but to study the geology, climate, and people of those areas as well. In fact, his interest in geology led him to collect many fossils, some high in the Andes Mountains of South America. Such findings helped to stimulate his thinking about how environments and organisms might have changed over time.
Evolution by Natural Selection

Darwin realized that Malthus’s hypotheses about human populations apply to all species. Every organism has the potential to produce many offspring during its lifetime. In most cases, however, only a limited number of those offspring survive to reproduce. Considering Malthus’s view and his own observations and experience in breeding domestic animals, Darwin made a key association. Individuals that have physical or behavioral traits that better suit their environment are more likely to survive and will reproduce more successfully than those that do not have such traits. Darwin called this differential rate of reproduction natural selection. In time, the number of individuals that carry these favorable characteristics will increase in a population. And thus the nature of the population will change—a process called evolution.2

Darwin further suggested that organisms differ from place to place because their habitats present different challenges to, and opportunities for, survival and reproduction. Each species has evolved and has accumulated adaptations in response to its particular environment. An adaptation is a feature that has become common in a population because the feature provides a selective advantage.2

Publication of Darwin’s Work

In 1844, Darwin finally wrote down his ideas about evolution and natural selection in an early outline that he showed to only a few scientists he knew and trusted. At about this time, both a newly published book that claimed that evolution occurred, and Lamarck’s hypotheses about evolution were harshly criticized. Shrinking from such controversy, Darwin put aside his manuscript.2

Darwin decided to publish after he received a letter and essay in June 1858 from the young English naturalist Alfred Russel Wallace (1823–1913), who was in Malaysia at the time. Wallace’s essay described a hypothesis of evolution by natural selection! In his letter, he asked if Darwin would help him get the essay published. Darwin’s friends arranged for a summary of Darwin’s manuscript to be presented with Wallace’s paper at a public scientific meeting.2

Figure 5  Political cartoon of Charles Darwin. This 1874 cartoon of Darwin with a monkeylike “ancestor” is an example of how some people ridiculed Darwin because of his work.

Antibiotics are powerful drugs that have saved many lives. Penicillin, the first antibiotic discovered, was observed to inhibit bacterial growth on Petri dishes by the scientist Alexander Fleming in 1928. Many other antibiotics have been discovered or synthesized since then. In the last several decades, the effectiveness of antibiotics has become compromised by the evolution of antibiotic-resistant strains of many species. Some diseases must now be treated with a “cocktail” of several different antibiotics to cure patients. Antibiotic resistance has become a problem because of the widespread use of antibiotics, not only for treatment of human diseases, but also for prevention of diseases in humans and domestic animals. With such widespread use, a mutation in a bacterium’s DNA that allows it to survive treatment will be perpetuated. Soon, bacteria with these mutations may constitute the majority of the species alive. TAKS 2 Bio 6C; Bio 3F
Answers to Analysis
1. the different things that can happen to an organism if it is exposed to change in its environment
2. Most mutations will be passed on because they are harmful only if an individual has two copies.
3. The survivors avoided chance death (a “die” card) and two copies of the mutation, which is “lethal” when expressed.
4. sample answer: does not distinguish between beneficial and harmful mutations; does not distinguish between living and reproducing

Darwin’s Theory
Darwin’s book On the Origin of Species by Means of Natural Selection appeared in November of 1859. Many people were deeply disturbed by certain suggestions of Darwin’s theory, such as that humans are related to apes, as Figure 5 on the previous page suggests. But Darwin’s arguments and evidence were very convincing, and his view that evolution occurs gained acceptance slowly from biologists around the world.

Darwin’s theory of evolution by natural selection is supported by four major points:

1. Variation exists within the genes of every population or species (the result of random mutation and translation errors).
2. In a particular environment, some individuals of a population or species are better suited to survive (as a result of variation) and have more offspring (natural selection).
3. Over time, the traits that make certain individuals of a population able to survive and reproduce tend to spread in that population.
4. There is overwhelming evidence from fossils and many other sources that living species evolved from organisms that are extinct.

Modeling Natural Selection
By making a simple model of natural selection you can begin to understand how natural selection changes a population.

Materials
paper, pencil, watch or stopwatch

Procedure
1. On a chalkboard or overhead projector, make a data table like the one shown below.

<table>
<thead>
<tr>
<th>Data Table</th>
</tr>
</thead>
<tbody>
<tr>
<td>Student name</td>
</tr>
</tbody>
</table>

2. Write each of the following words on separate pieces of paper: live, die, reproduce, mutate. Fold each piece of paper in half twice so that you cannot see the words. Shuffle your folded pieces of paper.

3. Exchange two of your pieces of paper with those of a classmate. Make as many exchanges with additional classmates as you can in 30 seconds. Mix your pieces of paper between each exchange you make.

4. Look at your pieces of paper. If you have two pieces that say “die” or two pieces that say “mutate,” then sit down. If you do not, then you are a “survivor.” Record your results in your class table.

5. If you are a “survivor,” record the words you are holding in the data table. Then refold your pieces of paper and repeat steps 2 and 3 two more times with other “survivors.”

Analysis
1. Identify what the four slips of paper represent.
2. Describe what happens to most mutations in this model.
3. Identify what factor(s) determined who “survived.”
4. Evaluate the shortcomings of this model of natural selection.

Teacher’s Notes
Remind students that individuals have two copies of each gene, and most mutations code for recessive traits, meaning that the genes are expressed only if an individual has two copies.

Teacher Edition
TAKS Obj 1 Bio/IPC 2B, 2C
TAKS Obj 2 Bio 6C
TAKS Obj 3 Bio 7B
TEKS Bio 3E, 6C, 7B; Bio/IPC 2B, 2C

Student Edition
TAKS Obj 1 Bio/IPC 2B, 2C
TAKS Obj 2 Bio 6D
TAKS Obj 3 Bio 7A
TEKS Bio 3F, 6D, 7A

Inclusion Strategies
- Learning Disability
- Gifted and Talented
- Attention Deficit Disorder

Using a box of animal crackers, have the students select several different “animals.” For each of the “animals” selected, have the student describe and draw changes that would have to take place for each of these “animals” to evolve to live in a water environment. Also have the student describe and draw changes if these “animals” had to evolve to an environment like that at the South Pole.

did you know?
Charles Darwin’s grandfather, Erasmus Darwin, wrote about evolution more than 60 years before his grandson’s theory was presented. Erasmus Darwin cited things such as the metamorphosis of insects, the new varieties produced by selective breeding, the variations among similar organisms in different climates, and the similarities of vertebrate structure as evidence that all life was “produced from a similar living filament.” Unlike his famous grandson, Erasmus Darwin attributed change among organisms to the inheritance of characteristics acquired either naturally or at the will of the organism. Bio 3F

pp. 280–281
**Darwin’s Ideas Updated**

Since the time Darwin’s work was published, his hypothesis—that natural selection explains how evolution happens—has been carefully examined by biologists. New discoveries, especially in the area of genetics, have given scientists new insight into how natural selection brings about the evolution of species. Darwin’s ideas, restated in modern terms, are summarized here.

