Many different forms of evidence support the theory that Earth is ancient and that species can change over time.

**10.1 Early Ideas About Evolution**  
TEKS 2B, 3F, 7B

**10.2 Darwin’s Observations**  
TEKS 3F, 7A, 7E

**10.3 Theory of Natural Selection**  
TEKS 3F, 7C, 7D, 7E

**Data Analysis**  
INTERPRETING LINE GRAPHS  
TEKS 2G

**10.4 Evidence of Evolution**  
TEKS 3F, 7A, 7B

**10.5 Evolutionary Biology Today**  
TEKS 7A, 7B

---

**ONLINE BIOLOGY**  
HMDScience.com

**ONLINE Labs**
- QuickLab Piecing Together Evidence
- Predator-Prey Pursuit
- Using Patterns to Make Predictions
- Adaptations in Beaks
- Biochemical Evidence for Evolution
- Video Lab Natural Selection Simulation

284  Unit 4: Evolution
How could evolution lead to this?

The star-nosed mole has a pink snout that is especially good at finding food. The snout’s 22 fingerlike rays can touch up to 12 objects in just one second. The mole also uses strong paddle-shaped feet for burrowing, and its large ear openings give it excellent hearing. These special traits make up for its poor vision—which it doesn’t really need underground.

**USING LANGUAGE**

**Hypothesis or Theory?** In everyday language, there is little difference between a *hypothesis* and a *theory*. But in science, the meanings of these words are more distinct. A *hypothesis* is a specific, testable prediction for a limited set of conditions. A *theory* is a general explanation for a broad range of data. A *theory* can include hypotheses that have been tested and can also be used to generate new hypotheses. The strongest scientific theories explain the broadest range of data and incorporate many well-tested hypotheses.

**YOUR TURN**

Use what you have learned about a hypothesis and a theory to answer the following questions.

1. List some scientific theories that you have heard of.
2. Make a simple concept map or Venn diagram to show the relationship between hypotheses and theories.
3. The word *theory* may also be used to describe general trends and areas of active investigation in a scientific field. In this context, what does the term *evolutionary theory* mean?
Early Ideas About Evolution

KEY CONCEPT There were theories of biological and geologic change before Darwin.

MAIN IDEAS
- Early scientists proposed ideas about evolution.
- Theories of geologic change set the stage for Darwin’s theory.

Connect to Your World

Why are there so many kinds of living things, such as the strange looking star-nosed mole? Earth is home to millions of species, from bacteria to plants to ocean organisms that look like they came from science fiction. The search for reasons for Earth’s great biological diversity was aided in the 1800s, when Charles Darwin proposed his theory of evolution by natural selection. But long before Darwin, evolution had been the focus of talk among scholars.

Early scientists proposed ideas about evolution.

Although Darwin rightly deserves much of the credit for evolutionary theory as we know it today, he was not the first person to come up with the idea. Evolution is the process of biological change by which descendants come to differ from their ancestors. This concept had been discussed for more than 100 years when Darwin proposed his theory of the way evolution works. Today, evolution is a central theme in all fields of biology.

The 1700s were a time of great advances in intellectual thought. Many fields of science developed new ways of looking at the world during that century. Four scientists in particular are important. They not only made valuable contributions to biology in general, but they also laid the foundations upon which Darwin would later build his ideas. FIGURE 1.1 highlights the work of some of these early scientists.

Carolus Linnaeus In the 1700s, the Swedish botanist Carolus Linnaeus developed a classification system for all types of organisms known at the time. Although Linnaeus used his system to group organisms by their similarities, the system also reflects evolutionary relationships. This system is still in use by scientists today. Years into his career, Linnaeus abandoned the common belief of the time that organisms were fixed and did not change. He proposed instead that some might have arisen through hybridization—a crossing that he could observe through experiments with varieties, or species, of plants.

A species is a group of organisms that are closely related and can mate to reproduce fertile offspring.
Georges-Louis Leclerc de Buffon  Buffon, a French naturalist of the 1700s, challenged many of the accepted ideas of the day. Based on evidence of past life on Earth, he proposed that species shared ancestors instead of arising separately. Buffon also rejected the common idea of the time that Earth was only 6000 years old. He suggested that it was much older. This argument was similar to that of Charles Lyell, a geologist whose work helped inspire Darwin’s writings. You will read more about Lyell later in this section.

Erasmus Darwin  Born in 1731, Charles Darwin’s grandfather was a respected English doctor and a poet. He proposed that all living things were descended from a common ancestor and that more-complex forms of life arose from less-complex forms. This idea was expanded upon 65 years later by his grandson.

Jean-Baptiste Lamarck  In 1809, the year of Darwin’s birth, a French naturalist named Lamarck proposed that all organisms evolved toward perfection and complexity. Like other scientists of the time, he did not think that species became extinct. Instead, he reasoned that they must have evolved into different forms.

Lamarck proposed that changes in an environment caused an organism’s behavior to change, leading to greater use or disuse of a structure or organ. The structure would become larger or smaller as a result. The organism would pass on these changes to its offspring. For example, Lamarck thought that the long necks of giraffes evolved as generations of giraffes reached for leaves higher in the trees. Lamarck’s idea is known as the inheritance of acquired characteristics.

FIGURE 1.1 Early Naturalists
Evolutionary thought, like all scientific inquiry, draws heavily upon its history. The published works of these scientists contributed important ideas prior to Darwin’s theory.

<table>
<thead>
<tr>
<th>1735 Systema Naturae</th>
<th>1749 Histoire Naturelle</th>
<th>1794–1796 Zoonomia</th>
<th>1809 Philosophie Zoologique</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carolus Linnaeus proposed a new system of organization for plants, animals, and minerals based upon their similarities.</td>
<td>Georges Buffon discussed important ideas about relationships among organisms, sources of biological variation, and the possibility of evolution.</td>
<td>Erasmus Darwin considered how organisms could evolve through mechanisms such as competition.</td>
<td>Jean-Baptiste Lamarck presented evolution as occurring due to environmental change over long periods of time.</td>
</tr>
</tbody>
</table>

Summarize  Explain why Darwin was not the first scientist to consider evolution. 2B, 3F
Lamarck did not propose how traits were passed on to offspring, and his explanation of how organisms evolve was flawed. However, Darwin was influenced by Lamarck’s ideas that changes in physical characteristics could be inherited and were driven by environmental changes over time.

**Compare** What common idea about organisms did these scientists share? **TEKS 3F**

---

**MAIN IDEA** **TEKS 7B**

**Theories of geologic change set the stage for Darwin’s theory.**

The age of Earth was a key issue in the early debates over evolution. The common view was that Earth was created about 6000 years earlier, and that since that time, neither Earth nor the species that lived on it had changed.

French zoologist Georges Cuvier did not think that species could change. However, he did think that they could become extinct, an idea considered radical by many of his peers. Cuvier had observed that each stratum, or rock layer, held its own specific type of fossils. **Fossils** are traces of organisms that existed in the past. He found that the fossils in the deepest layers were quite different from those in the upper layers, which were formed by more recent deposits of sediment. Cuvier explained his observations in the early 1800s with the theory now known as catastrophism, shown in **FIGURE 1.2**.

