UNIT A

Biological Diversity

In this unit, you will cover the following sections:

1.0 **Biological diversity is reflected in the variety of life on Earth.**

- **1.1** Examining Diversity
- **1.2** Interdependence
- **1.3** Variation within Species

2.0 **As species reproduce, characteristics are passed from parents to offspring.**

- **2.1** A Closer Look at Variation
- **2.2** Asexual and Sexual Reproduction

3.0 **DNA is the inherited material responsible for variation.**

- **3.1** DNA—Transmitter of Genetic Code
- **3.2** Cell Division
- **3.3** Patterns of Inheritance

4.0 **Human activity affects biological diversity.**

- **4.1** Reduction of Biological Diversity
- **4.2** Selecting Desirable Traits
- **4.3** Reducing Our Impact on Biological Diversity

Exploring

Preserving Biological Diversity

In 1991, researchers with the Central Rockies Wolf Project captured a female wolf. They fitted her with a satellite transmitter in Peter Lougheed Provincial Park, Alberta. Dubbed Pluie, the wolf remained in Kananaskis Country for six months. Then she took an amazing journey through 100 000 km^2 of protected areas and legal hunting grounds in Alberta, Montana, Idaho, and British Columbia. Pluie's story drew attention to how the Rocky Mountains are an important travel corridor for wide-ranging carnivores such as wolves and grizzly bears.

Pluie has inspired the Yellowstone to Yukon Conservation Initiative (Y2Y), a joint Canadian-U.S. network of over 270 organizations. The mission of Y2Y is to "combine science and stewardship in order to ensure that the world-renowned wilderness, wildlife, native plants, and natural processes of the Yellowstone to Yukon region continue to function as an interconnected web of life capable of supporting all of the natural and human communities that reside within it, for now and for future generations."

To reach this goal, Y2Y is working to establish a connected network of protected areas and wildlife movement corridors that run from the Greater Yellowstone ecosystem in Montana to the MacKenzie Mountains in the Northwest Territories and Yukon. Co-operating organizations include environmental advocacy groups such as the Canadian Parks and Wilderness Society (CPAWS), research-based groups such as the Eastern Slopes Grizzly Bear Project, and groups that represent recreation groups, such as Orion—The Hunter's Institute.

The Y2Y initiative is based on the well-established guidelines of conservation biology. Conservation biology is a wide-ranging field. It combines aspects of landscape ecology, economics, species variation, and genetics to help solve the difficult problems of preserving biological diversity. How will protecting a fully functioning mountain ecosystem help to preserve biological diversity? In this unit, you will find out by investigating the processes that enable species to survive.

SKILL PRACTICE

Exploring Wolf Population Trends

Alberta is home to 95 species of mammals, second only to British Columbia. One mammal, the black-footed ferret, has disappeared from Alberta. Three of Alberta's mammal species are considered at risk, 10 species are considered sensitive, while 57 species are considered secure by the Alberta Species at Risk Program.

Wolf populations in Jasper National Park have been monitored throughout the past 60 years. The size of these populations has been influenced by factors such as environmental conditions, availability of prey, and control programs. Four wolves per 1000 km^2 is considered to be a low number. Are Jasper's wolves in danger? Graph the numbers from these studies to find out.

Jasper National Park Wolf Population Studies	Date	Average Number of Wolves per 1000 km^2
Study 1	1946	4
Study 2	1970	4
Study 3	1975	8
Study 4	1986	3

- On a single graph, plot the data from the chart by date (oldest to most recent). What trends do you see in the data and in your graph? (You may wish to review Toolbox 7.)
- For each trend, suggest factors that may have affected the average number of wolves.
- Habitat loss can put a species at risk of extinction. It has been estimated that 97 ha of natural Canadian habitat are destroyed every hour. Use that figure to calculate the numbers of hectares lost in a day, a month, and a year.

Focus On

Social and Environmental Context

As you work through this unit, you will observe the tremendous variety of life on Earth and how this diversity helps to ensure survival of species. You will learn how species reproduce and will consider the role of genetics in the continuation of species. You will explore how human activity affects biological diversity and how science and technology can have intended and unintended effects on species and the environment. Your major goals will include developing your inquiry and decision-making skills.

Consider the following questions as you read and discuss, perform activities, and answer questions throughout the unit.

1. **What is biological diversity?**
2. **How do living things pass their characteristics on to future generations and why is this important?**
3. **What impact does human activity have on biological diversity?**

The answers to these and other questions will guide your learning about various life forms and how humans affect biological diversity. The project at the end of this unit will allow you to apply your knowledge of ecosystem, species, and genetic diversity and your skills in developing a strategy to maintain biological diversity in a local area.

1.0

Biological diversity is reflected in the variety of life on Earth.

Key Concepts

In this section, you will learn about the following key concepts:

- biological diversity
- species and populations
- diversity within species
- habitat diversity
- niches
- natural selection of genetic characteristics

Learning Outcomes

When you have completed this section, you will be able to:

- describe the relative abundance of species on Earth and in different environments
- describe examples of variation among species and within species
- explain the role variation plays in survival
- identify examples of niches and describe how closely related living things can survive in the same ecosystem
- explain how the survival of one species may be dependent on another species
- identify examples of natural selection

If you took a trip to a wetland ecosystem or carefully observed the life forms underneath a rotting log, you would realize that we are surrounded by an incredible diversity of life forms. If you consider the wide range of environmental conditions that exist on Earth, from the frigid cold of the poles to the steamy heat of the tropics, there is no single kind of organism that can survive in all of Earth's regions. Each area possesses its own unique community of characteristic life forms.

Tropical regions such as Costa Rica, Central America, contain the greatest variety of organisms. The picture above shows a small sample of the scarab beetles found in Costa Rica. Although they have many obvious similarities, each beetle is from a different species, each with its own unique characteristics.

Globally, the rate of extinction is on the rise. In the past, natural forces have caused extinctions, but increasingly they are being attributed to human influences. As a consequence, the variety of genetic material is decreasing.

1.1 Examining Diversity

Life exists on our planet in many forms. Biologists have identified over 1.5 million species of animals and more than 350 000 species of plants. A **species** is a group of organisms that have the same structure and can reproduce with one another. There are more species of insect than all of the other kinds of life forms combined. It is no wonder that they are considered the most successful form of life. Biologists estimate that there are probably somewhere between 30 million and 100 million kinds of organisms existing today. They have described only a small percentage of this total. Regardless of how unique they may appear, all life forms share certain characteristics. All living things are made of cells, need energy, grow and develop, reproduce, and have adaptations that suit them for the environment in which they live.

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Species Numbers

Even though scientists estimate that millions of species live on Earth today, this is just a tiny number compared with the total number of species believed to have lived on Earth since life began roughly 5 billion years ago. Scientists estimate that the species alive today represent only 1% of all the species that have ever lived.

Understanding Biological Diversity

Biological diversity refers to all the different types of organisms on Earth. However, scientists don't usually examine the entire Earth's biological diversity. They examine it in smaller groupings.

Diversity Between Ecosystems

In an **ecosystem**, living (biotic) things interact with other living and non-living (abiotic) things in a shared environment. Abiotic factors include air, water, and sunlight. Together, the living and non-living factors function as a system, hence the term "eco*system*." There is a huge variety, or diversity, of ecosystems on Earth. The number and types of species and abiotic elements can vary from ecosystem to ecosystem. A boreal forest ecosystem (Figure 1.1) has different types and levels of abiotic factors than a prairie slough ecosystem (Figure 1.2). These differences affect the number and type of species that can live there.

Figure 1.1 These woodland caribou share a boreal forest ecosystem with mosses, lichens, pine trees, black spruce, white spruce, poplars, wolves, grizzlies, wolverines, lynx, and a variety of birds.

Figure 1.2 This prairie slough teems with life such as dragonflies, mosquitoes, mallards and ruddy ducks, red wing blackbirds, bulrushes, sedge, and muskrats.

GIVE IT A TRY

Trekking Through Alberta's Landscape

Alberta Environment and the provincial government have approved the names of six natural regions making up the vast landscape of Alberta. Each region represents an ecological unit that has its own plants, animals, landscapes, and weather patterns. Each ecological unit is home to many different ecosystems. These regions are the Canadian Shield Natural Region, the Boreal Forest Natural Region, the Foothills Natural Region, the Rocky Mountain Natural Region, the Parkland Natural Region, and the Grassland Natural Region.

- Look at the map showing the location of these regions supplied by your teacher or on the Web site below. Brainstorm with a partner at least *three* plant and animal species you might expect to find on a trek through each region. Record your ideas in a table.
- Using the Internet or library resources, verify whether the plant and animal species you identified live in each region. Compile a class table of all the different species for each region and post it in your class. Begin your search at www.pearsoned.ca/scienceinaction.

Diversity Within Ecosystems

Scientists often examine the biotic factors of an ecosystem. When members of a species live in a specific area and share the same resources, these individuals form a **population**. For example, a population might be all the magpies that live in a certain park. When populations of different species live in the same area, these populations form a **community**. For example, the park contains a community because there are other populations that live in the park besides the magpies. It has populations of aspen trees, grasses, gophers, and so on. The community is the biotic component of an ecosystem. Different communities can also vary widely. For example a park with many formal gardens (but no trees) has a different community because it contains different populations of species than the park mentioned above.

Figure 1.3 The wildebeests, antelopes, and zebras in this picture are all different populations, but together they form part of the diverse community of living things on the Serengeti Plain in Tanzania, Africa.

Diversity Within Species

A species is a group of organisms that all have the same basic structure. However, if you look closely at any population, you will notice that there are subtle variations between the individual members of the population. For example, if you examined a population of magpies very closely, you might notice that bill shape or wingspan varied between individuals. Genetic diversity refers to the variations between members of a population. In any population, these variations are, for the most part, caused by subtle variations in the cells of the organisms.

An organism that shows a great deal of genetic diversity is the banded snail. Members of this species show a tremendous amount of variation in shell colouring as well as the banding on their shells. The colour can range from yellow to brown, and the bands on the shell can range from no bands to bands covering the whole of the shell. Each variation is a result of a variation in the genetic information in the animal's cells.

Some variations between individuals aren't even visible. For example, all human blood looks the same, but it can be classified into blood types. An individual can have one of four basic blood types: A, B, AB, or O.

In certain cases, humans purposely reduce the amount of variation between individual organisms. Over time, humans have bred plants and animals so that as many individuals as possible show the same useful characteristics. For example, individual wheat plants in a crop all have strong stalks and many large seeds.

You will learn more about genetic diversity in later sections.

Figure 1.4 In a field of wheat, individual wheat plants show very little variation. This lack of variation is a result of years of plant breeding.

Species Distribution

The species on our planet are not distributed evenly. Areas around the equator have the greatest number of plant species. These diverse plant communities in turn provide food and shelter to a wide variety of organisms. The number of plant and animal species is greatest in tropical regions. So the tropical rain forests in equatorial regions contain the greatest biological diversity. As you move north to the temperate and then the polar regions, you will find less biological diversity. For example, a survey of snake species in three regions revealed there were 293 species in tropical regions of Mexico, 126 species in the United States, and only 22 in Canada. This trend is found for all organisms. The Arctic and Antarctic regions contain the lowest biological diversity.

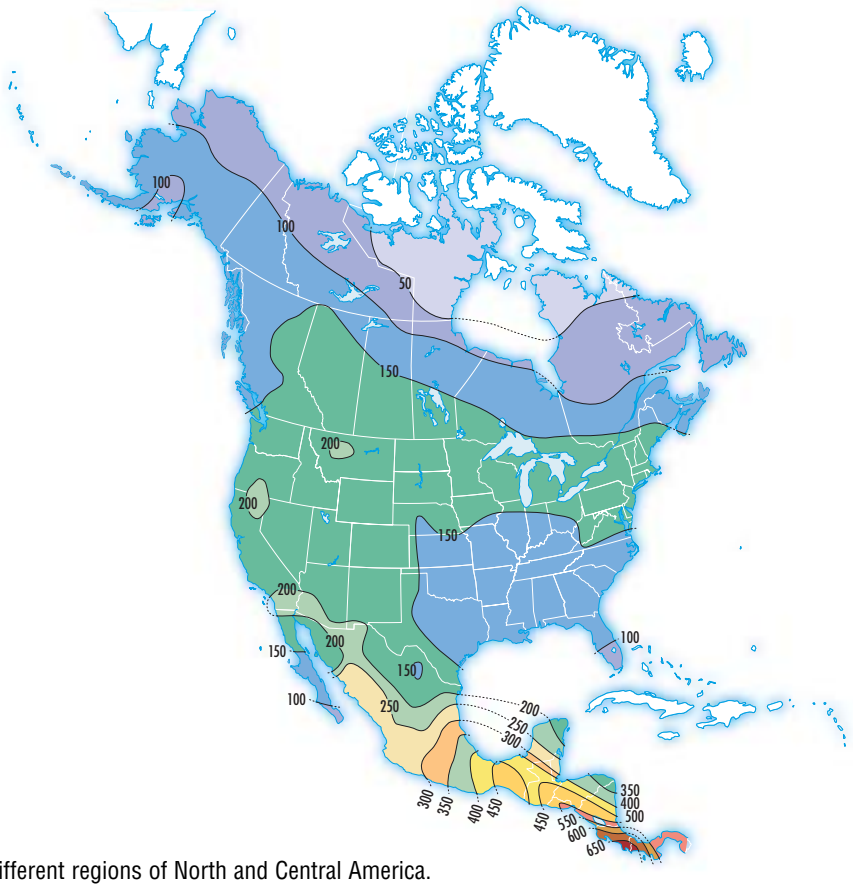

Figure 1.5 This map shows the number of bird species in different regions of North and Central America.

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How Many Kingdoms?

Increasingly, scientists are using a six-kingdom system of classifying organisms. Research has shown that one group of bacteria is genetically different from other bacteria. As a result, the kingdom Monera has been divided into two new kingdoms: Archaebacteria and Eubacteria.

Figure 1.6 Although the two owls look alike, the northern spotted owl on the right does not breed with the barred owl on the left. As a result, they are considered two different species.

Classifying Biological Diversity

In the 18th century, a Swedish scientist named Carolus Linnaeus, developed a system for naming organisms and for classifying them in a meaningful way. He used Latin because that was the common scientific language of his time. Linnaeus's naming system brought worldwide consistency to the naming of species, which could not be accomplished with common names. In his system, two words name each living thing: the first word indicates the name of the **genus** to which the organism belongs and the second word indicates the particular **species**. No two species can have the same name. Closely related species can have the same genus name, but not the same species name. The red wolf is called *Canis rufus*, the timber wolf is called *Canis lupus*, and the dog, *Canis familiaris*.

Linnaeus arranged species into groups based on their physical structure rather than on their habitat, which earlier systems had done. Modern scientists further developed Linnaeus's classification system. Latin continues to be the language of classification because it is a dead language, one that does not change over time. Because the same Latin names are used worldwide, each scientist will know which species another scientist is discussing.

Scientists have been using a five-kingdom classification system: Animalia (animals), Plantae (plants), Fungi (yeasts, moulds, and mushrooms), Protista (mostly single-celled organisms), and Monera (bacteria). Each **kingdom** is divided into a series of **phyla** (the plural form of **phylum**) and possibly **subphyla**. Each phylum is divided into **classes**, which are further subdivided into **orders**. Orders are divided into **families**, which divide into **genera** (the plural form of genus). Each genus is then separated into species.

An example of this classification system is illustrated in Figure 1.7 on page 13. Note that the classification of the three organisms becomes more specific as you move from kingdom to species.

*math*Link

Using data set 2 from the Skill Practice on page 13, convert each nanometre measurement into centimetres.

	White spruce	Wolf	Bull trout
Kingdoms	Plantae	Animalia	Animalia
Phyla	Coniferophyta (Conifers)	Chordata	Chordata
Subphyla	—	Vertebrata	Vertebrata
Classes	Pinopsida	Mammalia	Osteichthyes (Fish)
Orders	Pinales	Carnivora	Salmoniformes
Families	Pinaceae	Canidae	Salmonidae
Genera	*Picea*	*Canis*	*Salvelinus*
Species	*Picea glauca*	*Canis lupus*	*Salvelinus confluentus*

Figure 1.7 Classification of three organisms from a montane ecosystem

SKILL PRACTICE

Representing Data

TOOLBOX

Information comes in many forms including information represented in numbers. Often numerical data are hard to interpret, and scientists use charts or graphs to illustrate the patterns or trends in the data. For example, scientists use a pie chart to display data that is part of a whole. They also use bar graphs to show relationships between sets of data.

Below are two different sets of data. Determine which type of chart or graph would best represent these data sets and create the appropriate chart or graph for each set. (You may wish to review graphing in Toolbox 7.)

Data Set 1

- Two red-eyed, long-winged fruit flies could produce the following combinations for 16 offspring:
  - 9 out of 16 would have red eyes and long wings
  - 3 out of 16 would have red eyes and small wings
  - 3 out of 16 would have white eyes and long wings
  - 1 out of 16 would have white eyes and small wings

Data Set 2

- The size in nanometres (nm or 10^{-9} m) for the following viruses are:

smallpox virus	250 nm
flu virus	100 nm
yellow fever virus	22 nm
polio virus	20 nm
foot and mouth virus	10 nm

ACTIVITY **A-1**

Problem Solving

REPRESENTING BIOLOGICAL DIVERSITY

Biological Diversity on Earth	
Group of organisms	**Number of species**
plants	270 000
fungi and lichens	100 000
protozoans and algae	80 000
spiders and scorpions	75 000
mollusks	70 000
crustaceans	40 000
roundworms	25 000
fish	22 000
flatworms	20 000
earthworms and leeches	12 000
reptiles and amphibians	10 500
jellyfish, corals, and anemones	10 000
sponges	10 000
birds	10 000
bacteria	4 000
mammals	4 500
insects, centipedes, and millipedes	963 000
other	10 000

Recognize a Need

Scientists working to classify the range of life on Earth have come to a startling conclusion: Species of insects, centipedes, and millipedes outnumber mammals by a ratio of 214 to 1. That is, for every recorded species of mammal, there are 214 species of bugs that have been discovered. Scientists estimate that we have only just begun to uncover the diversity of insects on our planet.

The chart on the left lists the number of species in each of the major groups of organisms.

The Problem

For people to care about the biological diversity on Earth, they have to be aware of the number and types of organisms that share the planet with us. Design a way to visually summarize the information in the chart to clearly represent the numbers of different species that have been identified. Your model may be two- or three-dimensional, and you may use technology as appropriate.

Criteria for Success

To be successful, your representation must meet the following criteria:

1. solve the problem described above
2. be accurate
3. reflect the proportions of different species in relation to one another
4. be visually appealing to convey the information to a general audience

Brainstorm Ideas

5. Work with a partner or in a small group. Brainstorm ideas that would fit the criteria. All ideas should be considered and written down.
6. Look for ways to blend the best of the group's ideas.

Design a Model

7. Plan the design. Write down all the steps you will follow.
8. Create your representation.

Test and Evaluate

9. How effectively does your design convey the information? How does your work compare with that of your classmates?

Communicate

10. Share and compare your design with others in the class. Highlight the features that make your representation both accurate and effective.

Biological Diversity Under the Sea

Coral reefs have been called the "amazons of the oceans" because of the richness of their species diversity. Like tropical rainforests, coral reefs support many different communities of organisms surviving on limited nutrients. As in tropical rainforests, organisms that inhabit coral reefs have very efficient ways of recycling the limited nutrients that are available. Coral polyps form the living layer of a coral reef. These tiny organisms, in which some algae species live, provide energy for coral communities by converting sunlight to fuel. The hard, calcium carbonate layers of a coral reef are constructed by reef-building corals and certain types of algae. Coral reefs can be massive and thousands of years old.

Figure 1.8 Large coral reefs, like the Great Barrier Reef, can contain hundreds of species of coral and thousands of species of mollusks. Many fish, bird, and whale species are also associated with this ecosystem.

Check and Reflect

Key Concept Review

1. Explain what is meant by the term biological diversity.
2. In one or two sentences explain why so many different types of organisms exist on Earth today.
3. Describe how scientists classify an organism.

Connect Your Understanding

4 Explain how the classification system helps us to understand how living things are different from or related to each other.

5. Summarize, in your own words, ecosystem diversity, community diversity, and genetic diversity.
6. Compare and contrast the meanings of population and community.
7. Why is there more biological diversity closer to the equator than in Canada? Give reasons for your answer.

Extend Your Understanding

8. Imagine that you have to classify all the birds on Earth based on where they live. Design a system that starts with very broad categories of many members and goes to very specific groupings of one type of member.
9. Explain why preseving biological diversity is important to life on Earth.

reSEARCH

"Cat-egories "

Trace the classification for a house cat, including the kingdom, phylum, subphylum, class, order, family, genus, and species. What are some of the house cat's relatives? Prepare a poster or an electronic presentation of your findings. Begin your research at www.pearsoned.ca/scienceinaction.