**Change Within Populations**

Darwin’s key inference was based on the idea that in any population, individuals that are best suited to survive and do well in their environment will produce the most offspring. So, the traits of those individuals will become more common in each new generation.

Scientists now know that genes are responsible for inherited traits. Therefore, certain forms of a trait become more common in a population because more individuals in the population carry the alleles for those forms. In other words, natural selection causes the frequency of certain alleles in a population to increase or decrease over time. Mutations and the recombination of alleles that occurs during sexual reproduction provide endless sources of new variations for natural selection to act upon.

**Species Formation**

The environment differs from place to place. Thus, populations of the same species living in different locations tend to evolve in different directions. Reproductive isolation is the condition in which two populations of the same species do not breed with one another because of their geographic separation. As two isolated populations of the same species become more different over time, they may eventually become unable to breed with one another. Generally, when the individuals of two related populations can no longer breed with one another, the two populations are considered to be different species. As shown in Figure 6, the Kaibab squirrel, which lives on the North Rim of the Grand Canyon in Arizona, has a black belly and other characteristics that distinguish it from the Abert squirrel. The Abert squirrel, which has a white belly, lives on the South Rim of the Grand Canyon. Because they have been so isolated from one another, they have become different enough that biologists consider them separate species.

![Figure 6 Reproductive isolation in action](image)

**Math Connection**

In 1908, two scientists named Hardy and Weinberg developed a simple equation that can be used to determine the genotype frequencies in a population and to track their changes from one generation to another. This is known as the “Hardy-Weinberg equilibrium equation.” In this equation, \( p^2 + 2pq + q^2 = 1 \), \( p \) is defined as the frequency of the dominant allele and \( q \) as the frequency of the recessive allele for a trait controlled by a pair of alleles (A and a). The frequency of one plus the frequency of the other must equal 100%, or \( p + q = 1 \). The chances of all possible combinations of alleles occurring randomly is therefore \( (p + q)^2 = 1 \), or more simply, \( p^2 + 2pq + q^2 = 1 \). In this equation, \( p^2 \) is the frequency of homozygous dominant (AA) individuals in a population, \( 2pq \) is the frequency of heterozygous (Aa) individuals, and \( q^2 \) is the frequency of homozygous recessive (aa) ones.

**Math Skills**

Provide students with the information contained in the Math Connection: Hardy Weinberg Equilibrium at the bottom of this page. Tell them to consider the example of a flowering plant in which red color is dominant (“A” allele) and white color is recessive (“a” allele). Have them consider a population of 100 of these plants, of which 16 are white-flowered (“aa” genotype). Have them calculate the frequencies of the A allele (frequency = \( p \)) and the a allele (frequency = \( q \)). (Since \( q^2 \) is the frequency of the aa genotype, and \( q^2 = 0.16 \) \( 16/100 \), then \( q = 0.4 \) and \( p = 0.6 \).) Next, tell students that after a period of time there aren’t as many white-flowered plants around—only 4 out of 100 plants. Ask them what the new frequencies of the A allele and a allele are. (Since \( q^2 = 0.04 \), so \( q = 0.2 \) and \( p = 0.8 \).) **Logical**

**Demonstration**

Bring to class as many of the following food crops as possible: cabbage, Brussels sprouts, broccoli, cauliflower, kale, and kohlrabi. Try to bring a wild mustard plant or a picture of one. (This can be found in many biology and horticulture texts.) Point out the parts of the plants that are eaten. Tell students that all of these different varieties have been bred from the same species, *Brassica oleracea*. Ask students how these varieties of the same species could look so different. (There is so much variation in the genes of this species.) Is it possible for these varieties to become separate species? (yes) How? (Through isolation, their genetic make-ups may become so different that they can no longer interbreed.)

TAKS 2 Bio 6D (grade 11 only); TAKS 3 Bio 7A (grade 11 only)
The Tempo of Evolution

For decades, most biologists have understood evolution as a gradual process that occurs continuously. The model of evolution in which gradual change over a long period of time leads to species formation is called **gradualism**. But American biologists Stephen Jay Gould and Niles Eldredge have suggested that successful species may stay unchanged for long periods of time. Gould and Eldredge have hypothesized that major environmental changes in the past have caused evolution to occur in spurts. This model of evolution, in which periods of rapid change in species are separated by periods of little or no change, is called **punctuated equilibrium**.

Punctuated Equilibrium

**Teaching Strategies**

Explain that these models are just that: abstractions that describe and help us understand the mechanics of evolutionary change. Emphasize that a good scientist tries to make a model fit his or her research results, not the other way around.

**Quiz**

1. What is a feature called that provides a selective advantage to a population? (An adaptation)
2. At what level does evolution of organisms occur? (the population level)

**Alternative Assessment**

Have students make visual representations of the four major points that support Darwin’s theory. For example, for point 1 students could cut out pictures of different individuals of the same species and paste them onto the board. Below the pictures, they could list possible variations in the traits of the species.

**Answers to Section Review**

1. Darwin found fossils of armadillos that closely resembled living armadillos. He also observed the resemblance between organisms on the Galapagos Islands and those on the nearest coast. **Bio 3C, 3F**
2. Individuals with traits well-suited to their environment are more likely to survive and reproduce than individuals without such traits. **TAKS 3 Bio 7B**
3. Genetic variations in a population enable some organisms to produce more offspring than others. Over time, populations evolve and reflect the survival of organisms with the most advantageous heritable traits. **TAKS 1 IPC 3A, Bio 3A**
4. According to the punctuated equilibrium model, evolution occurs in spurts in response to strong environmental pressures. According to gradualism, species evolve gradually over long periods of time. **TAKS 1 IPC 3A; Bio 3A, 3E**
5. **TAKS Doctor**
   - A. Incorrect. Extinct populations cannot be acted upon by natural selection.
   - B. Correct. Isolation prevents interbreeding.
   - C. Incorrect. If two populations are interbreeding, they will not diverge into different species.
   - D. Incorrect. A single population of a species will remain a single species unless isolation occurs. **TAKS 3 Bio 7B**
The Fossil Record

Have you ever looked at a series of maps that show how a city has grown? Buildings and streets are added, changed, or destroyed as the years pass by. In the same way, fossils of animals show a pattern of development from early ancestors to modern descendants. Fossils offer the most direct evidence that evolution takes place. Recall that a fossil is the preserved or mineralized remains or imprint of an organism that lived long ago. Fossils, therefore, provide an actual record of Earth’s past life-forms. Change over time (evolution) can be seen in the fossil record. Fossilized species found in older rocks are different from those found in newer rocks, as you can see in Figure 7.

