10.1 Diversity of Life

EXPECTATIONS

- **Explain the process of adaptation of individual organisms to their environment.**
- **Analyze evolutionary mechanisms and their effects on biodiversity and extinction.**

The word "evolution" is commonly used in English but its meaning is often misunderstood or misused. In biology, **evolution** refers to the relative change in the characteristics of populations that occurs over successive generations. As you read through this unit, you will begin to better understand evolution and this definition will become clearer.

The grouse in Figure 10.1 lives in the boreal forest of northern Canada. Its brown, white, and black mottled feathers help it blend in with its environment. How do scientists explain that the grouse, and so many other living things, are so well suited to where they live? Recall what you have learned previously about adaptations and heredity. An **adaptation** is a particular structure, physiology, or behaviour that helps an organism survive and reproduce in a particular environment. Camouflage is one adaptation. The superb sense of smell of a shark or the bill shape of a shore bird are also adaptations.

Figure 10.1 This grouse is well-camouflaged in its forest environment. How could the coloration of *individuals* help the survival of a *population*?

Since adaptations help an organism survive, that organism will have a better chance of passing on to its offspring the particular characteristics that were advantageous to its survival. It is important to remember that although some differences between individuals are not outwardly evident, they do exist. For example, slight variations in bill size or shape, or mutations in a gene, are not immediately visible.

Meanwhile, environments can change: climates change over time, and droughts, floods, and famines occur. Thus, a characteristic that may not give an individual organism a particular advantage *now* may become critical for survival *later* if the environment inhabited by that species changes. This was demonstrated beautifully in the story of the English peppered moth.

The Peppered Moth Story

The story of the English peppered moth, *Biston betularia*, is often cited as an example of how the proportions of some inherited characteristics in a population change in response to changes in the environment. The peppered moth has two colour variations: greyish-white flecked with black dots (that resemble pepper) and black (see Figure 10.2 on page 335). In the past, the black variety was extremely rare. The first known black moth was caught in 1848 by lepidopterist R.S. Edleston. At that time, it was estimated that black moths made up less than two percent of the peppered moth population near Manchester, England. Yet 50 years later, in 1898, 95 percent of the moths in Manchester were of the black type. In rural areas, however, black moths were less frequent. What caused the sudden increase of black moths in Manchester? The answer lies in the behaviour and genetic makeup of the moths *and* the environment in which they lived.

Peppered moths are active at night. During the day, when they rest on the trunks of trees, they are

Figure 10.2 The frequency of flecked and black moths in this population of peppered moths changed in response to changes in the environment.

potential prey for birds. Until the mid-nineteenth century, the flecked moths in Manchester were camouflaged when they rested against the light-coloured lichens on tree trunks. The black moths, however, were easily seen and therefore easily preyed upon. The 50 years in which the black moths gradually became much more common in Manchester coincided with the Industrial Revolution in England. The air pollution from all the new factories killed the lichens, and soot began to cover Manchester's trees. As a result, the flecked moths were seen and eaten by birds and more black moths survived long enough to reproduce and pass on their genes to their offspring. Figure 10.2 shows how the peppered moth population evolved — that is, changed over the course of several generations.

The difference between the flecked and black forms of the peppered moth is caused by a single

THINKING LAB

Changes in Peppered Moth Populations

Background

The peppered moth story shows how genetic variety within a species can result in changes in the characteristics of a population when the environment changes. Since insects have a relatively short life cycle, this shift can happen quite quickly. In the 1950s, English biologist H.B. Kettlewell studied the camouflage adaptations in a population of flecked and black peppered moths.

Kettlewell raised over 3000 caterpillars to provide the adult moths. In a series of trials in the country and the city, he released and recaptured the moths. The number of moths recaptured in each trial indicated how well the moths survived in the environment.

You Try It

1. Examine the table on the right. Calculate the percentage of moths recaptured in each experiment.
2. Explain the differences in survival rates in the unpolluted and polluted environments.
3. Based on this lab, the information that has been presented so far in this chapter, and your understanding of genetics and evolution, discuss the following statements in a small group: Genes mutate. Individuals are selected. Populations evolve.
4. Discuss any other factors that may have influenced data in this study and the conclusions based on these data.

Numbers of peppered moths released and recaptured in polluted and unpolluted areas in England

Location		Number of flecked moths	Number of dark moths
Dorset (unpolluted)	released	496	488
	recaptured	62	34
Birmingham (polluted)	released	137	493
	recaptured	18	136

gene. Before the Industrial Revolution, more flecked moths survived and therefore passed on the gene for flecked-colouring in the **gene pool**. A gene pool is the total of all the genes in a population at any one time. However, when air pollution increased, more black moths survived with each successive generation and the ratio of flecked and black moths in the population essentially reversed. It is important to understand that the ratio of flecked to black moths in the *population* changed over successive generations. Individual moths were not transformed from flecked to black. A population is the smallest unit that can evolve.

