2.5 Evolutionary Theory

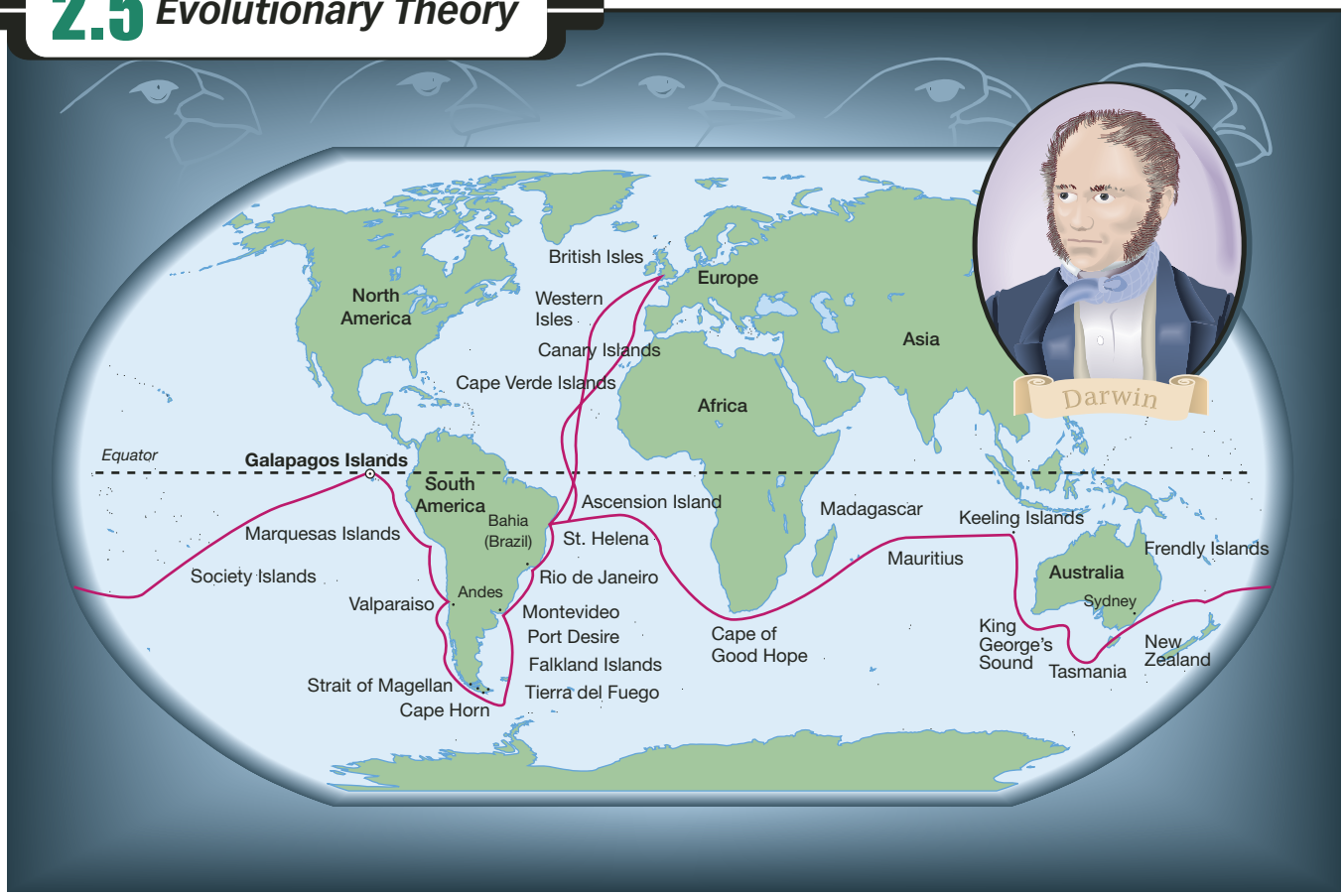


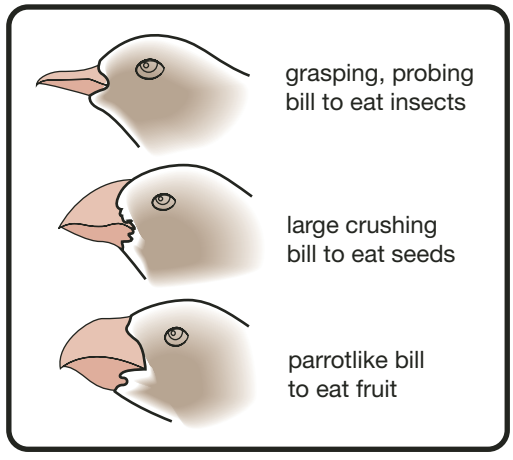
Figure D2.35: Charles Darwin and the HMS *Beagle* sailed around the world. The most famous stop they made was at the Galapagos Islands.

