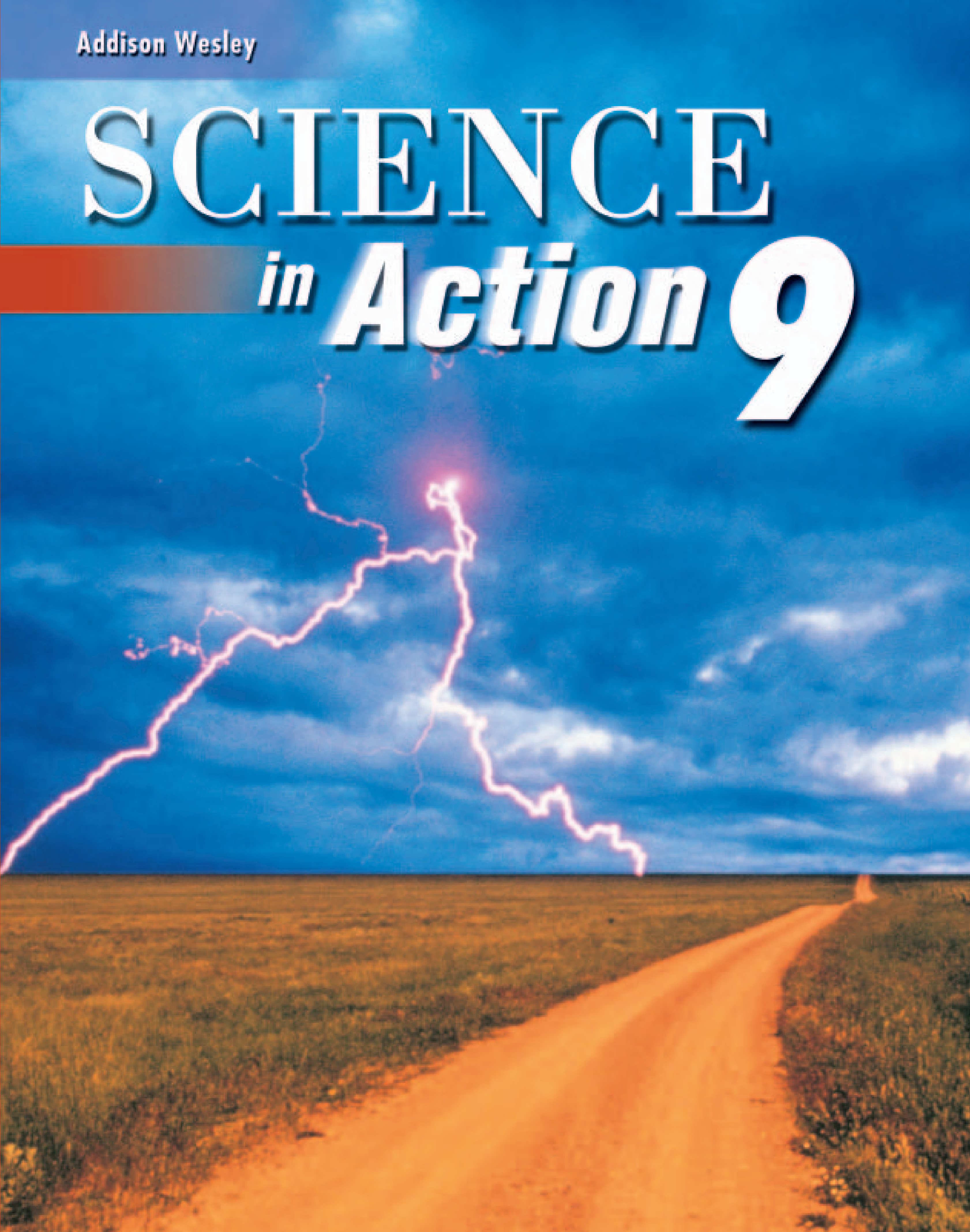
Addison Wesley

SCIENCE in Action 9



Addison Wesley

SCIENCE in Action 9

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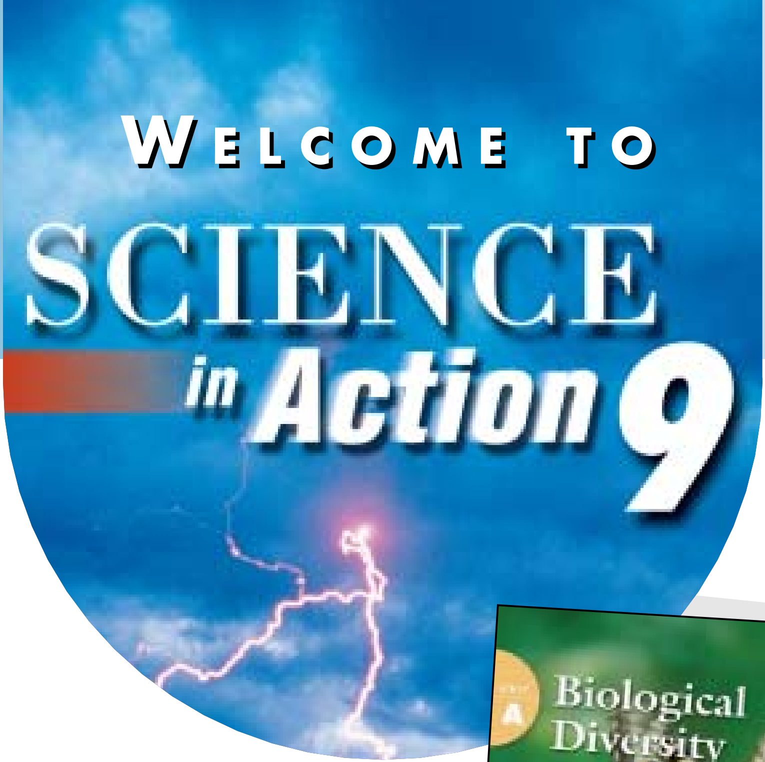
CONTENTS

WELCOME TO SCIENCE in Action 9

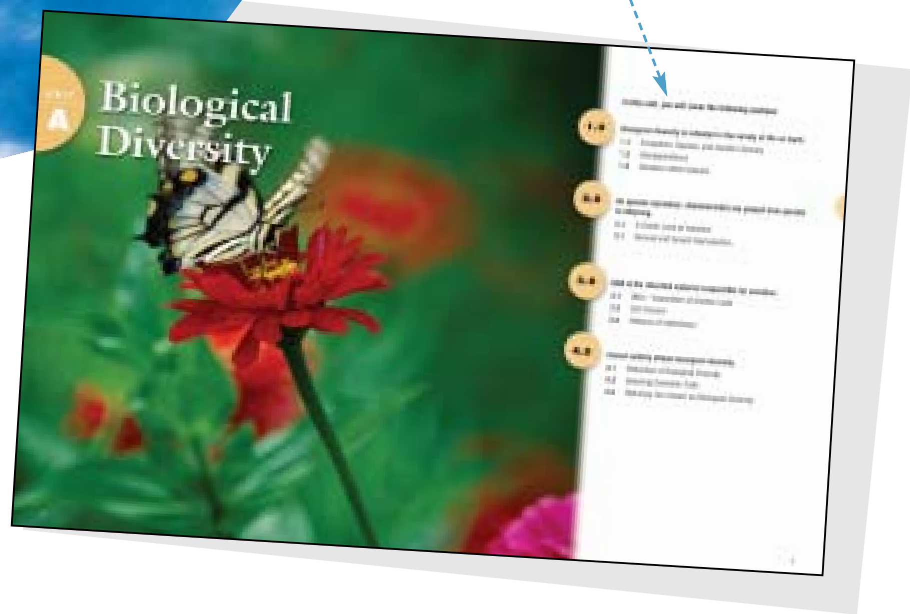


You are about to begin a scientific exploration using *Science in Action 9*. To assist you in your journey, this book has been designed with the following features to help you.

