CHAPTER

10 Principles of Evolution

KEY CONCEPTS

10.1 Early Ideas About Evolution

There were theories of biological and geologic change before Darwin.

10.2 Darwin's Observations

Darwin's voyage provided insights into evolution.

10.3 Theory of Natural Selection

Darwin proposed natural selection as a mechanism for evolution.

10.4 Evidence of Evolution

Evidence of common ancestry among species comes from many sources.

10.5 Evolutionary Biology Today

New technology is furthering our understanding of evolution.

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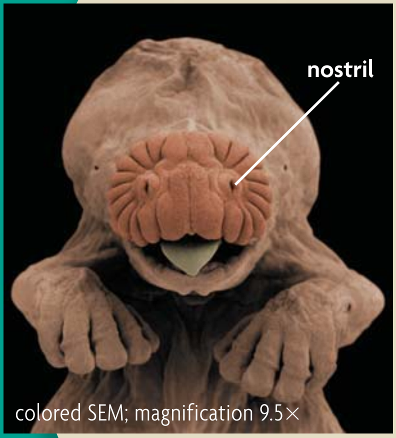
- Genetic Tools to Study Evolution

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.

Connecting CONCEPTS



colored SEM; magnification 9.5×

Genetics The pink rays that sprout around the star-nosed mole's nostrils develop differently from the body parts of any other animal. After the mole is born, the rays spring forward to form their "star." Scientists are researching whether the mole has a unique set of genes for development. In this chapter, you will learn how genes are involved in evolution.

10.1 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.

VOCABULARY

evolution, p. 298
species, p. 298
fossil, p. 300
catastrophism, p. 301
gradualism, p. 301
uniformitarianism, p. 301

Review
hybridization

REVIEW AT CLASSZONE.COM

Connect 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 something 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.

MAIN IDEA

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 how 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 came out with new ways of looking at the world. 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 10.1** highlights the work of some of these early scientists.

TAKING NOTES

Create a chart with a column for each scientist mentioned in this section and a second column for his contribution to evolutionary theory.

Scientist	Contribution
Linnaeus	
Buffon	

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 so similar to one another that they can reproduce and have 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.

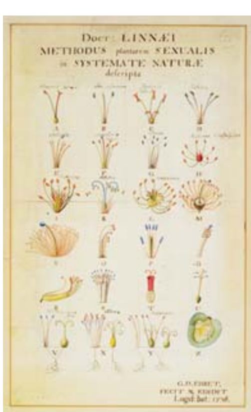
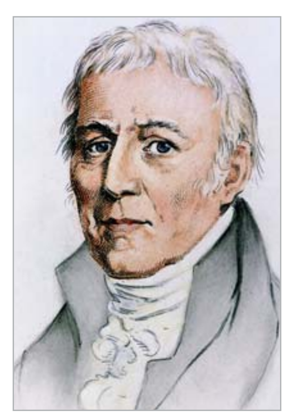
Lamarck proposed that changes in an environment caused an organism's behavior to change, leading to greater use or disuse of a structure or organ. The structure would become larger or smaller as a result. The organism would pass on these changes to its offspring. For example, Lamarck thought that the 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.

***Connecting* CONCEPTS**

Scientific Process Recall from **Chapter 1** that in every scientific field, knowledge is built upon evidence gathered by earlier scientists.

FIGURE 10.1 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.

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

Summarize **Explain why Darwin cannot be considered the first scientist to consider evolution.**

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 idea 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?**

MAIN IDEA

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 10.2**.