---

**CONNECT TO**

**EARTH SCIENCE**

Cuvier based his thinking on what we know as the law of superposition. It states that in a sequence of layered rocks, a given layer was deposited before any layer above it.

---

**FIGURE 1.2 Principles of Geologic Change**

Ideas from geology played a role in the development of Darwin’s theory.

<table>
<thead>
<tr>
<th>CATASTROPHEM</th>
<th>GRADUALISM</th>
<th>UNIFORMITARIANISM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volcanoes, floods, and earthquakes are examples of catastrophic events that were once believed responsible for mass extinctions and the formation of all landforms.</td>
<td>Canyons carved by rivers show gradual change. Gradualism is the idea that changes on Earth occurred by small steps over long periods of time.</td>
<td>Rock strata demonstrate that geologic processes, which are still occurring today, add up over long periods of time to cause great change.</td>
</tr>
</tbody>
</table>

**Compare and Contrast** How are these three theories similar, and what are their differences?
The theory of **catastrophism** (kuh-TAS-truh-fiHZ-uhhm) states that natural disasters such as floods and volcanic eruptions have happened often during Earth’s long history. These events shaped landforms and caused species to become extinct in the process. Cuvier argued that the appearance of new species in each rock layer resulted from other species moving into the area from elsewhere after each catastrophic event.

In the late 1700s, the Scottish geologist James Hutton proposed that the changes he observed in landforms resulted from slow changes over a long period of time, a principle that became known as **gradualism** (GRAJ-00-uh-liHZ-uhhm). He argued that the laying down of soil or the creation of canyons by rivers cutting through rock was not the result of large-scale events. He believed, rather, that they resulted from slow processes that had happened in the past. This idea has become so important to evolution that today the term gradualism is often used to mean the gradual change of a species through evolution.

One of the leading supporters of the argument for an ancient Earth was the English geologist Charles Lyell. In *Principles of Geology*, published in the 1830s, Lyell expanded Hutton’s theory of gradualism into the theory of **uniformitarianism** (yoo-oh-nuh-fawr-mih-TAIR-ee-uh-nihHZ-uhhm). This theory states that the geologic processes that shape Earth are uniform through time. Lyell observed processes that made small changes in Earth’s features. He inferred that similar changes had happened in the past. Uniformitarianism combines Hutton’s idea of gradual change over time with Lyell’s observations that such changes have occurred at a constant rate and are ongoing. Uniformitarianism soon replaced catastrophism as the favored theory of geologic change. Lyell’s theory greatly affected the scientific community—particularly a young English naturalist named Charles Darwin.

**Compare** What important concepts about Earth did Hutton and Lyell agree upon?

---

**10.1 Formative Assessment**

**REVIEWING MAIN IDEAS**

1. Briefly describe two ideas about **evolution** that were proposed by scientists in the 18th century. **TEKS 2B, 3F**

2. What ideas in Lyell’s theory of **uniformitarianism** were important for evolutionary theory? **TEKS 3F**

**CRITICAL THINKING**

3. **Contrast** What are the key differences between the theories of **gradualism** and **catastrophism**?

4. **Apply** Why are the ideas that Earth undergoes change and is billions of years old important for evolutionary theory? **TEKS 7B**

**CONNECT TO GENETICS**

5. How can you use the concept of genetic inheritance to disprove Lamarck’s idea of the inheritance of acquired characteristics?
Darwin’s Observations

**KEY CONCEPT** Darwin’s voyage provided insights into evolution.

**MAIN IDEAS**
- Darwin observed differences in appearance among island species.
- Darwin observed fossil and geologic evidence supporting an ancient Earth.

**Connect to Your World**

Maybe you would love the chance to sail around the world. Or maybe just the thought of it makes you seasick! In 1831, the ship HMS Beagle set sail from England on a five-year journey to map the coast of South America and the Pacific islands. Hired at first to keep the captain company, Darwin was interested in observing the land and its inhabitants. During the voyage, he read Lyell’s *Principles of Geology*. When the ship reached South America, Darwin spent most of his time ashore, where he found much evidence supporting Lyell’s views.

**MAIN IDEA**

Darwin observed differences in appearance among island species.

Darwin, shown in Figure 2.1, was struck by the variation of traits among similar species that he observed in all his travels. In biology, variation is the difference in the physical traits of an individual from those of other individuals in the group to which it belongs. Variation can occur either among members of different species (interspecific variation) or among individuals of the same species (intraspecific variation). Darwin noted that the species found on one island looked different from those on nearby islands and that many of the islands’ species looked different from those on the nearest mainland.

The differences between species on different islands was especially noticeable in the Galápagos Islands, an island chain off the coast of Ecuador in South America. Some differences seemed well suited to the animals’ environments and diets, as shown in Figure 2.2. For example, saddle-backed tortoises, which have long necks and legs, lived in areas with a lot of tall plants. Domed tortoises, with their shorter necks and legs, lived in wet areas rich in mosses and short plants. Similarly, finches with strong, thick beaks lived in areas with a lot of large, hard-shelled nuts, while those species of finch with more delicate beaks were found where insects or fruits were widely available.

These observations led Darwin to realize that species may somehow be able to adapt to their surroundings. An adaptation is a feature that allows an organism to better survive and reproduce in its environment. Adaptations can lead to genetic change in a population over time.

Connect What adaptations did Darwin see in the finches of the Galápagos Islands?
Darwin observed fossil and geologic evidence supporting an ancient Earth.

On his voyage, Darwin found fossil evidence of species changing over time. In Argentina, he found fossils of huge animals, such as *Glyptodon*, a giant armadillo. The fact that these fossils looked like living species suggested that modern animals might have some relationship to fossil forms. These fossils suggested that, in order for such changes to occur, Earth must be much more than 6000 years old.

During his voyage, Darwin also found fossil shells of marine organisms high up in the Andes mountains. Darwin later experienced an earthquake during his voyage and saw firsthand the result: land that had been underwater was moved above sea level. This experience explained what he saw in the Andes. Darwin’s observations on his voyage supported Lyell’s theory that daily geologic processes can add up to great change over a long period of time. Darwin later extended the ideas of an old Earth and slow, gradual change to the evolution of organisms. This became known as evolutionary gradualism.

Infer What could account for fossils of marine organisms being found on top of modern-day mountain ranges?

**FIGURE 2.2 Adaptations Within Species**

Galápagos tortoises (*Geochelone elephantopus*) are evidence that species can adapt to their environments.

Domed tortoises have a short neck and short legs, and live in areas with low vegetation.

Saddle-back tortoises have a high shell edge, allowing them to stretch their long necks.

Explain Why do these tortoises of the same species look different?

**MAIN IDEA TEKS 3F, 7A**

Darwin observed fossil and geologic evidence supporting an ancient Earth.