An outline gives you an overview of what you will be learning. You may want to use this as a guide to help you study.

1 Unit Outline

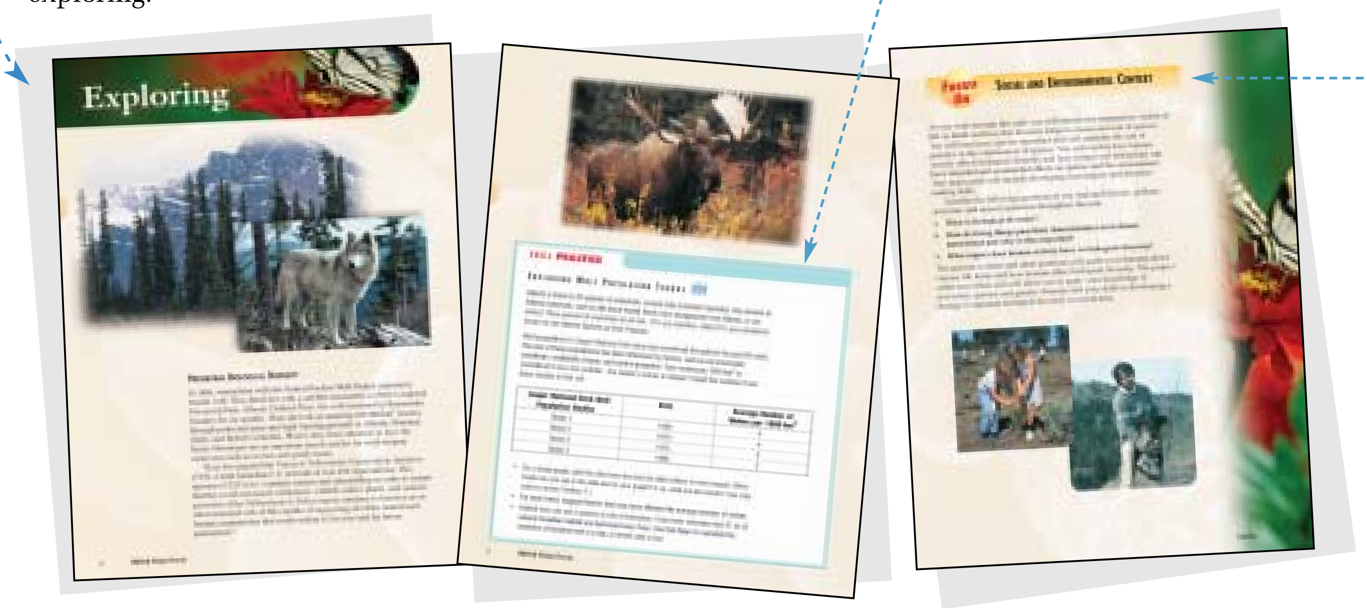
The book is divided into five **units**. Each unit opens with a large photograph that captures one of the ideas that will be covered in the unit.



2 Exploring

This section is an introduction. It has an interesting real-world example to introduce the unit. A hands-on activity introduces the topic of the unit and allows you to start thinking about what you will be exploring.

***SKILL* PRACTICE** activities give you an opportunity to practice and reinforce skills.



3 The Sections

Each section heading summarizes what you will learn in this section. These can help you organize your thoughts when you study.

Each section has two to five subsections. Each subsection heading clarifies and provides more information about the statement in the section heading.

The **Key Concepts** are the main ideas you will learn in this section. By the end of the section, you should be able to describe each concept.

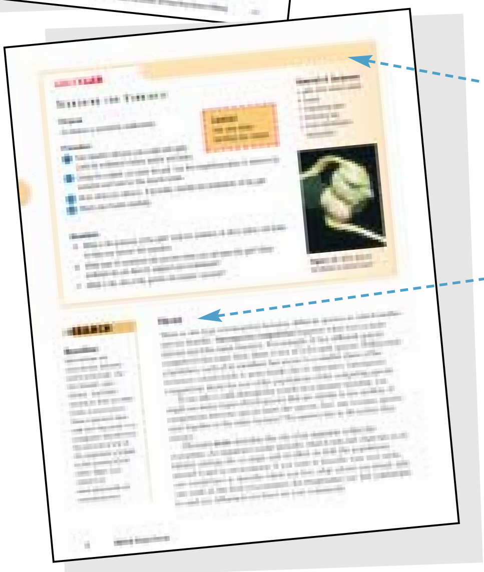
The **Learning Outcomes** outline what you should know and be able to demonstrate your understanding of on completing the section.

Check out this **Web site** for relevant links.

An ***info*BIT** is an interesting fact relevant to what you will be investigating in the subsection.

***GIVE IT A* TRY** activities will help you think about what you are learning.

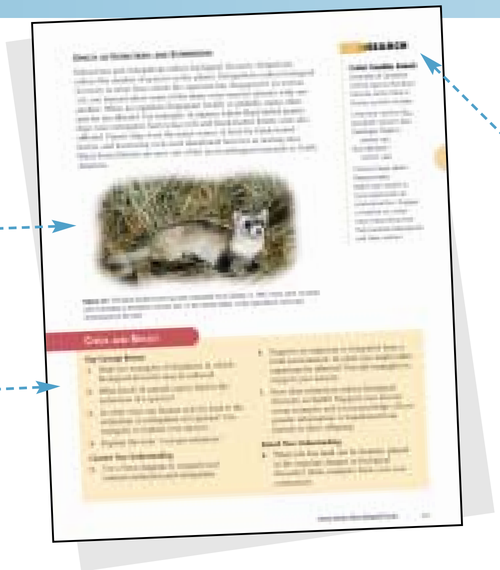
The **Focus On** section has several questions to help you think about what you are learning and how it connects to your life as you work through the unit. The questions focus on one of three areas or emphases of science: the nature of science, the relationship between science and technology, and the relationship of science and technology to society and the environment.