After observing such differences, Darwin predicted that intermediate forms between the great groups of organisms would eventually be found. Since Darwin’s time, many of these intermediaries have been found. For example, fossil intermediaries have been found between fishes and amphibians, between reptiles and birds, and between reptiles and mammals, adding valuable evidence about the fossil history of the vertebrates.

Today, Darwin’s theory is almost universally accepted by scientists as the best available explanation for the biological diversity on Earth. Based on a large body of supporting evidence, most scientists agree on the following three major points: 1. Earth is about 4.5 billion years old. 2. Organisms have inhabited Earth for most of its history. 3. All organisms living today share common ancestry with earlier, simpler life-forms.

Figure 7 Fossils. Fossils of early multicellular life-forms, such as the crinoid, occur in 800-million-year-old rocks found in Indiana. Fossils of the pterodactyl, an extinct reptile, occur in 140- to 210-million-year-old rocks.

Crinoid Pterodactyl
**Teach**

**Teaching Tip**

**Extinct Organisms** Tell students that scientists estimate that 99 percent of all animal and plant species that ever existed are now extinct. Most people do not realize how many species have been found by paleontologists. In the past few years, many new species have been discovered. For example, in one small area in Wyoming, early Eocene rocks have yielded fossils of more than 50 species of animals.

**Using the Figure**

Tell students that the first three animals in Figure 8 are known only from their fossil remains. The fourth animal is a living species. Note that the backbone of the Rodhocetus kasrani skeleton is not complete, as the tailbones shown in gray indicate. Tell students that it is rare to find a complete skeleton in any one fossil. As more skeletons of this species are found, all the species’ bones may eventually be found. Using their knowledge of anatomy, paleontologists project what these bones will look like. Ask students how the backbone changed relative to the time these animals spent in water. (The backbone became heavier.) What is the advantage of this change? (Whales use up-and-down motions of their bodies to swim. A heavier backbone better supports the muscles used for this motion.)

**Figure 8 Evidence of whale evolution**

Whales are thought to have evolved from an ancestral line of four-legged mammals, which are represented here by their fossils and artistic reconstructions showing what scientists think they may have looked like.

**Formation of Fossils**

The fossil record, and thus the record of the evolution of life, is not complete. Many species have lived in environments where fossils do not form. Most fossils form when organisms and traces of organisms are rapidly buried in fine sediments deposited by water, wind, or volcanic eruptions. The environments that are most likely to cause fossil formation are wet lowlands, slow-moving streams, lakes, shallow seas, and areas near volcanoes that spew out volcanic ash. The chances that organisms living in upland forests, mountains, grasslands, or deserts will die in just the right place to be buried in sediments and fossilized are very low. Even if an organism lives in an environment where fossils can form, the chances are slim that its dead body will be buried in sediment before it decays. For example, it may be eaten and scattered by scavengers. Furthermore,

**CHEMISTRY CONNECTION**

Scientists can determine the ages of fossils and other artifacts by measuring the amount of decay of radioactive atoms in the specimen or in the surrounding sediment. Since a radioactive atom is unstable, it will eventually change into a more stable atom. The term half-life describes how long it takes for one-half of the radioactive atoms in a sample to decay. For example, the half-life of carbon-14 is 5,730 years. (The most common form of carbon in living things is carbon-12.) When an organism dies, the carbon-14 it has steadily decreases as it decays, causing the ratio of carbon-14 to carbon-12 to decrease over time. If a fossilized organism has one-fourth the carbon-14 to carbon-12 ratio of a living organism, the fossil is 11,460 years old. (This is two half-lives of carbon-14.) Because the half-life of carbon-14 is relatively short, this radioisotope is only used for dating fossils and artifacts less than about 50,000 years old. To date older fossils, scientists use radioactive isotopes with longer half-lives. For example, uranium-235 has a half-life of 704 million years. 

**TEKS/TAKS**

- Student Edition
  - TAKS Obj 3 Bio 7A
  - TEKS Bio 7A

- Teacher Edition
  - TAKS Obj 3 Bio 7A, 7B
  - TEKS Bio 7A, 7B; IPC 8D

**pp. 284–285**
the bodies of some organisms decay faster than others do. For example, an animal with a hard exoskeleton (such as a crab) would have a better chance of becoming fossilized than would a soft-bodied organism, such as an earthworm.

Although the fossil record will never be complete, it presents strong evidence that evolution has taken place. **Paleontologists**, scientists who study fossils, can determine the age of fossils fairly accurately by using radiometric dating. Radiometric dating the sediments in which a fossil is found enables paleontologists to arrange fossils in sequence from oldest to youngest. When this is done, orderly patterns of evolution can be seen. Based on existing fossils, **Figure 8** shows an artist’s idea of the appearance of three extinct species that might have been ancestral to modern whales. They are arranged in the order that they evolved, based on their fossil’s age as determined by radiometric dating. 1

**MISCONCEPTION ALERT**

A discussion of vestigial structures begins on the next page. Many people think that structures are labeled as vestigial because they are useless. Many such structures do, in fact, have functions. Structures are labeled vestigial if they are smaller, less functional, or perform a different function from that of homologous structures in ancestral life forms. For example, the yolk sac of a mammal is homologous to the yolk sac of birds and reptiles, but it is considered vestigial because it does not provide nutrients for the growing embryo. However, the mammalian yolk sac does produce blood cells.