**10.2 Formative Assessment**

**REVIEWING MAIN IDEAS**

1. What accounts for the variation Darwin observed among island species? **TEKS 7E**

2. What did Darwin learn from the fossils that he observed on his voyage? **TEKS 3F, 7A**

**CRITICAL THINKING**

3. **Apply** Explain how wings are an adaptation for birds. **TEKS 7E**

4. **Synthesize** How did Darwin’s observations support Lyell’s theory of an ancient Earth undergoing continual geologic change? **TEKS 3F, 7A**

**CONNECT TO ECOLOGY**

5. Some birds in the Galápagos Islands build nests in trees, while others hide eggs in rock crevices. What could account for this difference in nesting behaviors? **TEKS 7E**
Theory of Natural Selection

VOCABULARY
- artificial selection
- heritability
- natural selection
- population
- fitness

KEY CONCEPT  Darwin proposed natural selection as a mechanism for evolution.

MAIN IDEAS
- Several key insights led to Darwin’s idea for natural selection.
- Natural selection explains how evolution can occur.
- Natural selection acts on existing variation.

Connect to Your World

Have you ever had an experience that changed your outlook or your opinion about an issue? Darwin began his voyage thinking that species could not change. However, his experiences during the five-year journey changed the way he thought about life and evolution. He became convinced that evolution occurs. But he had yet to determine how it could happen.

Several key insights led to Darwin’s idea for natural selection.

After his voyage, Darwin spent more than 20 years conducting research while thinking about the way evolution occurs. Although he had traveled the world, Darwin also found great insight in his home country of England. One important influence on Darwin’s research was the work of farmers and breeders.

Artificial Selection

Darwin noticed a lot of variation in domesticated plants and animals. The populations of domesticated species seemed to show variation in traits that were not shown in their wild relatives. Through selection of certain traits, breeders could produce a great amount of diversity. The process by which humans change a species by breeding it for certain traits is called artificial selection. In this process, humans make use of the genetic variation in plants and animals by acting as the selective agent. That is, humans determine which traits are favorable and then breed individuals that show those traits.

To explore this idea, Darwin turned to the hobby of breeding pigeons. Although Darwin had no knowledge of genetics, he had noticed certain traits being selected in animals such as livestock and pets. For thousands of years, humans had been breeding pigeons that showed many different traits, such as those in FIGURE 3.1. In order for artificial—or natural—selection to occur, the trait must be heritable. Heritability (HER-ih-tuh-BIHL-uh-tee) is the ability of a trait to be passed down from one generation to the next.
Darwin compared what he learned about breeding to his ideas on adaptation. In artificial selection, features such as reversed neck feathers, large crops, or extra tail feathers are favored over generations only if these traits are liked by breeders. However, breeders might also select against features that are not desirable or “useful.” During artificial selection, humans act as the selective agent. In nature, however, the environment creates the selective pressure that determines if a trait is passed on or not.

Darwin used this line of thinking for his theory of natural selection. **Natural selection** is a mechanism by which individuals that have inherited beneficial adaptations show differential reproductive success. In other words—they tend to produce more offspring on average than do other individuals. In nature, the environment is the selective agent. Therefore, in nature, characteristics are selected only if they give advantages to individuals in the environment as it is right now. Furthermore, Darwin reasoned, desirable breeds are not produced immediately. He knew that it sometimes took many generations for breeders to produce the varieties he had observed.

**Struggle for Survival**

Another important idea came from English economist Thomas Malthus. Malthus had proposed that resources such as food, water, and shelter were natural limits to population growth. That is, human populations would grow geometrically if resources were unlimited. Instead, disease and a limited food

**FIGURE 3.1 Artificial Selection of Pigeon Traits**

For thousands of years, new varieties of organisms, such as pigeons, have resulted from selective breeding for particular traits.

**SELECTIVELY BRED PIGEONS**

Jacobins are bred for their reversed neck feathers.

Croppers are bred for their inflatable crop.

Fantails are bred to have many tail feathers.

Connect What other species of organisms are often subjects of artificial selection?
supply kept the population smaller. Darwin reasoned that a similar struggle took place in nature. If resources are limited and organisms have more offspring than could survive, why do some individuals, and not others, survive?

Darwin found his answer in the variation he had seen within populations. A population is all the individuals of a species that live in an area. Darwin had noticed in the Galápagos Islands that in any population, such as the tortoises or the finches, some individuals had variations that were particularly well-suited to their environment. He proposed that these adaptations arose over many generations. Darwin called this process of evolution “descent with modification.”

**Explain** How did Malthus’s economic theory influence Darwin? TEKS 3F

**MAIN IDEA** TEKS 3F, 7D, 7E

Natural selection explains how evolution can occur.

Charles Darwin was not the only person to develop a theory to explain how evolution may take place. An English naturalist named Alfred Russel Wallace independently developed a theory very similar to Darwin’s. Both Darwin and Wallace had studied the huge diversity of plants and animals in the tropics, and both had studied the fossil record. In 1858, the ideas of Darwin and Wallace were presented to an important group of scientists in London. The next year, Darwin published his ideas in the book *On the Origin of Species by Means of Natural Selection*.

There are four main principles to the theory of natural selection: variation, overproduction, adaptation, and descent with modification.

- **Variation** The heritable differences, or variations, that exist in every population are the basis for natural selection. The differences among individuals result from differences in the genetic material of the organisms, whether inherited from a parent or resulting from a genetic mutation.
- **Overproduction** While having many offspring raises the chance that some will survive, it also results in competition between offspring for resources.
- **Adaptation** Sometimes a certain variation allows an individual to survive better than other individuals it competes against in its environment. More successful individuals are “naturally selected” to live longer and to produce more offspring that share those adaptations for their environment.
- **Descent with modification** Over time, natural selection will result in species with adaptations that are well suited for survival and reproduction in an environment. More individuals will have the trait in every following generation, as long as the environmental conditions continue to remain beneficial for that trait.

A well-studied example of natural selection in jaguars is shown in **FIGURE 3.2**. About 11,000 years ago, many species faced extinction. Large cats, including jaguars, faced a shortage of food due to the changing climate of that time. There were fewer mammals to eat, so the jaguars had to eat reptiles. In
the jaguar population, there were variations of jaw and tooth size that became important for survival. Like many other species, jaguars can produce more offspring than can be supported by the environment. Jaguars with the biggest jaws and teeth could prey more easily on the shelled reptiles. Because jaw size and tooth size are heritable traits and were beneficial, large jaws and teeth became adaptations for this population. The jaguars’ descendants showed modifications, or changes, over time.

In biology, the term **fitness** is a measure of the ability to survive and produce more offspring relative to other members of the population in a given environment. After the change in climate, jaguars that had larger teeth and jaws had a higher fitness than other jaguars in the population. Jaguars that ate less didn’t necessarily all die or stop producing altogether; they just reproduced a little less. Today, large teeth and jaws are considered typical traits of jaguars.