***QUICK*LAB** is a hands-on activity that explores a topic in the section.

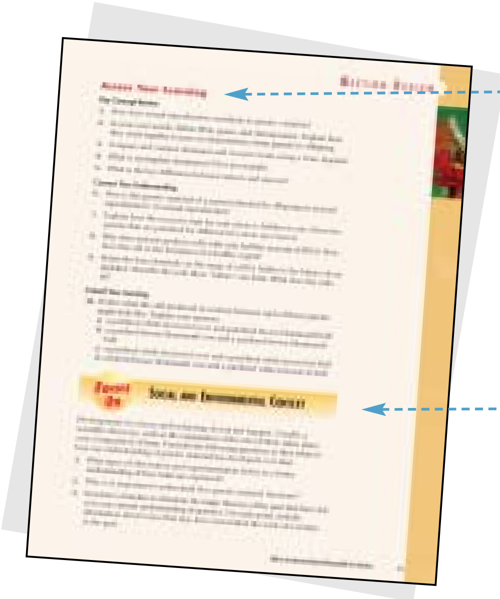
Topic subheadings make the text easier to follow.

You will find numerous photos and illustrations to help explain or clarify many of the ideas in this unit.



At the end of the subsection is a ***re*SEARCH**. This is an additional way to study one of the ideas in the subsection.

Check and Reflect questions provide opportunities for you to review the main ideas you have learned.



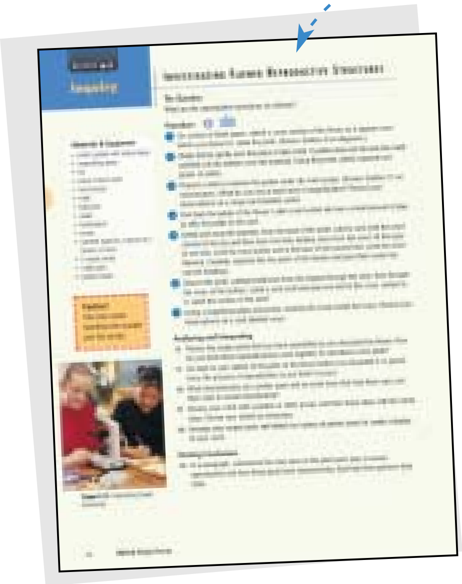
The **Section Review** has questions relevant to the whole section. Answering the questions will help you consolidate what you have learned in the various parts of the section.

The **Focus On** feature helps you organize and apply what you have learned in the section.

4 Science Activities

There are three main types of activities.

Problem Solving Activity: These are open-ended activities that allow you to be creative. You will identify a problem, make a plan, and then construct a solution. These activities tend to have very little set-up and there is usually no one correct solution.

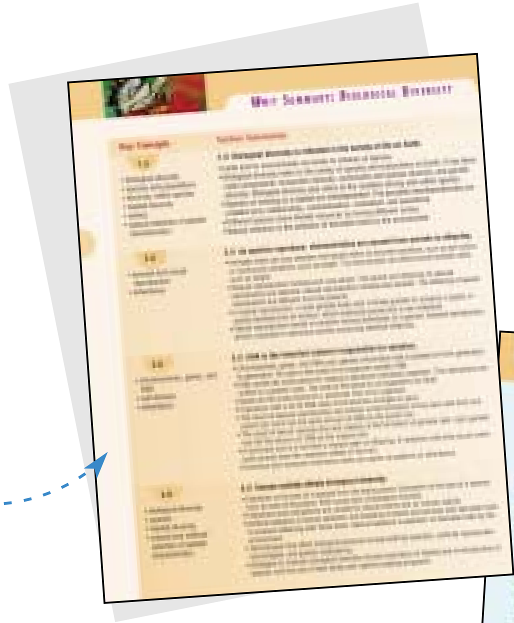


Inquiry Activity: These activities provide the opportunity for you to work in a lab setting. You will develop scientific skills of predicting, observing, measuring, recording, inferring, analyzing, and many more. In these activities, you investigate many different phenomena found in our world.

Decision Making Activity: These activities present issues or questions related to everyday life. You will need to analyze the issue and develop a conclusion based on the evidence you collect. Be prepared to present your conclusion to your classmates.

5 Unit Summary

At a glance, you can find out all the key concepts you have learned within the unit. You can also read the summary of ideas in each section of the unit. This is a good page to help you organize your notes for studying.



6 Unit Project

A project at the end of each unit presents a hands-on opportunity for you to demonstrate what you've learned. You'll work both in a group and individually. The project requires you to apply some of the skills and knowledge that you've acquired to a new situation.

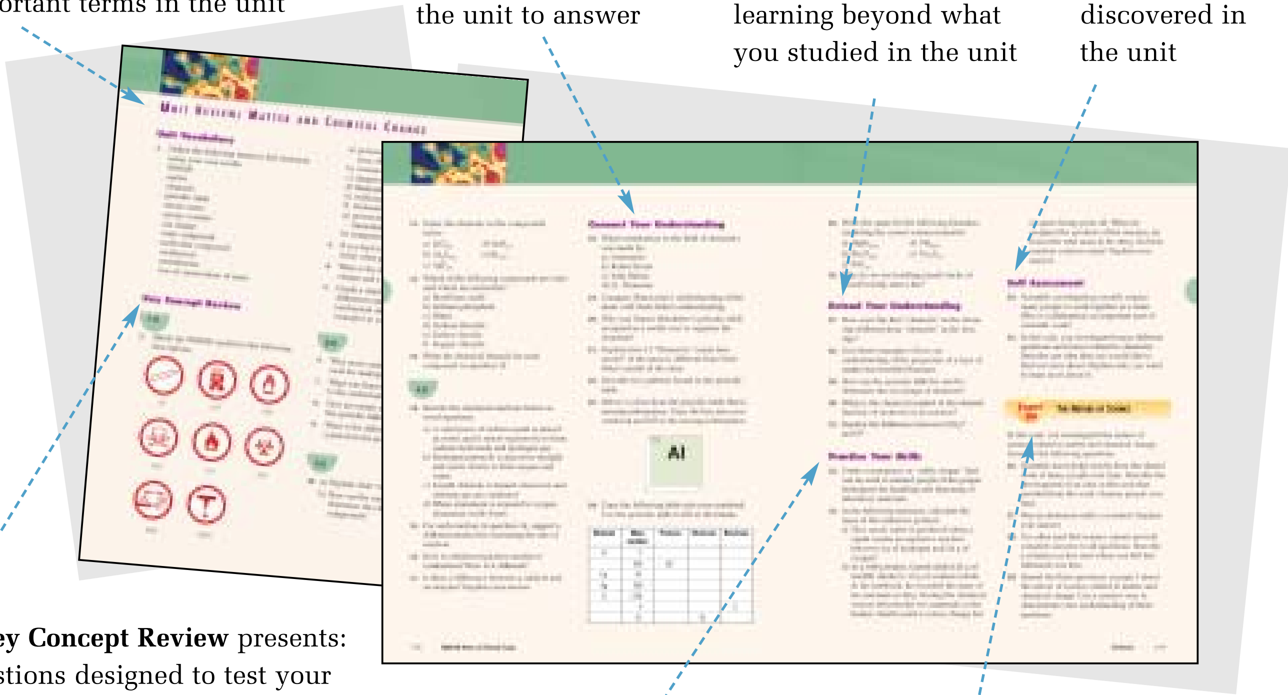
7 Unit Review

The **Unit Review** presents:

- a chance to review the important terms in the unit
- questions that require you to use the ideas in more than one section in the unit to answer

The **Extend Your Understanding** has:

- questions that have you apply your learning beyond what you studied in the unit
- opportunities to express your thoughts about ideas you have discovered in the unit



The **Key Concept Review** presents:

- questions designed to test your basic understanding of the key concepts in each section of the unit

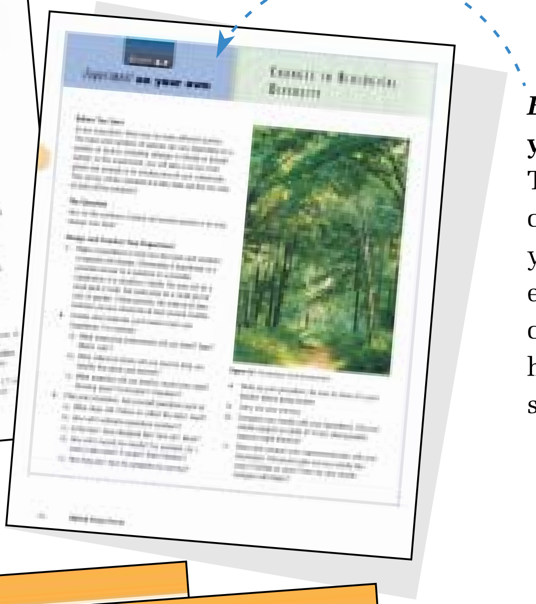
- questions that are related to specific skills you have learned in the unit
- questions that relate to the specific emphasis of the unit

8 Other Features

Here are other features you will find in each unit. Each one has a different purpose and is designed to help you learn about the ideas in the unit.

Science World
This feature is a case study about an issue that can have more than one solution or may involve several viewpoints.

Careers and Profiles
Here you will find profiles or interviews with people whose careers use the science and technology you study in the unit.

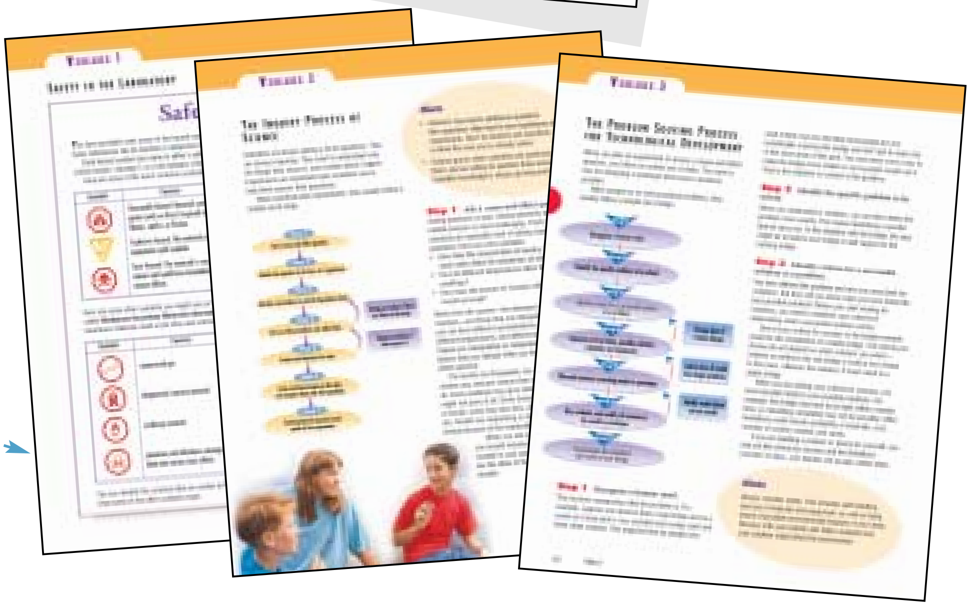


***math*Link**
These are opportunities for you to apply some of your math skills.

***Experiment* on your own**
This is your chance to design your own experiment to check out a hypothesis or to solve a problem.

9 The Toolbox

These pages provide references to lab safety and other basic scientific skills that will help you as you do the activities. Remember to check the toolbox when you need a reminder about these skills.



10 Icons

means you will be working with toxic or unknown materials and should wear safety goggles for protection or precaution

means you should wear a lab apron to protect clothing

means you should wear rubber gloves for protection when handling the materials

means you will be working with glassware and you should exercise caution to avoid breakage

TOOLBOX reminds you that you can find more information in the Toolbox section of the book

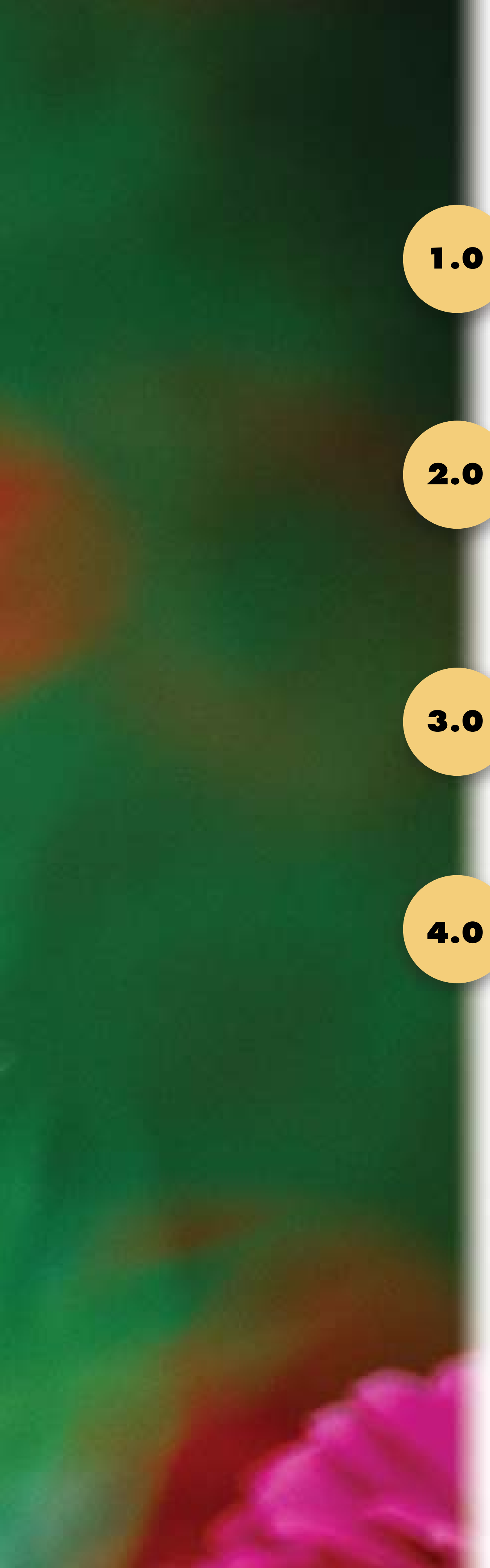
11 Glossary

The Glossary provides a comprehensive, alphabetical list of the important terms in the book and their definitions.