In 1831, Charles Darwin set sail on the British survey ship HMS *Beagle* for a round-the-world voyage. As the ship's naturalist, Darwin, then 22 years old, collected a huge number of species of plants and animals and made detailed drawings and written observations of the enormous variety and adaptations he observed.

The Galapagos Finches

Darwin was particularly fascinated with the organisms he observed on a chain of volcanic islands off the Pacific coast of South America. These were called the Galapagos Islands. Along these uninhabited islands are a variety of different climatic regions, each with its own unique ecosystem. The Galapagos have a variety of food sources in their different climatic regions. In each different region, Darwin found strong similarities between organisms living there, but he noticed that animals had adapted differently to take advantage of the local conditions. For example, because he found several varieties of finches that demonstrated so many similarities, he hypothesized they must be related. However, each species had a different beak type that appeared to be adapted for a diet specific to its particular region. Some finches had thick beaks best suited for crushing hard seeds; some finches had parrotlike beaks suitable for eating fruit; and some finches had slim beaks for catching insects.

Figure D2.36: These are examples of different beaks on Galapagos finches.



To explain the existence of so many finch species with unique traits—in this case beak types—Darwin suggested that the variety of finches on the islands all came from a common seed-eating finch ancestor. He believed that some seed-eating ancestral finches were blown to the islands from the mainland. Once on the island their populations soared because they were able to find abundant food and had no predators. As a result, many offspring were produced in their new habitat. Following this population explosion, the habitat soon lacked enough seeds to support the large finch population. As with all populations, there was variation in many traits including the beak characteristics of finches native to the island.

Those finches best suited to consume available food sources on the island would have survived to breed with other successful birds with similar beaks. As a result, the genes for their beak type were passed on to their offspring. Over generations, this gave rise to lines of birds that were each adapted to collecting a specific food source. Each line would be distinct in terms of beak shape, food eaten, mating behaviour, and other differences. The pressure of limited food enabled organisms with a variety of traits to exploit new food sources. Over many generations, several new finch species developed that were well-adapted to eating different foods than their ancestors did.

Practice

33. What is the most likely cause for variation in beak characteristics within the finch population native to the island?

34. Large, wide beaks are better suited for cracking open the hard shells of some types of seeds. Smaller, narrow beaks are better suited to catch insects.

- **a.** Suppose an original population of seed-eating finches was blown to an island that had a limited supply of hard-shelled seeds but an abundance of insects. Describe what characteristics of finch beaks would enable greater survival.
- **b.** Describe what effect a lack of variety of food sources would have on the bird population.
- **c.** Since beak shape is an inherited trait, describe changes within the population of finches on this insect-rich island after many generations.
- **d.** Identify the term that describes a structure, like a small, narrow beak, that improves the probability of a finch successfully reproducing and surviving in this particular island environment.

Investigation

Investigating Natural Selection: A Simulation

For this activity, forks with varied numbers and placements of tines represent variations in bird beaks.

Science Skills

- ✓ Performing and Recording
- ✓ Analyzing and Interpreting
- ✓ Communication and Teamwork

Purpose

You will determine what effect a variation in beaks has on the success of individuals and the possible characteristics of a bird population's next generation.

Materials

- large bowl
- small, soft candies or O-shaped cereal (e.g., Cheerios or Fruit Loops)
- several plastic forks with varied numbers and placements of tines
- small cups or containers (e.g., Dixie cups or Styrofoam cups)

Figure D2.37: This represents a parent bird feeding its chicks.

Prediction

Look at the variations in the number and arrangement of fork tines. Which variation do you think will be most successful at acquiring food?