**Compare and Contrast** What are the similarities and differences between natural selection and artificial selection?

**FIGURE 3.2 The Principles of Natural Selection**

Certain traits become more common in a population through the process of natural selection.

---

**OVERPRODUCTION**

A jaguar may produce many offspring, but not all will survive due to competition for resources.

**ADAPTATION**

Jaguars with larger jaws and teeth are able to eat shelled reptiles. These jaguars are more likely to survive and to have more offspring than jaguars that can eat only mammals.

**VARIATION**

Some jaguars, such as jaguar 1 shown here, may be born with slightly larger jaws and teeth due to natural variation in the population. Some variations are heritable.

**DESCENT WITH MODIFICATION**

Because large teeth and jaws are heritable traits, they become more common characteristics in the population.

---

**Summarize** How did large jaws and teeth become typical characteristics of jaguars? [TEKS] 7E
Scientists used mice to study whether exercise ability can improve in animals over several generations. In this experiment, mice were artificially selected for increased wheel-running behavior. The mice that were able to do the most wheel running were selected to breed the next generation. The control group represents generations of mice that were allowed to breed randomly.

- The x-axis shows different generations of mice, from Generation 1 to Generation 9.
- The y-axis shows the number of revolutions the mice ran on the wheel per day.
- The solid blue line represents the control group, in which generations of mice were allowed to breed randomly.
- The dotted orange line represents the generations of mice that were artificially selected based on their wheel-running ability. This is the experimental group.

1. **Interpret** What is the difference in results between the mice in the control group and the mice in the experimental group?

2. **Predict** Use the trend in the data to make a general prediction about the number of revolutions on the wheel per day for mice in Generation 10 of the experimental group.

**Main Idea**

Natural selection acts on existing variation.

Natural selection acts on phenotypes, or physical traits, rather than on genetic material itself. New alleles are not made by natural selection—they occur by genetic mutations. Natural selection can act only on traits that already exist.

**Changing Environments**

Ecologists Peter and Rosemary Grant observed an example of natural selection acting on existing traits within a population of medium ground finches on one of the Galápagos Islands. A drought in 1977 suddenly reduced the amount of small, soft seeds that the finches preferred. However, there were still plenty of large, tough-shelled seeds. Because the large-beaked finches in the population were able to crack the large, tough seeds, they did not starve. The next year, the Grants noted a big increase of large-beaked hatchlings. In contrast, most of the finches with small beaks had died.
Darwin’s theory predicted exactly what the Grants observed. A trait that was already in the population became favorable for survival because of a change in the environment, and thus was passed on to future generations.

As an environment changes, different traits will become beneficial. The numbers of large-beaked finches on this Galápagos Island kept rising until 1984, when the supply of large seeds went down after an unusually wet period. These conditions favored production of small, soft seeds and small-beaked birds. With evolution, a trait that is an advantage today may be a disadvantage in the future.

**Adaptations as Compromises**

One mistake people make about natural selection is to think that adaptive characteristics passed down over a long time result in individuals that are perfectly suited to their surroundings. This is not the case. For example, some structures may take on new functions. Pandas have a structure in their wrist that acts like a thumb. As pandas eat bamboo shoots, they hold the shoots as you would hold a carrot. However, a close look at the paw reveals that it has six digits: five digits that resemble your fingers, plus a small thumblike structure. The panda’s “thumb,” shown in **FIGURE 3.3**, is actually an enlarged wrist bone. The ancestors of today’s pandas had five full digits like today’s bears, but those early pandas with bigger wrist bones had an advantage in eating bamboo. Because of its size and position, this bone functions like a human thumb. It is not considered a true thumb, because it does not have separate bones and joints as a human thumb does. It is also not a typical wrist bone, as the bone is clearly longer than needed to function for the wrist. Instead, it functions both as a wrist bone and a thumb.

**Explain** Why is the panda’s “thumb” considered an adaptive compromise?

---

**10.3 Formative Assessment**

**REVIEWING MAIN IDEAS**

1. What did Darwin hope to learn about artificial selection by studying pigeons? **TEKS 7D, 7E**
2. What are the four principles of natural selection? **TEKS 7B**
3. Why must there be variation in the population in order for natural selection to occur? **TEKS 7D, 7E**

**CRITICAL THINKING**

4. **Evaluate** Explain why there was an increase in large-beaked finch hatchlings following a drought that left a finite amount of the small, soft seeds the birds preferred. **TEKS 7D**
5. **Synthesize** Why is it said that natural selection acts on phenotypes rather than on the genetic material of organisms? **TEKS 7E**

---

**CONNECT TO ECOLOGY**

6. You have learned that the environment affects how organisms change over generations. How would you explain a species that remains the same for millions of years? **TEKS 7B**
Evidence of Evolution

KEY CONCEPT Evidence of common ancestry among species comes from many sources.

MAIN IDEAS
- Evidence for evolution in Darwin’s time came from several sources.
- Structural patterns are clues to the history of a species.

Connect to Your World
Whenever you need to complete an assignment on an unfamiliar topic, you first need to gather information. The different pieces of information might come from the library, the Internet, your teachers, or maybe even your friends. Together, all these pieces help you to understand the topic. Darwin also drew information from many sources, all of which helped to strengthen his understanding of evolution.

Evidence for evolution in Darwin’s time came from several sources.

Darwin found evidence from a wide range of sources to support his argument for evolution. The most important and convincing support came from fossils, geography, developmental similarities, and anatomy.

Fossils
Even before Darwin, scholars studying fossils knew that organisms changed over time. Scientists who study fossils focus on more than just the fossil itself. They also think about its age, its location, and what the environment was like when the organism it came from was alive.

In the late 1700s, geologists wondered why certain types of fossils were found in some layers of rock and not others. Later studies suggested that the fossil organisms in the bottom, or older, layers were more primitive than those in the upper, or newer, layers. Geologists during this time were mostly interested in the order in which fossils were found within rock strata as a record of natural events such as earthquakes, not as proof of evolution. However, the sequential nature of fossil groups and other findings in the fossil record supported Darwin’s concept of descent with modification.

Geography
Recall that during the Beagle expedition Darwin saw that island plants and animals looked like, but were not identical to, species on the South American continent. He extended this observation, proposing that island species most closely resemble species on the nearest mainland.

FIGURE 4.1 This trilobite, an early marine invertebrate that is now extinct, was found in this loose rock bed in Ohio. Although far from modern-day oceans, this site is actually the floor of an ancient sea.
Darwin hypothesized that at some point in the past, some individuals from the South American mainland had migrated to the islands. This relationship between island and mainland species is today an important principle of **biogeography**, the study of the distribution of organisms around the world.

Different ecosystems on each island—with different plants, climates, and predators—had favored different traits in these migrants. Over time, these new traits became well established in the separate island populations, since the islands were too far apart for mating to occur.

One clear example of local adaptation is found in what are now known as Darwin's finches. The finches from the Galápagos Islands, shown in **Figure 4.2**, have distinct-looking beaks, as well as different habits, diets, and behaviors that evolved after generations of adaptation to specific island habitats. However, they all share a common ancestor from the South American mainland.