Now it's time to start. We hope you will enjoy your scientific exploration using *Science in Action 9*!

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

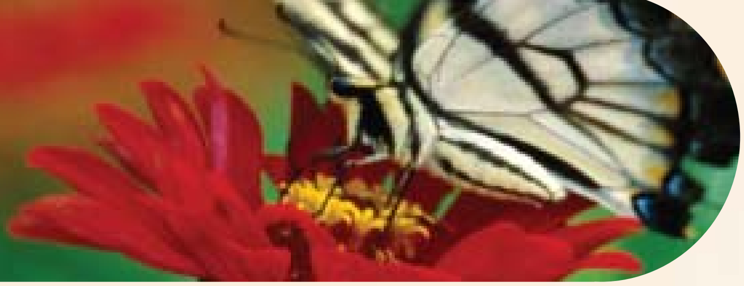
Human activity affects biological diversity.

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

TOOLBOX

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.

For Web links relating to 1.0, visit **www.pearsoned.ca/scienceinaction**

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.

*info***BIT**

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.

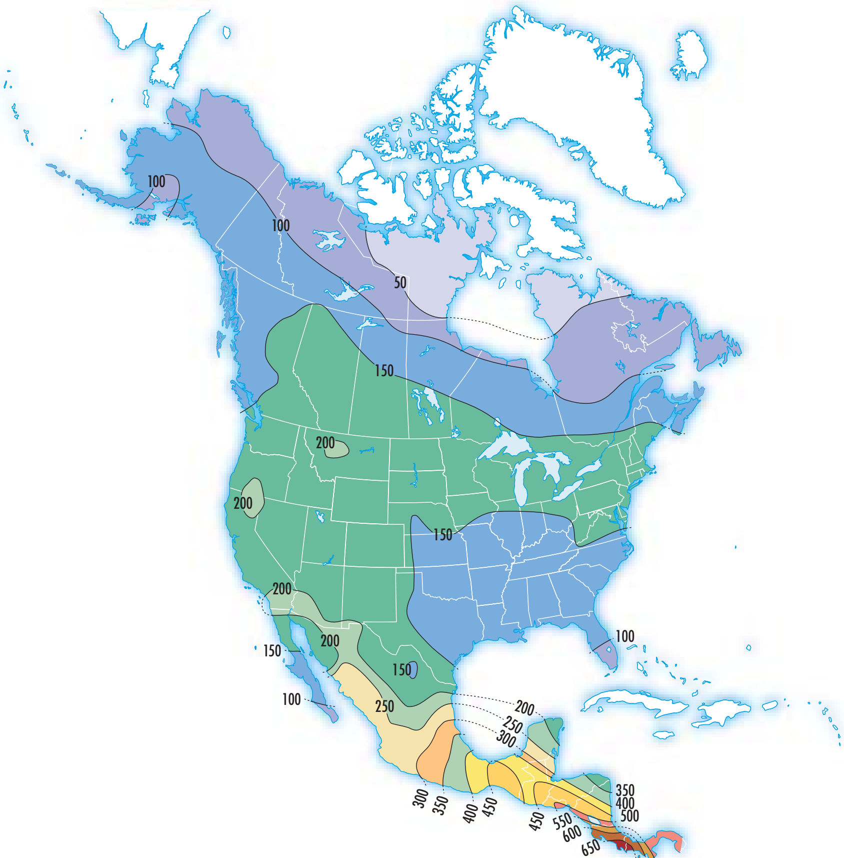


Figure 1.5 This map shows the number of bird species in different regions of North and Central America.

*info*BIT

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

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

TOOLBOX

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.

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.

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.

info**BIT**

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.

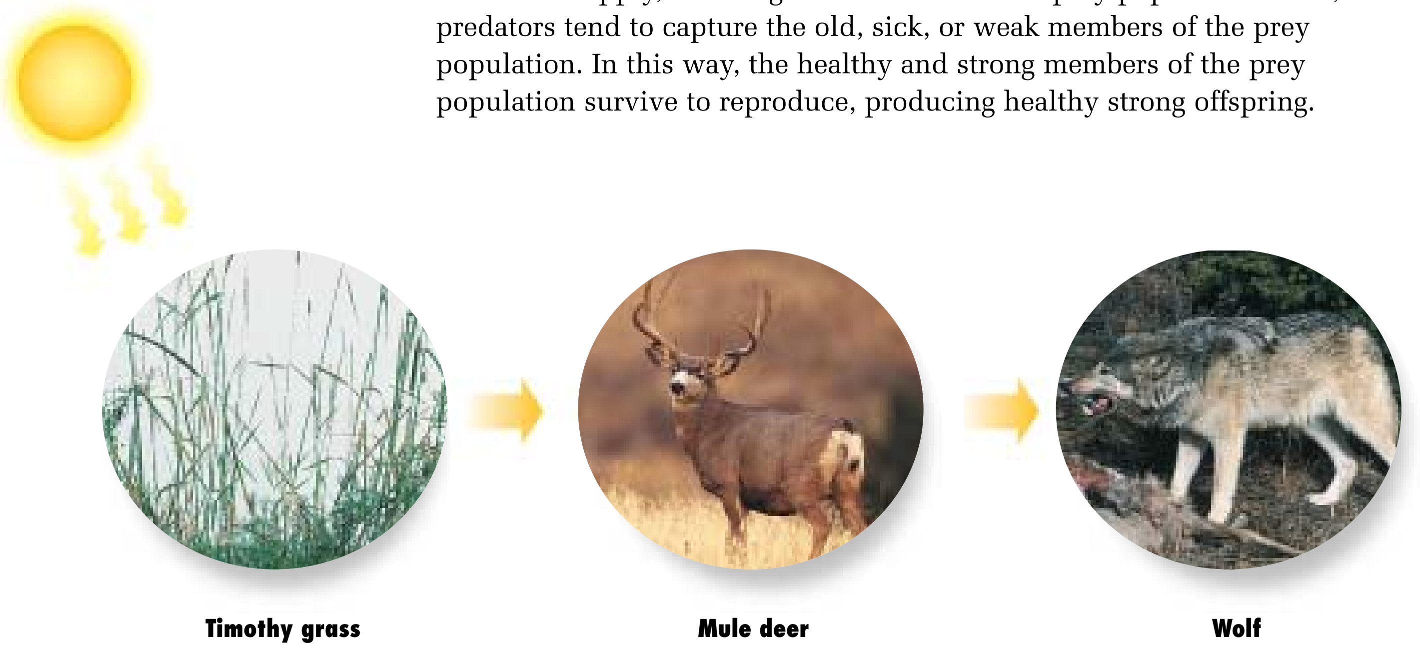


Figure 1.9 This food chain in a montane ecosystem illustrates interdependence. Timothy grass depends on the Sun's energy for growth. Mule deer (herbivores) depend on timothy grass as a food source. Wolves (carnivores) depend on animals such as mule deer for survival.

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).

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

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!

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

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.

QUICKLAB

Searching for Symbiosis

Purpose

To observe a symbiotic relationship

Procedure

Caution! Use care when handling the scalpel.

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.