In the 1950s, England started to enact clean-air legislation and lichens began to grow on trees again. As you might predict, the frequency of flecked moths increased in industrial areas such as Manchester. In these areas, nine out of 10 peppered moths were black in 1959. By 1985, five out of 10 were black, and the number dropped to three out of 10 by 1989. It is estimated that by 2010 the black peppered moth will again be as rare in Manchester as it was before the Industrial Revolution.

BIO FACT

The records and collections of lepidopterists were used by biologists to trace the spread of the black variety of peppered moth across England. Since the black moths were initially extremely rare, they created a frenzy among collectors in the mid-nineteenth century. The subsequent increase in the number of black moths collected from certain areas allowed historians and biologists to track colour changes in the populations of peppered moths.

Revisiting the Definition of Evolution

The peppered moth story demonstrates how a gene pool shifted from a population in which a particular gene coded for one expression of the characteristic (light, flecked colouring) in most individuals to a population in which the gene coded for a different expression of the characteristic (black colouring) in most individuals. Although no new species was formed, this *is* an example of evolution because there was a change in the gene pool of the population over successive generations. *Any shift in a gene pool is also used to*

Investigation 10 • A

SKILL FOCUS

- Predicting
- Performing and recording
- Communicating results

Diversity Within a Species

You have learned how diversity (also called variability) within a species can help populations survive environmental changes. Diversity within a species can be monitored genetically, or it can be demonstrated by measuring individuals within a population. In this investigation, you will measure a particular characteristic in each of three populations to determine variability within each population.

Pre-lab Question

- What would be the evolutionary advantage to a plant of having a larger seed?

Problem

How can variability among individuals be measured?

Prediction

Predict whether measurements of a particular characteristic (for example, length of bean seed) in a population would be evenly distributed throughout a population or whether most individuals would be the same length, with only a few individuals being longer or shorter than the norm.

Materials

10 kidney beans
callipers
string
10 lima beans
ruler
graph paper

Procedure

Part A

1. Use the callipers to measure the length of each of the 10 kidney beans.
2. Record your measurements.
3. Pool your measurements with other students in the class so you have between 50 and 100 measurements.
4. Calculate the average length of this population of kidney beans and prepare a bar graph of the class data.

define evolution. In fact, many scientists consider such a shift to be the most accurate and specific definition of evolution. This idea will be discussed in more detail in Chapter 12.

Natural Selection

The story of the peppered moths is an example of **natural selection**. Natural selection is a process whereby the characteristics of a population of organisms change because individuals with certain heritable traits survive specific local environmental conditions and pass on their traits to their offspring. You will learn more about natural selection later in this unit. For natural selection to occur there must be diversity *within* a species. Look around your classroom. You are all the same species but clearly there is a great deal of variety among you and your classmates. Without the extensive variability within a population, there would be no possibility for selection to occur. In the populations of peppered moths, the moths that survived were *selected*. In other words, *they survived the change in the environment around them*, and thus could reproduce and pass on the genes that coded for black. *Individuals* did not change colours during their lifetime; rather, the *populations* shifted in colour over time. The environment exerts a **selective pressure** on a population. In other words, an environmental condition can *select for* certain characteristics of individuals and *select against* those of others.

Artificial Selection

In the peppered moth story, change occurred naturally in the population in response to changes in the environment. However, people have been artificially selecting organisms for particular traits for centuries. Artificial selection for desirable traits has resulted in plants that are disease-resistant, cows that produce more milk, and racehorses that run faster. In **artificial selection**, a plant or animal breeder selects individuals to breed for the desired characteristics he or she wishes to see in the next generation. Figure 10.3 on page 338 shows some of the varieties of dogs that have been produced by artificial selection. As another example, a rose

Part B

1. Repeat the steps from Part A using lima beans.

Part C

1. Use the string to measure the length of your partner's forearm, from the crease inside the elbow to the wrist. Use the ruler to determine forearm length.
2. Record your data and pool your data with that of the rest of the class.

3. Calculate the average forearm length of students in your class and prepare a bar graph of the class data.

Post-lab Questions

1. How are your three graphs similar?
2. From your graphs, what can you conclude about the variability within a population? For example, is there a "typical" size, or is the distribution of individuals spread evenly from small to large?

Conclude and Apply

3. What advantage would large size have to a newly germinated seed? (Recall that a seed is stored food.)
4. What environmental pressures might favour small seeds?
5. Predict a situation (actual or imagined) in the environment in which having a longer forearm might be advantageous to a person's survival.

Exploring Further

6. Create a breeding strategy to favour the production of large seeds.

breeder could select the seeds from roses with a strong scent to produce generations of roses with an equally strong fragrance.

Artificial selection can also perpetuate characteristics that are not particularly desirable. For example, Pekinese and British bulldogs are bred for their flat faces, but this characteristic also results in severe respiratory problems. Hip dysplasia, a type of arthritis common in German shepherds, is also an unfortunate consequence of artificial selection.

