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.

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.

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 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.
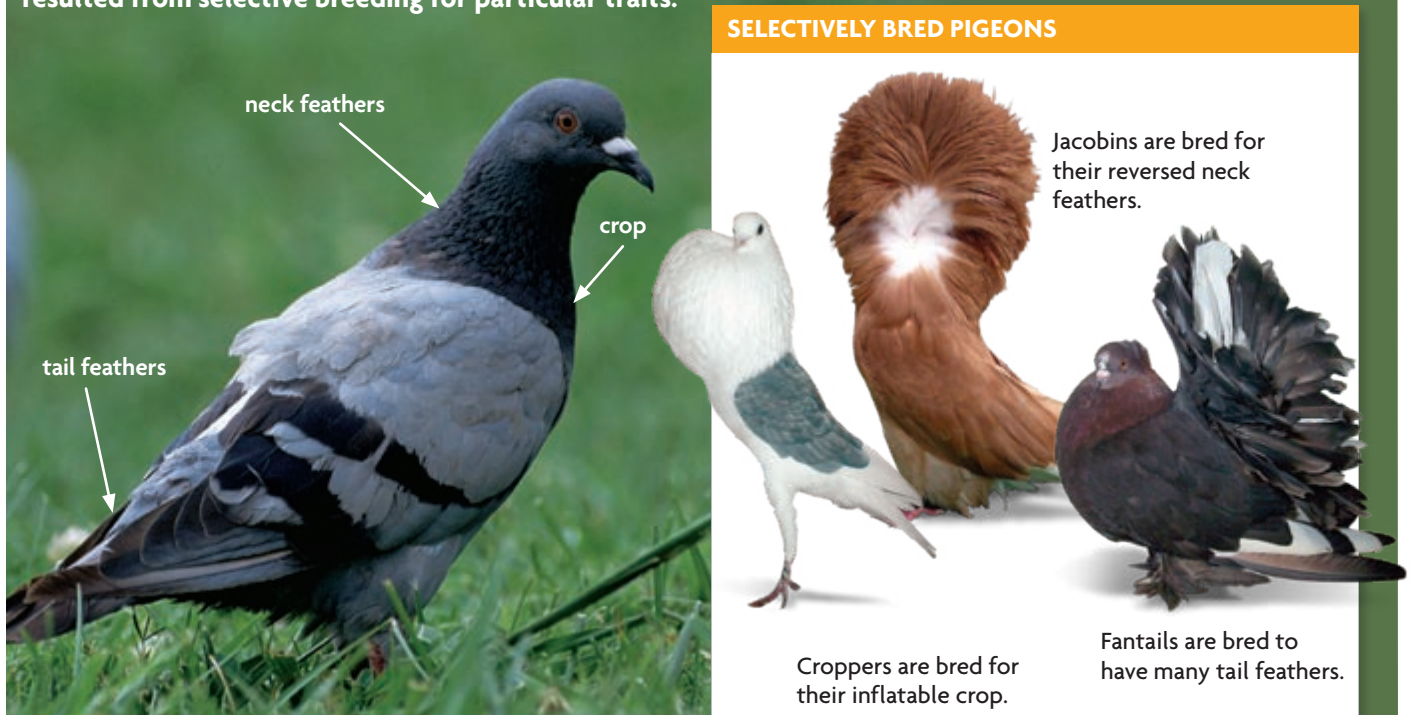
Darwin used this line of thinking for his theory of natural selection. **Natural selection** is a mechanism by which individuals that have inherited beneficial adaptations produce more offspring on average than do other individuals. In nature, the environment is the selective agent. Therefore, in nature, 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 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 supply kept the population smaller.

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.

neck feathers

crop

tail feathers

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?

READING TOOLBOX

VOCABULARY

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

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?

▶ 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 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