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Sharing Resources

Many species—especially birds—have restricted areas in which they forage (collect food). Researchers have found that the male red-eyed vireo forages for insect food in the upper canopy (9–15 m) of the trees they live in. The female collects insects in the lower canopy and nearer the ground (0–3 m). Male and female red-eyed vireos overlap only about 35% in their feeding areas. So even though they eat the same insects and are members of the same species, these birds find their food source in different areas and don't compete with each other.

1.2 Interdependence

No species can survive by itself. Each species is dependent on many other species in its environment. For example, plants produce oxygen as a by-product of photosynthesis and are therefore a major source of atmospheric oxygen needed by most other organisms on Earth. Plants also provide shelter and cover for many organisms. Mule deer, for example, need trees to shelter them from the wind and from predators such as wolves. Animals such as insects depend on flowering plants for food. Flowering plants depend on insects to transfer pollen from one flower to another, providing a means of fertilizing the plants.

In earlier studies, you learned that food chains and food webs illustrate the relationships between populations of organisms. Herbivores such as mule deer eat plants. Carnivores such as wolves eat herbivores. Decomposers such as bacteria and fungi break down both animals and plants once they're dead. The predator-prey relationship is one of the most obvious examples of interdependence between populations of species. If a population of predators such as the lynx grows so large that it eats too many of its prey, the snow-shoe hare, then lynx numbers must eventually decrease as its members die of starvation. As the lynx population decreases, the hare population will have a chance to recover and its numbers will increase. The cycle will then continue.

Although predators eat individuals in a prey population, the prey population benefits in many ways from this relationship. Predators reduce the size of the prey population. This prevents the prey from outstripping their food supply, resulting in starvation for the prey population. Also, predators tend to capture the old, sick, or weak members of the prey population. In this way, the healthy and strong members of the prey population survive to reproduce, producing healthy strong offspring.

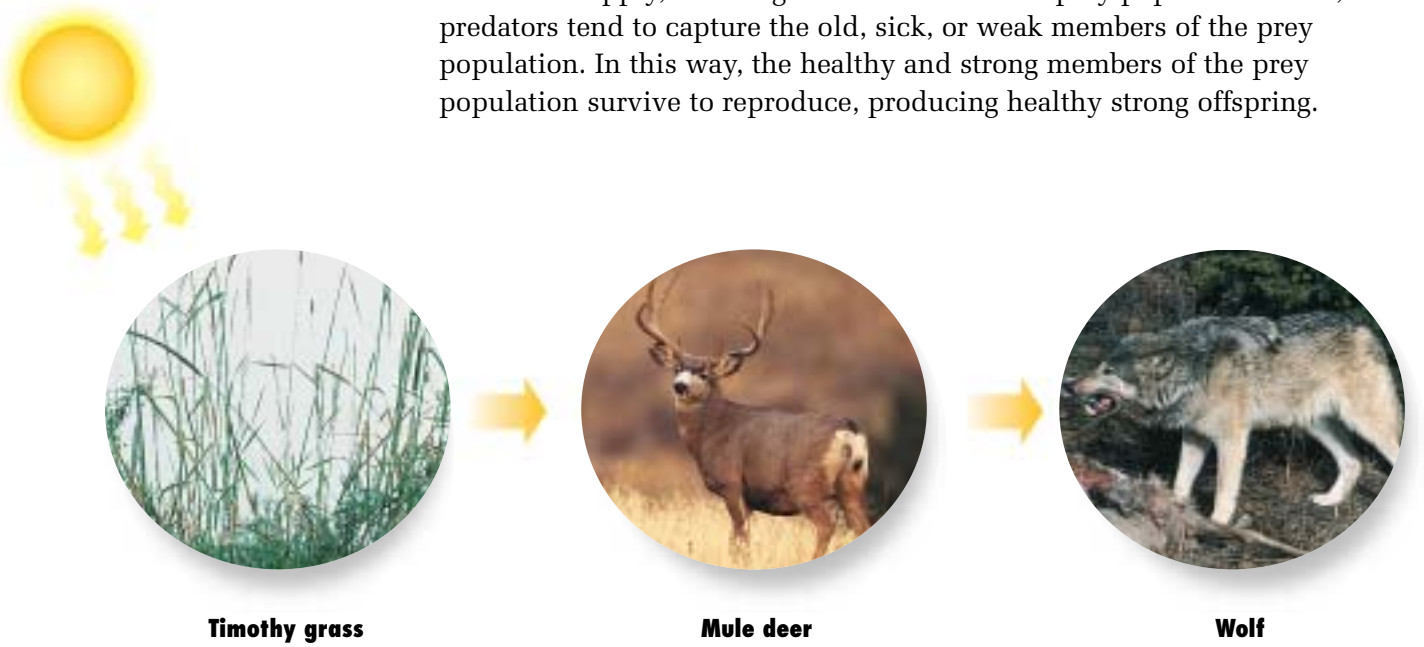

Figure 1.9 This food chain in a montane ecosystem illustrates interdependence. Timothy grass depends on the Sun's energy for growth. Mule deer (herbivores) depend on timothy grass as a food source. Wolves (carnivores) depend on animals such as mule deer for survival.

Symbiosis

Another type of interdependence is called **symbiosis** (*sym* meaning together, *bios* meaning life), which is an association between members of different species. There are several types of symbiosis and the difference among them is determined by whether the organisms benefit from or are harmed by the relationship.

In **commensalism**, one of the participating organisms benefits but the other does not. However, there is no harm done to the second organism. A bird that builds its nest in a tree, or a plant that grows high up on a tree to get sunlight but doesn't take nutrients from the tree are both examples of commensalism. Barnacles that attach themselves to whales in order to move to other areas are involved in commensalism. The barnacles benefit, but the whales are not affected (Figure 1.10).

As its root word *mutual* suggests, **mutualism** benefits both organisms. A lichen growing in the arctic tundra is a combination of two organisms: a fungus and an alga. Algal cells produce food for themselves and the fungus through photosynthesis, while the fungus protects the algal cells from dehydration. The bull's horn acacia tree is home to large numbers of ants. The tree gives the ants food and shelter, while the ants protect the tree from other animals feeding on it by attacking them. The ants have also been known to gnaw through vines that attach to the tree.

Another interesting example comes from Central America. The flower *Clusia* dispenses medicine to bees. As a bee pollinates the flower, it gets doused with a sticky resin spiked with a powerful antibiotic. Scientists suggest that the antibiotic in the resin kills bacteria commonly found in the bee's nest. When the bee makes an important house call to the plant, the bee gets medical attention free of charge!

In **parasitism**, one organism benefits and the other is harmed. A tapeworm attached to the intestinal wall of a human is an example. The tapeworm absorbs nutrients from the food in the intestine, leaving little food for the human host to absorb. Unlike the predator-prey relationship, parasites usually do not kill their hosts because the hosts represent their food supply. Parasitism is not limited to two organisms. For example, the Mexican bean beetle is a plant parasite. However, the beetle is parasitized by the tachinid fly which, in turn, is parasitized by the ichneumon wasp.

Symbiotic relationships are extreme examples of interdependence. One species' survival—particularly in a parasitic relationship such as a tapeworm and its host—depends directly on the health and survival of another species. For example, the tapeworm depends on its host for both its food and its habitat. Organisms involved in symbiotic relationships illustrate the importance of adaptations that help species survive in their unique environments.

Figure 1.10 The grey bumps on this whale are barnacles. The whale provides a method of transportation for the barnacles.

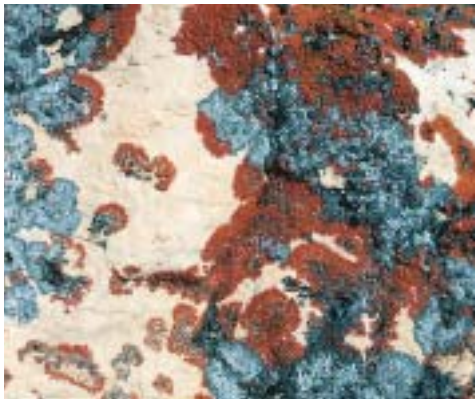

Figure 1.11 The interactions between the fungi and algae making up these lichens enhance the survival of each species.

QUICKLAB

Searching for Symbiosis

Purpose

To observe a symbiotic relationship

Caution!
Use care when handling the scalpel.

Procedure

1. Your teacher will give you a leaf with galls. Look for evidence of entry and/or exit holes.
2. Using the scalpel, cut open the gall. Use the magnifying glass to observe its contents and look for the insects inside.
3. Draw what you observe. If possible, identify the inhabitants of the gall.
4. Wash your hands carefully.

Questions

5. What is the purpose of the gall? Look for evidence of entry and/or exit holes to help you answer this question.
6. What type of symbiosis did you see when you cut open the gall? What evidence do you have to support your conclusion?
7. What is the role of the gall for the insects' survival?

Materials & Equipment

- galls from various plants
- scalpel
- magnifying glass
- dissecting tray
- insect identification keys/guides

Figure 1.12 What type of symbiosis is shown here?

reSEARCH

Mycorrhizae

Mycorrhizae are associations between plants and fungi. Use the Internet, your library, and other sources to find out what kinds of associations these organisms have and how they work. In a paragraph describe how the survival of one of the organisms is linked to the survival of the other. Begin your research at www.pearsoned.ca/scienceinaction.

Niches

There is one type of interaction between different species in which neither species benefits. **Interspecies competition** happens when two or more species need the same resource. For example, if two different species compete for the same food, there is less of it for each species. Within each population, each of its members has access to a smaller share of the resources, which leads to more deaths due to starvation. Interspecies competition limits the size of the populations of the competing species.

If you take a walk through the woods on a summer morning, you might see many types of bird species that are similar to one another. If competition between species hurts the species, how can so many species exist together in the same location? The answer lies in the niches they occupy.

The term **niche** describes the role of an organism within the ecosystem. An organism's niche includes what it eats and what eats it, its habitat, nesting site, or range, and its effect on both the populations around it and its environment. If you were to describe your own niche, you would have to describe where you live, what school you attend, jobs you work at, the food you consume, the temperature you feel comfortable in, and any influences you have on your community.

The niche occupied by a population in one area may not be the same as the niche occupied in a different area because the food supply and competitors may be different. In addition, the niche occupied by a species may change throughout its lifetime. The frog tadpole lives in an aquatic environment and consumes plant matter while the adult frog lives in both aquatic and terrestrial environments and is carnivorous.

Resource Partitioning

For similar species to coexist in an area, they must have slightly different niches. For example, five species of warblers (small songbirds) all feed on spruce bud worms. You would think that competition among the five species would harm them all. But because these species have different behavioural adaptations, each prefers to feed on worms at different parts of the tree. By doing this, the five species don't directly compete for the worms. Instead, they have divided up the resource (worms) among them in what is known as **resource partitioning**. Resource partitioning doesn't always involve food. For example, species may have slightly different niches in terms of nesting preferences or heat tolerance.

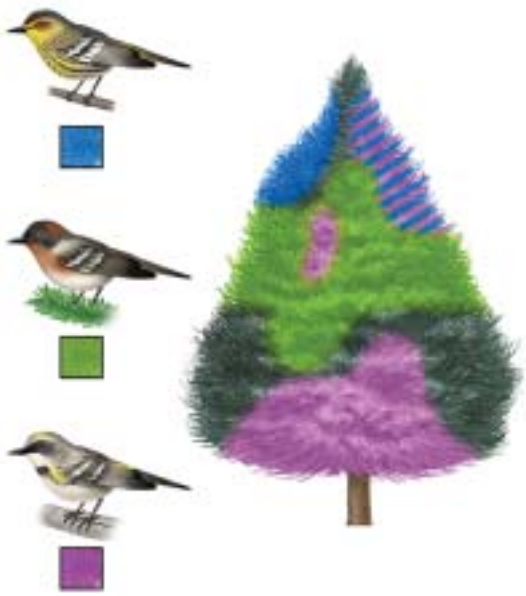

Figure 1.13 These three warbler species feed on spruce bud worms in different parts of a spruce tree. Their niches differ in the feeding location they prefer. Note that there is some overlap between the species.

Check and Reflect

Key Concept Review

1. List three different types of interdependence among living organisms. Provide an example of each.
2. How does the prey population benefit when individuals in this population are eaten by a predator?

Connect Your Understanding

3. Classify the following symbiotic relationships. Create a chart to record your data, use the coding "+" to represent a benefit, "–" to represent harm, and "n" to represent no benefit or harm. How would you use this coding to represent each organism involved in the following relationships? Explain your answer.
   a) mutualism b) parasitism c) commensalism
4. A student observes the following organisms in a 30 cm^2 section of the front lawn of your school: a dandelion; a small butterfly on the flower of the dandelion; a caterpillar eating the leaves of the dandelion; and a worm in the soil. Describe the niche of each organism.

Extend Your Understanding

5. Imagine your school is an ecosystem. Create a concept map showing the interdependence among students, teachers, classes, and grades in this "ecosystem."

1.3 Variation Within Species

Figure 1.14 Although the members of this species may look alike, they vary genetically from one another.

So far in this unit, you have seen that the stability of an ecosystem relies on the diversity of its communities and species and on the interactions among species. The many different species survive because of the relationships established in this complicated "jigsaw puzzle." Healthy ecosystems have a great deal of genetic diversity among the species that inhabit them. But biologists have also observed a great deal of variation *within* a population of a single species. For example, you and your classmates are all members of the same species, *Homo sapiens*, but each of you differs slightly in appearance. Some may have black hair, others blonde; some may be tall, others less tall. This kind of variation is seen in all species. Variation within a species is called **variability**.

Variability and Survival

Variability is important if the environment of the species changes. When the species has a great deal of variation among its individuals, it is more likely that some of the individuals will survive environmental changes. Environmental changes do not necessarily have to involve climatic changes. The introduction of a new predator, the spread of a new disease, the introduction of a toxic substance, or the elimination of a food source are all examples of environmental changes that could affect the survival of a species. In these cases, variability within the species will help the species survive.

*info*BIT

Coats of Many Colours

Even though its common name is the red fox, members of this species can have a wide variety of coat colours. Aside from the typical red coat, individuals may have grey-brown, silver, or even completely black coats.

For example, the fox shown in the infoBIT on page 20 has a dark coat instead of the more common red coat. Its dark coat may make it more conspicuous in fields and woods. But if this fox roams into a new habitat that has many black rocks, its dark coat may blend in better with its surroundings. By blending in better, the fox could pounce on its prey more easily. The fox's predators, such as wolves and lynx, might not spot it as easily. So variations in coat colour may allow different fox populations to survive in different habitats.

How variability helps in survival can also be seen in the growing resistance of certain strains of bacteria to antibiotics. One of the first antibiotics, penicillin, used to be very effective against some forms of bacteria. Today, it is far less effective. Researchers think that the over-prescription of antibiotics has allowed bacterial populations with variability to survive the application of antibiotics. A few resistant bacteria are not eliminated by the antibiotic that is administered, and reproduce to produce new generations of resistant bacteria. There is some fear that if this trend continues, resistant strains of bacteria may completely replace current strains and antibiotics will no longer be effective. To avoid this problem, most physicians believe that antibiotics should only be used when absolutely necessary.

*re*SEARCH

"Super Bugs"

Over time, some germs have become very resistant to medicines. Scientists sometimes refer to these as "super bugs." Find out more about a "super bug" and how it is now treated in human beings. Write a brief report based on your research. Begin your research at www.pearsoned.ca/scienceinaction.

SKILL PRACTICE

Measuring Variation in the Human Hand

Variation within a species may not be something that is immediately noticeable. Try this activity to measure the amount of variation within one human characteristic—hand span. Spread your left hand on a flat surface so that the tip of your thumb is as far as possible from the tip of your little finger. Ask a partner to measure and record your hand span in centimetres. Switch roles and measure your partner's hand span. Prepare a frequency distribution chart like the one below for hand span data from the class. Then plot your results in a line graph. (Review Toolbox 7.)

Hand span in cm	12 or less	13 to 16	17 to 20	21 to 24	25 to 28	29 or more
Number of students						

- What shape does the graph have? What does it show about variation in hand span among your classmates?
- Predict whether the graph would have the same shape if you measured the hand spans of students in grade 1 and in university.
- What advantage might large hands have given to early *Homo sapiens*? Small hands?
- What other human characteristics might be measured in the same way? What prediction could you make about index finger length in humans?

PROTECTIVE COLORATION AND SURVIVAL

Before You Begin

Many species show variation in colour and patterning which can allow individuals to blend in with their surroundings. Species that are found in a variety of habitats may show a wider range of colour and pattern variation than those that are found in only one habitat.

In this activity, you will model a population that exists in three different colours. Your task will be to investigate the relationship between an organism's survival and its colour relative to the colour of its surroundings. Coloured chips or blocks will represent a prey population and some students in your group will play the role of predators.

Materials & Equipment

- 60 chips of each of three different colours (coloured counters, coloured algebra tiles, lego blocks or similar)
- a piece of paper or cloth 75 cm × 75 cm, which matches one of the chip colours
- graph paper
- colour markers or pencil crayons

The Question

Does the colour of an organism affect the organism's chance of survival?

The Hypothesis

Reword the question in the form of a hypothesis.

Procedure

1. Your teacher will divide the class into groups of five. Three students are to play the role of predator, one student monitors the population and sets up the population for each generation, and one student records the results.
2. Your teacher will provide each group with a piece of paper or cloth, 75 cm × 75 cm, to represent the habitat. The colour of the paper or cloth will match one of the colours of the prey organisms.
3. Set up a data table similar to the one below and record the colour composition of generation 1. You will start with 20 chips of each colour in generation 1.

	Number of Colour #1	Number of Colour #2	Number of Colour #3
Generation 1			
Survivors of Selection 1			
Generation 2			
Survivors of Selection 2			
Generation 3			
Survivors of Selection 3			
Generation 4			
Survivors of Selection 4			
Generation 5			
Survivors of Selection 5			

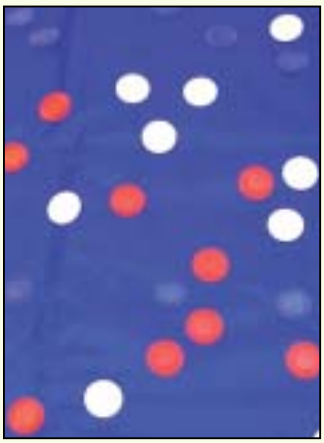

Figure 1.15(a) Step 4. Set-up for generation 1.

4. With the predators looking away, the designated monitor will set up the first generation of 60 individuals of the prey population on the habitat by randomly scattering 20 chips of each of the three different colours on the habitat. See Figure 1.15(a) for the set-up. The predators continue to look away from the habitat.
5. Have a predator turn around and very quickly take any chip, and then turn back. This represents selection of a prey animal to be eaten. Repeat the process with each of the other predators until each predator has taken 10 chips. The 30 chips that remain are the survivors.

6. Record the colour of the survivors and remove them from the habitat.
7. Assuming that each survivor produces 2 offspring of the same colour, the monitor and recorder determine the population composition for generation 2. The recorder records the number of chips of each colour that will make up generation 2.
8. The population monitor will set up generation 2 by placing the appropriate number of chips of each colour on the habitat.
9. Repeat steps 5–8 until 5 rounds of selection have been completed.
10. Compare the number of survivors of each colour that remain after each selection.

Analyzing and Interpreting

11. Plot bar graphs to show the number of survivors of different colours that remain after each selection. Decide first how you will show these results; for example, decide if you will show the results on one graph or three. Examine your set of graphs for trends.
12. How does the composition of the prey population at the end of selection 5 compare with the original composition of the prey population?
13. Share your results with groups who used a different background colour for the habitat. Compare your graphs with the graphs of the other groups. Do you see any trends?
14. How do the colours of the survivors relate to their habitat background? Suggest a possible explanation for this pattern.

Forming Conclusions

15. Based on class results, what conclusions can you draw about the role of coloration in an organism's survival?

Applying and Connecting

Imagine a species with two colour variations, one mostly green and one mostly brown. How might populations of this species change:

a) if the environment changes from green to brown?
b) if the environment becomes a patchwork of tiny green and brown splotches?

Survival of the Banded Snail

The banded snail, *Cepea nemoralis*, shown in Figure 1.15(b), lives in a wide range of habitats that vary from dark beech and oak woods to leafy hedges and grassy meadows. Its shell colour can vary from yellow through a range of pinkish browns to brown. Bands on the shell can be thin or thick and can range from one band to many covering the whole shell.

Scientists explain this range in variation by referring to the colour of the ground and vegetation in the snail's habitat. The foliage changes with the seasons. In spring there is little vegetation and the ground is brown, giving brown snails an advantage. Predators, like the song thrush, may not find them because they blend in with their surroundings. In summer, brown snails are more at risk when their shells contrast with green meadows. Because of the great variation, only part of the snail population may be predated in any season, ensuring the survival of the species.

Figure 1.15(b) Banded snails

Natural Selection

Figure 1.16 Cliff swallows

Another aspect of species survival and variability is natural selection. **Natural selection** occurs when the environment "selects" which individuals will survive long enough to reproduce.