Teaching Tip ———-**Basic**

**Penguins “Fly” Underwater**

Tell students that, although penguins are not able to fly in the air, the movement of their wings under water resembles the motion of the wings of birds that do fly. However, penguins have much heavier bones than birds that fly in the air. Ask students what adaptive advantage this might give penguins. (The hefty bone structure of a penguin’s wings is an advantage for moving through water, which is far denser than air. Also, heavier bones are not a disadvantage because of the buoyancy provided by water.) **TAKS 3 Bio 7B**

**Demonstration** ———-**General**

Have students study samples or pictures of different types of fossils. Ask how these organisms are similar to modern organisms. (Answers will vary. Students should note the similarities in bone and shell structure.) Diatomaceous earth used in aquarium filters provides excellent examples of microfossils for examination. **Visual** **TAKS 3 Bio 7A (grade 11 only)**
Teaching Tip

Making Mutations To show students that the amino acid sequence of a protein is determined by the nucleotide sequence of a gene, put the following sequence of nucleotide bases on the board or overhead: CUU, GUU, CCU, GGC, AGG. Have students look up the amino acids encoded by these triplets. (leucine, valine, proline, glycine, and arginine) Have students take turns substituting one of the other three nitrogen bases for a base in one of the triplets. Tell students that the substitutions they made represent mutations. Ask how mutations affect the proteins encoded by DNA. (Mutations change the proteins produced by changing the blueprints for their production.)

Using the Figure

Direct students’ attention to Figure 10. Ask them which species listed in this table shares the most recent common ancestor with humans. (gorilla) Ask them if a family tree produced with the amino acid data in Figure 10 would show the same relationships as a family tree based on nucleotide substitutions. (yes) Why? (A nucleotide sequence determines an amino acid sequence.)

Anatomy and Development

Comparisons of the anatomy of different types of organisms often reveal basic similarities in body structures even though the structure’s functions may differ between organisms. For example, sometimes bones are present in an organism but are reduced in size and either have no use or have a less important function than they do in other, related organisms. Such structures, which are considered to be evidence of an organism’s evolutionary past, are called vestigial structures. For example, the hind limbs of whales are vestigial structures.

As different groups of vertebrates evolved, their bodies evolved differently. But similarities in bone structure can still be seen, suggesting that all vertebrates share a relatively recent common ancestor. As you can see in Figure 9, the forelimbs of the vertebrates shown are composed of the same basic groups of bones. Such structures are referred to as homologous structures. That is, a similar structure in two organisms can be found in the common ancestor of the organisms.

The evolutionary history of organisms is also seen in the development of embryos. At some time in their development, all vertebrate embryos have a tail, buds that become limbs, and pharyngeal pouches. The tail remains in most adult vertebrates. Only adult fish and immature amphibians retain pharyngeal pouches (which contain their gills). In humans, the tail disappears during fetal development, and pharyngeal pouches develop into structures in the throat.

Figure 9 Homologous structures

The forelimbs of vertebrates contain the same kinds of bones, which form in the same way during embryological development.

Evolution

Vestigial structures

Molecules

Vertebrates

Proteins

Mice

Rhesus monkeys

Lampreys

Forelimbs

Birds

Dolphins

Humans

Whales

Pelvis

Chickens

Frogs

Humerus

Radius

Ulna

Carpals

Metacarpals

Phalanges

Penguin

Alligator

Bat

Human

Graphic Organizer

Use this graphic organizer with Reteaching on the next page.
Biological Molecules

The picture of successive change seen in the fossil record allows scientists to make a prediction that can be tested. If species have changed over time as the fossil record indicates, then the genes that determine the species' characteristics should also have changed by mutation and selection. As species evolved, one change after another should have become part of their genetic instructions. Therefore, more and more changes in a gene's nucleotide sequence should build up over time.

Proteins

This prediction was first tested by analyzing the amino acid sequences of similar proteins found in several species. Recall that the amino acid sequence of proteins is genetically determined. If evolution has taken place, then species descended from a recent common ancestor should have fewer amino acid differences between their proteins than do species that shared a common ancestor in the distant past.

Comparing one human hemoglobin protein with the same hemoglobin protein of other species reveals the predicted pattern, as shown in Figure 10. Species that shared a common ancestor more recently (for example, humans and gorillas) have few amino acid sequence differences. However, those species that share a common ancestor in the more distant past (such as gorillas and frogs) have many amino acid sequence differences.

Nucleic Acids

As you have read in an earlier chapter, nucleotide changes (such as nucleotide substitutions) cause changes in the amino acid sequence of a protein. Scientists evaluate the number of nucleotide changes that have taken place in a gene since two species diverged from a common ancestor by comparing the nucleotide sequence of genes. Using the data obtained from proteins and nucleotides, scientists generate hypotheses about how organisms are related through evolution. The hypotheses, based on molecular data, tend to reflect the relationships indicated by the fossil record.

Answers to Section Review

1. Answers will vary. The fossil record shows changes in organismal forms that can be traced forward and backward in time along different ancestral lines. TAKS 3 Bio 7A (grade 11 only)

2. Similarities in amino acid sequences suggest that organisms are related, and may indicate the degree of relatedness. Differences in amino acid sequences suggest that mutations have introduced genetic variation into populations of organisms that eventually resulted in evolution. Bio 9A

3. Anatomical similarities between living species, such as similar bones used for similar functions, suggest that these species may have evolved from a common ancestor. TAKS 3 Bio 7A (grade 11 only)

4. A. Incorrect. These two animals should have relatively similar nucleotide sequences because they are both primates and thus closely related. B. Incorrect. These two animals should have somewhat similar nucleotide sequences because they are both mammals. C. Incorrect. These two animals should be related and have similar nucleotide sequences because they are both vertebrates (shark and invertebrate). D. Correct. The shark is a vertebrate, and the butterfly is an invertebrate. They are the least related and would have the least similar nucleotide sequences. TAKS 2 Bio 6D; Bio 8B

Figure 10

Hemoglobin Comparison

<table>
<thead>
<tr>
<th>Species</th>
<th>Amino Acid Differences from Human Hemoglobin Protein</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gorilla</td>
<td>1</td>
</tr>
<tr>
<td>Rhesus monkey</td>
<td>8</td>
</tr>
<tr>
<td>Mouse</td>
<td>27</td>
</tr>
<tr>
<td>Chicken</td>
<td>45</td>
</tr>
<tr>
<td>Frog</td>
<td>67</td>
</tr>
<tr>
<td>Lamprey</td>
<td>125</td>
</tr>
</tbody>
</table>

Hemoglobin Comparison Table. The more similar organisms' hemoglobin proteins are, the more recent the organisms' common ancestor is likely to have been.

Section 2 Review

1. Relate how the fossil record provides evidence that evolution has occurred. TAKS 3 Bio 7A (grade 11 only)

2. State how comparing the amino acid sequence of a protein can provide evidence that evolution has taken place. 9A

3. Describe how comparing the anatomy of living species provides evidence of evolution. TAKS 3 Bio 7A

4. TAKS Test Prep Which two organisms would likely have the least-similar nucleotide sequences in a given gene? 6D 8B

A. chimpanzee and gorilla
B. gorilla and dog
C. dog and shark
D. shark and butterfly

Quiz

1. What does the presence of hind limb remnants in the whale indicate? (The presence of these bones indicates that whales evolved from a land-dwelling ancestor.)