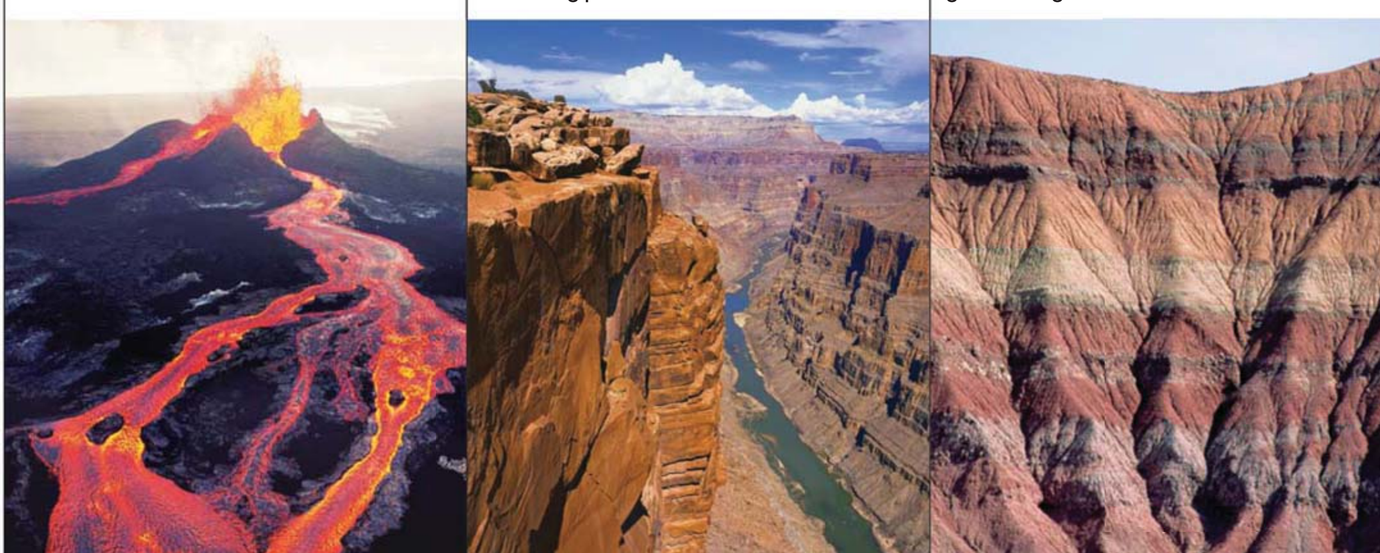
***Connecting* CONCEPTS**

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 10.2 Principles of Geologic Change

Ideas from geology played a role in Darwin's developing theory.

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



Compare and Contrast **How are these three theories similar, and what are their differences?**

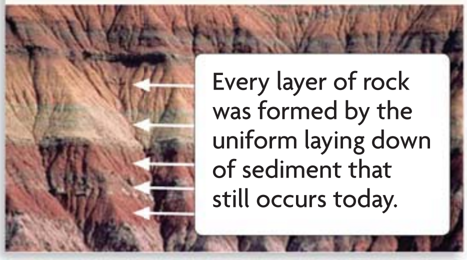
The theory of **catastrophism** (kuh-TAS-truh-FIHZ-uhm) states that natural disasters such as floods and volcanic eruptions have happened often during Earth's long history. These events shaped landforms and caused species to become extinct in the process. Cuvier argued that the appearance of new species 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-oo-uh-LIHZ-uhm). He argued that the laying down of soil or the creation of canyons by rivers cutting through rock were not the result of large-scale events. Rather, 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-nuh-FAWR-mih-TAIR-ee-uh-NIHZ-uhm). 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.

VISUAL VOCAB

Uniformitarianism proposes that present geologic processes are the key to the past.



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

VOCABULARY

The names of these geologic theories can be broken down into familiar words.

- *Catastrophe* means "sudden disaster."
- *Gradual* means "moving or changing slowly."
- *Uniform* means "always staying the same."

Connecting CONCEPTS

Scientific Process Recall from **Chapter 1** that in science, the term *theory* describes a well-supported explanation that incorporates observations, inferences, and tested hypotheses.

10.1 ASSESSMENT

ONLINE QUIZ ClassZone.com

REVIEWING MAIN IDEAS

1. Briefly describe two ideas about **evolution** that were proposed by scientists in the 18th century.
2. What ideas in Lyell's theory of **uniformitarianism** were important for evolutionary theory?

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?

Connecting CONCEPTS

5. **Genetics** How can you use the concept of genetic inheritance to disprove Lamarck's idea of the inheritance of acquired characteristics?

10.2 Darwin's Observations

KEY CONCEPT Darwin's voyage provided insights into evolution.

MAIN IDEAS

- Darwin observed differences among island species.
- Darwin observed fossil and geologic evidence supporting an ancient Earth.

VOCABULARY

variation, p. 302
adaptation, p. 302

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Connect Lyell's views of gradual geologic change greatly influenced Darwin's thinking. In 1831, the ship HMS *Beagle* set sail from England 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 among island species.

Darwin, shown in **FIGURE 10.3**, 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 (*inter*specific variation) or among individuals of the same species (*intra*specific 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 10.4.** 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 in its environment. Adaptations can lead to genetic change in a population over time.