READING TOOLBOX

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 |

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.
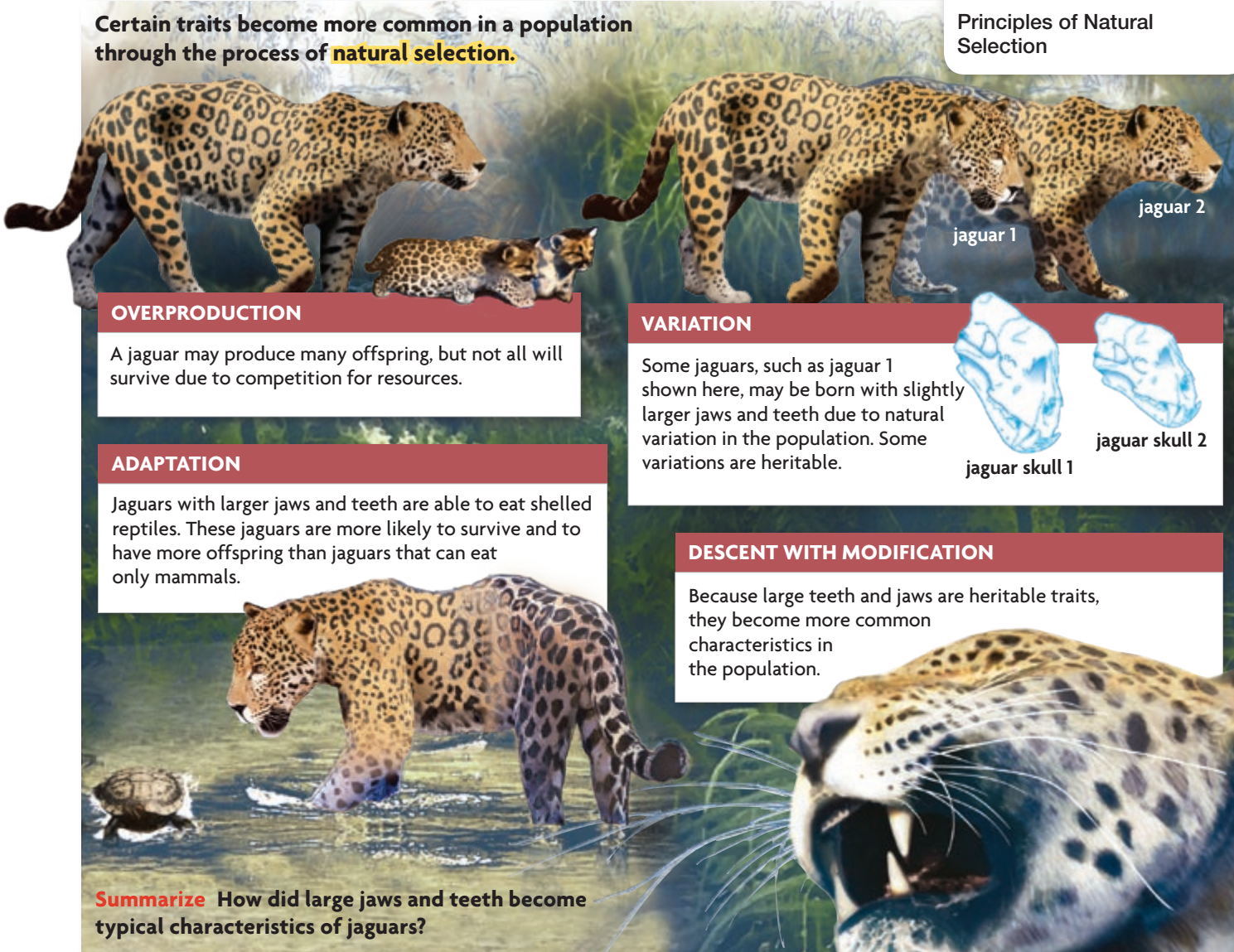
jaguar 1

jaguar 2

OVERPRODUCTION

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

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.

jaguar skull 1

jaguar skull 2

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.
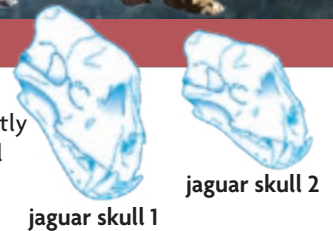
DESCENT WITH MODIFICATION

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?

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 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.

GRAPH 1. SELECTION OF EXERCISE ABILITY
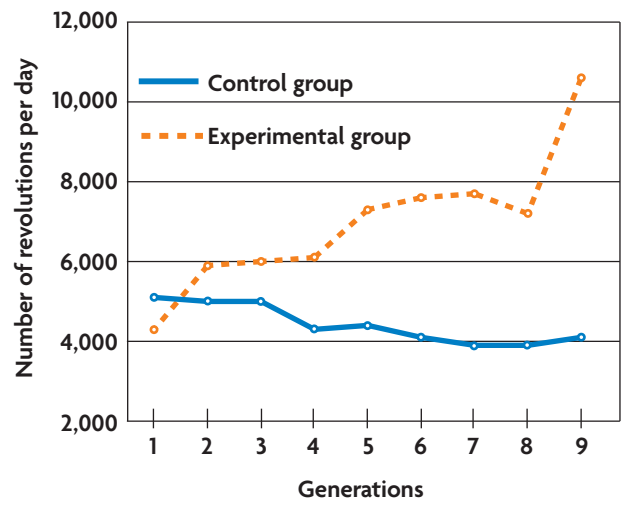
Source: Swallow et. al, *Behavior Genetics* 28:3.

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.

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Natural Selection

▶ **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.
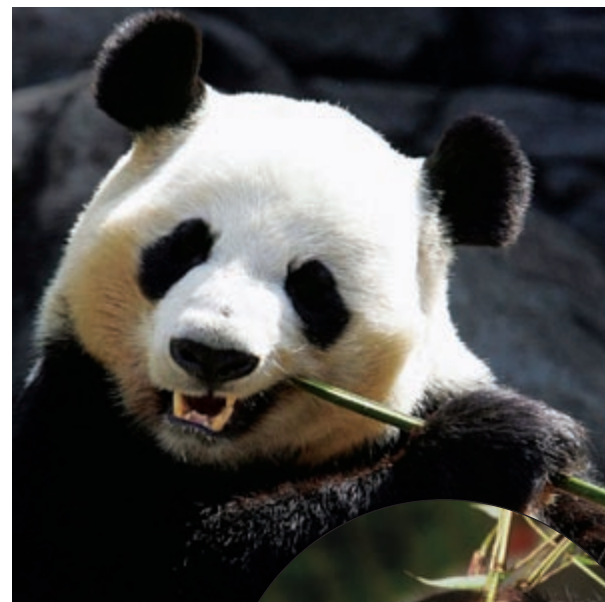

five digits

wrist bone

FIGURE 3.3 A panda's wrist bone also functions like a thumb.

Explain Why is the panda's "thumb" considered an adaptive compromise?

(tr) ©AP/Wide World Photos; (br) ©Keren Su/Corbis

10.3 Formative Assessment

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?

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?