An example of natural selection in our own time occurred in southwestern Nebraska. In May 1996, a severe cold spell gripped the area for six days. Dr. Charles Brown, who had been studying the same colony of cliff swallows for 17 years, watched about 30 000 birds, or about half of the colony, die of starvation. Why did some birds die and others survive? To answer this question, Dr. Brown and Mary Bomberger Brown collected more than 1800 dead cliff swallows. They measured the beaks, wings, and legs of the dead birds and then measured the same structures on about 1000 survivors. They discovered that the survivors were larger overall, with bigger beaks and legs. They were also more symmetrical—both sides of their bodies matched. Because of an extensive banding program, the Browns were able to determine that before the severe weather, the non-survivors were just as healthy as the survivors. The Browns hypothesized that the bigger birds were selected for survival because their larger size allowed them to store more fat and their greater symmetry allowed them to forage with less energy loss. The offspring of the survivors were also large and symmetrical.

Check and Reflect

Key Concept Review

1. What is variability?
2. In your own words, define natural selection.

Connect Your Understanding

3. Describe several examples of changes in the environment that might select some individuals in a species for survival over other individuals. Explain your answers.
4. Describe an example where variability within a species has helped a species survive an environmental change.

Extend Your Understanding

5. Suppose a population of sparrows migrating south for the winter is blown off course by a storm and the sparrows become isolated on an island. The only food source available on the island is a plant that produces large seeds. Predict which birds in the population, those with large beaks or those with small beaks, will survive to continue their migration or to populate the island. Explain your answer.

Assess Your Learning

Key Concept Review

1. Write a definition of biological diversity that includes a description of its three main components.
2. Define the terms niche and symbiosis. Explain how these terms are related.
3. How does variability within a species affect its survival?

Connect Your Understanding

4. Using examples, explain ways in which different species living within an ecosystem depend on one another.
5. How does natural selection enhance or reduce the variability of a species? Explain your answer using an example.
6. Restate the meaning of interspecies competition in your own words. Use an example to illustrate.
7. How does variation within a species contribute to the health of the species? Of an ecosystem?
8. Describe your niche.

Extend Your Understanding

9. To help you organize your learning about biological diversity, construct a mind map as a frame in which to record your notes. Compare your work with a partner to be sure you have captured all the main ideas and important details in this section.
10. Rewrite the information in this section, simplifying it so that it could be easily understood by a grade 4 student. Be sure to explain how diversity among species and within species contributes to species survival.

Focus On Social and Environmental Context

Activities designed to meet human needs and encourage technological development can have intended and unintended effects on other species and the environment.

1. Explain how you think biological diversity benefits humans and other forms of life on Earth.
2. Almost half of all animal life forms on the planet are insects. How important is it to preserve those species? Should we be concerned about ensuring that something as small as the fruit fly is not eliminated? Why or why not? Would we be better off without insects? Support your answer.

2.0

As species reproduce, characteristics are passed from parents to offspring.

Key Concepts

In this section, you will learn about the following key concepts:

- asexual and sexual reproduction
- inheritance

Learning Outcomes

When you have completed this section, you will be able to:

- distinguish between asexual and sexual reproduction and describe examples of each type of reproduction
- describe types of variations found within a species and determine whether they are discrete or continuous
- distinguish between heritable and non-heritable characteristics

When you walk around a greenhouse, you might notice the number of possible shapes and sizes of plants. You might also notice that particular species have particular characteristics. For example, a Boston fern has large green leaves and no real stem. The coleus plant, however, has leaves of many different colours growing out of a central stem. What process ensures that these characteristics in a species are passed down from generation to generation? The answer is reproduction.

If you look at two coleus plants, you would see that although they have many similarities in their characteristics, each plant can also have its own unique versions of certain characteristics. For example, all coleus plants have velvety leaves, but one plant's leaf colour may be dark purple, while another's is red and yellow. In this section, you will discover how these variations in characteristics occur.

2.1 A Closer Look at Variation

In subsection 1.0, you explored how variation contributes to species survival. In the example of the coleus plant, you can see that certain characteristics, such as leaf colour, can vary among plants of the same species. Not all variations are as evident as leaf colour. For example, Jack pines exhibit variation because some trees of this species resist drought better than other Jack pines. Magpies show variation because some members of this species can fly longer distances. Different cells of the same bacteria may vary, making some more resistant to antibiotics.

Figure 2.1 Although these penguins look almost identical, they vary from one another in subtle ways.

To better understand variation, scientists may explore which characteristics species pass along from generation to generation, and how these characteristics show up in individuals. Scientists may also examine other factors, such as the role of the environment in variation.

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Ancient Breeding Activities

Although the people living near the Persian Gulf during ancient times did not know about modern-day genetics, they did understand that characteristics were passed from parents to offspring. Archeologists discovered a 6000-year-old engraved stone tablet that was used to record the characteristics of five generations of horses. As well, they found evidence that these people followed the same rules that plant and animal breeders of today use to "shape" the characteristics of offspring.

GIVE IT A TRY

Observing Variation in Human Characteristics

Humans have many characteristics that can vary. Some of us are tall, others are short; some have curly hair, some have straight hair. Some people can bend their thumbs back toward their wrists. And some have earlobes that hang loose, but others have earlobes attached to their heads. Even hairlines can vary.

Take a quick survey of your class to find out how many people:

- can or cannot bend their thumb joint "backward" without adding pressure
- have earlobes that are attached or separate
- have a pointed or smooth hairline

Draw a data table to record your results. Create a graph that will best illustrate your results.

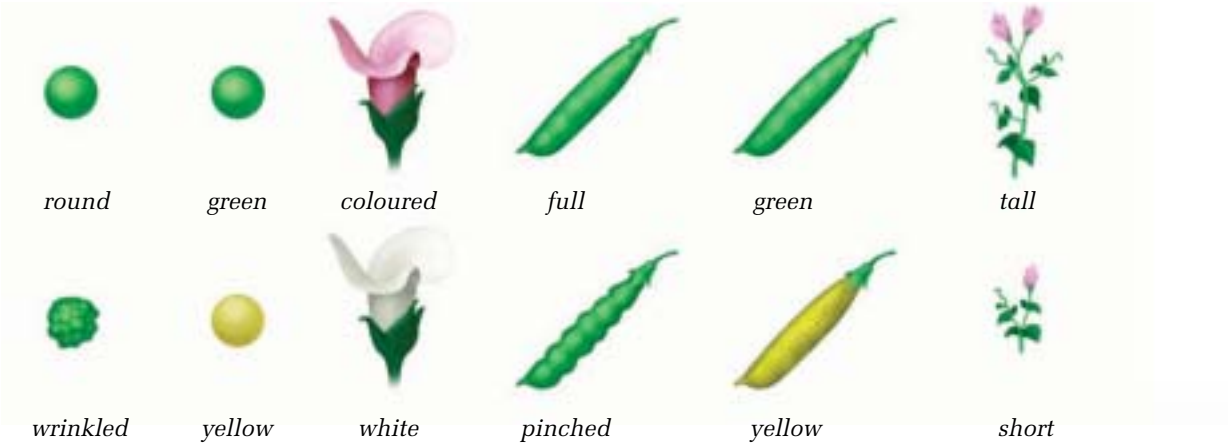


Figure 2.2 Some of the characteristics in pea plants that scientists have studied include seed shape, seed colour, flower colour, pod shape, pod colour, and plant height.

Heritable and Non-Heritable Characteristics

Heritable characteristics are passed on from generation to generation. Some examples of inherited characteristics are eye colour, hair type, and skin colour. **Non-heritable characteristics** are acquired. That is, they are not passed on to other generations. A person who has learned to play the piano, for example, will not have children who are born knowing how to play. The ability to play an instrument is an acquired characteristic. Similarly, if someone dyes his or her hair a different colour, his or her children will not inherit the dyed colour.

Discrete and Continuous Variation

Figure 2.3 This kangaroo is an albino. Pigmentation is a discrete variation: albino or pigmented.

Variations can be either discrete or continuous. **Discrete variation** refers to differences in characteristics that have a defined form. You can think of discrete variation as being the "either/or" form of a characteristic. For example, a cat either has blue eyes or does not have blue eyes. A mouse is either an albino or it is not an albino. Your earlobes are either attached or they are not. **Continuous variation** refers to differences in characteristics that have a range of forms. They are not one form or another. For example, the height of adult humans can range from 1.2 m to 2.1 m. In squirrels, mass can range anywhere between 133 g and 249 g.

Variation and the Environment

Some variations in individual organisms result from interactions with the environment. Imagine, for example, you have two plants that are completely identical. If you put one plant in a sunny window and the other in a dim closet, they would soon begin to look very different. The one in the sunlight would be green and bushy, but the plant in low light would be a pale green and spindly.

Height is a heritable characteristic. But height can be affected by diet. In general, North Americans are taller than they were in the 19th century because of better nutrition and access to a wide variety of food. There have always been shorter people and taller people, but North Americans living in the 19th century would likely have been somewhat shorter than North Americans living today.

Variations caused by interactions with the environment are not heritable. You would not expect all the offspring of a plant grown in dim light to look like its parents unless they too were grown in low-light conditions. Similarly, if a child of tall parents doesn't receive proper nutrition, he or she probably will not be as tall as his or her parents.

*re*SEARCH

Environment's Role

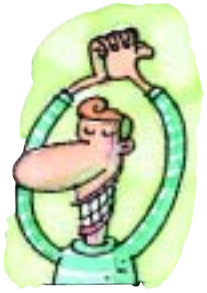
Investigate how plants, such as hydrangea and the water buttercup, exhibit variation depending on the environment they live in. Use books or electronic resources for your research. Prepare a chart to display your findings.

GIVE IT A TRY

Is It Discrete or Continuous?

On a signal from your teacher, and with your eyes closed, quickly clasp your hands together above your head, interlocking your fingers. Now look to see which thumb is on top: left or right? Try clasping your hands with the other thumb on top. Note which way feels more natural. Report your personal hand-clasping preference.

- On a chart, record the observations of the class for *Left Thumb on Top* versus *Right Thumb on Top*.
- From the class data, try to determine if there is a hand-clasping preference. Decide whether it seems to be discrete or continuous. Explain your answer.



Check and Reflect

Key Concept Review

1. Give one example of a heritable characteristic and one example of a non-heritable characteristic. Use examples different from those in the text.
2. What is discrete variation? What is continuous variation?

Connect Your Understanding

3. Some characteristics are heritable but can also be affected by the environment. Explain how this is true for height in humans.
4. Describe how the environment may affect variation in plants.
5. A scientist wants to study continuous variation in a mouse population. What mouse characteristics would she or he investigate?

Extend Your Understanding

6. Observe your thumb and the thumbs of your classmates. You will see that there are two types: a straight thumb and a bent-backward (or hitchhiker's) thumb. What type of variation does thumb shape show?

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Parthenogenesis

In some species of animals, particularly social insects, such as ants and bees, and in rotifers (microscopic invertebrates), a unique method of asexual reproduction has been observed. Parthenogenesis, meaning "virgin birth" in Greek, is the term used to describe the process that transforms unfertilized eggs into mature organisms. In bees, unfertilized eggs become male drones, while the fertilized eggs become female workers and queens. The process has also been observed in more complex animals, such as snakes, and more rarely in plants, such as figs, where it is called parthenocarpy.

Figure 2.4 Yeast cell budding

Figure 2.5 Spores can survive unsuitable growing conditions because they remain dormant. When conditions improve, spores can produce new plants.

2.2 Asexual and Sexual Reproduction

Reproduction produces new individuals of a species. The way a species reproduces determines how much variation the new individuals will have.

Reproduction can produce new individuals that are identical to or very different from one another.

Asexual Reproduction

Asexual reproduction involves only one parent. All the offspring that result from asexual reproduction are identical to that parent. In other words, they all inherit identical characteristics because the adult makes an exact copy of itself. There are several different forms of asexual reproduction, such as binary fission, budding, spore production, and vegetative reproduction.

Binary Fission

Only one-celled organisms, such as bacteria, and some protists, such as amoebas and some algae, reproduce by binary fission. During **binary fission**, a cell splits exactly in two, producing two identical individuals.

Budding

Organisms such as hydra and yeast reproduce asexually by **budding**. During budding, the parent produces a small bud, or a smaller version of itself. In animals, such as hydra, the bud eventually detaches and becomes a new individual identical to its parent. This is also true of yeast, which is a unicellular fungus. In other animals, such as coral, the offspring remains attached to the parent, forming a large structure composed of many identical individuals.

Spore Production

Many fungi, green algae, some moulds, and non-flowering plants such as ferns reproduce by producing spores. **Spores** are similar to seeds, but are produced by the division of cells of the parent, not by the union of two cells. One individual will produce many spores, and each spore can develop into a new individual identical to the parent.

Vegetative Reproduction

Most plants are able to reproduce by vegetative reproduction, another form of asexual reproduction. **Vegetative reproduction** is the reproduction of a plant that does not involve the formation of a seed. If you take a cutting from a coleus plant and place it in water, the cutting will grow roots and eventually develop into a whole new plant. This is one form of vegetative reproduction. Many plants, such as strawberries or spider plants, grow runners that produce new plants along them. Tubers, such as potatoes on a potato plant, and bulbs, from which daffodils and tulips develop, are also forms of vegetative reproduction. The roots of aspen trees produce a form of shoot called a sucker. If the sucker becomes physically separated from the original tree, it will grow into a new aspen tree (Figure 2.6). In all these cases, the new individual plants that are produced will be genetically identical to their parent plant and to one another.

Figure 2.6 The individual trees in a stand of aspens are often identical to one another, as a result of vegetative reproduction.

Figure 2.7 Offspring of this plant form at the edges of the leaf.

SKILL PRACTICE

Representing Asexual Reproduction

TOOLBOX

To help them better understand the processes of asexual reproduction, scientists use diagrams to record their observations. By comparing such illustrations, they can identify differences and similarities among asexually reproducing organisms.

Review the different forms of asexual reproduction described on pages 30–31. Make notes on each type and make a labelled diagram to show how an organism reproduces by that form.

- Compare your diagrams. Describe any similarities among them.
- Describe any differences.
- Using print and electronic resources, find and illustrate an example of an asexually reproducing organism not described in this section.

Figure 2.8 Diagrams help scientists compare organisms.

infoBIT

Hermaphrodites

Common garden worms and slugs are hermaphrodites. Hermaphrodites can produce both male and female gametes. Although most slugs and worms usually prefer to mate with other individuals of their species, in times of environmental stress, they can fertilize themselves.

Sexual Reproduction

Sexual reproduction usually involves two individuals. Most species of animals and flowering plants reproduce sexually. The offspring of sexual reproduction will have a mix of the characteristics of both individuals, ensuring that there is always a mix of characteristics in each generation.

You might think that sexual reproduction always involves a male and a female, as it does in humans and other mammals. However, sexual reproduction also occurs in species that we may not think of as having males and females, such as flowering plants and coral. These species have specialized forms of sexual reproduction.

Sexual reproduction in plants or animals relies on the union of two specialized cells known as **gametes**. A gamete is a cell that has one role only, which is to join with another gamete during reproduction.

Sexual Reproduction in Animals

Almost all animal species, from fungi to protists, from salmon to dragonflies to bears, reproduce sexually. Although the details may vary, the important events in animal reproduction are the same. Sexual reproduction involves specialized cells known as gametes (sex cells). The male gametes are called **sperm cells**, and the female gametes are known as **egg cells (ova)**. The union of the sperm cell with the egg cell occurs during mating and is called **fertilization** (Figure 2.10). The cell created by the joining of the two gametes is known as a **zygote**. The zygote is the first cell of a new individual. The zygote then divides into two cells. The same divisions are repeated during a process called **cleavage**. Continued cell division results in a new multicellular life form referred to as an **embryo**.

Depending on the species, the development of the embryo may occur inside the female parent, which happens in most mammals, or outside, in an egg, which happens in most other types of animals. The new individual will show some of the characteristics of its female parent and some of its male parent. Although the new individual may resemble one parent more than the other, it will not be identical to either parent.

Figure 2.9 Only one of the many sperm cells surrounding the egg will fertilize the egg.

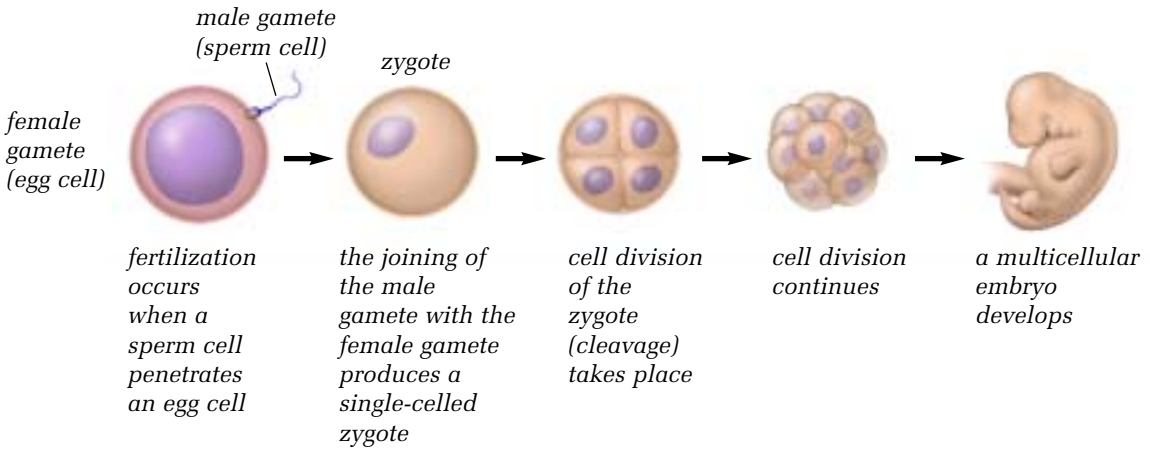

Figure 2.10 Sexual reproduction in animals involves specialized cells called gametes.

Sexual Reproduction in Plants

As in animals, sexual reproduction in plants requires the joining of a male gamete with a female gamete to produce a zygote and an embryo. Most plants produce both male and female gametes. However, some produce only female gametes and others only male.

Figure 2.11 shows the parts of a flower that are involved in reproduction. Most flowers have all of these parts, although the shapes and sizes of each flower vary. Some flowers are large and showy. Others are hardly noticeable (Figure 2.12). **Pollen** contains the male gametes of a plant. Pollen is found on the **stamen**, or male part, of the plant. **Ovules** contain the female gametes of a plant. Ovules are found in the **pistil**, or female part of the plant.

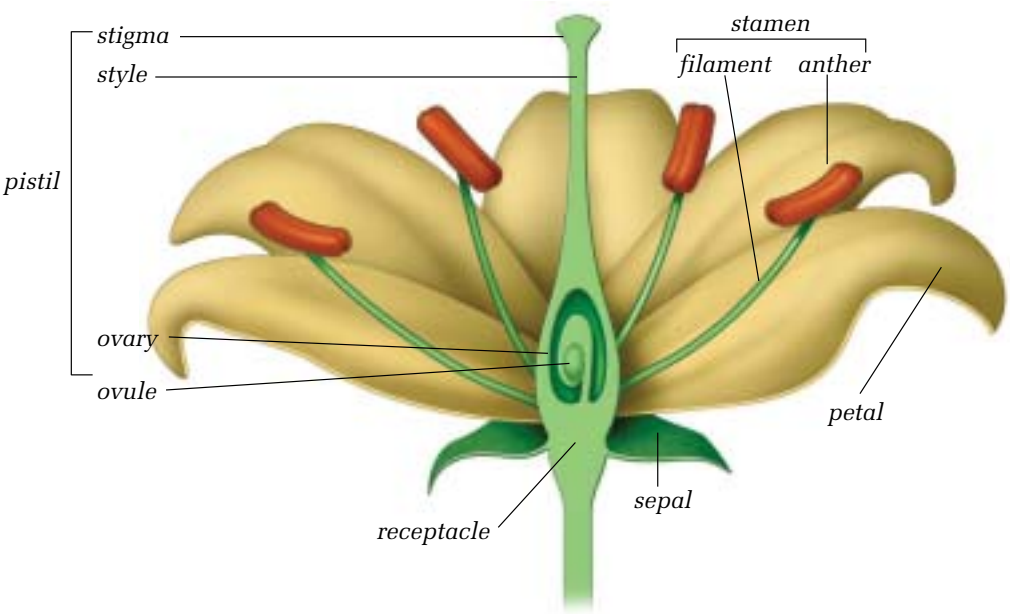

Figure 2.11 Flower parts involved in reproduction

Pollination occurs when pollen is transferred from the **anther** of the stamen to the **stigma** of the pistil. Fertilization occurs when the male and female gametes unite. **Cross-pollination** occurs when the pollen of one plant is carried to the stigma of another by wind, water, or animals, such as bees or butterflies. **Cross-fertilization** occurs when a grain of this pollen produces a long tube that eventually grows down the **style** into the **ovary** that contains the ovules. (Pollen grains and ovules are sacs that contain sex cells.) A gamete in the pollen grain and a gamete in an ovule join and, as in animals, a zygote is formed. The zygote then begins a series of divisions to produce an embryo.