Since Darwin’s time, the same pattern of evolution on islands has been studied in many living things, such as fruit flies and honeycreepers found among the Hawaiian Islands. A 2011 study analyzing DNA from all living species of Hawaiian honeycreepers indicated that they are all likely descended from a population of rosefinches that arrived in Hawaii from Asia sometime between 7.2 million and 5.8 million years ago. The evidence from this study also indicated that nearly all species of honeycreepers likely diverged between 5.8 million and 2.4 million years ago, the same period during which the island of Oahu first appeared. Like the honeycreepers, most species of plants and animals on the Hawaiian Islands are not found anywhere else on Earth, and the age of these species is close to the age of the islands on which they live.

**Developmental Similarities**

A study proposing a relationship between barnacles, which are fixed in place as adults, and crabs, which are mobile at all stages in their life cycles, fascinated Darwin. Darwin collected specimens of barnacles over many years of research.

---

**FIGURE 4.2 Variation in Galápagos Finches**

**Finches on certain Galápagos Islands live in different environments and have beaks of different sizes and shapes.**

**Infer** What different environmental conditions might be found on the islands that these two species of finch inhabit?

- **Small tree finch** *Camarhynchus parvulus*:
  - Species in the genus *Camarhynchus* have biting strength at the tips of their beaks, which is useful for tearing vegetation.

- **Large cactus finch** *Geospiza conirostris*:
  - Species in the genus *Geospiza* have thick beaks and can feed on large, hard seeds that require strength for crushing.
In making his observations of these crustaceans, he noticed, as shown in Figure 4.3, that although adult crabs and barnacles are significantly different, their free-swimming larvae are very similar in appearance. These observations formed an important part of Darwin’s evidence for common descent.

**Notochord**  In the same fashion, embryos of vertebrates share many similar characteristics. For example, the embryos of fish, birds, reptiles, and mammals all have a flexible support rod in their backs called a notochord, for which the phylum Chordata is named. Primitive chordates, such as the fish-like lancelet, keep their notochords throughout their lives, while in the vertebrates, the notochord develops into part of the vertebral column.

**Dorsal nerve cord**  Within the notochord of both the lancelets and embryonic vertebrates lies a hollow nerve cord that runs along the dorsal, or back side, of the animal and extends into a flexible tail. Many vertebrates retain their tails as they develop a bony axial skeleton. However, in human embryos, the tail is generally absorbed into the other tissues prior to birth. In extremely rare cases, human babies are born with a short tail made of soft tissue, but the vast majority of humans only have a “tailbone” (the coccyx) at the end of the spine that does not extend to the outside.

**Pharyngeal arches**  All chordate embryos have six structures known as pharyngeal arches, separated by slits. The upper arches develop into structures of the face, ears, and jaws. In adult fish, the two lower arches become the gills. However, in humans, the fifth arch disappears and the third, fourth, and sixth arches develop into the nerves, bones, and other structures of the throat.

The similarity of features in vertebrate embryos, shown in Figure 4.4, has been the subject of controversy since the late 1800s, when Natural History of Creation (Natürliche Schöpfungsgeschichte) was published by German scientist Ernst Haeckel. A great follower of Darwin’s theory, Haeckel maintained that...
the stages of development found in vertebrate embryos reflected the stages of evolution for each of those organisms. This became known as the recapitulation theory and was stated as “ontogeny recapitulates phylogeny.”

His book and its accompanying drawings, which were borrowed and adapted from vertebrate anatomy experts of the time, immediately drew criticism from those who disputed evolutionary theory. Despite this, for many years, Haeckel’s drawings commonly appeared in textbooks throughout the world. When photography became more widely used, some scientists pointed out discrepancies in size and scale between Haeckel’s drawings and photographs. Other scientists argued that Haeckel openly stated in the captions of his drawings that he deliberately reduced them to similar sizes to enable observers to make comparisons. Although Haeckel revised and added new evidence with each of the five editions of his book, his reputation never recovered from the accusations of fraud. His recapitulation theory is no longer under serious consideration by scientists.

With today’s technology, scientists have shown that all vertebrates have a set of very similar genes that direct the development of body structures from a basic body plan. These genes, the Hox genes, are discussed in more detail in the chapter Invertebrate Diversity. Evidence such as this suggests that vertebrates and other organisms evolved from distant common ancestors.

Evaluate What aspects of Ernst Haeckel’s book led to criticism by his peers? [TEKS] 3F

FIGURE 4.4 Developmental Homologies

Although humans, pigs, and chickens appear different from each other as adults, several of the same structures can be seen at various stages in their developing embryos.

Analyze How would these similar structures provide evidence of a common vertebrate ancestor? [TEKS] 7A
Anatomy

Some of Darwin’s best evidence came from comparing the body parts of different species. Chief among such evidence were homologous structures. Homologous structures (huh-MAHL-uh-guhs) are features that are similar in structure but appear in different organisms and have different functions. Their appearance across different species offers strong evidence for common descent. It would be unlikely for many species to have such similar anatomy if each species evolved independently.

The most common examples of homologous structures are the forelimbs of tetrapod vertebrates. The forelimbs of humans, bats, and moles are compared in Figure 4.5. In all of these animals, and indeed in every tetrapod, the forelimbs have several bones that are very similar to each other despite their different functions. Notice also how the same bones vary in different animals. In addition to this, all tetrapods, including birds, will have five digits on their limbs at some point in their development. Homologous structures are different in detail but similar in structure and relation to each other.

In using homologous structures as evidence of evolution, Darwin posed a logical question: If each of these groups descended from a different ancestor, why would they share these homologous structures? A simple answer is that they share a common ancestor.

The idea of common descent provides a logical explanation for how homologous structures appeared in diverse groups. Having similar structures doesn’t always mean two species are closely related, however. Some structures found in different species have the same functions but did not evolve from a common ancestor.

**FIGURE 4.5 Homologous Structures**

Homologous structures, though they often have differing functions, are the result of a common ancestor.

![Human hand](image1)
![Bat wing](image2)
![Mole foot](image3)

Notice that each of these homologous structures uses the same bones in relation to the others.

**Apply** What body part of a dolphin is homologous to the structures shown above? TEKS 7A
Suppose two organisms have similar needs caused by the environment. For example, two different organisms benefit from the ability to fly. Both can develop similar adaptations using different body parts. Think about the wings of bats and the wings of flying insects. Clearly these organisms differ in more ways than they are similar. Insects are arthropods, while bats are mammals. The wings of bats and insects are called analogous structures, as shown in Figure 4.6. Analogous structures (uh-NAL-uh-guhs) are structures that perform a similar function—in this case, flight—but are not similar in origin. This means that in each of the organisms, the analogous structures did not derive from the same original structure. Bat wings, when examined closely, have the same bone structure as an elongated hand, connected by thin skin. In contrast, insect wings do not have bones, only membranes that are supported by a series of long veins with cross-connections for strength. The similar function of wings in bats and flying insects evolved separately. Their ancestors faced similar environmental challenges and evolved similar adaptations to overcome those challenges.