2. What is a vestigial structure? (bones or other structures that are present in an organism but are reduced in size and either have no use or have a less important function than they do in other related organisms)

Alternative Assessment

Tell students that the earliest phylogenetic diagrams were constructed using only evidence of morphological characteristics. Ask students why such diagrams might not reflect true evolutionary relationships. (Similar morphological characteristics might reflect adaptation to a similar environment, rather than a common ancestry.) Have students use library resources to construct phylogenetic diagrams of an organism or organisms of their choosing. Remind them to consider more than morphological characteristics. Bio 8B

Answers to TAKS Test Prep

A. Correct. These two animals should have relatively similar nucleotide sequences because they are both primates. B. Incorrect. These two animals should have somewhat similar nucleotide sequences because they are both mammals. C. Incorrect. These two animals should be related and should have nucleotide sequences that are more similar than those of a vertebrate (shark and invertebrate). D. Correct. The shark is a vertebrate, and the butterfly is an invertebrate. They are the least related and would have the least similar nucleotide sequences.
Section 3

Examples of Evolution

Natural Selection at Work

How does evolution occur? The heart of Darwin’s theory of evolution is that natural selection is the mechanism that drives evolution. Darwin wrote: “Can we doubt . . . that individuals having any advantage, however slight, over others, would have the best chance of surviving and of procreating their kind? On the other hand, we may feel sure that any variation in the least degree injurious would be rigidly destroyed. This preservation of favorable variations, I call Natural Selection.” In his writings, Darwin offered examples of how natural selection has shaped life on Earth. There are now many well-known examples of natural selection in action.

The key lesson scientists have learned about evolution by natural selection is that the environment dictates the direction and amount of change. If the environment changes in the future, the set of characteristics that most help an individual reproduce successfully may change. For example, the polar bear’s white fur, shown in Figure 11, enables it to hunt successfully in its snowy environment. In a warmer environment, having white fur would no longer be an advantage.

Factors in Natural Selection

The process of natural selection is driven by four important points that are true for all real populations:

1. **All populations have genetic variation.** That is, in any population there is an array of individuals that differ slightly from each other in genetic makeup. While this may be obvious in humans, it is also true in species whose members may appear identical, such as a species of bacteria.

2. **The environment presents challenges to successful reproduction.** Naturally, an organism that does not survive to reproduce or whose offspring die before the offspring can reproduce does not pass its genes on to future generations.

3. **Individuals tend to produce more offspring than the environment can support.** Thus individuals of a population often compete with one another to survive.

4. **Individuals that are better able to cope with the challenges presented by their environment tend to leave more offspring than those individuals less suited to the environment do.**

---

Focus

Overview

Before beginning this section review with your students the objectives listed in the Student Edition. This lesson provides examples of population changes that have resulted from natural selection. It also describes how the process of evolution may result in the formation of new species.

Bellringer

Have student groups brainstorm to identify characteristics of birds that provide information about their diets. (This information could be inferred from beak characteristics. A large, anvil-like beak suggests a diet of the flesh of animals. A very large claw-like beak suggests a diet of insects or possibly nectar. A long, narrow beak suggests a diet of insects or possibly large seeds. A large, anvil-like beak suggests a diet of nectar. A very large claw-like beak suggests a diet of insects or possibly large seeds. A long, narrow beak suggests a diet of the flesh of animals.)

Motivate

Discussion/Question

Point out that within the phylum Arthropoda, the class Insecta has more species than any other class. In fact, about one-third of all animals are beetles, which constitute just one order of insects. To date, more than 1 million species of insects have been classified, and many scientists estimate that there are probably several million more. Ask students how they think so many different kinds of species of insects could have evolved. (Insects are adapted to many different kinds of environments and rely on many different kinds of food sources.)

Key Terms

divergence
speciation
subspecies

Objectives

- Identify four elements in the process of natural selection.
- Describe how natural selection has affected the bacteria that cause tuberculosis.
- Relate natural selection to the beak size of finches.
- Summarize the process of species formation.

---

Chapter Resource File

- Lesson Plan
- Directed Reading
- Active Reading
- Data Sheet for Math Lab

---

Transparencies

- TT Bellringer
- TT Beak Size Variation
- TT Mating Activity in Raven Species

---

IPC Benchmark Review

To prepare students for the TAKS and accompany the discussion of fossils, have students review The Rock Cycle TAKS 4 IPC 8A on pp. 1052–1053 of the IPC Refresher in the Texas Assessment Appendix of this book.
Example of Natural Selection

The lung disease tuberculosis (TB) is usually caused by the bacterium Mycobacterium tuberculosis, shown in Figure 12, and it kills more adults than any other infectious disease in the world. In the 1950s, two effective antibiotics, isoniazid and rifampin, became available, and they have saved millions of lives. In the late 1980s, however, new strains of M. tuberculosis that are largely or completely resistant to isoniazid and rifampin appeared. Rates of TB infection began to skyrocket in many countries, and in 1993 the World Health Organization declared a global TB health emergency.

How did antibiotic-resistant strains of M. tuberculosis evolve? A detailed look at a single typical case reveals how: through natural selection. This case is of a 35-year-old man living in Baltimore who was treated with rifampin for an active TB infection. After 10 months, the antibiotics cleared up the infection. Two months later, however, the man was readmitted to the hospital with a severe TB infection, and despite rifampin treatment, he died 10 days later. The strain of M. tuberculosis isolated from his body was totally resistant to rifampin.

How had TB bacteria within his body become resistant to rifampin? Doctors compared DNA of the rifampin-resistant bacteria to DNA from samples of normal, rifampin-sensitive M. tuberculosis. There seemed to be only one difference: a single base change from cytosine to thymine in a gene called rpoB.

Evolution of Antibiotic Resistance

Rifampin acts by binding to M. tuberculosis RNA polymerase, preventing transcription and so killing the bacterial cell. The mutation in the polymerase's rpoB gene prevents rifampin from binding to the polymerase. The mutation, however, does not destroy the polymerase's ability to transcribe mRNA. The mutation likely occurred in a single M. tuberculosis bacterial cell sometime during the first infection. Because its polymerase function was no longer normal, the mutant bacterium could not divide as rapidly as normal bacteria can, but it still could divide. The antibiotic caused the normal bacterial cells to eventually die. The mutant bacteria continued to grow and reproduce in the antibiotic-containing environment.