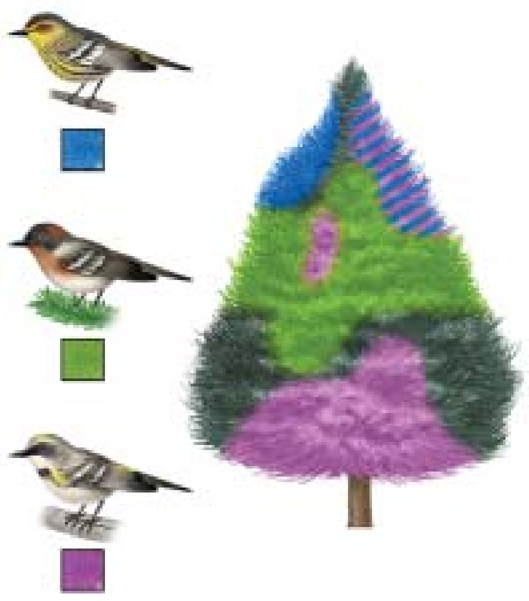


Figure 1.13 These three warbler species feed on spruce bud worms in different parts of a spruce tree. Their niches differ in the feeding location they prefer. Note that there is some overlap between the species.

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

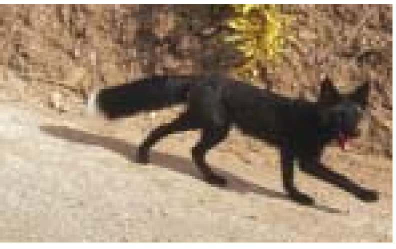
5. Imagine your school is an ecosystem. Create a concept map showing the interdependence among students, teachers, classes, and grades in this "ecosystem."

1.3 Variation Within Species

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

*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.

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.

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.

reSEARCH

"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?

ACTIVITY A-2

Inquiry

PROTECTIVE COLORATION AND SURVIVAL

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

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.

The Question

TOOLBOX

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			

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.

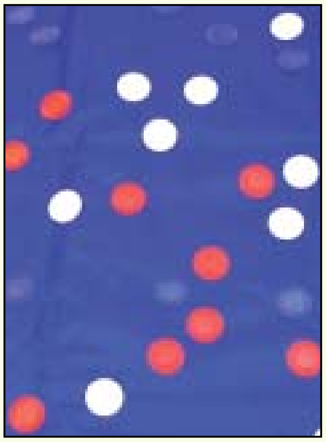


Figure 1.15(a) Step 4. Set-up for generation 1.

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

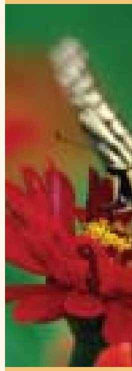
1. What is variability?
2. In your own words, define natural selection.

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.

For Web links relating to 2.0, visit www.pearsoned.ca/scienceinaction

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.

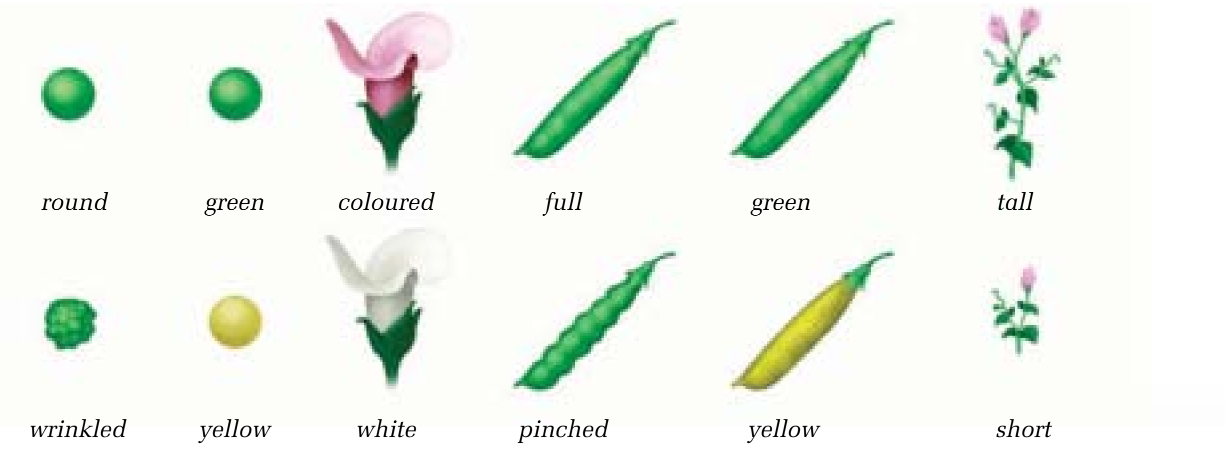


Figure 2.2 Some of the characteristics in pea plants that scientists have studied include seed shape, seed colour, flower colour, pod shape, pod colour, and plant height.

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.

reSEARCH

Environment's Role

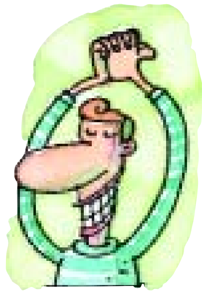
Investigate how plants, such as hydrangea and the water buttercup, exhibit variation depending on the environment they live in. Use books or electronic resources for your research. Prepare a chart to display your findings.

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?

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.

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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.

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.

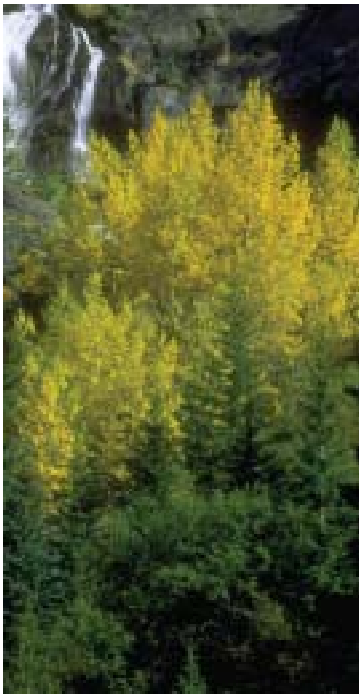

Figure 2.6 The individual trees in a stand of aspens are often identical to one another, as a result of vegetative reproduction.

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.

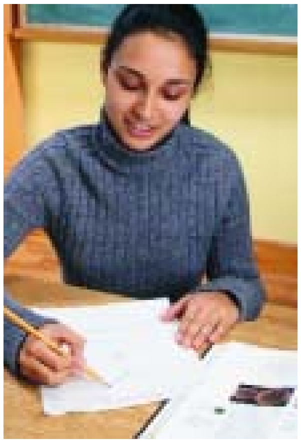

Figure 2.8 Diagrams help scientists compare organisms.

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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.

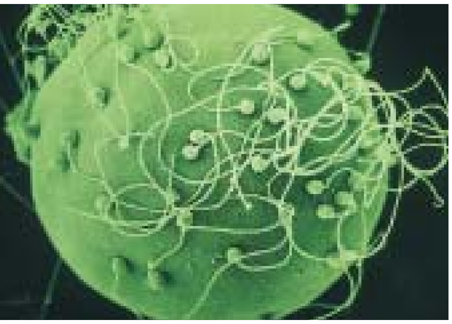

Figure 2.9 Only one of the many sperm cells surrounding the egg will fertilize the egg.