Analyze Using the terms homologous and analogous, identify which group of structures provides evidence for a common ancestor. Explain.

QUICKLAB INFERRING TEKS 7A

Piecing Together Evidence
Evolutionary biologists and paleontologists rarely get all of the pieces of what they are studying. In this activity, you will receive pieces of “evidence” about a picture in order to make observations, inferences, and predictions about it.

PROBLEM How are inferences modified when new information is obtained?

PROCEDURE
1. Using the three strips that your teacher has provided, write down all observations and inferences that you can make about this picture.
2. Make a prediction about the picture’s topic, using your observations as supporting evidence for your prediction.
3. Record observations, inferences, and a prediction for each remaining strip of “evidence” that you receive from your teacher.

ANALYZE AND CONCLUDE
1. Analyze What inferences did you modify as you gathered more evidence from your teacher?
2. Provide Examples What type of evidence might paleontologists find that would allow them to see the big picture of a species’ evolutionary past?
Main Idea

Structural patterns are clues to the history of a species.

Some organisms have structures or organs that seem to lack any useful function, or at least are no longer used for their original purpose. For example, snakes have tiny pelvic bones and stumplike limbs, even though snakes don’t walk. Underdeveloped or unused features are called vestigial structures. Vestigial structures (veh-STIHJ-ee-uhl) are remnants of organs or structures found in an early ancestor that no longer serve a useful function or may now serve a different function. As vertebrates, snakes share a common ancestor with tetrapods such as lizards and dogs. The tiny pelvic bones and hind limbs in many snakes are homologous to the pelvic bones of tetrapods.

The wings of ostriches are another example of vestigial structures. Ostriches use wings for balance but not to fly, as shown in Figure 4.7. Over generations, their increasingly large bodies and powerful long legs may have been enough to avoid predators. If ancient ostriches could escape by running or by kicking viciously, their large wings would no longer have been useful. Thus, the genes coding for large wings were not preserved over generations.

Examples of vestigial structures are found in many organisms. In humans, the appendix is often cited as an example of a vestigial structure. The appendix is a remnant of the cecum, a major part of the large intestine in plant-eating mammals. It helps to digest the cellulose in plants. As omnivores, humans do not eat much cellulose and the appendix cannot digest cellulose. Whether or not the appendix retains any function is still not certain.

Vestigial structures did not get smaller in one individual organism. It took many generations for those organs to shrink. Today, biologists consider vestigial structures among the most important examples demonstrating how evolution works.

Summarize What are vestigial structures, and how do they demonstrate common ancestry? TEKS 7A

Formative Assessment

Reviewing Main Ideas

1. Describe the four sources of evidence for evolution upon which Darwin based his ideas on common ancestry. TEKS 8F, 7A
2. Why are vestigial structures considered critical evidence of evolution? TEKS 7A

Critical Thinking

3. Evaluate How would you assess the biogeographic evidence used to explain the divergence of Hawaiian honeycreeper species? TEKS 7A
4. Apply How can a bat’s wing be considered both a homologous structure and an analogous structure? TEKS 7A

5. Wisdom teeth are a third set of molars that usually appear in humans between the ages of 17 and 25, and often need removing because they crowd out other teeth. Explain why wisdom teeth are vestigial structures. TEKS 7A
**Online Biology**

**Change Comes Naturally**

**Evolution by Natural Selection**
See how disease-causing bacteria can evolve resistance to antibiotics.

**Finch Beak Data**
Find out how beak depth in a species of Darwin’s finches differs between islands with different levels of competition.

**Natural Selection**
See a population evolve—or not. Discover how populations can evolve, and how each principle of natural selection is important to the process.
Evolutionary Biology Today

**KEY CONCEPT** New technology is furthering our understanding of evolution.

**MAIN IDEAS**
- Fossils provide a record of evolution.
- Molecular and genetic evidence support fossil and anatomical evidence.
- Evolution unites all fields of biology.

**Connect to Your World**

Darwin had spent many years collecting evidence of evolution from different fields of science before publishing his results. Since that time, technology has advanced greatly. Scientists can now share information and examine evidence that was only dreamed about in the 1800s. In particular, the relatively new fields of genetics and molecular biology have added strong support to Darwin’s theory of natural selection. They have shown how hereditary variation occurs.

**MAIN IDEA**

**TEKS 7A, 7B**

**Fossils provide a record of evolution.**

**Paleontology** (pay-lee-ahn-TAHL-uh-jee), the study of fossils or extinct organisms, continues to provide new information and support current hypotheses about how evolution occurs. The fossil record is not complete, because most living things do not form into fossils after they die, and because fossils have not been looked for in many areas of the world. However, no fossil evidence that contradicts evolution has ever been found.

In Darwin’s time, paleontology was still a new science. Darwin worried about the lack of transitional fossils between groups of organisms. Since Darwin’s time, however, many transitional forms between species have been discovered, filling in large gaps in the fossil record. The fossil record today includes many thousands of species that show the change in forms over time that Darwin outlined in his theory. These “missing links” demonstrate the evolution of traits within groups as well as the common ancestors between groups.

Although scientists classify organisms into groups, the mix of traits in transitional species often makes it difficult to tell where one group ends and another begins. One example of transitional species in the evolution of whales is shown in **FIGURE 5.1.** *Basilosaurus isis* had a whalelike body, but it still had the limbs of land animals.

**Infer** Why are fossils such as *Basilosaurus isis* considered transitional fossils? **TEKS 7B**

---

**FIGURE 5.1** This skeleton of *Basilosaurus isis* was found in a desert in Egypt in 2005. It lived about 40 million years ago and has characteristics of both land and marine animals.
Molecular and genetic evidence support fossil and anatomical evidence.

As with homologous traits, very different species have similar molecular and genetic mechanisms. Because all living things have DNA, they share the same genetic code and make most of the same proteins from the same 20 amino acids. DNA or protein sequence comparisons can be used to show probable evolutionary relationships between species.

**DNA sequence analysis** Recall that the sequences of nucleotides in a gene change over time due to mutations. DNA sequence analysis depends on the fact that the more related two organisms are, the more similar their DNA will be. Because there are thousands of genes in most organisms, DNA contains a huge amount of information on evolutionary history.

Because all living organisms share the same genetic code and use the same 20 amino acids, it has been possible to determine that organisms share a remarkable number of proteins that are similar to one another. Due to mutations, the sequences of nucleotides change over time. Thus, comparing the sequences of DNA in organisms can show evolutionary relationships among the organisms. Scientists hope to eventually be able to correlate changes in DNA sequences with past geological events.

**Pseudogenes** Sequences of DNA nucleotides known as pseudogenes also provide evidence of evolution. Pseudogenes are like vestigial structures. They no longer function but are still carried along with functional DNA. They can also change as they are passed on through generations, so they provide another way to figure out evolutionary relationships. Functioning genes may be similar in organisms with similar lifestyles, such as a wolf and a coyote, due to natural selection. Similarities between pseudogenes, however, must reflect a common ancestor.