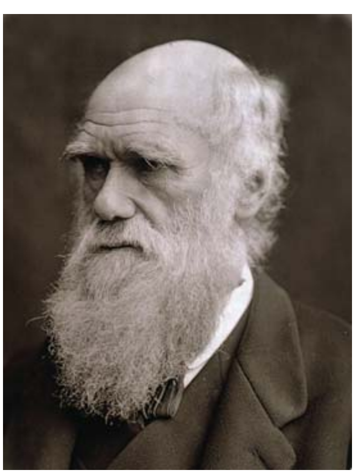


FIGURE 10.3 Darwin spent more than 20 years compiling evidence before publishing in 1859 his ideas on how evolution works.

Connect What adaptations did Darwin see in the finches of the Galápagos Islands?

FIGURE 10.4 Adaptations Within Species

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

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

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

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

Galápagos Islands

MAIN IDEA

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.

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

10.2 ASSESSMENT

ONLINE QUIZ
ClassZone.com

REVIEWING MAIN IDEAS

1. What accounts for the **variation** Darwin observed among island species?
2. What did Darwin learn from the fossils that he observed on his voyage?

CRITICAL THINKING

3. **Apply** Explain how wings are an **adaptation** for birds.
4. **Synthesize** How did Darwin's observations support Lyell's theory of an ancient Earth undergoing continual geologic change?

Connecting CONCEPTS

5. **Ecology** 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?

10.3 Theory of Natural Selection

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.

VOCABULARY

artificial selection, p. 304
heritability, p. 304
natural selection, p. 305
population, p. 306
fitness, p. 307

Review
phenotype,
competition

REVIEW AT CLASSZONE.COM

Connect Although Darwin began his voyage thinking that species could not change, his experiences during the five-year journey altered his thinking. Variation of similar species among islands, fossil evidence, and geologic events convinced him that evolution occurs. But he had yet to determine *how* evolution could happen.

MAIN IDEA

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 how evolution occurs. Although he had traveled the world, Darwin also found great insight in his home country of England. One important influence of Darwin's 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. Humans had been breeding pigeons for thousands of years, producing pigeons, such as those in **FIGURE 10.5**, that showed many different traits. 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, if a feature is not desirable or "useful," it might be selected against. 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.

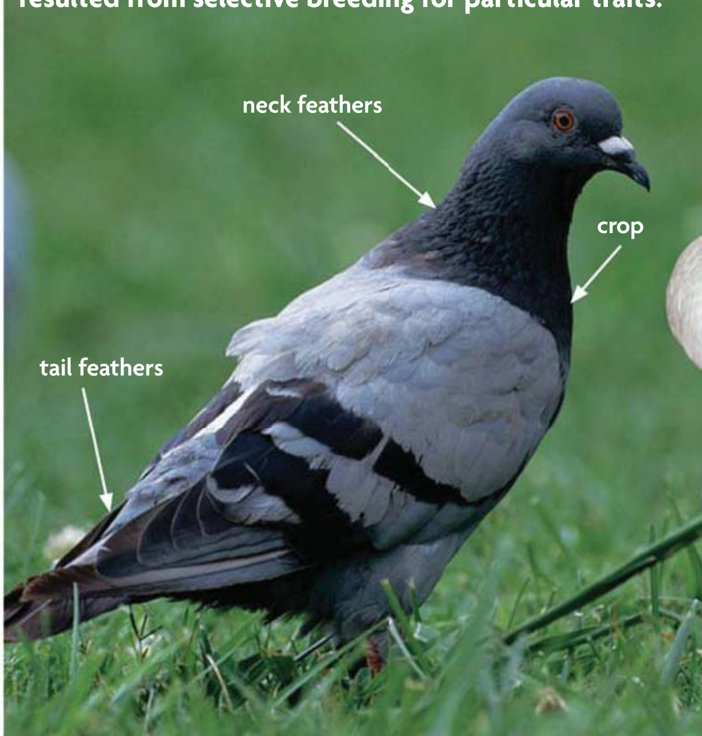
Darwin used this line of thinking for his theory of natural selection. **Natural selection** is a mechanism by which individuals that have inherited beneficial adaptations produce more offspring on average than do other individuals. In nature, the environment is the selective agent. Therefore, in nature, characteristics are selected only if they give advantages to individuals in the environment as it is right now. Furthermore, Darwin reasoned, breeds are not produced perfectly all at once. He knew 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 supply kept the population smaller.