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.

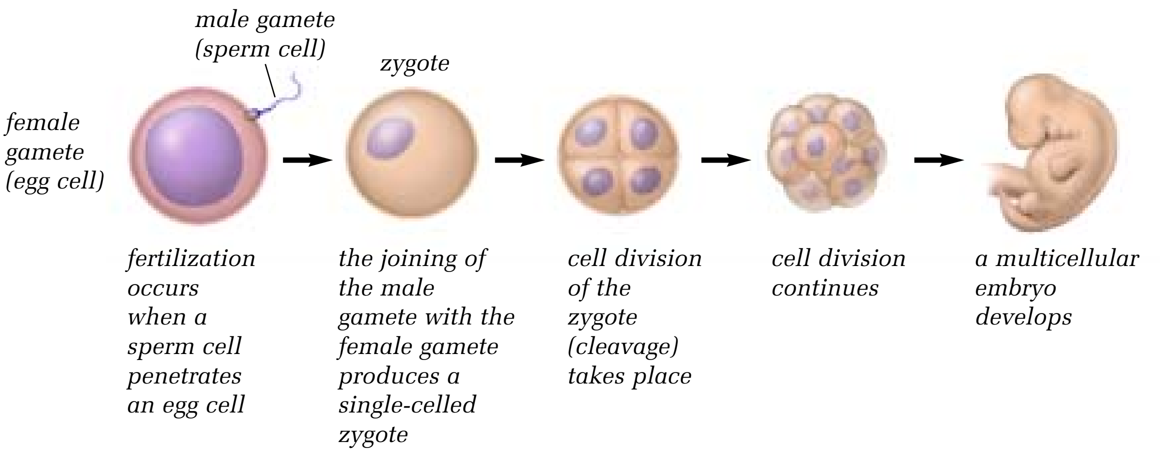

Figure 2.10 Sexual reproduction in animals involves specialized cells called gametes.

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.

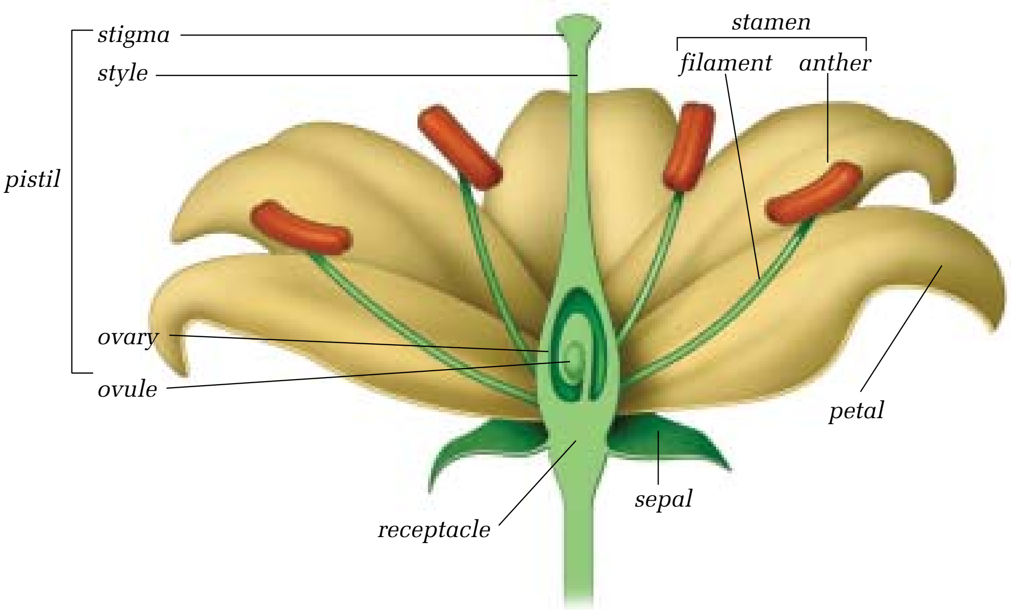

Figure 2.11 Flower parts involved in reproduction

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*.

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

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.

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.

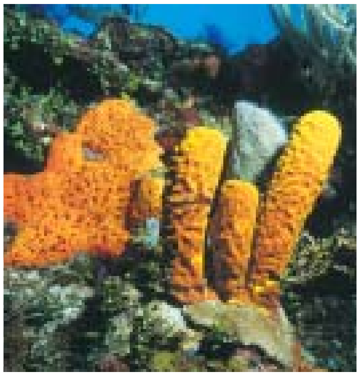

Figure 2.14 To reproduce sexually, sponges release sperm cells into the water, which are captured by special cells and carried to egg cells.

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.

For Web links relating to 3.0, visit www.pearsoned.ca/scienceinaction

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).

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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.

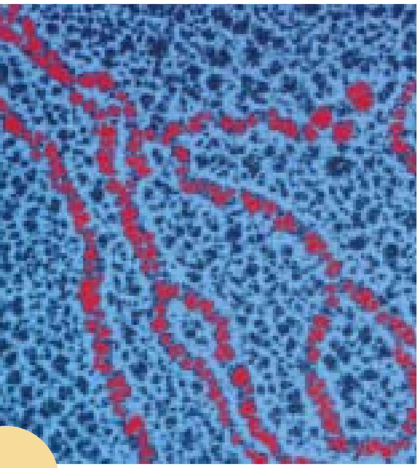

Figure 3.2 Micrograph of DNA

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.