Because the total number of M. tuberculosis bacteria was reduced drastically by the first antibiotic treatment, the patient’s infection had seemed to clear. However, mutant, antibiotic-resistant bacteria survived and continued to grow in his body. The mutant bacteria could reproduce more effectively in the presence of the antibiotic than the normal bacteria could. Therefore, the mutant bacteria became more common in the bacterial population, and they eventually became the predominant type. When the patient became acutely ill again with TB, the M. tuberculosis bacterial cells in his lungs were the rifampin-resistant cells. In this way, natural selection led to the evolution of rifampin resistance in M. tuberculosis.

Natural selection has made insect pests harder to fight. When DDT was first introduced, for example, it was a highly effective insecticide. Over time, DDT became less and less effective; individuals that were resistant to the insecticide survived and produced the next generation. In fact, many populations of insects are now resistant to DDT. Although DDT is now banned in the United States because of its persistent toxicity, farmers have repeatedly had to deal with insect populations that develop resistance to insecticides.
Evolution in Darwin’s Finches

Darwin collected 31 specimens of finches from three islands when he visited the Galápagos Islands. In all, he collected 9 distinct species, all very similar to one another except for their bills. Two ground finches with large bills feed on seeds that they crush in their beaks, while two with narrower bills eat insects. One finch is a fruit eater, one picks insects out of cactuses, and yet another creeps up on sea birds and uses its sharp beak to drink their blood.  

Darwin suggested that the nine species of Galápagos finches evolved from an original ancestral species. Changes occurred as different populations accumulated adaptations to different food sources. This idea was first tested in 1938 by the naturalist David Lack. He watched the birds closely for five months and found little evidence to support Darwin’s hypothesis. Stout-beaked finches and slender-beaked finches were feeding on the same sorts of seeds. A second, far more thorough study was carried out over 25 years beginning in 1973 by Peter and Rosemary Grant of Princeton University. The Grants’ study presents a much clearer picture that supports Darwin’s interpretation.  

It was Lack’s misfortune to study the birds during a wet year, when food was plentiful. The size of the beak of the finch is of little importance in such times. Slender and stout beaks both work well to gather the small, soft seeds which were plentiful.

During dry years, however, plants produce few seeds, large or small. During these leaner years, few small, tender seeds were available. The difference between survival and starvation is the ability to eat the larger, tougher seeds that most birds usually pass by. The Grants measured the beaks of many birds every year. They found that after several dry years, the birds that had longer, more-massive beaks had better feeding success and produced more offspring.  

When wet seasons returned, birds tended to have smaller beaks again, as shown in Figure 13. The numbers of birds with different beak shapes are changed by natural selection in response to the available food supply, just as Darwin had suggested.  

Many people think that selection pressure induces changes. For example, people think that antibiotics induce mutations in bacteria that make them antibiotic resistant. Remember, natural selection does not induce changes in the genes of organisms; rather it selects for those genes that are most adaptive. Genes for antibiotic resistance are already present in many bacteria, but organisms expressing these genes do not predominate until they are grown in the presence of antibiotics and the resistance provides a survival advantage.
Formation of New Species
Species formation occurs in stages. Recall that natural selection favors changes that increase reproductive success. Therefore, a species molded by natural selection has an improved "fit" to its environment. The accumulation of differences between groups is called **divergence** (die VUHR jehn). Divergence leads to the formation of new species. Biologists call the process by which new species form **speciation** (spee see AY shun).

Forming Subspecies
Separate populations of a single species often live in several different kinds of environments. In each environment, natural selection acts on the population. Natural selection results in the evolution of offspring that are better adapted to that environment. If their environments differ enough, separate populations of the same species can become very dissimilar. Over time, populations of the same species that differ genetically because of adaptations to different living conditions become what biologists call **subspecies**. The members of newly formed subspecies have taken the first step toward speciation. Eventually, the subspecies may become so different that they can no longer interbreed successfully. Biologists then consider them separate species.

Maintaining New Species
What keeps new species separate? Why are even closely related species usually unable to interbreed? Once subspecies become different enough, a barrier to reproduction, like the one shown in **Figure 14**, usually prevents different groups from breeding with each other.

**Real Life**

**Why do we find certain people pretty or handsome?**

Some evolutionary biologists think that many traits that contribute to a person's attractiveness actually reveal the person's fitness as a mate.

**Finding Information**
Research and compare hypotheses concerning biological and cultural reasons that people judge others as attractive.

**Logical**

**Real Life**

Sequential Diagram of Speciation
Have students make a Graphic Organizer that shows each step of speciation in the proper sequence. Have students use the following terms: divergence, isolation, natural selection, new species, and variation.

**Analyzing Change in Lizard Populations**

**Skills Acquired**
Interpreting, analyzing, concluding, predicting

**Teacher’s Notes**
Point out to students that the graph shown here is a scatter plot. The data points on such a graph are not connected by lines. Rather, these graphs illustrate the distribution and patterns of the data.

**Answers to Analysis**

1. The average hind limb length of each population changed in response to differences in the average perch diameter of plants on the different islands.
2. The population could evolve and have longer average hind limbs, or it could go extinct.
3. The experiment illustrates that characteristics of populations can change over time in response to environmental pressures.

**TAKS 1 Bio 2C, 2D**
There are several types of barriers that may isolate two or more closely related groups. For example, groups may be geographically isolated or may reproduce at different times. Physical differences may also prevent mating, or they may not be attracted to one another for mating. The hybrid offspring may not be fertile or suited to the environment of either parent.

Biologists have seen the stages of speciation in many different organisms. Thus, the way that natural selection leads to the formation of new species has been thoroughly documented. As changes continue to build up over time, living species may become very different from their ancestors and from other species that evolved from the same recent common ancestor, leading to the appearance of new species.

**Quiz**

1. Divergence can lead to the formation of new _______ and new _______. (subspecies, species)
2. If two similar species of flowering plants bloom at different times, what is the name of the process that keeps these species separate? (reproductive isolation)

**Alternative Assessment**

Have students make a labeled diagram showing the process of natural selection using species of their choice. The chosen species could be one the student makes up. In their diagrams, students should include the four important points about natural selection discussed in this section. Bio 3E

---

**Section 3 Review**

1. List four elements of natural selection. TAKS 3 Bio 7B
2. Describe the mechanism that causes population changes in antibiotic-resistant bacteria. TAKS 3 Bio 7B
3. Identify what caused the change in the finch’s beaks as seen in the Grants’ study. TAKS 3 Bio 7A
4. Describe how speciation takes place. TAKS 3 Bio 7A
5. Critical Thinking Evaluating Results Based on the results of David Lack’s study and the Grants’ study of finches, what conclusion can you make about the length of time required for evolution of a new species to take place? TAKS 3 Bio 7B
6. The beaks of finches on the Galápagos Islands enlarged over generations in response to _______. TAKS 3 Bio 7B
   A. isolation.  B. pollution.  C. rain.  D. limited food supply.