Procedure

step 1: Your teacher will divide you into groups and place you around the classroom. The spot where you have been placed will represent your nest. One of you will be the parent bird, and the others will be chicks. Each chick gets a small cup to represent a hungry chick mouth. Each parent bird gets a unique fork. Note that each fork has been modified, in terms of the number and placement of tines, to represent a type of beak for getting food.

step 2: A single bowl will be filled with candy or cereal and placed in a central location an equal distance away from all groups. The bowl of cereal will represent the island's food source.

step 3: Your teacher will indicate when to begin. At this time, parent birds will move to the food source using only the forks to retrieve food for their chicks. Any food dropped cannot be picked up. It must stay on the fork until it is put into the mouth of a chick (the cup). You may not actually eat the cereal unless your teacher has told you to do so. The chicks must stay in the nests. Your teacher will tell you when feeding ends.

step 4: Count the number of food items placed in your cups. Your teacher will let you know how many food items in a cup are needed for a chick to survive to adulthood.

Analysis

1. Was your prediction correct? Which fork variation was the best at getting food? Which beak variations were least able to cope in the island ecosystem as a result of the available food source?
2. Explain how competition affected the success of the parents and chicks.
3. Why was the food source approximately the same distance from each nest?
4. Describe some adaptations that would make the chicks more successful at acquiring food brought from the parent.
5. If conditions remained the same, how would the bird population characteristics have changed after several generations? Keep in mind that beak variations are inherited from parents.

Evaluation

6. Describe how this investigation could more accurately simulate a natural population.

Extension

7. Think back to the coloured toothpick activity from the beginning of Chapter 2. How is this investigation similar? How is it different?

Darwin's Theory of Evolution

In 1859, Charles Darwin published his book, *On the Origin of Species by Means of Natural Selection*, in which he described his **theory of evolution**. Darwin did not invent the word *evolution* (it literally means unrolling or opening out), but he used it in a biological sense to mean a change in the characteristics of a population over time. He said that all life on Earth shared a common ancestor. The entire first printing of his book sold out on its first day of publication. His writing was very controversial because it went against the common belief of the time that organisms were fixed in their present form and had remained unchanged since Earth was created. As you have seen from your previous work with fossils, organisms have changed over geological time. This is an observable fact. What continues to be a controversial issue is the explanation as to how these changes occurred.

Based on his experiences and observations, Darwin described his **theory of natural selection**. This theory is based on three observations.

Observation 1: Organisms usually produce more offspring than can survive.
Observation 2: There is variation among individuals with respect to any trait in a population.
Observation 3: Organisms within a population compete for limited resources.

Darwin's theory stated that since resources for the group are limited, only those individuals with the variety of the trait that makes them best adapted to out-compete others for resources in their environment are most likely to survive. The best-adapted individuals in the population are considered to have greater **Darwinian fitness** because they will be able to survive, breed, and pass on their traits to their offspring. Darwinian fitness is not a measure of speed, strength, or health, although these things may influence reproductive success.

- **theory of evolution:** a theory stating that the nature of a population gradually changes form over time
- **theory of natural selection:** a theory stating that evolution takes place because more organisms are produced than can survive, and that only the organisms best suited to their environment survive to reproduce and, in turn, pass on their advantageous traits to their offspring
- **Darwinian fitness:** the reproductive success of an organism

Over many generations of breeding, the traits that provide the most advantages to an organism will become those traits more frequently seen in offspring, while the less-useful varieties will be seen less often. Darwin hypothesized that over time this process, which resulted in the change in traits seen within the population, could result in the development of a species that appeared different from its ancestor. This theory also became known as *the survival of the fittest*.

Biologists maintain that there are two essential requirements necessary for natural selection to occur:

- There must be a genetic basis for the variation observed in some trait.
- There must be differences in the rate of survival and reproduction associated with the possession of a certain trait.

Darwin's theory of natural selection defines success in terms of what organisms live to reproduce and pass along their traits to their offspring. Successful organisms will have their traits determine the characteristics seen in the future population. These changes to the population could occur in small, gradual steps over a long time frame (gradualism), or as larger changes over a shorter time (punctuated equilibrium). The ability of Darwin's theory to explain both scenarios is the reason the theory continues to be used.