FIGURE 10.5 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

Connect **What other species of organisms are often subjects of artificial selection?**

Darwin reasoned that a similar struggle took place in nature. Resources were limited, and organisms had more offspring than could ever survive. Why did some individuals, and not others, survive?

VOCABULARY

The term *descent* is used in evolution to mean the passing of genetic information from generation to generation.

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?**

MAIN IDEA

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 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.*

TAKING NOTES

Write a sentence in your own words that summarizes each of the four principles of natural selection.

variation
overproduction
adaptation
descent with modification

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 10.6.** 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.

VOCABULARY

In everyday language, *fitness* means "physically fit." In biology, however, fitness is related to reproductive success.

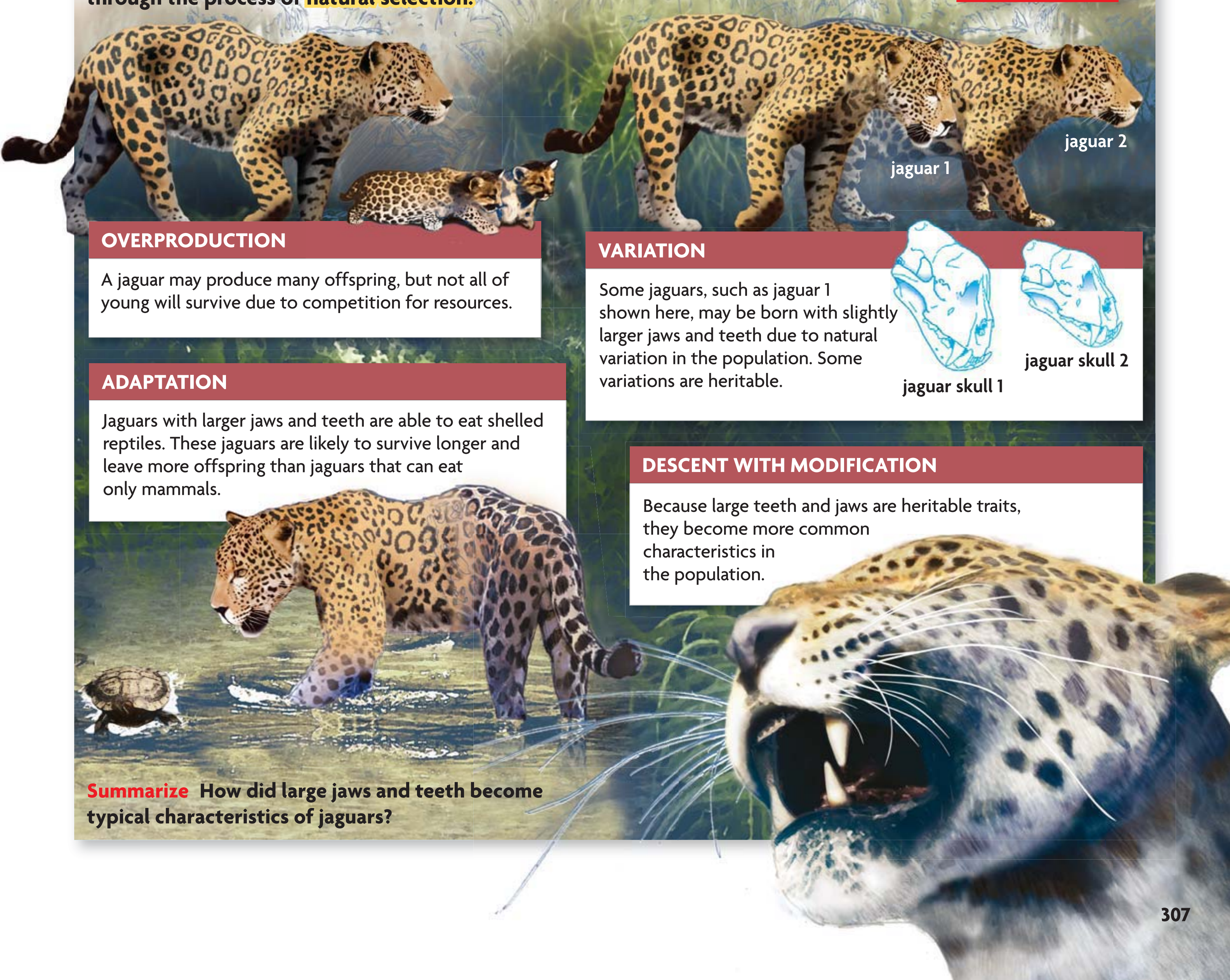
Compare and Contrast **What are the similarities and differences between natural selection and artificial selection?**

Animated BIOLOGY

Watch the principles of natural selection in action at ClassZone.com.