**Protein comparisons** Similarities among cell types across organisms can be revealed by comparing their proteins, a technique called molecular fingerprinting. A unique set of proteins are found in specific types of cells, such as liver or muscle cells. Computers are used to search databases of protein sequences and look for homologous sequences in different species. Cells from different species that have the same proteins most likely come from a common ancestor. For example, the proteins of light-sensitive cells in the brainlike structure of an ancient marine worm, as shown in **FIGURE 5.2**, were found to closely resemble those of cells found in the vertebrate eye. This resemblance shows a shared ancestry between worms and vertebrates. It also shows that the cells of the vertebrate eye originally came from cells in the brain.

**Homeobox genes** As you will learn in the chapter Invertebrate Diversity, homeobox genes control the development of specific structures. These sequences of genes are found in many organisms, from fruit flies to humans. They also indicate a very distant common ancestor. Evidence of homeobox gene clusters are found in organisms that lived as far back as 600 million years ago.

**VOCABULARY**

**Pseudogene** A DNA sequence that resembles a gene but seems to have no function. _Pseudo-_ means “false” or “deceptive.”

**FIGURE 5.2** The eye spots of this ragworm have light-sensitive cells with a molecular fingerprint similar to that of a vertebrate eye.

**TEKS 7A**

**EXPLAIN** How have protein comparisons helped determine ancestral relationships between organisms?
Fossil Evidence
There are many transitional fossils that have characteristics of both land mammals and whales. These are a few examples.

**Dorudon** about 40 million years ago
Tiny hind legs were useless on land, and a shorter neck and longer tail makes *Dorudon* similar to modern-day whales. Its ankle joints closely resemble those of modern ungulates.

**Ambulocetus natans** about 50 million years ago
With a name that means “the walking whale that swims,” *Ambulocetus natans* was an amphibious fish eater the size of a sea lion.

**Pakicetus** about 50 million years ago
*Pakicetus* had a whale-shaped skull and teeth adapted for hunting fish. However, with ear bones that are in between those of land and aquatic mammals, it could not hear well underwater or make deep dives.

Vestigial Evidence
Many modern whale species have vestigial pelvic and leg bones. They also have vestigial nerves for the sense of smell, and small muscles devoted to external ears that no longer exist.

Embryological Evidence
Whale embryos have features such as hind leg buds and nostrils that resemble those of land animals. Nostrils are at the end of the whale’s snout early in development but travel to the top of the head to form one or more blowholes before birth.

Molecular Evidence
The DNA sequences of milk protein genes in whales and hoofed mammals are very similar, as demonstrated by the DNA fragments below.

<table>
<thead>
<tr>
<th>Species</th>
<th>DNA Sequence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hippopotamus</td>
<td>TCC TGGCA GTCCA GTGGT</td>
</tr>
<tr>
<td>Humpback whale</td>
<td>CCC TGGCA GTGCA GTGCT</td>
</tr>
</tbody>
</table>

CRITICAL VIEWING
Whales are divided into two groups: toothed whales, such as the orca pictured above, and baleen whales, such as the humpback whale pictured on the next page. Which would you predict is most closely related to *Dorudon*? Explain.
Evolution unites all fields of biology.

Scientists are still actively studying evolution through natural selection. The 21st century is an exciting time to study evolutionary biology. New tools are providing more data than ever before. Considering the number of proteins in a single organism, the amount of data gathered through molecular evidence alone is overwhelming.

Scientists from many fields of science are shedding new light on the mechanisms and patterns of evolution. In some cases, the use of modern technology has supported fossil evidence. For example, you have read that fossil evidence suggests that early ancestors of whales were hoofed land mammals. Comparing the examples from the fossil record shown in FIGURE 5.3 highlights the transitional characteristics between land mammals and whales. Shifts in skull shape, modified limb structures, and changes in tail length provide evidence for the descent of modern whales from a common ancestor with the group of hoofed mammals that includes deer, antelope, and hippopotamuses. Comparisons of milk protein genes confirm this relationship and even provide evidence that the hippopotamus is the closest living land animal related to whales.

The basic principles of evolution are used in fields such as medicine, geology, geography, chemistry, and ecology. The idea of common descent helps biologists understand where new diseases come from, as well as how to best manage endangered species. There is so much more waiting to be discovered about life on Earth. As the great geneticist Theodosius Dobzhansky (1900–1975) once noted, “Nothing in biology makes sense except in the light of evolution.”

**Evaluate** How would you rate the strength of the support provided by fossil evidence for common ancestry among groups such as land mammals and whales? Explain. [TEKS 7A]

**Connect to**

**Genetics**

6. Researchers have found that a gene controlling reproduction is linked to the gene for the number of digits an organism has. How does this help explain why many vertebrates have five digits per limb, despite the fact that there is no fitness benefit in having five rather than six or four? [TEKS 7A]
10 Summary

KEY CONCEPTS
10.1 Early Ideas About Evolution
There were theories of biological and geologic change before Darwin. Early biologists suggested that different species might have shared ancestors, and geologists observed that new species appeared in the fossil record. Charles Lyell proposed the theory of uniformitarianism to explain how present-day observations explain past events.

10.2 Darwin's Observations
Darwin's voyage provided insights into evolution. Darwin observed variations between island species on his voyage, such as with the Galapagos tortoises. He noticed that species have adaptations that allow them to better survive in their environments. He also observed fossil evidence of species changing over time.

10.3 Theory of Natural Selection
Darwin proposed natural selection as a mechanism for evolution. Natural selection is a mechanism by which individuals that have inherited beneficial adaptations produce more offspring on average than do other individuals. Natural selection is based upon four principles: overproduction, variation, adaptation, and descent with modification.

10.4 Evidence of Evolution
Evidence of common ancestry among species comes from many sources. Fossil evidence is a record of change in a species over time. The study of biogeography showed that species could adapt to different environments. Two species that exhibit similar traits during development likely have a common ancestor. Vestigial and homologous structures also point to a shared ancestry.

10.5 Evolutionary Biology Today
New technology is furthering our understanding of evolution. Modern techniques, such as DNA sequence analysis and molecular fingerprinting, continue to provide new information about the way evolution occurs. Evolution is a unifying theme of all the fields of biology today.

READING TOOLBOX
SYNTHESIZE YOUR NOTES

Main Idea Web Use a main idea web to summarize the four principles of natural selection.

Concept Map Use a concept map like the one below to summarize what you know about evolutionary evidence.
Reviewing Vocabulary

Vocabulary Connections
The vocabulary terms in this chapter are related to each other in various ways. For each group of words below, write a sentence or two to clearly explain how the terms are connected. For example, for the terms variation and natural selection, you could write “Natural selection depends on heritable variations.”

1. catastrophism, gradualism
2. population, variation
3. adaptation, evolution
4. vestigial structure, analogous structure
5. fossil, paleontology

6. The term homologous comes from the Greek word homos, which means “the same.” Explain how this meaning relates to homologous structures.