The environment has a crucial role in natural selection. The environment establishes the criteria for determining which organisms will be successful. Observe the photo of the meteorite striking Earth in the chapter introduction. Although no one can say for certain whether a deep-impact event occurred, the geological evidence suggests that some kind of catastrophe triggered a sudden change in Earth's climate about 65 million years ago. In cooler environments, large dinosaurs were unable to survive and did not reproduce to pass on their genetic traits to future generations. By comparison, the small, warm-blooded mammals were more successful in these changed environments. The more successful mammals had physical traits that allowed them to survive in the new environment, enabling them to reproduce and pass on favourable genetic traits.

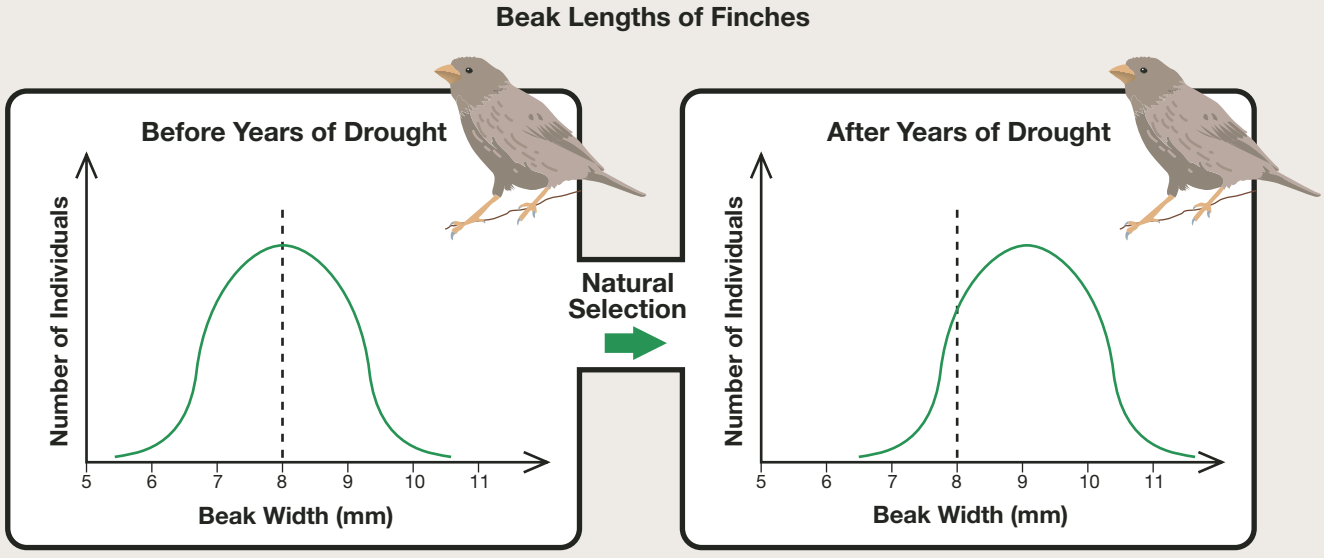
Practice

35. Recall the several populations you studied earlier in Chapter 2. How are these two criteria for natural selection demonstrated by changes within the snail population?

Use the following information to answer question 36.

Natural selection can also be described graphically. The left graph shows study results on an island in which data was collected on beak widths in finches. This graph shows variety in the finch population from the narrow-beaked finches (6 to 7 mm) that ate caterpillars to the wide-beaked finches (9 to 10 mm) that ate large seeds.

The right graph shows how the population changed after years of drought on the same island. During drought years, the plants produced few leaves, which resulted in a dramatic decline in the food source for caterpillars. This, in turn, had an effect on the finch population.



36. Explain how these graphs describe the process of natural selection occurring over time within the finch population on this island.

In the two decades after his voyage, Darwin spent time developing his theory and continued to collect further evidence. However, Darwin didn't publish his theory until a colleague, Alfred Russel Wallace, sent Darwin a paper called *The Struggle for Existence*. In his paper, Wallace came to a similar conclusion. Darwin and Wallace presented their work together to the scientific community in 1858. The next year, Darwin published his famous *Origin of Species*. Darwin is given greater credit than Wallace for developing the theory of natural selection because Darwin spent so much time researching and then writing his book.