---

**Answers to Section Review**

1. (1) genetic variation, (2) environmental challenges to reproduction, (3) overproduction of offspring and a struggle for survival and (4) an increase in the number of individuals with characteristics suited to the environment. TAKS 3 Bio 7B
2. Bacteria have genetic variations that enable some to survive and reproduce in the presence of antibiotics. The non-resistant bacteria die, while the resistant bacteria reproduce. TAKS 3 Bio 7B
3. The changes in the finches’ beaks were a response to changes in their food sources that were caused by climate changes. TAKS 3 Bio 7A (grade 11 only)
4. As populations of a species spread throughout an environment, they are exposed to varying conditions (environmental pressures). Over time, the separate populations become distinct and split into ecological races, and eventually, separate species. TAKS 3 Bio 7A (grade 11 only)
5. It would take at least several generations and would depend on how long it takes an organism to reach reproductive maturity. TAKS 3 Bio 7B
6. A. Incorrect. The populations of finches were not isolated from one another. B. Incorrect. There was no evidence of pollution. C. Incorrect. Rain did not cause beak enlargement (though lack of rain, indirectly, was involved). D. Correct. Finch’s with larger beaks were able to eat the larger, tougher seeds. TAKS 3 Bio 7B
Key Concepts

1. **The Theory of Evolution by Natural Selection**
   - Charles Darwin concluded that animals on the coast of South America that resembled those on the nearby islands evolved differences after separating from a common ancestor.
   - Darwin was influenced by Thomas Malthus, who wrote that populations tend to grow as much as the environment allows.
   - Darwin proposed that natural selection favors individuals that are best able to survive and reproduce.
   - Under certain conditions, change within a species can lead to new species.
   - Gradualism is a process of evolution in which speciation occurs gradually, and punctuated equilibrium is a process in which speciation occurs rapidly between periods of little or no change.

2. **Evidence of Evolution**
   - Evidence of orderly change can be seen when fossils are arranged according to their age.
   - Differences in amino acid sequences and DNA sequences are greater between species that are more distantly related than between species that are more closely related.
   - The presence of homologous structures and vestigial structures in vertebrates suggests that all vertebrates share a common ancestor.

3. **Examples of Evolution**
   - Individuals that have traits that enable them to survive in a given environment can reproduce and pass those traits to their offspring.
   - Experiments show that evolution through natural selection has occurred within populations of antibiotic-resistant bacteria and in Darwin’s finches.
   - Speciation begins as a population adapts to its environment.
   - Reproductive isolation keeps newly forming species from breeding with one another.

**Key Terms**

<table>
<thead>
<tr>
<th>Section 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>population (278)</td>
</tr>
<tr>
<td>natural selection (279)</td>
</tr>
<tr>
<td>adaptation (279)</td>
</tr>
<tr>
<td>reproductive isolation (281)</td>
</tr>
<tr>
<td>gradualism (282)</td>
</tr>
<tr>
<td>punctuated equilibrium (282)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Section 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>paleontologist (285)</td>
</tr>
<tr>
<td>vestigial structure (286)</td>
</tr>
<tr>
<td>homologous structure (286)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Section 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>divergence (291)</td>
</tr>
<tr>
<td>speciation (291)</td>
</tr>
<tr>
<td>subspecies (291)</td>
</tr>
</tbody>
</table>

---

**Answer to Concept Map**

The following is one possible answer to Performance Zone item 15 on the next page.

```
Evolution [is driven by] natural selection, which requires conditions in the environment. This results in divergence, which can lead to speciation and does not occur if species cannot adapt. This process can lead to extinction.
```

---

**Chapter Resource File**

- **Science Skills Worksheet**
- **Critical Thinking Worksheet**
- **Test Prep Pretest**
- **Chapter Test**

---

**TAKS Benchmark Review**

To prepare students for the TAKS, have students review *Waves: Types of Waves in Real Systems* and *Electromagnetic Waves TAKS Obj 5 IPC 5A* on pp. 1059–1061 of the IPC Refresher in the Texas Assessment Appendix of this book.
ANSWERS

Using Key Terms
1. a. TAKS 3 Bio 7B  
2. b. TAKS 3 Bio 7A (grade 11 only)  
3. d. TAKS 3 Bio 7B  
4. a. TAKS 3 Bio 7B  
5. a. An adaptation is a trait that enables an organism to better survive in its environment; natural selection is the process by which populations change in response to their environment. b. Extinction refers to the death of all members of a species; isolation refers to the separation of populations of the same species and their resulting inability to interbreed. c. Populations are groups of individuals of the same species living in the same area; subspecies are populations of the same species that differ genetically because of adaptations to different conditions. d. The word homologous refers to structures that share a common ancestry. The word vestigial refers to structures that are reduced in size and have no function or a less important function than they do in other, related organisms. e. Divergence is the accumulation of differences between groups; speciation is the process by which species form.

Understanding Key Ideas
6. b. TAKS 3 Bio 7B  
7. b. TAKS 3 Bio 7B  
8. a. TAKS 3 Bio 7B  
9. It may indicate that these animals share a common ancestor. TAKS 3 Bio 7B  
10. No; there is no genetic variation upon which natural selection can operate. TAKS 3 Bio 7B  
11. The greater the number of nucleotide differences between two species, the more distant is their most recent common ancestor. TAKS 2 Bio 6A; TAKS 3 Bio 7B  
12. Subspecies are populations of the same species that differ genetically because of adaptation. This is the first step toward speciation. TAKS 3 Bio 7B  
13. Meiosis is beneficial to the evolution of a species because it provides a source of genetic variation upon which natural selection can act.