The embryo will eventually develop into a new individual. In most plants, the embryo is produced inside a seed. The seed protects the embryo and stores food for the embryo to use when it begins to grow into a new individual. Unlike animals, the new embryo may not begin to grow for some time, but stays dormant within the seed until it has suitable growing conditions. Plants that are produced from cross-fertilization will show some of the characteristics from the parent that donated female gametes and some from the parent that donated male gametes. It will not be identical to either parent.

Figure 2.12 Unlike roses and lilies, the flowers of prairie cord grass are very small and hardly noticeable. Grasses like this depend on wind for pollination.

ACTIVITY **A-3**

Inquiry

INVESTIGATING FLOWER REPRODUCTIVE STRUCTURES

The Question

What are the reproductive structures of a flower?

Procedure

1. On a piece of blank paper, sketch a cross section of the flower as it appears now, before you dissect it. Label the parts.
2. Shake the lily gently over the piece of dark cloth. If pollen does not fall onto the cloth, carefully rub the anthers over the material. Using the probe, gently separate out grains of pollen.
3. Prepare a slide to examine the pollen under the microscope. (Review Toolbox 11 on microscopes.) What do you see at each level of magnification? Record your observations on a recipe card labelled *pollen*.
4. Peel back the petals of the flower. Label a card *petals* and use a small amount of glue to affix the petals to the card.
5. Gently pull away the stamens from the base of the pistil. Label a card with the word *stamen* at the top and then draw two lines leading away from the word. At the base of one line, write the word *anther* and at the base of the second line, write the word *filament*. Carefully separate the two parts of the stamen and glue them under the correct headings.
6. Dissect the pistil, cutting lengthwise from the stigma through the style, then through the ovary at the bottom. Label a card *pistil* and glue one-half of the cross section to it. Label the section of the pistil.
7. Using a magnifying glass and probe, examine the ovule inside the ovary. Record your observations on a card labelled *ovary*.

Analyzing and Interpreting

8. Review the recipe cards that you have assembled as you dissected the flower. How do you think these separate pieces work together to reproduce a new plant?
9. Go back to your sketch of the parts of the flower before you dissected it. In pencil, show the process of reproduction as you think it occurs.
10. What characteristics do a pollen grain and an ovule have that help them carry out their roles in sexual reproduction?
11. Review your work with a partner or other group, and then share ideas with the whole class. Revise your sketch as necessary.
12. Arrange your recipe cards and sketch on a piece of poster board to create a display of your work.

Forming Conclusions

13. In a paragraph, summarize the roles each of the plant parts play in sexual reproduction and how these parts have characteristics that help them perform their roles.

Materials & Equipment

- small scalpel with sharp blade
- magnifying glass
- lily
- piece of dark cloth
- microscope
- slide
- coverslip
- water
- eyedropper
- probe
- labelled diagram of parts of a flower (in text)
- 5 recipe cards
- white glue
- poster board

Caution!
Use care when handling the scalpel and the probe.

Figure 2.13 Examining flower structures

Advantages and Disadvantages of Asexual and Sexual Reproduction

Variation helps a species survive by giving it the ability to survive changes in its environment. You have seen that the way an organism reproduces affects how much variation will occur in its offspring. Asexual reproduction produces no variation in heritable characteristics. Could it ever help a species not to have variation?

Advantages and Disadvantages of Asexual Reproduction

Asexual reproduction does not require any specialized cells or a way of bringing gametes together. As a result, asexual reproduction can produce lots of individuals very quickly. For example, if conditions are right, a bacterium can reproduce asexually every 20 min. Over a 12-h period, a single bacterium can divide to produce 10 million copies of itself. This is a great advantage in environments that do not change very much. For example, bacteria that live in the gut of an animal will always have a warm, moist environment to live in while the animal is alive. Producing many copies of a bacterial cell that is suited to that environment is a safer bet for survival than producing a smaller number of bacteria with many variations that may never be needed. Species that reproduce asexually invest energy to produce as many identical copies of themselves as possible to build a large population quickly.

The main disadvantage of asexual reproduction is that if conditions become unfavourable, the entire population may be wiped out. For example, every single one of those 10 million identical bacteria could be killed if they have no resistance to an antibiotic that is applied to them.

Advantages and Disadvantages of Sexual Reproduction

Sexual reproduction has the advantage of providing lots of variation, which helps species survive environmental change. The main disadvantage of sexual reproduction is that it takes a lot of energy. A flowering plant, for example, has to produce all the parts of its flower, as well as pollen grains and ovules in order to reproduce. The flower parts must provide a way for the gametes to meet, such as producing lots of pollen to be blown by the wind or by attracting pollinators. The flower must also protect and nurture the embryo in a seed until the seed is dispersed. Therefore, an organism that reproduces sexually puts a lot of energy and time into producing variable offspring. Because of this great demand, sexually reproducing organisms can only produce a limited number of offspring.

Organisms that Reproduce both Sexually and Asexually

Some species have the ability to reproduce both sexually and asexually by various means. Most plants that produce seeds by sexual reproduction can also reproduce asexually, either from cuttings or by producing structures such as bulbs or runners.

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Alternating Asexual and Sexual Reproduction

Some simple life forms, such as the jellyfish, will alternate between sexual and asexual reproduction. That is, one generation will be produced sexually and the next, asexually. Mosses also follow this pattern. Research other examples of life forms that fall into this category. Write a paragraph about the advantage to a species of alternating different forms of reproduction? Begin your research at www.pearsoned.ca/scienceinaction.

Figure 2.14 To reproduce sexually, sponges release sperm cells into the water, which are captured by special cells and carried to egg cells.

Some plants can use their seeds to reproduce both asexually and sexually. In the asexual method, embryos develop in the seeds without the contribution of sperm cells. These seeds will grow into plants that are genetically identical to the parent plant. Some species of grasses, sunflowers, and roses can do this.

Some animal species can also reproduce both ways. Aphids are small insects that feed on the sap of certain plants. Throughout the growing season, females produce live female young without fertilization, or asexually. These all-female young mature and also reproduce asexually. Over the summer, several generations are produced. In the fall, when days shorten and the temperature drops, the females produce a generation that includes both males and females. These males and females reproduce sexually and lay eggs that will hatch in the spring to produce new colonies. Sponges can also reproduce both sexually and asexually (Figure 2.14).

Check and Reflect

Key Concept Review

1. What is a zygote and how is it formed?
2. Define asexual reproduction. List three examples of asexual reproduction.
3. Make a table to compare the male and female gametes in plants. Indicate where they are found.
4. List three ways in which pollination can occur. Give an example of each.

Connect Your Understanding

5. What is similar about sperm cells and egg cells? What is different?
6. List the steps of fertilization and embryo development in animal sexual reproduction. Be sure to include the words "gametes" and "zygote" in your description.
7. Explain what happens to male and female gametes during sexual reproduction in plants and animals.
8. Using a Venn diagram, compare and contrast sexual and asexual reproduction.

Extend Your Understanding

9. *An individual produced by asexual reproduction may be identical to one of its parents.* Do you agree or disagree with this statement? Support your answer.
10. Use a simple sketch to illustrate the process of fertilization in plants.
11. A flower produces a seed. Explain why this is an example of sexual reproduction.

Assess Your Learning

Key Concept Review

1. Give three examples of a heritable characteristic.
2. Make a table to compare the advantages and disadvantages of sexual and asexual reproduction.
3. An amoeba reproduces by binary fission. Briefly describe the process of binary fission. Explain whether it is an example of sexual or asexual reproduction.

Connect Your Understanding

4. A person with hitchhiker's thumb plays guitar with a local rock band. Explain how she displays both heritable and non-heritable characteristics.
5. Compare the process of fertilization in plants and animals.
6. Using a diagram, explain how a zygote forms in a flowering plant.
7. Compare discrete and continuous variation using a Venn diagram.
8. Describe the steps of vegetative reproduction that occur when a plant is grown from a cutting. Why is this process considered to be an example of asexual reproduction?

Extend Your Understanding

9. Imagine a population of Martians. In this population, there are only three types of eye colour: black, bright purple, and orange. However, there are many different leg and arm lengths in the population. How would you describe the variation for eye colour as opposed to the variation for arm and leg length in the Martian population?
10. Imagine an organism that lives where there are often big changes in environmental conditions. What type of reproduction would be more advantageous for this organism? Explain your answer.

Focus On Social and Environmental Context

Our knowledge about how organisms reproduce and how variation within species is maintained has been enhanced by increasingly sophisticated technology. Think about what you have learned in this section about variation and answer these questions.

1. If you were researching plants to grow in colder climates, why would an understanding of the variations within a plant species be important?
2. Why is it important to understand the advantages and disadvantages of both sexual and asexual reproduction?
3. Based on what you have learned in this section, what are three questions you have that are related to the information presented?

3.0

DNA is the inherited material responsible for variation.

Key Concepts

In this section, you will learn about the following key concepts:

- chromosomes, genes, and DNA
- cell division
- inheritance

Learning Outcomes

When you have completed this section, you will be able to:

- describe the relationship among chromosomes, genes, and DNA, and their role in storing genetic information
- distinguish between cell division during asexual reproduction and cell division during sexual reproduction
- investigate the transmission of characteristics from parents to offspring, and identify examples of different patterns of inheritance
- identify examples of dominant and recessive characteristics

One of the most endangered species on Earth is the Bengal tiger. These tigers, once plentiful on the subcontinent of India, have dwindled from 40 000 in 1900 to 4500–6000 today. Most scientists speculate that the Bengal tiger will disappear unless humans act to prevent its extinction. One important way to save the Bengal tiger (and other species threatened with extinction) is to develop captive breeding programs.

Like all sexually reproducing species, the Bengal tiger has the best chance of long-term survival if there is a lot of variation within the species. Without variation, the species would be unable to survive changes in the environment, and would be more vulnerable to extinction. But with so few Bengal tigers left, how can that variation be maintained?

One tiger looks very like another to our eyes, but there are ways of finding subtle differences between individuals. Using modern technology, geneticists and zoo staff can analyze the tigers' genetic material to determine how similar two tigers are. To do this, scientists and breeders must have a thorough knowledge of the structure of genetic material and how it functions. They also have to be familiar with patterns of inheritance. This knowledge helps them analyze the tigers' genetic material, decide if the two tigers are different enough from each other to breed, and predict the characteristics the cubs are likely to have.

3.1 DNA—Transmitter of Genetic Code

In section 2.0, you learned that the offspring of a sexually reproducing species are not genetically identical to their parents. If they were identical, there would be little variation among the members of a species. However, these offspring do resemble their parents because particular characteristics are passed on from generation to generation. People have taken advantage of this transmission of genetic information between parents and offspring to produce many breeds of domestic plants and animals. However, unlike breeding programs to help save the Bengal tiger, the breeding of purebred dogs was not intended to promote variation. But many different breeds of dogs were developed that had specific, desired characteristics. This has made *Canis familiaris* one of the most physically varied species on Earth (Figure 3.1).

infoBIT

Gene Map Complete

In February 2001, two groups of scientists simultaneously announced they had completed a first draft of a map of all the genes in a human. They estimated that humans have about 30 000 genes. Previously, scientists had thought we had about 100 000 genes.

GIVE IT A TRY

SUPERDOGS

Humans and dogs have had a close relationship since the end of the Ice Age, roughly 12 000 years ago. Descended from wolves, many of the approximately 400 modern breeds of dog we see today still share many physical characteristics with wolves. Some scientists think that canids (early dogs) adapted to human settlement. Others think that humans chose canids whose aggressive behaviours had been selected out. One of the extraordinary abilities of dogs is their capacity to learn and be trained.

As a class brainstorm a list of superdogs, such as TV show dogs or dogs that perform special tasks, such as police dogs.

- Determine the breed of each superdog.
- Choose one dog and, in pairs, brainstorm a list of characteristics your dog displays that help it do its job. Infer which characteristics are typical of the breed.
- If you have time, research the characteristics your dog's breed typically has. Begin your search at www.pearsoned.ca/scienceinaction.
- Prepare a chart to compare and contrast the characteristics of your superdog with those of a typical dog of the breed. What similarities and differences do you find?

Figure 3.1 These animals are all the same species. Selecting parents, over many generations, for a particular characteristic, such as ear shape, eventually produced these very different breeds.

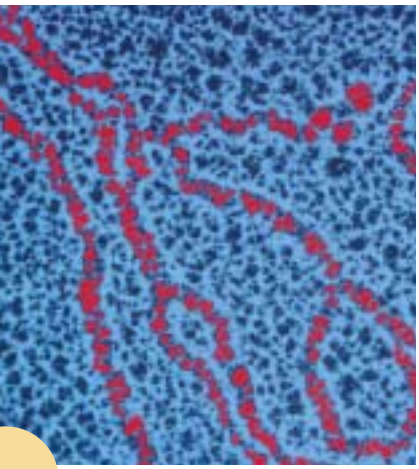

Figure 3.2 Micrograph of DNA

DNA

Why do the puppies of Chihuahua dogs turn out to be Chihuahuas? Why don't they turn out looking like Dalmations instead? The reason is that the Chihuahua parents pass on a "blueprint" to their offspring, so that each puppy receives a complete set of instructions for making a Chihuahua dog. Every multicellular organism on Earth contains a blueprint for making a copy of itself in each of its body cells.

Imagine how much information must be in these blueprints and how many different blueprints there are. For example, a parrot's blueprint must describe how to make all its different coloured feathers, its specially designed beak, and its remarkable voice. The blueprint for a spruce tree must have instructions for making the straight, slim needles, the sticky, perfumed resin, and the thick, tall trunk. What could store so much information, and pass it on from generation to generation? Canadian scientist Oswald Avery helped to answer this question when he proposed that a large molecule first found in cells' nuclei is responsible for storing such information and passing it on. This molecule, deoxyribonucleic acid, or **DNA** for short, is the inherited material responsible for variation.

All living organisms contain DNA in their cells. When the cells of the organism, such as the cells of mammals and plants, contain a nucleus, DNA is found in the nucleus. Figure 3.3 will remind you of where the nucleus of a cell can be found.

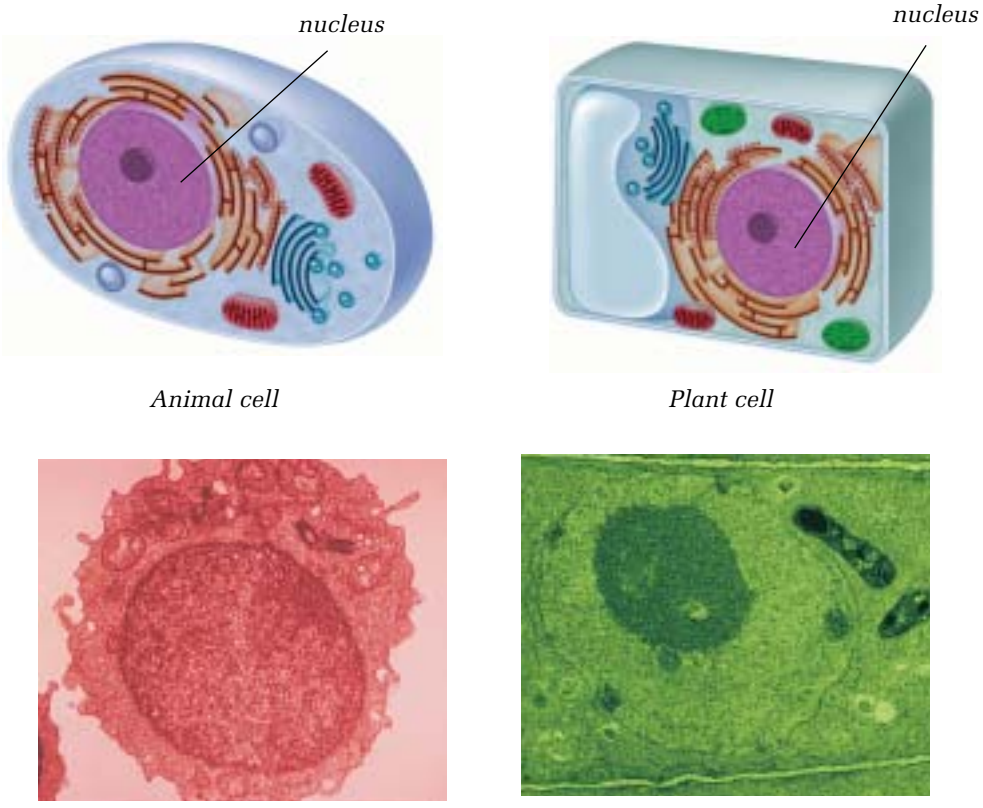

Figure 3.3 Study the location of the nucleus in the animal cell diagram and the plant cell diagram. Now locate the nucleus of each cell in the micrographs below the diagrams.

DNA and the Genetic Code

DNA was first identified in 1869, but little was known about the structure of the molecule or its role in heredity. After analyzing cells of many different organisms—ranging from bacteria to plants and animals—scientists found DNA in all of them. In 1944, Avery confirmed that DNA was the material of inheritance and this posed a new question. How could the blueprints for so many different organisms be passed on by what seemed to be exactly the same molecule? Solving this puzzle was one of the greatest scientific achievements of the last century, and involved two scientists whose names became known worldwide, James Watson and Francis Crick. By unravelling the structure of DNA, Watson and Crick revealed how the same chemical building blocks could carry such a wide range of instructions needed for the diversity we observe in the living world.

The DNA molecule can be compared to a ladder that has been twisted into a continuous spiral (Figure 3.4). The uprights of the twisted molecular ladder are identical all along its length. However, the rungs *vary* in composition. Each individual rung pairs up just two of the following four chemicals: guanine (orange), cytosine (blue), adenine (green), and thiamine (violet), or G, C, A, and T, for short.

The arrangement of these four chemicals, G, C, A, and T, forms a code that cells can read. You know that the 26 letters in our alphabet can be rearranged to form the millions of words we can read. Similarly, the **genetic code** is based on arranging the four chemical "letters" into "words," or instructions, that describe how to make any particular organism. In other words, all the blueprints for all the species on Earth are written in the same language!

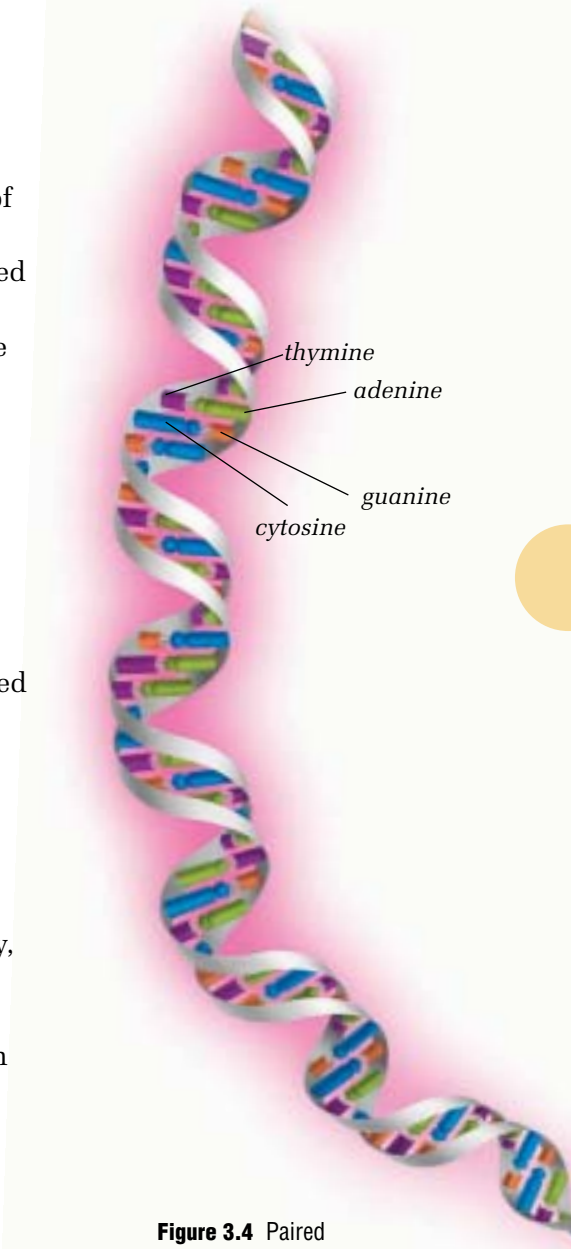

Figure 3.4 Paired chemicals make up the "rungs" of the DNA "ladder" and form the genetic code. The overall shape of the DNA molecule is helical, like the spiral binding on a notebook.

Chromosomes

DNA contains all the instructions for an organism's characteristic features. Because every organism has so many physical and chemical characteristics, there is a lot of DNA in a cell. If the DNA from a typical human body cell was stretched out, it would be about two metres long, more than 1 000 000 times longer than the cell it came from! To fit such a large amount of DNA into their cells, organisms arrange their DNA into packages. These packages are called **chromosomes**.