Jean-Baptiste Lamarck

Before Darwin and Wallace proposed the theory of evolution, a French biologist named Jean-Baptiste Lamarck had proposed a different reason about why populations changed. He hypothesized that organisms changed during their lives to meet the challenges of their environment and then these changes were passed on to their offspring. Organisms could produce new or improved parts to better adjust to their environment. Parts not used would eventually disappear.

Lamarck used his model for change to explain how giraffes got such long necks. He said giraffes started out with short necks, but when lower leaves on the trees were removed, they had to stretch to reach higher leaves. All this neck stretching meant that the next generation of giraffes was born with longer necks. The stretched-neck trait was passed on until long-necked giraffes were able to reach even the highest tree leaves. There was no proof for Lamarck's idea of the inheritance of acquired characteristics, so his ideas were dismissed. Although Lamarck turned out to be wrong, he is considered to be important because he got people thinking about how species change over time.

Recent advances in the understanding of genetics show that unless there is a change in the genes responsible for a trait, there will be no resulting change to that trait. In the case of the giraffe, stretching to reach higher leaves will not mean a change in its genes, so it will not result in a new trait for its offspring to inherit.

Figure D2.38: The long necks of giraffes are due to genetics, rather than stretching.

Practice

37. Using Darwin's theory of natural selection, explain how giraffes acquired long necks.

38. A bodybuilder spends a lot of time at the gym lifting weights to acquire a muscular body. He is convinced that this behaviour will cause him to have muscular children. Is his opinion consistent with Darwin's theory or Lamarck's theory?

39. Certain dog breeds have their tails cut short (or cropped) at birth. What would Lamarck predict would happen to this breed's tails after several generations?

40. In the oral traditions of many First Nations people, stories are told of how many plants and animals came to possess their special features. There are several versions of a legend that tells the story of how the beaver once had a round and fluffy tail but acquired a flat tail by having a rock or tree fall onto it.

- **a.** Is this explanation more like Lamarck's theory of change or Darwin's?
- **b.** Explain how the beaver may have developed its flat tail. Use Lamarck's theory of inheritance of acquired characteristics.
- **c.** Use Darwin's theory of natural selection to explain how the beaver may have developed its flat tail.

41. Research and summarize another legend that explains why an organism has an adaptation. For example, read "How the Bear Lost Its Tail" or "How Raven Got Its Black Colour." Use Lamarck's theory and then Darwin's theory to explain how this organism acquired the adaptation. Share the two different explanations in an oral presentation. You can find these legends on the Internet or in various book collections.

More Evidence for Evolution

The geological record clearly shows Earth has undergone dramatic changes over time, and the fossil record indicates organisms did not remain static. The theory of evolution provides an explanation of how such changes to organisms would have taken place. The theory of evolution is well-supported by many pieces of evidence. Each piece alone is not proof of the theory, but together they make a strong case for its validity. Note these examples.

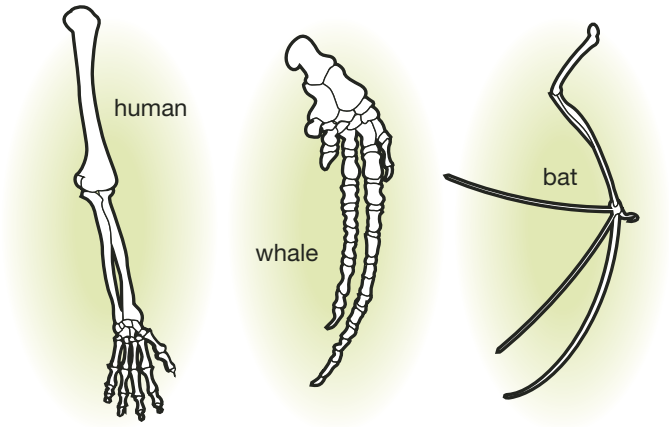


Figure D2.39: Homologous structures—a human arm, a whale flipper, and a bat wing—are all just variations in size and shape of the same number of bones. These structures appear to have a similar origin and, therefore, suggest a shared ancestor.