7. The term vestigial comes from the Latin word vestigium, which means “track or footprint.” Explain how this meaning relates to vestigial structures.

Reviewing MAIN IDEAS

8. Describe one idea about evolution that was proposed before Darwin published his theory of natural selection.

9. Briefly explain how the geologist Charles Lyell influenced Darwin’s ideas about how evolution works.

10. What insights did Darwin gain from observing island organisms such as the Galápagos tortoises and finches? **TEKS 7E**

11. On his voyage, Darwin found fossils of extinct organisms that resembled living organisms and shells of marine organisms high up in the mountains. How did these observations provide evidence that Earth is very old?

12. Thomas Malthus was an economist who proposed that resources such as food, water, and shelter are natural limits to human population growth. Explain how Darwin extended this idea in his theory of natural selection. **TEKS 7D**

13. Why is heritability important for both natural and artificial selection? **TEKS 7D**

14. Natural selection is based on four main principles: variation, overproduction, adaptation, and descent with modification. Briefly explain how each of these principles is necessary for natural selection to occur. **TEKS 7D, 7E**

15. Explain how the sequential nature of fossil groups found in rock strata supports Darwin’s principle of “descent with modification.” **TEKS 7B**

16. Embryology provides evidence of evolution by revealing developmental homologies among species. Analyze and evaluate one example of such embryological evidence. **TEKS 7A**

17. Give an example of a vestigial structure and explain how vestigial structures are significant to evolution.

18. Paleontology is the study of fossils or extinct organisms. Explain how this field is important to evolutionary biology.

19. How are genes and proteins similar to homologous structures when determining evolutionary relationships among species? **TEKS 7A**

20. Explain what the following quote by Theodosius Dobzhansky means: “Nothing in biology makes sense except in the light of evolution.”
Critical Thinking

21. **Compare**  Jean-Baptiste Lamarck hypothesized that changes in an environment led to an organism’s greater or lesser use of a body part. Although his hypothesis was incomplete, what ideas related to evolution did Lamarck and Charles Darwin share? **TEKS 3F**

22. **Evaluate**  What types of scientific evidence provide support for common ancestry among groups such as land mammals and whales? How would you assess the relative strength of these different types of evidence? **TEKS 7A**

23. **Analyze**  The turkey vulture and the California condor both feed upon dead animals, known as carrion. Neither species of bird has feathers on its head. Explain how natural selection may have played a role in the featherless heads of these carrion eaters. **TEKS 7E**

24. **Analyze**  What are three trends that biologists have identified in the transitional characteristics of different groups in the whale fossil record? **TEKS 7B**

**Interpreting Visuals**

Use the following diagram, which shows the evolution of the wild mustard plant, to answer the next three questions.

![Diagram of wild mustard plant evolution]

25. **Infer**  Traits of the wild mustard plant have been emphasized by artificial selection to produce different vegetables. In some varieties, the flower heads were emphasized. In other vegetables, it was the leaves or the stems that were to be eaten. Which traits were emphasized to produce broccoli? Cabbage?

26. **Apply**  Describe a procedure humans may have used to produce broccoli, which has small flowers and thick stems.

27. **Predict**  What would a protein comparison of broccoli, cabbage, and cauliflower confirm about their relationships to each other? **TEKS 7A**

Analyzing Data  **Interpret Line Graphs**

One hundred million seabirds use the island of Gaugh, in the South Atlantic Ocean, as a critical nesting ground. Non-native carnivorous mice eat the helpless seabird chicks at a rate of about 1 million per year. Prior to the arrival of the mice, no natural predators existed on the island, so the birds did not evolve any defense mechanisms. Scientists estimate the current population of the mice at 700,000. The graph below displays a projection of seabird casualties and changes in the size of the mouse population.

**SEABIRD CASUALTIES AND MOUSE POPULATION**

![Line graph showing seabird casualties and mouse population over 20 years]

28. **Interpret**  What does the graph show about seabird casualties and the mouse population over a 20-year period?

29. **Predict**  Imagine that some seabirds began defending their nests from the mice, and that this behavior is heritable. What changes might such a graph show over the next 20 years? Explain.

Making Connections

30. **Write a Scenario**  Imagine a way in which seabirds could adapt to the mouse population and avoid predation of their chicks. Then consider how, after many generations, the mouse population could counter this defense and again limit the seabird population. What are possible adaptations that could lead to this co-evolution of mice and seabirds? **TEKS 7E**

31. **Synthesize**  Look again at the picture of the star-nosed mole. Its claws are well adapted for breaking through soil. How could natural selection have played a role in this trait becoming common among star-nosed moles? **TEKS 7C, 7E**
MULTIPLE CHOICE

1. As developing embryos, some organisms appear to have features that are similar in structure. As these organisms continue their development, features that were similar in the embryonic stage develop into different structures that have different functions. What type of evidence of common ancestry do these features represent?
   A. vestigial structures
   B. homologous structures
   C. analogous structures
   D. fossil structures

2. Although the fossil record is incomplete, paleontologists continue to search for fossils that are commonly referred to as “missing links.” What evidence of evolution do discoveries of fossil evidence known as “missing links” provide to scientists?
   A. Discoveries of “missing links” provide fossil evidence that contradicts the theory of evolution.
   B. Discoveries of “missing links” show that organisms once thought to be related are not.
   C. Discoveries of “missing links” serve as transitional species that show the evolution within and between related groups.
   D. Discoveries of “missing links” serve as additional evidence that organisms do not change or evolve.

3. All vertebrates have very similar Hox genes. How does this provide evidence suggesting vertebrates evolved from a common ancestor?
   A. Greater similarity of genes indicates closer evolutionary relationships among species.
   B. Species with major differences in Hox genes would have gone extinct.
   C. The greater the number of Hox genes present, the greater the relationship among species.
   D. Hox genes control the same genes in all species of vertebrates.

4. The diagram below represents several sedimentary rock layers in which fossils of different organisms have been found. The rock layers show no evidence of having been disturbed since their formation.
   ![Rock Layers Diagram]

What information about the ages of the fossils relative to each other can be explained by their positions in these rock layers?
   A. The rock layers do not provide any information about the ages of the fossils relative to each other.
   B. The rock layers suggest that the fossils in layer A are much older than those in layers B, C, D, and E.
   C. The rock layers suggest that the oldest fossils are in layer E and the youngest are in layer A.
   D. The rock layers suggest that all of the fossils found in the rocks will be of the same age regardless of the type of organism the fossil represents.

5. An herbicide killed 99% of a weed population. Which of the following is the best biological explanation for some weeds being able to survive?
   A. Some individuals were able to evolve before the spraying.
   B. The spray caused some individuals to mutate, and they were able to survive and reproduce.
   C. Each individual occupied a different ecological niche and so some were unaffected.
   D. Genetic variation in the population allowed some weeds to survive.

THINK THROUGH THE QUESTION

Consider what conditions must be present for natural selection to occur.