In organisms such as plants and animals, the chromosomes are located inside the cell nucleus. Each human cell nucleus, for example, contains 46 chromosomes. You could think of one chromosome as a single volume of an encyclopedia, and the set of chromosomes as the complete encyclopedia. If you were missing a single volume of an encyclopedia, you could be missing information you might need some time in the future. This is also true for our chromosomes. One chromosome contains only part of the instructions for making a human. All of our nuclei, except for those in the gametes, must have a complete set of chromosomes.

ACTIVITY **A-4**

Decision Making

USEFUL GENES?

The Issue

What are the questions and issues raised by new technologies for recombining genetic material?

Background Information

New genetic technologies and research like the Human Genome Project have allowed scientists to investigate the human genetic code better than ever before. The goal of the project was to identify all of the genes that comprise the human body. In the course of their research, scientists discovered that the human genome consists of about 30 000 genes. This was surprising as scientists expected to find 100 000 genes. Scientists now suggest that the role of human genes is much more complex than originally thought.

Having such detailed information on human DNA has advanced research on a variety of genetic technologies, such as cloning, and genetic disorders, such as cystic fibrosis, muscular dystrophy, and Huntington's disease. Such emerging technologies have led to a variety of questions and issues related to their development and application in both genetic research and treating genetic disorders.

Figure 3.5 Collecting samples for the Human Genome Project

Analyze and Evaluate

Select Part A or B and write a short report using the following questions as your guide. Use library resources and internet resources that have been approved by your teacher. Begin your search for information at www.pearsoned.ca/scienceinaction. Be sure to evaluate your sources in terms of how recent they are and how reliable the information seems.

Part A—New Genetic Technologies to Treat Genetic Disorders

1. Select one of the genetic disorders mentioned on this page or a disorder of your choice.
2. Research how the disorder is being treated today.
3. Describe how emerging genetic technologies may be used to treat this disorder in the future.
4. What potential questions or issues may arise from the use of this new treatment?

Part B—Emerging Recombinant Genetic Technologies

1. Select one of the genetic technologies from Section 4.2 on pages 67 and 68 or another genetic technology you have heard about.
2. Research and describe how this technology works.
3. Describe possible applications for this technology.
4. What potential questions or issues may arise from the use of this new technology?

For humans, a complete set has 46 chromosomes. For dogs, however, a complete set has 78 chromosomes, and for cats, the number is 38. In most familiar organisms, the chromosomes are organized into pairs. So the body cells of a human contain 23 pairs of chromosomes, while a dog's body cells contain 39 pairs, and a cat's body cells contain 19 pairs.

These examples show that chromosome number varies from one species to another. It is important to realize that the composition of the chromosomes varies as well. For example, the eyes of a typical dog have round pupils, while the eyes of a typical cat have slit-shaped pupils. So the dog's chromosomes must contain genetic code that reads "make round pupil." The cat's chromosomes must contain a different genetic code, one that reads "make slit-shaped pupil." Such differences are the source of diversity from one species to another.

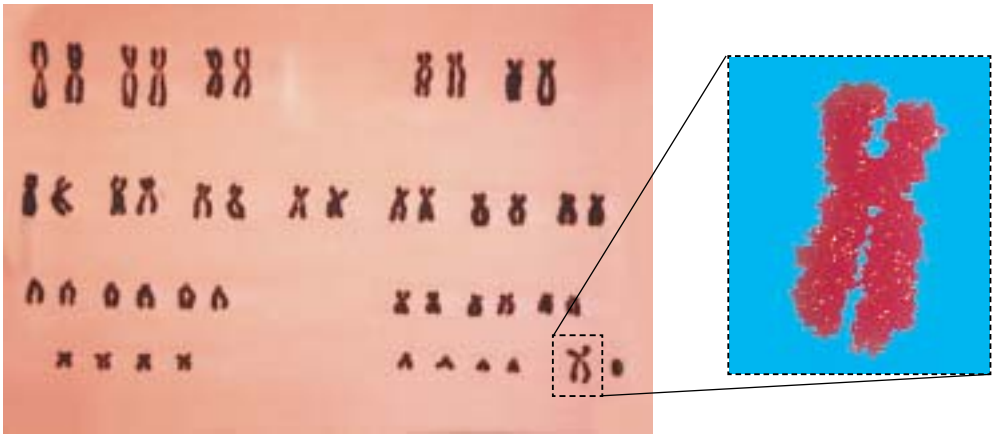

Figure 3.6 The 23 pairs of chromosomes of the human male. On the right, a close up of the X chromosome.

GENES

Current scientific thinking is that genes are responsible for the inheritance of an organism's characteristic features. A single **gene** is an uninterrupted segment of DNA, which contains coded instructions.

Much of the early research into genes was carried out on the fruit fly. Researchers found that:

- Genes are located on the chromosomes.
- Each chromosome contains numerous gene locations.
- Like chromosomes, genes come in pairs.
- Both genes in a pair carry DNA instructions for the same thing. Leg length in the fruit fly is an example.
- In the fruit fly, the two leg-length genes occupy matching locations on the two chromosomes.
- The DNA code may not be exactly the same in both locations.

Figure 3.7 David Vetter, the "bubble boy," lived for 12 years inside a plastic bubble. He had Severe Combined Immune Deficiency (SCID), a genetic disorder that made his body incapable of fighting disease. The gene for SCID is found on the X chromosome.

*re*SEARCH

Canadian Contributions to Genetics

Research the work of Canadian scientists, such as Oswald Avery and Irene Ayako Uchida, and their contributions to our knowledge of inheritance and genetics. Develop a short script for a documentary that could be made about their achievements.

ACTIVITY **A-5**

Problem Solving

SHOWING THE RELATIONSHIPS

Recognize a Need

A grade 8 class has just studied the structure of cells and the students are interested in learning more about genetic material and how it is organized. Their science teacher has asked you to explain to them the relationships among DNA, genes, and chromosomes.

The Problem

Design a way to visually summarize the relationships among DNA, genes, and chromosomes. Be creative. It could be a poster, Web page, model, skit, story, song, or any other method you choose to convey the information.

Criteria for Success

To be successful, your presentation must meet the following criteria:

- solve the problem described above
- show the relationships accurately
- be appealing and understandable for grade 8 students

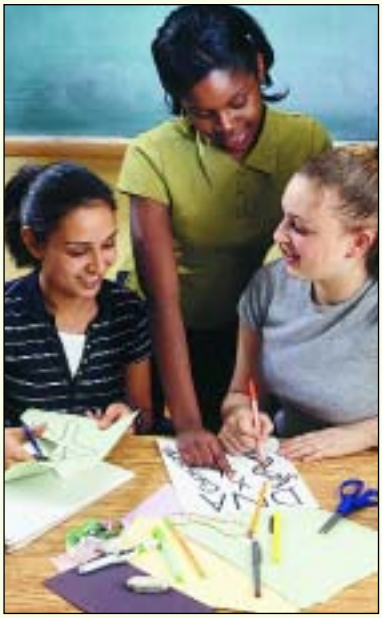

Figure 3.8 Planning a presentation to explain relationships among DNA, genes, and chromosomes

Brainstorm Ideas

1. Work with a partner or in a small group. Brainstorm ways to convey the information. All ideas should be considered.
2. Look for ways to blend the best of the group's suggestions.

Design Your Presentation

3. Plan out your presentation. Write out your plan in detail.
4. Create your presentation.

Test and Evaluate

5. How effectively does your presentation convey the information?
6. How does your work compare with that of your classmates?

Communicate

7. Share and compare your design with others in the class. Highlight the features that make your presentation both accurate and effective.
8. Is there anything you could do to improve your design?
9. As you were completing your presentation, did you have any questions about the relationships among DNA, genes, and chromosomes?
10. Assess your group's effectiveness at planning and creating your design. What did you do well? What could you improve?

Offspring inherit genes from both parents. For example, a fruit fly inherits one gene for leg length from its mother and one from its father. However, the leg-length gene exists in two possible forms: short leg or long leg. The wing-shape gene also exists in two possible forms: long or dumpy. So the two genes in a particular pair may not be identical.

Much of what scientists have learned about inheritance in fruit flies can be applied to most other organisms, including humans. In fact, most genes in most species exist in an array of possible forms that differ as to their exact DNA sequence. These possible forms are known as **alleles**.

To understand how chromosomes, genes, and alleles are linked to inherited characteristics, think about dogs. All dogs belong to the same species, and all ordinary, healthy dogs have a hairy coat. So we could begin by thinking of "hairy coat" as an example of an inherited characteristic.

But when we observe dogs, we see many different versions of "hairy coat." The hair may be straight or curly, short or long, coarse or fine, and the alternative versions of coat colour are almost too numerous to count.

Observing this variation, we can make three inferences. First, "hairy coat" is almost certainly more than just a single characteristic, it must involve a combination of several characteristics. Second, more than one gene pair may be involved in determining the individual details of a dog's hairy coat. For example, there could be one gene pair for hair length, a second gene pair for waviness, and another gene pair for texture. Third, there may be several possible alleles for each gene pair. For coat colour alone, there must be ten or more possible alleles, all in just one species!

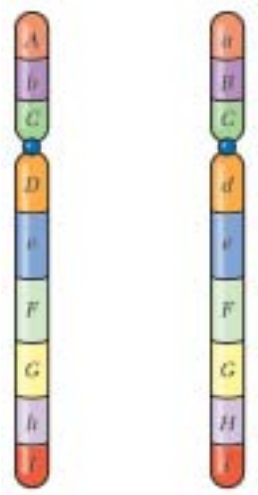

Figure 3.9 A chromosome pair. Each member carries the same genes. The different alleles are marked by uppercase and lowercase letters.

Check and Reflect

Key Concept Review

1. Define the term DNA in your own words and explain its function.
2. What four chemicals make up the genetic code? Describe how these chemicals are arranged in a DNA molecule.
3. What is a chromosome? Describe its function.
4. What is an allele? Describe its function.
5. Create a mini-dictionary of the key terms in this subsection. Use colours or illustrations as aids for remembering the terms and their meanings.

Connect Your Understanding

6. Explain why chromosomes are considered to be the "source of diversity."
7. Which of the following contain DNA? Explain your answer.
   a) chromosome
   b) nucleus of a cell
   c) gene
8. Explain how a chromosome may be involved in the inheritance of a disease, such as Severe Combined Immune Deficiency.

Extend Your Understanding

9. Create a mind map illustrating the relationship among DNA, genes, and chromosomes. What is their role in storing genetic material?
10. If a chromosome is compared to a book, what would the words in the book be compared to? Explain your answer.

3.2 Cell Division

You have learned that the outcome of asexual reproduction is the production of offspring genetically identical to the parent. You have also seen that the outcome of sexual reproduction is the production of offspring that are genetically different from their parents. Scientists have spent many centuries exploring the processes that result in these outcomes.

Cell Division and Asexual Reproduction

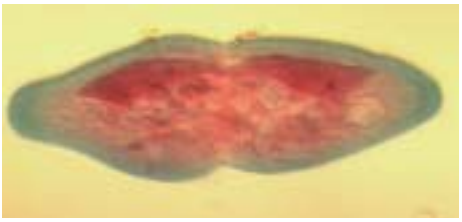

Figure 3.10 In asexual reproduction, the two new paramecium cells must get the same amount of DNA.

When a unicellular paramecium splits to form two new organisms during binary fission, its cell contents are divided equally between the two new cells (Figure 3.10). But if its DNA molecules were divided between the two organisms, each new individual would have only half the DNA of the parent cell, and half the genetic information it would need to function. To avoid this, the parent cell first makes an exact copy of its DNA, and each chromosome doubles. For a short time, the parent cell has twice the amount of DNA it usually has. When the cell eventually divides, each new cell gets one complete copy of the DNA.

In multicellular organisms, such as humans, petunias, and gophers, the process that produces two new cells with the same number of chromosomes is called **mitosis**. Mitosis occurs in the body cells of multicellular organisms and is responsible for the growth and cellular repair of a multicellular organism.

Cell Division and Sexual Reproduction in Plants and Animals

During sexual reproduction, the specialized sex cells (gametes) unite to form a zygote, which then develops into a new organism. One parent (the male) provides the male gamete and the other parent (the female) provides the female gamete. If the sex cells contained the same amount of DNA as every other cell, then the zygote would receive twice the amount of DNA it needs. **Meiosis** is a type of cell division that produces cells with only half the DNA of a normal cell. Because each gamete has only half the DNA of a normal cell, when the male and female gametes unite, the zygote has a complete set of DNA.

Meiosis involves two cell divisions, not just one. Recall that organisms that undergo sexual reproduction contain pairs of chromosomes. Each chromosome in the pair contains the same set of genes, but may contain different alleles (forms) of those genes. A gamete must contain only one copy of each different chromosome. To do this, cells must divide twice (Figure 3.11).

*info*BIT

A Hypothesis That Changed

Until the late 1600s, scientists hypothesized that a human child was the product of only one parent. They thought that sperm held a fully formed tiny fetus that grew in size for nine months until it was large enough to be born. Around 1685, Anton van Leeuwenhoek improved the microscope, which provided evidence that no longer supported this hypothesis.

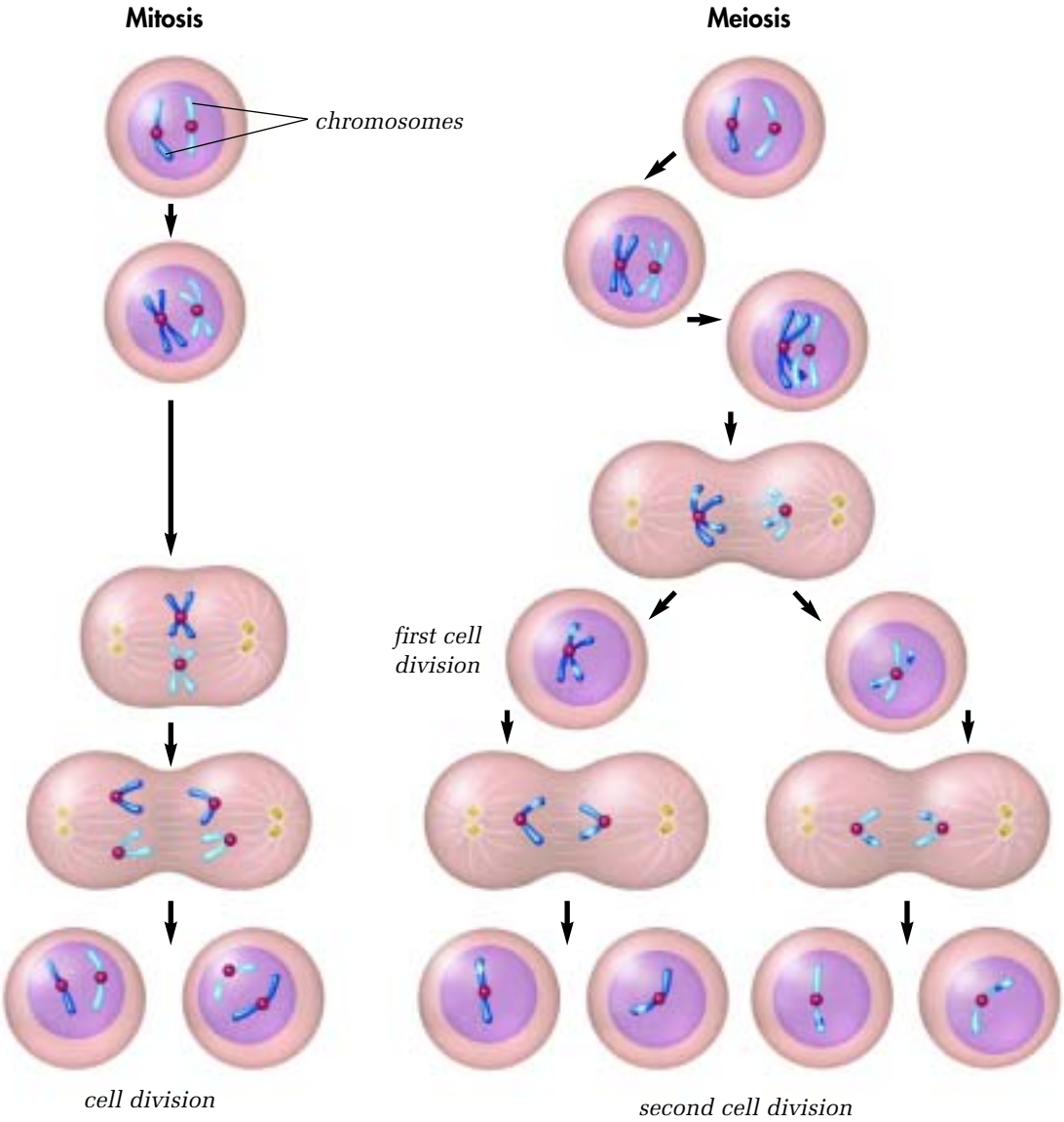

Figure 3.11 Comparison of mitosis and meiosis. Mitosis produces two offspring cells with the same number of chromosomes as the parent cell. Meiosis produces four sex cells that have *half* the number of chromosomes as the parent cell.

rESEARCH

Neverending Cells

When Henrietta Lacks' physician removed cells from her body in 1951 to test for cervical cancer, neither of them could have imagined that these cells would still be reproducing today. Since 1951, scientists all over the world have used HeLa cells in their explorations of cell structure and genetics. Usually, human body cells can divide only about 50 times in the laboratory before they die. So what made Henrietta's cells so special? Research the history of the HeLa cell and prepare a report. Begin your search at www. pearsoned.ca/scienceinaction. Include information about Henrietta and her family. Explore any issues that may have arisen from the use of her cells for research.

GIVE IT A TRY

WHO HAS WHAT NUMBER?

Organisms of the same species have the same number of chromosomes, but different species have different numbers of chromosomes. Copy this table into your notebook and complete the table to compare chromosome numbers in some common species.

Organism	Number of chromosomes in a cell at the end of mitosis	Number of chromosomes in a body cell	Number of chromosomes in a gamete	Number of chromosomes in a zygote	Number of pairs of chromosomes
cabbage	18				
black bear					38
human			23		
peanut	40				

CHECK AND REFLECT

Key Concept Review

1. Describe a type of cell division that occurs during the asexual reproduction of a unicellular organism.
2. What type of cell division is required for sexual reproduction? How does it differ from cell division during asexual reproduction?
3. Describe the type of cell division that occurs in the body cells of multicellular organisms.

Connect Your Understanding

4. Using diagrams, explain what happens to the DNA during cell division to produce sex cells (gametes).
5. When a cell divides during asexual reproduction, it divides its cell contents between the two resulting cells. Describe what happens to the DNA of the cell during this type of cell division. Explain how this process ensures that the same characteristics are passed from generation to generation.
6. Why does sexual reproduction produce offspring with characteristics that are different from their parents, whereas offspring produced through asexual reproduction are identical to their parents?

Extend Your Understanding

7. If the amount of DNA in a gamete of an organism is n, is the amount of DNA in the body cells of that organism equal to $\frac{1}{2}n$, n, or $2n$? Explain.
8. Which form of cell division—binary fission or meiosis—poses the lower risk for the transmission of genetic disorders? Support your answer.

Careers and Profiles

Dietician/Genetic Associate

Barb Marriage holds a unique and challenging position with the University of Alberta's Department of Medical Genetics. Barb combines her background in nutrition with her knowledge of human genetics to work with people who have inherited *metabolic disorders* or *inborn errors of metabolism*. Most of her 165 patients have conditions that deal with enzyme deficiencies, including: PKU, maple sugar urine disease, galactosemia, glycogen storage disease, Gaucher disease, and lysosomal storage diseases. These conditions require specialized diets that need to be monitored by someone like Barb. Her Bachelor of Science degree and Masters of Science degree in nutrition have led to her working on completing a Ph.D. in Medical Sciences.

Diagnosing and treating the conditions are only part of Barb's role. Genetic counselling, working with lab personnel, co-ordinating other health professionals and resources, and acting as an advocate for funding and government support are also part of her job.

Because 95% of Barb's patients are children, she works closely with their families to provide ongoing support. Her relationships with these people often continue for many years, and she gets a lot of satisfaction from her involvement with the families. Receiving cards and photographs from patients' families and being invited to take part in special family events are examples of the rewards that make her career gratifying. In cases where a child's disease is especially serious, personal contact is very important. It requires a special touch and sensitivity to the family's values and beliefs.

Barb's professional schedule is hectic. An average week includes 60 hours of work. She is also on call for emergencies 24 hours a day, 7 days a week. However, that still leaves some spare time for her to be a marathon runner. She also has an interest in sports medicine. In 2001, she accompanied a men's sports team to Japan, providing medical and nutritional assistance.

Figure 3.12 Being a dietician and a genetic associate has many challenges and rewards.