FIGURE 10.6 The Principles of Natural Selection

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



Summarize **How did large jaws and teeth become typical characteristics of jaguars?**

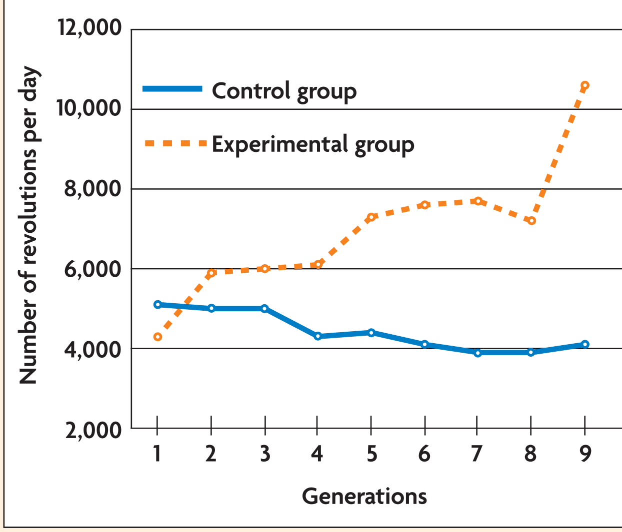
DATA ANALYSIS

INTERPRETING LINE GRAPHS

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 the 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 activity. This is the experimental group.

GRAPH 1. SELECTION OF EXERCISE ABILITY



Source: Swallow et. al, *Behavior Genetics* 28:3.

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.

FIGURE 10.7 A panda's wrist bone also functions like a thumb.

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 10.7**, 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?**

NSTA scilinks.org SCILINKS

To learn more about natural selection, visit scilinks.org.
Keycode: MDL010

10.3 ASSESSMENT

ONLINE QUIZ ClassZone.com

REVIEWING MAIN IDEAS

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

CRITICAL THINKING

4. **Evaluate** Explain why the phrase "survival of the fittest" does not accurately reflect Darwin's concept of evolutionary **fitness.**
5. **Synthesize** Why is it said that natural selection acts on phenotypes rather than on the genetic material of organisms?

Connecting CONCEPTS

6. **Ecology** 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?

10.4 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.

VOCABULARY

biogeography, p. 311
homologous structure, p. 312
analogous structure, p. 313
vestigial structure, p. 314

REVIEW AT CLASSZONE.COM

Connect How genetic inheritance works was not known while Darwin was working on his theory of natural selection. However, Darwin documented natural selection from every angle available at the time. His thoroughness was important. It left no doubt in the minds of scientists that all organisms have a past history. Today, the concept of evolution ties together all fields of biology.

MAIN IDEA

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, embryology, and anatomy.

Fossils

Even before Darwin, scholars studying fossils knew that organisms changed over time. Scientists who study fossils study 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 were interested in fossil sequences as a record of events such as earthquakes that disturb rock strata, not as proof of evolution. However, these and other findings in the fossil record supported Darwin's concept of descent with modification.

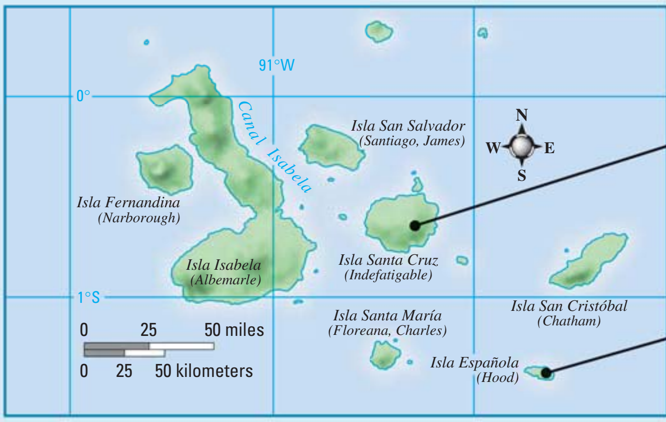
FIGURE 10.8 This trilobite, an early marine invertebrate that is now extinct, was found in this loose rock bed in Ohio. Although far from modern-day oceans, this site is actually the floor of an ancient sea.