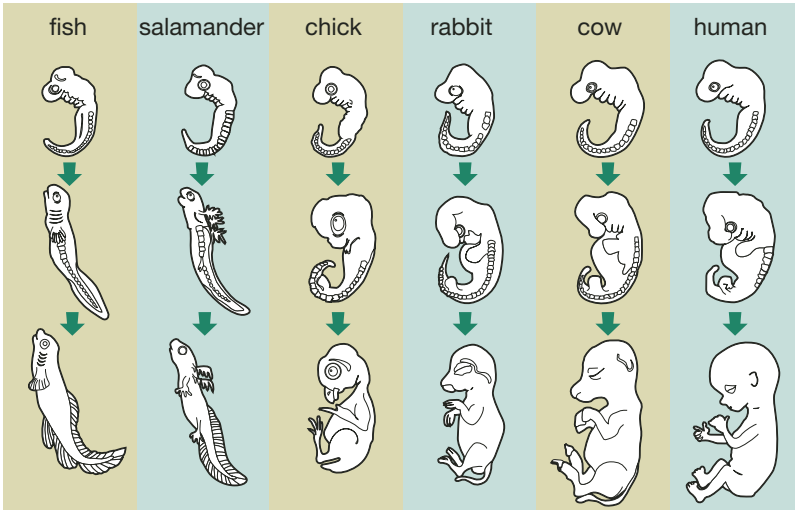


Figure D2.40: Similarity among embryos—in the embryo stage, most vertebrates (organisms with backbones) look similar and follow a comparable development. For example, human embryos have gills at one stage of development and then lose them at a later stage. This similarity seems to suggest a common ancestor among vertebrates.

Figure D2.41: Vestigial structures—Tiny, useless wings on an insect and the dew claws on a dog have no apparent function. The presence of these vestigial structures suggests that the organism's ancestors had a more useful version of the body part. Through adaptation over time the role for these structures has been lost.

Figure D2.42: Biochemical evidence—The proteins in all organisms are produced from the same set of 20 amino acids. This unity of composition and function suggests that all forms of life are related to some extent, having common ancestors in the earliest organisms.

Figure D2.43: Evolution of behaviour—Some behaviours have a genetic basis. If these inherited behaviours affect an organism's fitness to the environment, then behaviour can evolve by natural selection. The calling songs of crickets meet this criteria and, therefore, are an example of an evolved behaviour.

Figure D2.44: Biogeography—Organisms separated by geographical barriers like oceans and mountain chains that show related characteristics suggests a common ancestor migrated long ago. It also suggests the two populations changed in different ways to become distinct species.

A Case Study of Natural Selection: The Peppered Moth

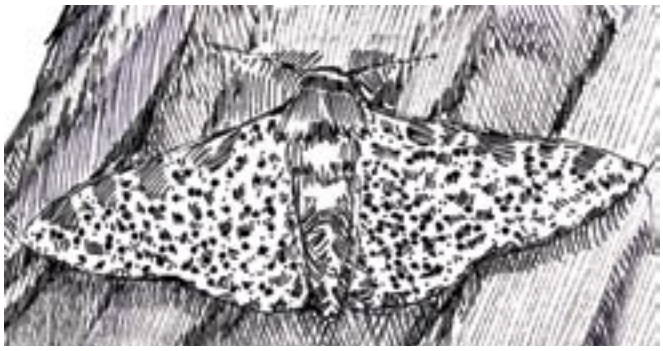


Figure D2.45: The peppered moth is a great example of natural selection.

One of the best examples of the process of natural selection affecting a population is that of the peppered moth. The moth is called *peppered* because it looks like someone has sprinkled pepper on its white wings. This moth is only active during the night—it's nocturnal—and spends its days resting on the bark of trees where its peppered colour blends in well with the colour of trees to camouflage it from predators. Pure black members of this species are only spotted very rarely.

Manchester, England, was at the heart of the Industrial Revolution in the 1800s. In Manchester, the machines of numerous factories used energy produced by burning massive amounts of coal. The combustion of coal resulted in large amounts of soot being created from the chimneys, and this in turn began covering the buildings and trees around Manchester. With the black soot covering many surfaces, including trees, the once well-camouflaged, light-coloured moth stood out on the black background. The rare black variation was then better camouflaged. Birds easily found the light-coloured peppered moths because they stood out on the black trees. Because of increased success in predation, fewer white moths were able to survive. Over about 100 years, a majority of the peppered-moth population living in the soot-covered forests near Manchester were black. In unpolluted forests, the black form was still rare.

Practice

42. What caused the appearance of the rare black form of the peppered moth?

43. Explain how a variety in coloration was beneficial to the population.

44. Describe a change in conditions over time that would cause a decline in the number of black moths and a corresponding increase in the peppered moths around Manchester.