Overhunting can result in future generations that have a higher proportion of individuals *without* the favourable trait. For example, in the 1970s and 1980s, between 10 and 20 percent of all wild elephants in Africa were being killed by ivory poachers each year. Since poachers preferred elephants with large tusks, elephants with smaller tusks were less likely to be killed. Elephants with no tusks were not shot at all. Since that period, elephant watchers and biologists have noticed more and more tuskless elephants in the areas that experienced the most intense poaching pressure.

The key difference between natural and artificial selection is that in natural selection, the environment plays the role that humans play in artificial selection. In natural selection, the environmental conditions determine which individuals in a population are most fit to survive in the current conditions. This, in turn, affects the proportion of genes among individuals of future populations because the genes from the surviving individuals are passed on to their offspring. When discussing natural selection and evolution, the word "fit" or "fitness" is often used. **Fitness** in this sense refers to how well an organism fits with its environment. A high degree of fitness means that an organism will survive and reproduce, thereby passing on its advantageous genes to its offspring.

Natural Selection Is Situational

It is important to note that natural selection does not anticipate change in the environment. Instead, natural selection is situational. It is essentially by chance that a trait that might at one time have no particular relevance to survival (for example, black coloration in moths) becomes the trait that helps a population survive. This trait then persists within a population in response to changes in the environment via subsequent inheritance of the trait by the offspring of survivors. Adaptations that are beneficial in one situation may be useless or detrimental in another. This has been demonstrated in the work of Peter and Rosemary Grant in their study of finches in the Galápagos Islands.

For over 20 years, the Grants have been studying medium ground finches (*Geospiza fortis*), one of the 13 species of finches in the Galápagos Islands.

Figure 10.3 All dogs are members of the same species, *Canis familiaris*, yet artificial selection has resulted in a wide variety of breeds.

These birds use their strong beaks to crush seeds, and tend to prefer small seeds that are produced in profusion during the wet years in the islands. Fewer small seeds are produced during dry years, and the Grants found that during these times the finches also have to eat larger seeds, which are harder to crush. As part of their study, the Grants measured the depth (dimension from top to bottom) of the finches' beaks. They found that the average beak depth in the population changes over the years. During droughts, the population's average beak depth increases. During wet periods, the average beak depth in the population decreases again. The Grants' study demonstrates a change in the finch population in response to the environmental conditions. During dry periods, birds with stronger (that is, slightly larger) beaks have an advantage because they are better able to crack large seeds. Since these birds have a feeding advantage, they survive in greater numbers and have greater potential to pass the gene for a larger beak on to their offspring.

This difference in ability to crack larger seeds within the finch population can only happen because there is variety within the population. As you found when you did the investigation on page 336, not all kidney beans are identical in length, nor are the forearms of all Grade 12 students. *It is the variety that is already present within a population that allows change to occur in response to local environmental conditions.* Natural selection acts like an editor; it only works with what is already present in a population.

The finches reproduce once a year. The Grants have been able to monitor morphological changes in the population only by measuring and monitoring the birds year after year as part of their multi-year study. In other organisms that reproduce more quickly, such as insects and bacteria, the change in a population in response to local environmental conditions can be observed in a much shorter time. How do you think natural selection is involved in insects becoming resistant to pesticides or in bacteria becoming resistant to antibiotics? This idea will be discussed further in subsequent chapters.

BIO FACT

As part of their study, the Grants needed to measure the force required to open seeds. Peter Grant designed a unique device with the help of an engineer from McGill University in Montréal. The "McGill nutcracker" looks like pliers with a scale attached. When a seed is squeezed with the pliers, a scale measures the force required to crack the seed.

SECTION REVIEW

1. **K/U** Can individuals evolve? Explain your answer.
2. **K/U** Give two definitions of evolution.
3. **K/U** How are adaptations and evolution related to each other?
4. **K/U** Describe how the study of peppered moths by Kettlewell demonstrates evolution in action.
5. **K/U** Define the term "gene pool."
6. **C** Explain the term "selective pressure" as it relates to the study of evolution.
7. **C** In a population of sparrows, most birds have a bill that is about 10 mm long. Some birds, however, have bills that are slightly longer or slightly shorter than the average. Explain why this variation within the population is important when discussing evolution.
8. **K/U** Give one example of artificial selection and one example of natural selection. What is the major difference between the two types of selection?
9. **MC** Give some examples of how people have used artificial selection to create new varieties of plants or animals. Describe the possible economic and environmental impacts of these new varieties.
10. **I** How would you test the hypothesis that larger finches on the Galápagos Islands had a greater survival rate in wet years than in dry years? What factors would you measure?
11. **C** With a partner, discuss what your understanding of evolution was before you read this section. Has your understanding changed in any way now that you have completed this section? If so, how has your definition of evolution changed?
12. **C** Explain what is meant by the statement "Natural selection is situational."