Using Key Terms
1. The process by which a species becomes better adapted to its environment is called a. gradualism. 7B  
   b. adaptation. 7B  
   c. natural selection. 7B  
   d. reproductive isolation. 7B  
2. Anatomical structures that share a common ancestry are called _______ structures. 7A  
   a. vestigial  
   b. homologous  
   c. analogous  
   d. evolutionary  
3. In Lack’s study, the effect of weather on the size of the finch’s beak is an example of 7B  
   a. speciation.  
   b. reproductive isolation.  
   c. fossilization.  
   d. natural selection.  
4. The process by which isolated populations of the same species become new species is called 7B  
   a. speciation.  
   b. reproductive isolation.  
   c. genetic variation.  
   d. natural selection.  
5. For each pair of terms, explain the differences in their meanings.  
   a. adaptation, natural selection  
   b. extinction, reproductive isolation  
   c. population, subspecies  
   d. homologous, vestigial  
   e. divergence, speciation

Understanding Key Ideas
6. According to the modern theory of evolution, a. Lamarck was completely wrong. 7B  
   b. random gene mutation is a part of evolution.  
   c. punctuated equilibrium has replaced natural selection.  
   d. the diversity of life-forms resulted from the inheritance of acquired characteristics.  
7. With respect to the problem of antibiotic-resistant tuberculosis, which entity evolves? 7B  
   a. the patient  
   b. the bacterium  
   c. the antibiotic  
   d. None of the above.  
8. What is true about gradualism with respect to punctuated equilibrium? 7B  
   a. Each is a model of evolution.  
   b. Neither is a model of evolution.  
   c. Only gradualism portrays true evolution.  
   d. Only punctuated equilibrium portrays true evolution.  
9. Adult lobsters and barnacles look very different. The larvae of barnacles and lobsters, however, are practically identical. What does this indicate about the evolutionary history of these organisms? 7B  
11. Explain the relationship between the number of nucleotide differences between two species and the time since the species shared a common ancestor. 6A 7B  
12. What is a subspecies, and how is formation of a subspecies related to the process of speciation? 7A  
13. How is meiosis beneficial to the evolution of a species by natural selection? (Hint: See Chapter 7, Section 1.)  
14. Explain the advantage of Other than punctuated equilibrium, what naturally occurring phenomena might explain large gaps in the fossil record? 7A  
15. Concept Mapping Make a concept map that shows how natural selection leads to speciation. Try to include the following terms in your map: evolution, natural selection, genetic variation, environment, speciation, and divergence. 2C 3C

Assignment Guide

<table>
<thead>
<tr>
<th>Section</th>
<th>Questions</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1, 2, 6, 8, 13, 14, 16, 17, 19, 20, 21</td>
</tr>
<tr>
<td>2</td>
<td>7, 9, 11, 18, 22</td>
</tr>
<tr>
<td>3</td>
<td>3, 4, 5, 10, 12, 15, 18, 22</td>
</tr>
</tbody>
</table>
Critical Thinking

16. Applying Information If a favorable trait increases the life span of an organism without affecting reproductive success, does evolution occur? TAKS 3 Bio 7B

17. Evaluating Analyze Darwin’s theory of evolution by natural selection and describe one strength and one weakness. TAKS 3 Bio 7B

18. Justifying Conclusions About 40 years after the publication of On the Origin of Species, genetics was recognized as a science. Explain how information about genetics might support Darwin’s theory of evolution. TAKS 3 Bio 7B

19. Applying Information What effect would the time from the beginning of an organism’s life to the point of reproduction have on the rate of evolution of a species, and why? TAKS 3 Bio 7B

Alternative Assessment

20. Being a Team Member With two to three other students, locate and examine photographs and drawings of the tortoises that Darwin observed on the Galápagos Islands. Plan and produce a mural showing the tortoises in their natural environment. TAKS 3 Bio 8B

21. Communicating Prepare an oral report on the biological research of Alfred Russel Wallace. Present your findings to your class. TAKS 3 Bio 2D 3F

22. Career Connection Paleontologist Research the field of paleontology, and write a report on your findings. Your report should include a job description, training required, kinds of employers, growth prospects, and starting salary. TAKS 3 Bio 3D

TAKS Test Prep

Use the diagram below and your knowledge of science to answer questions 1–3.

[Diagram showing relationships between woodpecker finch, warbler finch, glyptodont, armadillo, recent common ancestor (finch-like bird), and remote common ancestor (armadillo-like mammal)]

1. The diagram implies that warbler finches and armadillos TAKS 3 Bio 7B
   A. are unrelated.
   B. share a recent common ancestor.
   C. share a remote common ancestor.
   D. did not evolve from older forms of life.

2. Which organism has DNA that is probably most similar to the glyptodont's DNA? TAKS 3 Bio 7A
   F. woodpecker finch
   H. early vertebrate
   G. warbler finch
   J. armadillo

3. Because the woodpecker finch and the warbler finch are different species, they probably TAKS 3 Bio 7B
   A. cannot interbreed.
   B. lack homologous structures.
   C. develop from very different embryos.
   D. are more similar to glyptodonts than to each other.

Test Tip
Do not be fooled by answers that may seem correct to you because they contain unfamiliar words.

Standardized Test Prep

1. A. Incorrect. Warbler finches and armadillos are distantly related. B. Incorrect. Warbler finches and armadillos do not share a recent common ancestor. C. Correct. Warbler finches and armadillos share a remote common ancestor (early vertebrate). D. Incorrect. Both warbler finches and armadillos evolved from older forms of life. TAKS 3 Bio 7B

2. F. Incorrect. See answer J. G. Incorrect. See answer J. H. Incorrect. The glyptodont and an early vertebrate are more distantly related than the glyptodont and the armadillo, so their DNA is not the most similar. J. Correct. The glyptodont and armadillo diverged most recently from one another, so their DNA is most similar. TAKS 3 Bio 7A (grade 11 only)

3. A. Correct. By definition, different species can not interbreed. B. Incorrect. Different species might have homologous structures. C. Incorrect. Different species might or might not have very different embryos. D. Incorrect. The woodpecker finch and the warbler finch are more similar to each other than they are to glyptodonts. TAKS 3 Bio 7B

Alternative Assessment

20. Answers will vary. Bio 8B

21. Answers will vary. Students should note that Wallace collected insects on an 1848 expedition to the Amazon. He also made observations in the Malay Archipelago between 1854 and 1862. Wallace discovered that animals on the western islands of the Malay archipelago differed sharply from those on the eastern islands. TAKS 1 TAKS 1 Bio IPC 3A; Bio 3A

22. Paleontologists are scientists who study fossils and other remains of past life. They are concerned with all aspects of ancient life, including the environments that existed at the time. Paleontologists usually have at least an undergraduate degree in zoology and/or geology, including training in chemistry and physics. University and museum jobs usually require a Ph.D. Most paleontologists are employed by universities, museums, or large oil and construction companies. Growth potential for this field is fair. Starting salary will vary by region. Bio 3D