45. If predators like birds were removed from the area, how might this affect the coloration of moths over time?

46. Does the peppered moth's situation support Darwin's theory of natural selection?

Why Sex?

Each of your cells carries all the information to make an exact copy of you. Could any cell in your body be used to develop a replica or clone of you? Advances in technology may have made this possible. In 1996, scientists in Scotland successfully cloned a sheep named Dolly. She was an exact copy of the adult sheep whose cell she was cloned from. Many plants reproduce naturally by cloning or by **asexual reproduction**. Detached cells grow into new identical plants. Gardeners take advantage of this ability by taking cuttings from plants.

asexual reproduction: the production of identical offspring from a single parent cell by budding, by the division of a single cell, or by the division of the entire organism into two or more parts

ROSLIN INSTITUTE EDINBURGH

Figure D2.46: The world was introduced to a cloned sheep named Dolly in 1996.

Asexual reproduction requires only one parent—this makes it a quick and efficient process. So why do most organisms reproduce sexually? Imagine a population of identical organisms. When environmental conditions change, the population may not be able to cope with the new environment.

Now imagine a population in which each individual is a little bit different. With sexual reproduction, each offspring receives a different combination of the parents' genes. As seen in this chapter, variation within a population, whether it be snails or peppered moths, is a result of sexual reproduction. This process allows for the mixing of parental traits. The overall effect is to increase the degree of variation within the population. The environment selects the varieties with traits that make them fittest for survival in that set of conditions. The result of the breeding of successful organisms is to change the population's appearance. As the population shifts to have more organisms possessing certain traits, the population adapts to remain successful in its environment, and the process of evolution is observed.

2.5 Summary

Evolution is the slow and gradual change in the characteristics of population over time. Darwin proposed that natural selection is the mechanism that drives evolution. Lamarck proposed the idea of the inheritance of acquired characteristics. This proved to be incorrect.

Selective breeding, vestigial structures, look-alike embryos, and the geology and paleontology of Earth are examples of pieces of evidence that support Darwin's theory of evolution.

Sexual reproduction creates variation and improves the chances of success in a population.

2.5 Questions

Knowledge

1. Define the following terms.

- **a.** theory of natural selection
- **b.** Darwinian fitness

2. List the two requirements necessary for natural selection to occur.

Applying Concepts

3. Cheetahs have evolved over millions of years to be the fastest land organisms on Earth. Use the theory of natural selection to explain how the cheetah became so fast.

4. Through selective breeding, a horse has been sired to be a great runner. He becomes a champion racing horse and breaks several track records. When the owner goes to breed the horse, it is discovered that the horse is sterile and cannot sire offspring.

- **a.** In biological terms, describe the fitness of this horse.
- **b.** Why is the chance of mutation high in purebred animals such as racehorses?
- **c.** What would be the benefit of using this horse as the parent for many clones? What would be the disadvantage?

5. A pod of dolphins is placed in an aquarium. They are fed a large amount of fish, are given vitamin supplements, and receive regular medical checkups. The pod members are larger and more active than the wild members of their population. Is this an example of evolution? Explain your answer.

6. A common variety of banana reproduces by cloning rather than by sexual reproduction—tiny seeds in the banana are sterile. A disease has been infecting banana trees and has destroyed many plantations. Why would banana growers be more concerned about the future of this popular banana variety than they would about other types of fruit that experience disease?

Photo Credits and Acknowledgements

All photographs, illustrations, and text contained in this book have been created by or for Alberta Education, unless noted herein or elsewhere in this Science 20 textbook.

Alberta Education wishes to thank the following rights holders for granting permission to incorporate their works into this textbook. Every effort has been made to identify and acknowledge the appropriate rights holder for each third-party work. Please notify Alberta Education of any errors or omissions so that corrective action may be taken.

Legend: t = top, m = middle, b = bottom, l = left, r = right

501 Copyright © 2006 Alberta Education and its licensors. All rights reserved. **502** (second from br) © 2005-2006 www.clipart.com (br combined photo) Copyright © 2006 Alberta Education and its licensors. All rights reserved. **503** (mr) ROSLIN INSTITUTE EDINBURGH **504** (all) Photodisc/Getty Images