1. What special skills would a person need to be a successful dietician? Genetic associate?
2. Does being a dietician or a genetic associate seem like an appealing career? Why or why not?

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The Science of Genetics

Genetics is the study of how heritable characteristics are passed on from generation to generation. Genetics began with the careful work of an Austrian monk, Gregor Mendel (1822–1884). Starting with carefully chosen parents that had several observable characteristics, Mendel traced the patterns of inheritance in pea plants over several generations, and discovered some fundamental principles that led to modern genetics.

3.3 Patterns of Inheritance

Long before research scientists discovered chromosomes and genes, plant and animal breeders were conducting experiments in controlled breeding. To prevent unwanted outcomes, only animals with the most desirable characteristics, or **traits**, were allowed to reproduce. Early experiments in controlled breeding were not always successful. Mating champion males with champion females did not always produce champion dogs, horses, cattle, or cats. But by keeping written records of failures as well as successes, the breeders began to detect certain basic patterns of inheritance. Scientists now explain the patterns they discovered in terms of alleles. In this subsection, you will focus on the inheritance of coat colour in cats, and will consider only two coat colours: black and white.

Purebred versus Hybrid

A breeder who wishes to produce white cats should choose **purebred** parents: cats whose ancestors have produced only white offspring for several generations. The term "true-breeding" is applied to such a lineage. Preferably, the chosen parents will come from two different true-breeding lineages of white cats. Similarly, a breeder who wishes to produce black cats should choose purebred parents from lineages that breed true for black coat colour.

An individual produced by crossing two purebred parents that differ in a trait such as coat colour is known as a **hybrid**. Now, suppose a purebred black cat is crossbred with a white cat. What pattern of inheritance will be observed in the hybrid offspring?

Dominant Traits

Figure 3.13 shows the result of crossbreeding a purebred white female cat with a purebred black male cat. Notice that every kitten in the resulting litter has a black coat. Crossing a purebred black female with a purebred white male will produce the same result. No matter how many times the experiment is repeated, all of the offspring will have black coats: never white, never grey, only black. Black coat colour in cats is an example of a **dominant trait**.

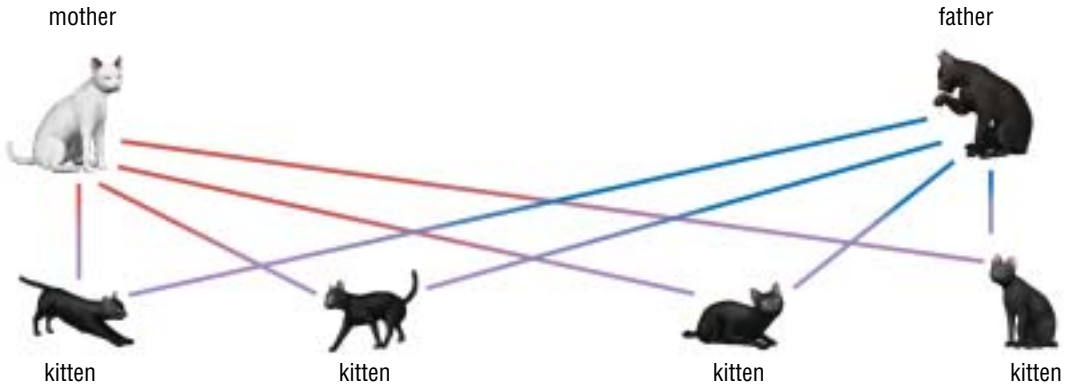

Figure 3.13 Cross between purebred white female cat and purebred black male cat. Black fur is the dominant trait.

By definition, the kittens are hybrids, but they *look* exactly like purebred black kittens. There is no outward sign that their mother had a white coat. Why is that? Recall that all offspring of sexual reproduction inherit genes from both parents. Both genes in a pair carry DNA instructions for the same thing; in this case the "thing" is coat colour. However, the specific DNA instructions carried by the alleles may not be identical.

We can see that the hybrid kittens have inherited an allele for black coat colour from their father. We can infer that the hybrid kittens must also have inherited an allele for white coat colour because no alternative alleles are present in the mother's lineage. However, the DNA code carried by the white-coat allele has somehow been ignored, or suppressed. Only the DNA instructions carried by the black-coat allele have actually been carried out. So, mating unlike purebred cats has revealed that DNA instructions carried by the black-coat allele are dominant over the DNA instructions carried by the white-coat allele.

Recessive Traits

Has the white-coat allele in the hybrid kittens been completely dominated by the black-coat allele? To find out, a second experiment can be conducted crossbreeding hybrid black offspring once they become adults. Figure 3.14 shows the average results of this experiment: three out of every four kittens will have black coats, while one will be white. If the experiment is repeated until there are 100 offspring, you might expect about 75 to be black and about 25 to be white.

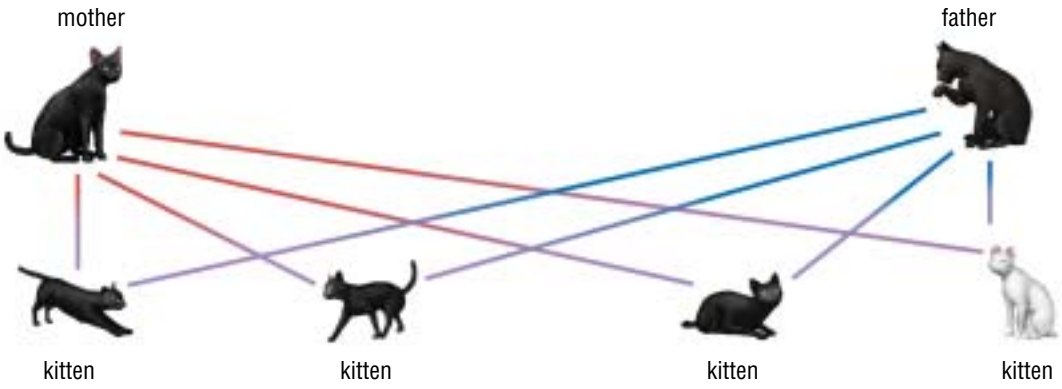

Figure 3.14 The kittens from Figure 3.13 are the parents in this cross.

In this new experiment, each hybrid parent possessed one black-coat allele, and one white-coat allele, though neither showed any sign of white fur. When the hybrid cats were crossed, each parent passed on one allele for coat colour to each kitten. (Remember, parents can only pass on half of their chromosomes, thus, half of their genes.)

A kitten from the experiment on page 51 might receive alleles in four possible combinations:

1. *One black-coat allele from its hybrid father and one black-coat allele from its hybrid mother.* The two sets of DNA instructions "agree" with each other, so the kitten will have black fur.
2. *One black-coat allele from its mother and one white-coat allele from its father.* The DNA instructions "contradict" each other, but we have seen that black fur is a dominant trait. The kitten will have black fur.
3. *One white-coat allele from its mother and one black-coat allele from its father.* Again, the DNA instructions "contradict" each other, but black fur is a dominant trait. The kitten will have black fur.
4. *One white-coat allele from its mother and one white-coat allele from its father.* This time, the DNA instructions "agree" with each other, so the kitten will have white fur.

White fur is thus an example of a **recessive trait**, and the allele for white fur is an example of a recessive allele. The allele for black fur is an example of a dominant allele. A recessive trait appears in the offspring only if two recessive alleles are inherited. In contrast, even one dominant allele will cause the dominant trait to appear.

GIVE IT A TRY

Exploring Genetic Possibilities

In sexual reproduction, chromosomes are inherited in pairs: one from each parent. In an offspring, the combination of alleles carried on the chromosomes determines what the offspring is like.

In fruit flies, there are two possible alleles for leg length: long-leg and short-leg.

- Suppose a fruit fly inherits two long-leg alleles. Will this fruit fly develop long legs or short legs? Explain your reasoning.
- Suppose a second fruit fly inherits two copies of the short-leg allele. Will this fruit fly develop long legs or short legs? Explain your reasoning.
- Suppose a third fruit fly inherits one short-leg allele and one long-leg allele. Explain why you cannot be sure what leg length this offspring will develop.

In fruit flies, there are two possible alleles for eye colour: red-eye and purple-eye.

- List three possible ways to pair these alleles.
- For each pair, what eye colour you would expect an offspring to develop? Explain why you cannot be sure for all three cases.

In fruit flies, there are two possible alleles for wing shape: long-wing and dumpy-wing.

- List three possible ways that these alleles might be paired in an offspring.
- For each pair, what wing shape would you expect an offspring to develop? Explain why you cannot be sure for all three cases.

An individual fruit fly might have long legs, purple eyes, and long wings. What other combinations of leg length, eye colour, and wing shape are possible? Make sketches to illustrate your answer.

Other Patterns of Inheritance

Incomplete Dominance

The dominant-recessive pattern of inheritance does not always prevail. When a purebred snapdragon bearing red flowers is crossed with a purebred snapdragon bearing white flowers, the offspring are neither red nor white. Instead, the flowers are pink, a colour intermediate between red and white (Figure 3.15). This pattern of inheritance is known as **incomplete dominance**. Both the white-flower allele and the red-flower allele have played a part in determining the flower colour of the offspring plants. Neither the white trait nor the red trait is truly dominant, and neither is truly recessive.

Figure 3.15 Four o'clock flowers also show incomplete dominance. The pink-flowered plants in the middle had a parent with red flowers and a parent with white flowers.

Offspring Unlike Either Parent

You know that human babies inherit their DNA from their parents, and the offspring are never exactly like either parent. Suppose a father has black hair and brown eyes. The mother has brown hair and brown eyes. Their baby has red hair and blue eyes. Why does this happen?

Scientists once hypothesized that eye colour was determined by just one pair of alleles at a single gene location. So they thought that a baby's blue eyes were caused by two recessive alleles: one from each parent. Modern geneticists know it is not that simple. Two blue-eyed parents can produce a brown-eyed child. It is even possible for a person to have one blue eye and one brown eye. Thus, the inheritance of eye colour in humans is too complex to be explained solely by the dominant-recessive pattern or even by incomplete dominance.

Similarly, incomplete dominance cannot explain the baby's red hair. Its coppery colour is not what would be expected by "mixing" brown pigment and black pigment. For hair colour, eye colour, and skin colour, many gene locations and several possible alleles may be involved.

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More Patterns

Another pattern of inheritance is called "codominance." Compare it to incomplete dominance. Write a paragraph to explain how similar or how different the two patterns of inheritance are.

Environmental Factors

In section 2.0, you learned that environmental factors, such as poor nutrition, can prevent children from growing as strong or as tall as their genes would normally allow. While genes play a vital role in determining development, the action of the genes is greatly influenced by the environment in which an offspring develops. For example, the presence of alcohol in a pregnant woman's bloodstream can interfere with the normal development of brain structures and facial features, even though the baby's DNA is normal. This condition is known as fetal alcohol syndrome. In the late 1950s, the drug thalidomide was taken by pregnant women to lessen the effects of morning sickness. One of its many effects on the fetus was the abnormal development of limbs. Many "thalidomide babies," as they came to be known, were born with flipper-like arms or legs. As adults, however, several of these individuals had perfectly normal children, showing that their DNA was normal.

Check and Reflect

Key Concept Review

1. Explain how dominant and recessive traits differ from each other.
2. How does a purebred individual differ from a hybrid individual?
3. List examples of dominance, recessiveness, and incomplete dominance. Use a different example for each from those given in the text.

Connect Your Understanding

4. How could two black cats produce a kitten that has white fur? Use a diagram to explain your answer.
5. If you wanted to be certain that a trait would appear in the offspring of the plants or animals that you were breeding, what would you have to find out about the parents? Explain your answer.
6. Suppose a new flower in your garden displays an intermediate colour. For example, you begin to see orange flowers although you originally planted only red and yellow flowers. What pattern of inheritance would you be observing in this situation? Explain your answer.

Extend Your Understanding

7. Can dominance or recessiveness explain why two cats from the same litter may be different masses or have different leg lengths? Explain your answer.

Assess Your Learning

Key Concept Review

1. How does sexual reproduction contribute to genetic variation?
2. In your own words, define DNA, genes, and chromosomes. Explain how they work together to pass on characteristics from parents to offspring.
3. Compare and contrast dominant and recessive traits using a Venn diagram.
4. What is incomplete dominance? Give an example.
5. What is the key difference between mitosis and meiosis?

Connect Your Understanding

6. How is the genetic material of a parent inherited by offspring in asexual reproduction? In sexual reproduction?
7. Explain how the recessive trait for coat colour is hidden in cats when two parents that are purebred for different fur colour are crossed.
8. Why does meiosis produce cells with only half the amount of DNA? How does this aid in the formation of a healthy zygote?
9. Relate the four chemicals on the rungs of a DNA ladder to the letters of our alphabet. Describe the code these "letters" can form. What does the code do?

Extend Your Understanding

10. Predict what the calf produced in a union between each of these parents might look like. Explain your answers.
    a) a purebred white (recessive) cow and a purebred brown (dominant) bull
    b) a purebred brown (dominant) cow and a purebred brown (dominant) bull
    c) a purebred white (recessive) cow and a purebred white (recessive) bull
    d) a hybrid brown (dominant) cow and a purebred white (recessive) bull

Focus On Social and Environmental Context

Developments in science and technology do not just happen. Usually, a scientific discovery, such as the explanation of the role of DNA, takes place over a long period of time. Consider the following questions as they relate to how our understanding of genetic material has developed over time.

1. What types of observation and experimentation led us to a better understanding of how traits are expressed?
2. Why is it important to understand how genetic material functions?
3. Construct a timeline to illustrate the major theories of the past that have led us to our current understanding of genetics. Include any information about issues that may have surrounded the work of scientists in the past.

4.0 Human activity affects biological diversity.

Key Concepts

In this section, you will learn about the following key concepts

- biological diversity
- species
- habitat diversity
- natural and artificial selection of genetic characteristics

Learning Outcomes

When you have completed this section, you will be able to:

- distinguish between artificial and natural selection
- describe the effects of extinction and extirpation on biological diversity
- evaluate the success and limitations of local and global strategies in minimizing loss of species diversity
- describe new technologies for recombining genetic material
- describe the use of biotechnology in various fields

What would be the ideal vacation for you? You might tour the famous museums of the world to view masterpieces of art. You could visit the main cities of the world, to visit their architectural treasures. Or you might seek out the beautiful examples of our biological heritage in the nature preserves, national parks, and zoos of the world. More people are choosing this last type of vacation. Our appreciation and curiosity for the other types of life on Earth are increasing as we realize that species can be lost forever.

Nature preserves and national parks are not just for our enjoyment. They also play an important role in global strategies to maintain biological diversity by preserving important habitats and the species that depend on them. Today, zoos play an active role in preserving biological diversity through breeding programs and other efforts. In many cases, by trying to meet our needs, humans have unknowingly caused so much change to the environment that many species have been unable to adapt, and have disappeared. In recent years, however, both experts and volunteers have turned their attention to preserving the world's biological diversity and, sometimes, have been able to reverse some of the damage that has been caused.

For Web links relating to 4.0, visit **www.pearsoned.ca/scienceinaction**

4.1 Reduction of Biological Diversity

Species and ecosystems on Earth and the ecological processes of which they are part are being stressed by urbanization and the expansion of human industries such as agriculture and forestry. The resulting decline in genetic, species, and ecosystem diversity threatens the ecological, economic, and cultural benefits we currently derive from Earth's living resources. The extinction of some species, the decrease in population of other species, and the degradation of ecosystems reduces biological diversity on Earth.

Figure 4.1 Only 2100 Indian rhinoceroses remain in the wild.

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A Lesson in Extinction

One animal you will never see is the dodo, a flightless bird that once inhabited Mauritius, an island in the Indian Ocean. The dodo had no predators. Portuguese explorers first landed on the island in 1505, bringing with them cats, rats, dogs, and pigs. These introduced animals ate the dodos' eggs, and the sailors who stopped on the island used the adult dodo as a source of food. The dodo became extinct within 200 years of first human contact, probably around 1681.

GIVE IT A **TRY**

Choices in Our World

Balancing human needs and the needs of other organisms is often very difficult. To grow our food, for example, land must be cleared of sensitive native plants.

With a partner, choose one of the following scenarios. Discuss the effects of the changes to the environment and to the organisms that live there. What choices will need to be made? Why? Could any of the changes be avoided? How?

1. A new school is built in a neighbourhood. Construction takes place on land that has a grove of aspen trees and native grasses. The trees are removed so the workers can park their vehicles during construction. The native grasses are replaced by the school building, tarmac basketball courts, and non-native grass for sports fields.
2. A river is dammed to provide irrigation water for neighbouring farms. During construction, all the aquatic plants at the river's edge are removed. A concrete retaining wall is built that runs about 10 km in either direction from the dam. A path is paved and fencing is installed, sod is laid, and picnic benches are installed to make a riverfront park. The grass is maintained through regular mowing and pesticide applications.

Extinction and Extirpation

Extinction is the disappearance of every individual of a species from the entire planet. Extinction is a natural part of Earth's history. Scientists estimate that 99% of all the species that have ever existed are now extinct. Most mass extinctions, like the one that killed off the dinosaurs, were likely caused by catastrophic events. These are events such as earthquakes or volcanic eruptions that cause sudden changes in the environment. The last major environmental change was about 1.8 million years ago during the Pleistocene epoch, which is commonly known as the Ice Age.

However, most extinctions are not mass extinctions. They take place over longer periods of time. Scientists speculate, though, that the rate at which species are becoming extinct is increasing. More species will disappear over the next decade than disappeared the decade before, so the biological diversity of the planet is decreasing more and more rapidly.

Figure 4.2 Fossils provide us with evidence of many species that have disappeared from our planet in the past.

Extirpation is a local extinction, or the disappearance of a species from a particular area. The grizzly bear was once commonly found from the mountains of British Columbia to the Manitoba Prairies. They had a rich supply of fish, small mammals, and plants on which to feed. Grizzlies are now mainly found only in the mountains, and their current range is threatened by increasing urbanization. Road building and other activities related to the search for natural resources, such as oil and gas, have also had an impact on the grizzlies' range.

The woodland caribou is currently at risk of being extirpated from the boreal forests of northern Alberta because of habitat degradation resulting from logging, forest fires, and increased interspecies competition.

The swift fox was once common in Alberta, but by 1928 this species was completely extirpated from Canada. The Alberta Department of Environmental Protection, working with groups such as the World Wildlife Fund, is trying to reintroduce the fox to Alberta. To do this, a major breeding program is under way.

The table below shows some of the at-risk species in Alberta. Endangered species are ones that are in immediate danger of extinction or extirpation. Threatened species are likely to become endangered if their current declines are not reversed. Species that are of special concern are ones that are particularly vulnerable to natural events or human activities.

Status	Mammals	Birds	Fish & Amphibians	Plants
Extirpated	black-footed ferret grizzly bear (prairie population)	greater prairie-chicken		
Endangered	swift fox	burrowing owl whooping crane mountain plover piping plover sage grouse sage thrasher Eskimo curlew		tiny cryptanthe
Threatened	wood bison	peregrine falcon prairie loggerhead shrike Sprague's pipit	short-jawed cisco	Western blue-flag soapweed Western spiderwort slender mouse-ear-cress sand verbena
Special Concern	woodland caribou wolverine Ord's kangaroo rat	ferruginous hawk long-billed curlew short-eared owl yellow rail	great plains toad Northern leopard frog (prairie population) Western silvery minnow	Bolander's quillwort hare-footed locoweed smooth goosefoot tall wooley-heads

Natural Causes of Extinction and Extirpation

Earlier in this unit, you learned that sexual reproduction is responsible for variation within species. These variations are important so that, through natural selection, a species can survive changes in its environment. However, if the population does have variation, why do species still disappear?

Natural selection is usually a slow process. Even if there is a lot of variation within a species, sometimes the environment changes too much and too quickly for the species to survive. For example, dinosaurs were once the most successful species on the planet, and yet all dinosaur species disappeared about 65 million years ago. In the past, most extinctions and extirpations were due to natural causes, such as:

- catastrophic events such as volcanic eruptions, floods, or fires
- lack of food due to overpopulation
- disease

Not all extinctions happened millions of years ago. In the 19th century, the American chestnut was one of the most numerous trees in forests of the eastern United States. In the summer, its creamy-white blossoms made mountains in the Appalachians appear as if snow-covered. The nuts were a source of food for wildlife, livestock, and humans. These were giant trees, up to 30 m tall, and the wood had many uses.

In 1904, the chestnut blight, a disease caused by a fungus, appeared in the American chestnuts in New York City. This fungus came from Asia and quickly spread because the North American trees had little resistance. By 1950, the species had essentially disappeared. Attempts are continuing to create a blight-resistant strain in order to bring this species back from the edge of extinction.

Catastrophic events are still occurring today. For example, some species that once lived on the side of Mount Etna, Sicily, were extirpated from that area because of the volcanic eruption in 2001 that resulted in long-term changes to that environment.