Geography

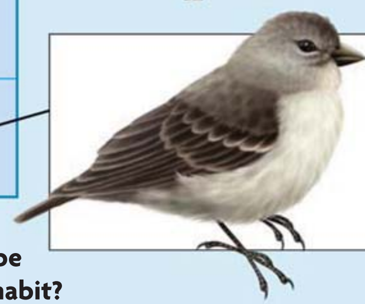
Recall that during the *Beagle* expedition Darwin saw that island plants and animals looked like, but were not identical to, species on the South American continent. He extended this observation, proposing that island species most closely resemble species on the nearest mainland. He hypothesized that at some point in the past, some individuals from the South American mainland had migrated to the islands.

FIGURE 10.9 Variation in Galápagos Finches

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



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.



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.

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

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 10.9**, 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 on the Hawaiian Islands. Darwin was the first scientist to establish this relationship between island and mainland species. Today this is an important principle of **biogeography,** the study of the distribution of organisms around the world.

Embryology

A study proposing a relationship between crabs, which can walk, and barnacles, which are fixed in one place as adults, fascinated Darwin. He had collected barnacles for many years and had noted that immature crabs and barnacles, called larvae, were similar. As **FIGURE 10.10** shows, barnacle and crab larvae both swim and look alike, but the adult animals look and behave very differently.

FIGURE 10.10 Although adult crabs and barnacles look and behave very differently, they can look identical as larvae. This suggested to Darwin that they share a common ancestor.

Larva

Adult crab

Adult barnacles

Like larvae, embryos of vertebrates can be hard to tell apart. For example, fish, birds, reptiles, and mammals all have gill slits as embryos. The gill slits become gills in adult fish. In mammals, the gill slits develop into structures of ears and throats. These observations formed an important part of Darwin's evidence for common descent. The similar features of embryos in very different organisms suggest evolution from a distant common ancestor.

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.

VOCABULARY

A tetrapod is a four-limbed animal. *Tetra-* means "four," and *-pod* means "foot."

The most common examples of homologous structures are the forelimbs of tetrapod vertebrates. The forelimbs of humans, bats, and moles are compared in **FIGURE 10.11**. In all of these animals, 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. 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.

FIGURE 10.11 Homologous Structures

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

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?**

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.

Suppose two organisms have similar needs caused by the environment. For example, two different organisms need to be able 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 10.12**. **Analogous structures** (uh-NAL-uh-guhs) are structures that perform a similar function—in this case, flight—but are not similar in origin. Bat wings have bones. In contrast, insect wings do not have bones, only membranes. The similar function of wings in bats and flying insects evolved separately. Their ancestors faced similar environmental challenges and came upon similar solutions.

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

FIGURE 10.12 ANALOGOUS STRUCTURES

Analogous structures evolved separately and are not evidence of a common ancestor. A bat's wing has bones, whereas insect wings do not.

QUICK LAB **INFERRING**

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?

MATERIALS

picture cut into strips

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?

FIGURE 10.13 Vestigial structures, such as the wings of an ostrich, are organs or structures that are greatly reduced from the original ancestral form and have little or no current use.

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 that had a function in an early ancestor. 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 have wings that they use for balance but not to fly, as shown in **FIGURE 10.13.** Over generations, their increasingly large bodies and powerful long legs may have been enough to avoid predators. If ostriches that lived long ago 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 an example of a vestigial structure. The appendix is a remnant of the cecum, which makes up a large 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. The human appendix does not have the ability to digest cellulose. In fact, it performs no known function at all.

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?**

10.4 ASSESSMENT

ONLINE QUIZ
ClassZone.com

REVIEWING MAIN IDEAS

1. Describe the four sources of evidence for evolution upon which Darwin based his ideas on common descent.
2. Why are **vestigial structures** considered critical evidence of evolution?

CRITICAL THINKING

3. **Hypothesize** Describe how some of the Galápagos finch species, which traditionally were seed eaters, evolved over generations to prefer insects over seeds.
4. **Apply** How can a bat's wing be considered both a **homologous structure** and an **analogous structure**?

Connecting CONCEPTS

5. **Human Biology** 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.