Overspecialization

Sometimes organisms have adaptations that suit them to only a narrow set of environmental conditions. This probably happens because the environment that the organism inhabits remains unchanged for a very long time. Biologists call this **overspecialization**. Overspecialization is another natural cause of extinction. The best-known example of overspecialization is the giant panda that eats only one thing, bamboo shoots. Because the panda only eats bamboo, it cannot switch to other sources of food. Bamboo forests sometimes die off or are cut down, reducing the pandas' food supply. So although habitat destruction affects the survival of the species, the pandas' overspecialization makes them even more vulnerable to extinction.

Figure 4.3 Damage caused by chestnut blight

Figure 4.4 The northern leopard frog has been extirpated from central Alberta.

Human Causes of Extinctions and Extirpations

Today, most extinctions and extirpations are due to human activity. If you have ever watched a new neighbourhood being built, you know that humans can change the environment very quickly. Because human populations continue to grow, and require land for houses and food production, human activity is now the leading cause of worldwide species loss.

Habitat Destruction

Humans cause rapid changes to habitat in a variety of ways. Construction of buildings, agricultural development, logging, and the damming of rivers all change environments. These activities are necessary to meet human needs. For example, large tracts of land were cleared of all native vegetation to make way for fields and pastures to grow crops and raise livestock, which are our food supply. But unfortunately, these changes also have brought about the loss of many species. In Canada, prairie species have been affected the most, because the grasslands provided the best farm sites. In fact, only 20% of the area once covered by native prairie species is still in its natural condition.

Pollution is a particular kind of habitat destruction. Pollution often affects not only the immediate area where humans are but also areas farther away. For example, pesticides, herbicides, and fertilizers used in farming may be washed into the nearby water system, and may unintentionally cause the death of native species. Some chemicals can cause an increase in the number of birth defects in species. This often occurs first in aquatic species such as fish, frogs, and toads. For example, pollution of breeding sites is thought to be the main cause of the dramatic reduction of the great plains toad in Alberta. This toad is now in the Special Concern category.

Figure 4.5 Habitat destruction is a global problem. This rain forest in Brazil is being cleared for farmland.

The effects of habitat destruction in tropical areas can be severe. Because tropical rain forests have the highest diversity of species of any area on the planet, loss of these habitats can cause the extinction or extirpation of a very large number of species.

Introduction of Non-Native Species

Throughout our history, migrating humans have carried with them many species on which they relied. The corn that First Nations people grew at the time of European settlement originally came from South America. Horses and cattle were unknown in the Americas until the arrival of Europeans.

When introduced species use the same resources as native species, they compete with the native species and cause the number of native species to decline, simply because there is less of everything. Cattle now graze where bison once roamed, and attempts to reintroduce the bison are limited due to the competition for grazing resources. Some introduced species, such as the invasive purple loosestrife, may have arrived in North America in a number of ways. Seeds may have been lodged in the ballast of a ship, stuck in the coats of animals, or carried by settlers who wanted to be reminded of home. Since its introduction, purple loosestrife has spread rapidly, out-competing native species, partly because no native species eat the purple loosestrife.

Figure 4.6 Wild bison once numbered in the millions.

Over-Hunting

Over-hunting was the major cause of the decline and eventual extirpation of the plains bison over most of its range, and of the extinction of the passenger pigeon. In the 19th century, flocks of passenger pigeons were so large that people reported being unable to hear the sound of a gunshot when they flew overhead. Passenger pigeons were hunted mainly for sport. The sport was so popular that the population declined dramatically. The last passenger pigeon died in captivity on September 1, 1914. Sometimes species were hunted to deliberately extirpate them. Black-tailed prairie dogs were considered a great menace to farmers and ranchers because they ate grain and dug holes causing cattle and horses to break legs. In the 1930s, large-scale poisoning campaigns reduced prairie dog numbers.

ACTIVITY A-6

Decision Making

BALANCING ACT

The Issue

Should human activities be restricted in our national parks?

Background Information

In Canada, grizzlies are now extirpated from the Prairies, and are found only in forested regions of Alberta, British Columbia, Yukon, Northwest Territories, and Nunavut. Here they can find an adequate food supply. They can also find appropriate habitat in which to make their dens and to provide refuge from human disturbance.

Figure 4.7 Grizzly bears need large areas of land undisturbed by human activity.

Although we may think of grizzlies as aggressive animals, they usually prefer to avoid humans. National parks are meant to preserve natural areas and the animals that inhabit them, but most of us also expect to be able to enjoy many outdoor activities in these parks. In Alberta, Banff and Jasper National Parks have ski areas, hotel facilities, swimming pools, and large camping facilities for recreation.

Analyze and Evaluate

Research the kinds of human activities currently allowed in national parks. Begin your search at www.pearsoned.ca/scienceinaction. Draw a concept map to show the social, economic, and environmental consequences of these activities.

Analyze your research and describe how these activities affect grizzly bears or other animals in the parks.

Write a proposal to Canadian Heritage Parks Canada recommending which human activities should be allowed in national parks and to what extent. Support your proposal with your research. Include a brochure for the public, to educate them about this issue.

ACTIVITY **A-7**

Experiment **on your own**

CHANGES IN BIOLOGICAL DIVERSITY

Before You Start

In any ecosystem, there may be many different species. The types and numbers of species can vary depending on a number of factors, including changes in climate or human activity. In this experiment, you will take a survey of all plants and animals in an existing area of your community. This survey will be repeated at a later date and the two sets of data will be compared.

The Question

How do the numbers of plant and animal species in an area change over time?

Design and Conduct Your Experiment

1. Make a hypothesis to test how the types and numbers of species will change. (Remember a hypothesis is a possible answer to a question or a possible explanation of a situation.) Ideally, the area will be a local park or field, but could also be a small plot of soil, or garden. If time permits, the interval of time between surveys should be at least several months.
2. Decide what materials you'll need to test your hypothesis. For example:
   a) What measuring instruments will you need? Tape? Metric ruler?
   b) What reference books will you need to help you identify the plants and animals?
   c) What materials will you need to record your data? Drawing paper? Grid paper? Calculator?
3. Plan your procedure. Ask yourself questions such as:
   a) What steps will I follow to collect the data I need?
   b) How will I estimate population numbers?
   c) Is the test I have designed fair? How do I know?
   d) How will I record my results? For example, do I need a data chart? A graph? Both? Neither?
   e) How long do I have to complete my surveys?

Figure 4.8 Surveying a local environment

4. Write up your procedure. Be sure to show it to your teacher before going further.
5. Carry out your surveys.
6. Compare your results with your hypothesis. Did your results support or refute it? If not, what possible reasons might there be?
7. Share and compare your experimental plan with your classmates. Did anyone plan surveys exactly like yours? Similar to yours? How do your results compare with theirs?

Effects of Extinctions and Extirpations

Extinctions and extirpations reduce biological diversity. Extinctions reduce the number of species on the planet. Extirpations reduce biological diversity in areas from which the organism has disappeared. In section 1.0, you learned about some of the many ways species interact with one another. When an organism disappears locally or globally, many other species are affected. For example, in regions where black-tailed prairie dogs were extirpated, burrowing owls and black-footed ferrets were also affected. Prairie dogs were the major source of food for black-footed ferrets, and burrowing owls used abandoned burrows as nesting sites. Black-footed ferrets are now one of the most endangered animals in North America.

Figure 4.9 The black-footed ferret has been extirpated from Canada. In 1997, there were 12 males and 18 females at the Metro Toronto Zoo. In the United States, small populations have been reintroduced to the wild.

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Extinct Canadian Animals

Examples of Canadian animal species that have become extinct due to human activity include:

Great Auk—extinct 1844
Sea Mink—extinct 1894
Passenger Pigeon—extinct 1914
Blue Walleye—extinct 1965

Find out more about these animals. Begin your search at www.pearsoned.ca/scienceinaction. Prepare a timeline or a short report describing how they became endangered and then, extinct.

Check and Reflect

Key Concept Review

1. State two examples of situations in which biological diversity may be reduced.
2. What kinds of natural causes lead to the extinction of a species?
3. In what ways can human activity lead to the extinction or extirpation of a species? Use examples to explain your answer.
4. Explain the term "overspecialization."

Connect Your Understanding

5. Use a Venn diagram to compare and contrast extinction and extirpation.
6. Suppose an organism is extirpated from a local environment. In what way might other organisms be affected? Provide examples to support your answer.
7. How does extinction reduce biological diversity on Earth? Support your answer using examples and your knowledge of how genetic information is transferred from parents to their offspring.

Extend Your Understanding

8. What role has land use by humans played in the ongoing changes in biological diversity? State examples from your own community.

*info*BIT

Beefier Cows

Scientists working at Alta Genetics Inc. of Calgary were the first to use genetically engineered cattle that would produce more beef.

4.2 Selecting Desirable Traits

What did you have for breakfast this morning? Did you have cereal or toast? How about a glass of orange juice? The particular grains and fruits used in these and many other foods are probably a product of artificial selection. **Artificial selection** is the process of selecting and breeding individuals with desirable traits to produce offspring that have these desired traits. Recall that in natural selection the environment "selects" traits. In artificial selection, humans select traits.

Consider the example of horse breeding. By combining the genes of champion parents, breeders hope to create offspring that have the prized traits of both parents. If those horses are bred with other champion horses when they reach maturity, the chances of producing the desired traits in succeeding generations increase (Figure 4.10). The same is true of breeders of other animals such as livestock (cows, sheep, pigs) and domestic animals (dogs, cats, birds, guinea pigs, hamsters).

Figure 4.10 These horses have been bred for their size.

In a breeder's population, however, every individual is selected in the same way. Only those with a trait the breeder wants, such as a particular feather colour, in the case of domestic finches, will be allowed to breed. In contrast, natural selection "selects" traits that are useful for the survival of the individuals with those traits and allows them to breed.

Artificial selection can also be applied to both food and ornamental plants. For example, by taking the seeds of the healthiest or best producing plants and sowing them the following year, farmers can generally "weed out" less desirable traits and promote more desirable ones.

Humans have practised artificial selection since we first began to farm about 10 000 years ago. After so many generations of artificial selection, most of our plants no longer resemble the wild species from which they were bred. Corn, for example, was bred by native peoples from a species of grass called teosinte. Teosinte produced much smaller cobs and far fewer seeds than modern-day corn.

Figure 4.11 The drawing of a very early variety of corn (left) is based on archeological samples. It doesn't look very similar to the corn we eat today (right).

Biotechnology

Native peoples practised an early form of **biotechnology** when they gathered seeds from the biggest and healthiest corn plants. This benefited them because they were able to develop more productive strains of corn.

Agricultural producers benefit when they can be sure that the wheat they plant or the calf that is born in their herd will have the traits that are most valuable in the marketplace. Although artificial selection has successfully produced most of our world's crops and livestock, it takes a very long time (many generations of the plants and animals) to get an organism with the desired combination of traits. For instance, livestock breeders have to breed cows over many generations to get a whole herd that produces large quantities of milk. Scientists and breeders have, therefore, developed technologies that can speed up this process. These technologies can range from "low tech" to extremely "high tech."

Figure 4.12 Identical organisms produced by technology are called clones, such as this carrot plant grown from a few cells taken from another carrot plant.

Creating Plant Clones

When a grower finds a plant that has very desirable traits, he or she would like more plants like it, or many clones of it. The simplest way to create a **clone** is by taking a cutting from a plant and growing an identical plant from the cutting. Horticulturalists do this routinely. The drawback is that this ideal plant has only so many leaves that can be cut off to use as cuttings.

Scientists have developed a quicker way to create clones. Cells are removed from an individual plant that has the particular traits that are wanted. These cells are placed on a Petri dish or bottle containing nutrients and hormones the cells need. Once these cells have developed into seedlings, they can be transplanted into the soil. Because the starting point is a cell rather than an entire part of the plant, many more clones can be produced from a single plant (Figure 4.12).

Artificial Reproductive Technology

Artificial reproductive technology refers to any artificial method of joining a male and female gamete. Most livestock in Canada are produced by some method of artificial reproduction. In **artificial insemination**, sperm are harvested from a bull with desired characteristics and are inserted into many female cows. The advantage of this technology is that the bull's sperm can be in several places at once and more cows can be inseminated.

Another reproductive technology is **in vitro fertilization**. In this technology, sperm from a prize bull and eggs from a prize cow are harvested from the animals. In a laboratory, the eggs and sperm are placed in a Petri dish, and the eggs are fertilized. This produces many more embryos than could be produced naturally. Each embryo is implanted into a different cow. These cows will eventually give birth to many calves, all of which will be brothers and sisters.

Figure 4.13 The beef industry relies on artificial reproduction technology to produce cattle with traits chosen to provide us with high quality meat.

Scientists can also determine the sex of the embryos before they are implanted into a cow to develop. By choosing only female embryos, dairy farmers can therefore be guaranteed that all their calves will be female, rather than having to use their resources to raise unneeded males.

Genetic Engineering

Genetic engineering refers to any technology that directly alters the DNA of an organism. Genetic engineering is a rapidly developing science, and every new advance increases our ability to control the characteristics of organisms.

Figure 4.14 This plant was grown from cells that had a firefly gene inserted into them. When the gene is activated, the plant glows.

Many of the genetic engineering techniques involve inserting a gene from one species into another species. Bacteria are genetically engineered to produce life-saving medicines such as insulin. Insulin is a substance that many diabetics use to control the level of sugar in their blood. Just 20 years ago, insulin had to be extracted from the pancreas of cattle, and it was expensive to produce. Today, the human insulin-producing gene is inserted into the bacteria's DNA. Because the bacteria reproduce so rapidly, bacterial colonies can produce insulin quickly and cheaply. Now most of the world's supply of insulin comes from genetically engineered bacteria.

A micro-organism called *Bacillus thuringiensis* produces a toxin commonly called Bt, which is poisonous to many insects. Scientists have isolated the gene that contains the instructions for making Bt toxin and have inserted it into the DNA of plants. These genetically engineered plants now produce Bt toxin! Since the 1990s, cotton, corn, and potatoes have been engineered to produce Bt toxin. Because insects that eat the engineered plants die, growers never need to apply pesticides to the engineered plants.

Some varieties of canola are naturally resistant to an insect called the flea beetle, while others are not. When flea beetles attack a field of canola, the crop is likely to be devastated, leaving the grower with nothing to sell. Unfortunately, the most valuable varieties of canola do not have a gene for flea beetle resistance, so most growers have to use pesticides to protect their crop from the beetle. Scientists have been able to transfer this gene from beetle-resistant varieties to other canola varieties that have higher yields. The growers who use the genetically engineered canola get canola with high yields and, because it's beetle-resistant, it doesn't have to be sprayed with pesticides.

Biotechnology and Society

Development of technology that allows us to select or introduce desirable traits of the organisms around us has given humans some important benefits. However, as with any technology, we need to use these technologies responsibly and be aware of the possible risks as well as the benefits.

Risks in Animals

In agriculture, most individuals in a crop or livestock population are extremely similar as a result of generations of artificial selection. Artificial reproductive technologies can reduce the genetic variation in breeding lines of livestock. In artificial insemination, sperm from just a few animals are used to impregnate many females. With in vitro fertilization, the embryos created from the eggs and sperm of just two individuals are implanted in other cows.

Now scientists and breeders are able to produce an identical copy of a single animal. The most famous example of this is a sheep named Dolly (Figure 4.15). Dolly was produced in Scotland in 1997, and is an exact duplicate of her mother.

Animals like Dolly have been cloned for a variety of reasons. Some, like the rhesus monkey ANDi (a backward abbreviation of inserted DNA), have been genetically altered as part of research programs into human diseases. Other animals, such as cattle, are being cloned as potential large-scale producers of meat and milk. Herds of such genetically identical individuals may be far more susceptible to disease than more genetically variable herds.

Figure 4.15 Dolly's cells appear the same age as her mother's, even though Dolly is six years younger.

Cloning and genetic engineering are still in their infancy and have been fraught with difficulties. Cattle cloners have reported numerous examples of unsuccessful pregnancies, birth defects, and deaths among clones. The reasons are as yet unclear. Some researchers speculate that something about the process of removing the nucleus from the donor egg may be responsible. Dolly herself has developed arthritis, although it is not known why.

ACTIVITY **A-8**

Decision Making

SALMON FARMING AND VARIABILITY

The Issue

Will salmon farming help or hurt the recovery of wild salmon in Canada?

Background Information

In the 1990s, the salmon populations on both the Atlantic and Pacific coasts were on the verge of collapse, causing governments to call a halt to all commercial salmon fishing. Many people who had made a living from salmon fishing were suddenly out of work. There were various reasons why the salmon stocks had declined so suddenly, and people had different proposals as to how to let the salmon population recover while still meeting society's desire for salmon.

Fish farms mainly in New Brunswick's Bay of Fundy and off the B.C. coast produce more that 72 000 tonnes of salmon a year. The federal government is a strong supporter of fish farming and recently made available $75 million for research and development. Government estimates suggest that by the year 2025, the world will need 55 million tonnes more seafood than wild stocks can provide. To meet that demand, fish farming as an industry will have to grow by 350%.

But is the advance of fish farming practices coming at the expense of stocks of wild salmon? Why is the wild species still facing extinction? What impact does commercial fish farming have on wild populations? Tests are under way to selectively breed for bigger and faster growing salmon as well as to genetically modify the fish against common parasitic diseases. Researchers in the federal department of fisheries have now developed 20 new transgenic breeds of salmon that grow seven times faster than wild salmon.

Analyze and Evaluate

1. Research the positive and negative impacts that fish farming may have on wild populations. Begin your search at www.pearsoned.ca/scienceinaction. Decide how you will evaluate your information sources.
2. What other factors may be affecting the survival of the wild salmon population?
3. What are the costs and benefits of fish farming and commercial fishing to meet the short- and long-term food needs of society?
4. Prepare an oral presentation in which you defend your position on fish farming. Present your view by role playing from ONE of the following perspectives. You are a fish farmer speaking to a group opposed to fish farming OR you are a fish-farming opponent speaking to an association of fish farmers.

Figure 4.16 Salmon farming pens

Risks in Plants

Most of our plant crops were produced by artificial selection of wild plants. Weeds are often the wild relatives of crop plants. Some crops have been genetically engineered to resist herbicides. This allows farmers to spray the crop with herbicide, killing the weeds but not the crop. However, there have been unforeseen problems. Many crop plants can still cross with their wild weed relatives. There have been reported cases of genetically engineered canola interbreeding with weeds, and the weeds' offspring have become resistant to herbicide.

Check and Reflect

Key Concept Review

1. How does artificial selection differ from what you learned earlier in this unit about natural selection? Use examples in your explanation.
2. Describe two examples of technologies that humans use to select the traits of organisms.
3. Who were the earliest "plant technologists" in North America? What crop did they develop and how?

Connect Your Understanding

4. How have reproductive technologies benefited agricultural industries in Alberta? Provide examples. What human needs do these technologies reflect?
5 Simplify an explanation of artificial selection in a way that a student in grade 4 could easily understand it.
6. What are some advantages of biotechnology such as cloning? What are some disadvantages?
7. What are some intended and unintended consequences for the environment as a result of developments in biotechnology?

Extend Your Understanding

8. Scientists have created crops that contain a toxin that kills any insect that eats them. Some farmers have been growing corn plants that contain this toxin. Corn without this toxin is a food supply for the corn weevil, which destroys the corn crop, and the monarch butterfly, which is a protected species. What advice would you give to farmers growing this crop?
9. Predict what some potential impacts or issues might be related to an increasing use of biotechnology such as cloning and genetic engineering.

*re*SEARCH

Golden Rice

Rice does not normally contain vitamin A. Swiss scientists have recently created a genetically engineered strain of rice that does contain vitamin A. Research this so-called golden rice and find out the reasons for developing it and why some groups have concerns about its use. Begin your search at www.pearsoned.ca/scienceinaction. Prepare a short report.

4.3 Reducing Our Impact on Biological Diversity

Figure 4.17 Leaders of indigenous peoples living in the rain forests of South America attended the Earth Summit to voice their concerns about the clearing of rain forests.

Preserving global biological diversity was given international recognition at the Earth Summit in Rio de Janeiro in 1992. World leaders at the summit, including Canada's Prime Minister Jean Chrétien, signed a treaty called the United Nations Convention on Biological Diversity. This Convention outlined the importance of maintaining ecosystem, species, and genetic diversity in preserving the living resources of Earth. This agreement has three goals: conservation of biological diversity; sustainable use of the components of biological diversity; and fair and equitable sharing of the benefits arising from the use of genetic resources.

Each country that signed the treaty agreed to set national policies in place that outlined how to achieve these goals. In Canada, the federal government created the Canadian Biodiversity Strategy in 1995, which describes how Canada will maintain biological diversity for the future.

Strategies to Conserve Biological Diversity

The conservation of biological diversity requires the elimination or reduction of the adverse impacts to biological diversity that result from human activity. In order to promote biological diversity, the Canadian Biodiversity Strategy focusses on in-situ and ex-situ conservation, along with promoting the sustainable use of resources and an ecological approach to the management of human activities.

Protected Areas

Canada's first national park, Banff, was established in 1885. Currently, 244 540 km^2 of the Canadian landscape is protected in a series of national parks. Each province in Canada also has its own protected-area strategies, which include the future development of additional provincial parks, recreation areas, and ecological preserves. The protected areas of Canada allow organisms to live relatively undisturbed in their natural habitats. **In-situ conservation** refers to the maintenance of populations of wild organisms in their functioning ecosystems. It allows the ecological processes of an area to continue undisturbed.

Species with large ranges, such as caribou, wolves, and bears, are being given added protection as organizations, such as those involved with the Yellowstone to Yukon Conservation Initiative, work to create a network of protected areas. No single protected area can offer enough land space or habitat diversity to support all native species or ecosystems. Linking protected areas together provides corridors for movement and exchange of genetic material essential for the maintenance of biological diversity. The creation of these protected areas depends on the co-operation of national, provincial, and municipal governments, along with the support of other organizations, and citizens. The Wagner Natural Area, just west of Edmonton, is a rich peatland environment that exists today because of the efforts of individuals, groups, and the Alberta government. The area is protected under the Ecological Reserves and Natural Areas Act. Many governmental and non-governmental organizations buy land to provide habitat for plant and animal species.

Restoration of Ecosystems and Species

Canada has also developed various programs to restore endangered species, as well as damaged habitats, to a healthy state. These two goals are linked because most species can never recover unless they have habitat in which to live. This is especially true of species that were extirpated from an area, such as the prairie population of grizzly bears, because of changes made to their habitat.

Charities, not-for-profit organizations, volunteer groups, and private landowners also contribute to restoring species and habitat. The Nature Conservancy of Canada, for example, helps to acquire land or raise money to ensure the ongoing protection of natural areas. The Nature Conservancy works with local conservation groups, private citizens, and corporations to increase the amount of habitat available for native plants and animals. Many private landowners also contribute by returning a percentage of their property to its natural state. At 1943 ha, the Ann and Sandy Cross Conservation Area, just southwest of Calgary, is an example of one of the largest private gifts of land made in North America. Ducks Unlimited Canada, through its Prairie Conservation of Agriculture, Resources and the Environment (CARE) program promotes the restoration or improvement of available cover in large wetland areas. Landowners are encouraged to restore nesting areas through the seeding of native grasses and shrubs in order to improve waterfowl nesting success.

*info*BIT

Raising Endangered Species

At the San Diego zoo, chicks of the endangered California condor are being reared by hand. Their human caregivers wear gloves that look like adult condor heads so that the birds don't associate humans with their parents. The caregivers pick up pieces of meat while wearing the glove and hand it to the chick, so it looks like an adult condor is giving the chick food. That way, when they are extremely young, chicks don't actually see humans.

Figure 4.18 The Alberta Cows and Fish Program worked with local landowners to restore Callum Creek in southern Alberta. Callum Creek before restoration (left) and five years after cows were moved to other grazing areas (right).

Restoring a species that has been extirpated requires a lot of money and time. For example, the swift fox was listed as extirpated from Canada in 1928. Native to short- and mixed-grass prairie regions, the swift fox started to decline in the late 1800s when agriculture began to change its prairie habitat, and it began to face increased competition from species such as coyotes. The swift fox was also vulnerable to poisoning programs aimed at wolves and coyotes. As you learned in subsection 4.1, a captive breeding program began in 1973 and the first swift fox was released into the wild along the Alberta and Saskatchewan border in 1983. The efforts of the Alberta government and organizations such as the World Wildlife Fund resulted in successful reintroduction efforts. A winter census in 1997 estimated the population of swift foxes in the area to be 192. The swift fox, however, is still listed as an endangered species in Alberta.

In 1992, the Friends of Fish Creek, a non-profit organization, formed to assist in the protection, preservation, and enhancement of the natural and human heritage of Fish Creek Park in Calgary. Every July, the society organizes "Purge the Spurge." Volunteers gather to hand pull leafy spurge, a non-native noxious weed that threatens to take over the park and destroy wildlife habitat. The weeds are hand pulled in areas where other control methods can't be used.

Figure 4.19 Planting native plant species is one strategy for maintaining biological diversity.

Resource Use Policies

Federal and provincial governments have laws to protect species that are endangered (species with very few individuals left in the wild) or threatened (species that are decreasing rapidly in the wild). Any species that is classified as endangered or threatened is protected by law from hunting and capture, or in the case of plants, from being picked or transplanted. The National Accord for the Protection of Species at Risk was created in 1994, and was signed by all the provinces and territories of Canada. The accord paved the way for each province to develop legislation to protect their vulnerable plants and animals.

The goal of the Accord for the Protection of Species at Risk is to "prevent species in Canada from becoming extinct as a consequence of human activity." The participants in the accord have agreed to recognize species assessments made by the Committee on the Status of Endangered

Wildlife in Canada (COSEWIC). They have also agreed to establish legislation and programs to effectively protect species within their own province or territory and to protect threatened or endangered species. Nationally, the federal government is developing the Species at Risk Act. In Alberta, the Endangered Species Conservation Committee (ESCC) was created under the Wildlife Act of 1998 to study and determine species at risk in Alberta. The ESCC produces a status document on Alberta's plants, mammals, reptiles, amphibians, and birds every five years.

Controlling the Spread of Exotic Species

Past experience has shown that bringing species into a new environment can have disastrous consequences for the native ecosystem. Recall purple loosestrife, the herbaceous wetland perennial introduced into Canada from Europe in the 1800s. Purple loosestrife invades native wetland communities forming a single species stand by germinating and growing faster than any other wetland species (Figure 4.20). Purple loosestrife has no natural enemies. No bird, mammal, or fish feeds on it or uses it for shelter. Purple loosestrife reduces the size and diversity of natural plant communities and has been designated as a noxious weed by Alberta Agriculture. If purple loosestrife is found in an area, measures must be taken to control it. Volunteers are vital in pulling purple loosestrife and monitoring infested sites throughout the province. To control purple loosestrife and other invasive species, federal, provincial, and municipal governments continue to develop policies to prevent their spread. Although these programs are developed and enforced by governments, their success ultimately depends on the actions of individuals.

Figure 4.20 (Left) Purple loosestrife takes over a wetland. (Right) This species of weevil feeds exclusively on purple loosestrife and is used by groups such as the Manitoba Purple Loosestrife Project to help control the plant's spread.

Conservation of Genetic Resources

Ex-situ conservation refers to the conservation of components of biological diversity outside of a natural habitat. Like in-situ conservation, ex-situ conservation plays a vital role in species preservation. In some cases, ex-situ conservation offers the only chance of survival for some endangered species and plays an important role in conserving economically valuable genetic resources for forest, aquatic, and agricultural purposes.

rESEARCH

Cloning Endangered Species

In 2001, a company called Advanced Cell Technologies attempted to clone an endangered species called the gaur, a wild ox from India. Look up magazine and newspaper articles about the gaur and find out how Advanced Cell Technologies planned to clone the animal and whether they were successful. Prepare a short report on your findings.

Conservation of genetic resources is any activity that helps to store as many gene variations as possible of the world's species. This is a huge task since some scientists estimate that there are as many as 10 million different species in the world. Conserving genetic resources began with seed banks, which store seeds from the many varieties of crop plants. Most seed banks started as a voluntary exchange program between farmers. By keeping a seed bank, farmers had access to all the crop varieties available, so that if environmental or market conditions changed, they could plant a more suitable variety.

As we learned more about the importance of biological diversity, seed banks were expanded. Experts realized that it was important to keep seeds of the wild ancestors of our crop species, because these species often had useful characteristics that our advancing technology might be able to use in the future. Today, the world's seed banks are administered by an international group of scientists, known as the International Plant Genetics Resources Institute (IPGRI). The scientists are responsible for determining which country will maintain the seed bank of particular species. Canada maintains the seed bank for barley and oats.

Figure 4.21 This seed bank stores varieties of wheat.

Preserving the genes of animals is much more difficult. Plant seeds can be stored for long periods. In contrast, the egg and sperm cells of animals can be stored only for relatively short periods, so populations of living animals must also be maintained. Most of us would like wild animals to be "stored" in their wild habitats, but some species may already have too little habitat for this to be possible. These animals may escape extinction by captive breeding programs run mainly by zoos. These programs assess the variation of the individuals in the collections of zoos worldwide, and breed the animals that have the most variation. Sadly, this may soon be the fate of the giant panda and the Bengal tiger. Sometimes the animals are exchanged between zoos, but many times breeding takes place by using artificial reproduction technologies such as those used in cattle farming. Some species, such as the whooping crane, will breed in captivity, while others will not.

ACTIVITY A-9

Decision Making

SAVING THE WHOOPING CRANE

The Issue

Which strategies have been most effective in saving the whooping crane from extinction?

Background Information

Wetlands include marshes, swamps, and bogs, and provide habitats for a large number of species. One such species is the endangered whooping crane, which is the symbol of a government program called RENEW (Recovery of Nationally Endangered Wildlife). As of April, 2001, the number of whooping cranes in the wild in North America was only 263. Amazingly, 177 of these live in conserved wetland habitats in Wood Buffalo National Park. Most of these birds were not born in the park, but were released from captive breeding programs.

Figure 4.22 Loss of wetland habitat has pushed the whooping crane near to extinction.

The prairies were once dotted with small wetlands called "prairie potholes," which provided habitat for the whooping crane and other species. Most experts agree that the whooping crane has become endangered due to habitat loss because so many of these potholes were drained to make way for farms, industry, or housing, or to control mosquito populations. Governments, environmental groups, fishing and hunting associations, zoos, local community groups, and private land owners have started to work together to bring back the whooping crane.

Analyze and Evaluate

Use the Internet and the library to investigate the strategies being used for conservation of the whooping crane. Begin your search at www.pearsoned.ca/scienceinaction. Try to find the most recent information available from expert sources, such as conservation groups, zoos, or universities.

Write a paragraph summarizing the conservation strategies for the whooping crane. Your paragraph should describe the habitat needs of the whooping crane, any changes in areas that could provide suitable habitat, and data on the change in the whooping crane population over the last 10 years.

Based on your research, create a report card on our progress in saving the whooping crane. Which strategy or strategies was most effective in increasing the population of the whooping crane?

GIVE IT A TRY

Do You Affect Biological Diversity?

Preserving biological diversity requires everyone to think about the world in a different way. How much do your personal activities affect other living things?

Make a record of your main activities for a week. For everything you note, ask yourself if you affected other living things. For example, if you cut across a field on the way to school, you might compact the soil and make a bare patch where plants can't grow. If you print out a Web page instead of reading it on your computer, you are indirectly reducing the amount of forest.

At the end of the week, report to your class whether you think your actions contributed to loss of biological diversity. Can you think of anything you might do differently?

Check and Reflect

Key Concept Review

1. What is in-situ conservation? How does it preserve biological diversity?
2. Why is it important to protect networks of ecosystems and habitats? Provide an example of a species that would benefit from such protection and state why.
3. How have governments been involved in the protection of vulnerable species? Provide an example of a government policy.
4. What methods have been used to conserve genetic resources? List some examples.

Connect Your Understanding

5. In a short paragraph, explain how a protected area, such as a national park, is an example of in-situ conservation.
6. Why do exotic species have such an impact on local ecosystems? Why are exotic species, such as purple loosestrife, a threat to biological diversity?
7. What is the value of preserving the seed of wild plant ancestors and other varieties of crop plants grown today?

Extend Your Understanding

8. You have just signed up to help with the annual "Purge the Spurge" campaign in Fish Creek Provincial Park. Given what you may already know about spurge, why might this be a worthwhile activity? What impact, if any, do you predict your action will have on species diversity? Explain your answer.

Unit Summary: Biological Diversity

Key Concepts	Section Summaries
1.0 • biological diversity • species and populations • diversity within species • habitat diversity • niches • natural selection of genetic characteristics	**1.0 Biological diversity is reflected in the variety of life on Earth.** • Earth and its environments are home to millions of species. • Biological diversity refers to the variety of species and ecosystems on Earth. It has three main components: ecosystem diversity, community diversity, and genetic diversity. Biological diversity also refers to the variation among and within species. • Species co-existing in a habitat are interdependent. The possible interdependencies are predator-prey relationships, commensalism, mutualism, and parasitism. • Different species share limited resources by having different niches. • Natural selection is the selection of desirable traits by the environment.
2.0 • asexual and sexual reproduction • inheritance	**2.0 As species reproduce, characteristics are passed from parents to offspring.** • Heritable traits can vary between individuals either as discrete variations, such as eye colour, or continuous variations, such as height. The environment can affect some heritable traits, such as height. • Asexual reproduction involves only one parent. The parent and offspring of asexual reproduction are identical. Sexual reproduction involves two parents. The offspring of sexual reproduction are different from the parents. • In sexual reproduction, a male gamete fuses with a female gamete to produce a zygote. A zygote develops into an embryo, which eventually grows into a new individual. • Sexual reproduction results in variation among individuals of a species. Asexual reproduction allows a species to reproduce quickly producing identical offspring.
3.0 • chromosomes, genes, and DNA • cell division • inheritance	**3.0 DNA is the inherited material responsible for variation.** • Chromosomes, genes, and DNA carry genetic information that is passed on from generation to generation. All cells in the body of an organism contain DNA. • DNA carries the instructions for making a particular individual organism. The instructions are written in a genetic code. The code is the same for all organisms on Earth. • Genes are the instructions for the particular characteristics of an organism. • Organisms with a lot of DNA have chromosomes arranged in pairs. • The result of binary fission and mitosis is the formation of two new cells from one parent cell. Each has the same amount of DNA as the parent cell. • The result of meiosis is the formation of gamete cells. Each gamete has half the amount of DNA as the original cell. • A dominant trait is seen in offspring whenever the dominant allele is present. A recessive trait is seen in offspring only if two recessive alleles are present. • Dominant and recessive inheritance does not explain all patterns of inheritance.
4.0 • biological diversity • species • habitat diversity • natural and artificial selection of genetic characteristics	**4.0 Human activity affects biological diversity.** • Extinction is the loss of a species from the entire planet. Extirpation is the loss of a species from an area of the planet. Both cause reduction of biological diversity. • Extinctions and extirpations are caused by natural events and by human activity. • Artificial selection is human selection and breeding of plants and animals with desirable traits to produce offspring with those traits. Natural selection is selection of desirable traits by the environment. • Technologies that affect biological diversity include artificial selection, artificial reproductive technologies, and genetic engineering. • Strategies to maintain biological diversity include restoration of habitat and re-introduction of species, and the use of seed banks and captive breeding programs.

Zoos and Biological Diversity

The Issue

Do we need zoos? Many people are troubled by the idea of keeping wild animals in captivity. It can seem cruel to keep species such as the polar bear or antelope, animals that wander many kilometres every day in the wild, in small enclosures. Animals are kept in a climate that can be very different from their natural habitats. Most animals also have a unique social structure that cannot be duplicated in captivity.

It can seem that zoos keep animals in these false environments only to serve human interest. However, many zoos such as the Calgary Zoo, have taken on a leading role in conserving species at risk of extinction or extirpation. Zoo supporters argue that without these conservation projects, many animals would have an even greater risk of extinction.

Here are some of the arguments for and against keeping animals in zoos.

Zoos Have an Important Role in Maintaining Biodiversity	Zoos Meet Human Needs Far More than Animal Needs
Zoos provide refuge for animals with damaged or eliminated habitat.	Zoos design the enclosures so that humans can observe the animals, which puts many of the animals under stress.
Zoos help to maintain biodiversity by participating in animal breeding programs with other zoos.	The money spent on establishing and maintaining zoos would be better spent on habitat protection and rehabilitation of animals' natural habitats.
Zoos conduct and support research that assists efforts to improve existing habitat and to re-establish extirpated species.	Many animals will not breed in captivity, so their genes are lost forever.

Does the Calgary Zoo meet all the needs of its inhabitants?

Go Further

Now it's your turn. Look into the following resources for information to help you form your own opinion.

- Look on the Web: Check out Web sites about zoos around the world (including Calgary and Edmonton) and their research programs.
- Ask the Experts: Talk to an expert about the issue. When you do your Internet search, you may find e-mail listings of specific people who can provide you with information.
- Check Newspapers and Magazines: Follow current stories about the issue in newspapers and magazines.
- Check Out Scientific Studies: Look for scientific studies about zoos.

Analyze and Address the Issue

You are an expert on conservation of species and you have been asked to write a proposal about the role of zoos in maintaining biological diversity in our world. In your proposal, consider the different perspectives on this issue. Support your proposal with research data and include the risks and benefits of adopting your proposed strategy.

PROJECT

MAINTAINING LOCAL BIOLOGICAL DIVERSITY

Monte Verde Cloud Forest in Costa Rica

Getting Started

The Kew Seed Bank in England holds seeds for almost 4000 different species of plant life—about 1.5% of known flora on Earth. By having a large supply of the plants' seeds, the bank hopes to protect some of the 34 000 plant species currently at risk for extinction worldwide. The National Institute of Biodiversity in Costa Rica is using a technique called "bioprospecting" to study the ways in which animal and plant resources may be useful to humans. They locate, describe, and collect species that are not endangered. Researchers then develop extracts from the plants, insects, and micro-organisms, which are then analyzed to determine their use in pharmacological, agro-industrial, and biotechnology industries. Any university or company working with the National Institute of Biodiversity has to commit to reinvesting 50% of profits from products developed from these natural resources in conservation. Also in Costa Rica, 22 260 ha of rainforest within the Monte Verde Cloud Forest have been purchased with the donations from school children around the world. Called the Children's Eternal Rainforest, it is now the largest private reserve in Costa Rica and is administered by the Monte Verde Conservation League. The area earned the name the Children's Eternal Rainforest because thousands of species of trees, and the

animals that depend on them, are now protected from logging and deforestation. These are only three examples of strategies that have been successful in helping to maintain biological diversity. What strategies are being used in your community?

In this unit, you have learned about the diversity of life on Earth both among species and within. You have also learned that natural selection and human activity may reduce biological diversity on Earth.

This project will allow you to apply what you've learned to researching and making a presentation on a local strategy for maintaining biological diversity.

Your Goal

Working with a partner, learn more about a local strategy for maintaining biological diversity. Put together a presentation to share this information with others. Your presentation may be multimedia (e.g., PowerPoint presentation, video), in poster format, or an oral presentation. Strive to find a creative and interesting way to convey your new learning. Include your opinion on how successful the strategy has been and any recommendations that you would have for the future.

What You Need to Know

To find a local conservation project you may wish to contact environmental groups in your area or a government agency for ideas. If you use the Internet as part of your research, be sure to follow your school's acceptable user policy. Begin your search at www.pearsoned.ca/scienceinaction.

Steps to Success

1. Work with a partner. Brainstorm possibilities for a strategy that will be the focus on your research. Writing to local environmental groups, reading newspaper and magazine articles, using e-mail, and checking Web sites are examples of ways to gather the background information that you will need for your presentation.
2. Select the type of presentation that you will use and begin to develop a plan for sharing your research findings.
3. Be sure to include your own assessment of how effective the strategy has been in terms of maintaining biological diversity, and any suggestions you have for improving the use of the strategy in the future.
4. Present your work to the class.

How Did It Go?

5. In paragraph form, answer the following questions:
   - Describe your research process. How effective was it?
   - How well did you and your partner work together? How effectively did you make decisions and come to agreements?
   - What part of this project did you find to be the most challenging? the easiest?
   - How did your presentation compare with your original ideas? What changes did you make and why?
   - What would you do differently next time?

Unit Review: Biological Diversity

Unit Vocabulary

1. Create a concept map that illustrates your understanding of the following terms and how they relate to biological diversity.

   species
   natural selection
   interdependence
   niches
   asexual reproduction
   sexual reproduction
   artificial selection
   extinction
   extirpation

Key Concept Review

1.0

2. How is a population related to a community? Refer to a pond environment to illustrate your answer.
3. What is genetic diversity?
4. Outline the three levels of biological diversity. Give an example of each.
5. Using an example, explain how species are dependent on many other species in their environments.
6. What is a niche? Describe the niche of a wolf in the Canadian Rockies.
7. In parasitism, how does the parasite depend on its host for survival?
8. Why is the niche a species occupies important to its survival?
9. Describe one major threat to biological diversity.
10. Illustrate the meaning of ecosystem diversity.

2.0

11. What is similar about sperm cells and egg cells? What is different?
12. What is a zygote? How is it formed?
13. Differentiate between heritable and non-heritable characteristics. Provide examples of each type.
14. Distinguish between discrete and continuous variation and provide three examples of each.
15. Outline the path of development in animals from gametes to embryo.
16. Sketch the parts of a flower that are involved in reproduction. Describe how each part functions in cross-fertilization.
17. What form of asexual reproduction do yeast cells use and how does it work?
18. Explain the difference between asexual and sexual reproduction and the advantages and disadvantages of each in terms of biological diversity.
19. Use a table or Venn diagram to compare the different forms of asexual reproduction.