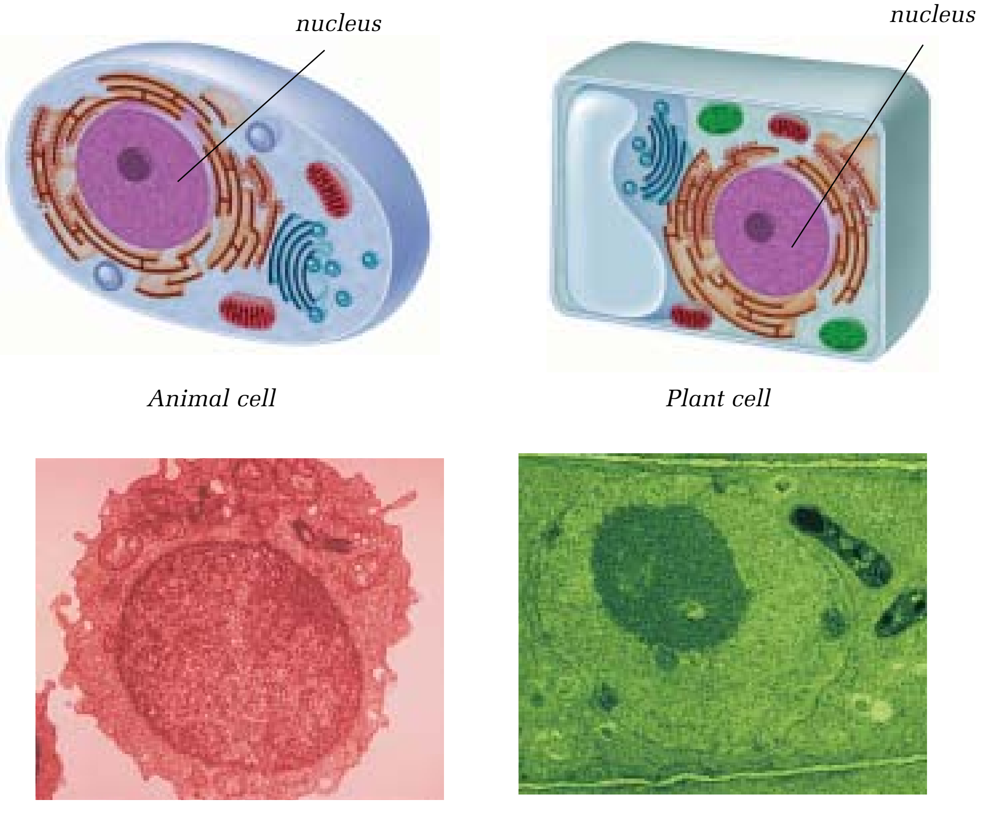

Figure 3.3 Study the location of the nucleus in the animal cell diagram and the plant cell diagram. Now locate the nucleus of each cell in the micrographs below the diagrams.

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!

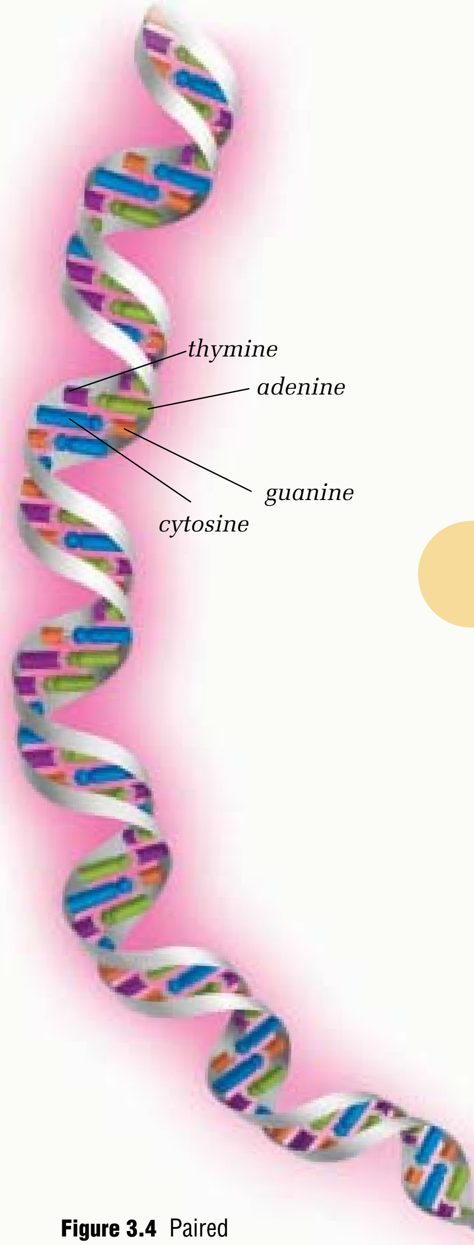

Figure 3.4 Paired chemicals make up the "rungs" of the DNA "ladder" and form the genetic code. The overall shape of the DNA molecule is helical, like the spiral binding on a notebook.

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

TOOLBOX

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.

reSEARCH

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.

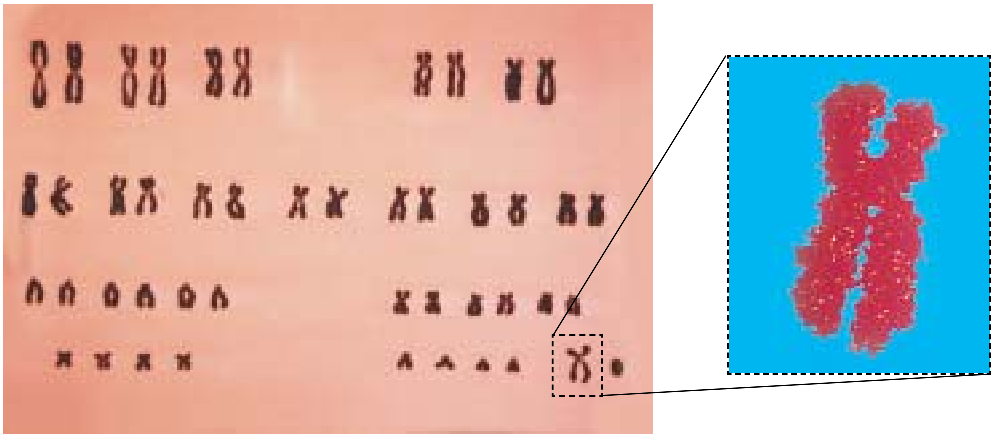

Figure 3.6 The 23 pairs of chromosomes of the human male. On the right, a close up of the X chromosome.

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.

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

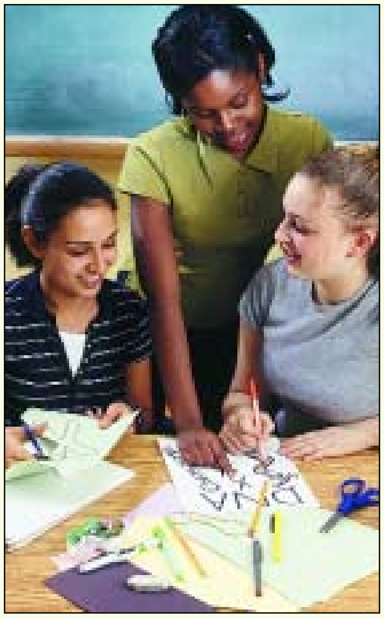

Figure 3.8 Planning a presentation to explain relationships among DNA, genes, and chromosomes

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!

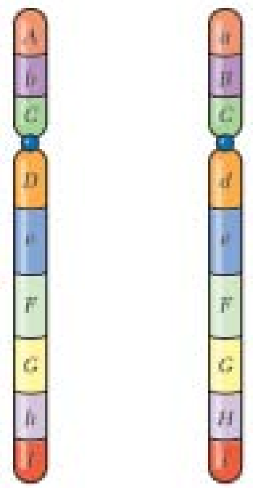

Figure 3.9 A chromosome pair. Each member carries the same genes. The different alleles are marked by uppercase and lowercase letters.

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

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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.

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

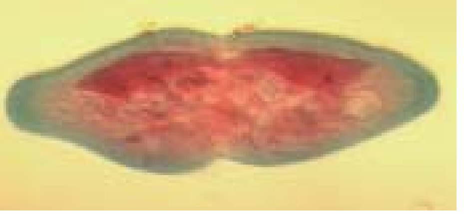

Figure 3.10 In asexual reproduction, the two new paramecium cells must get the same amount of DNA.

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).

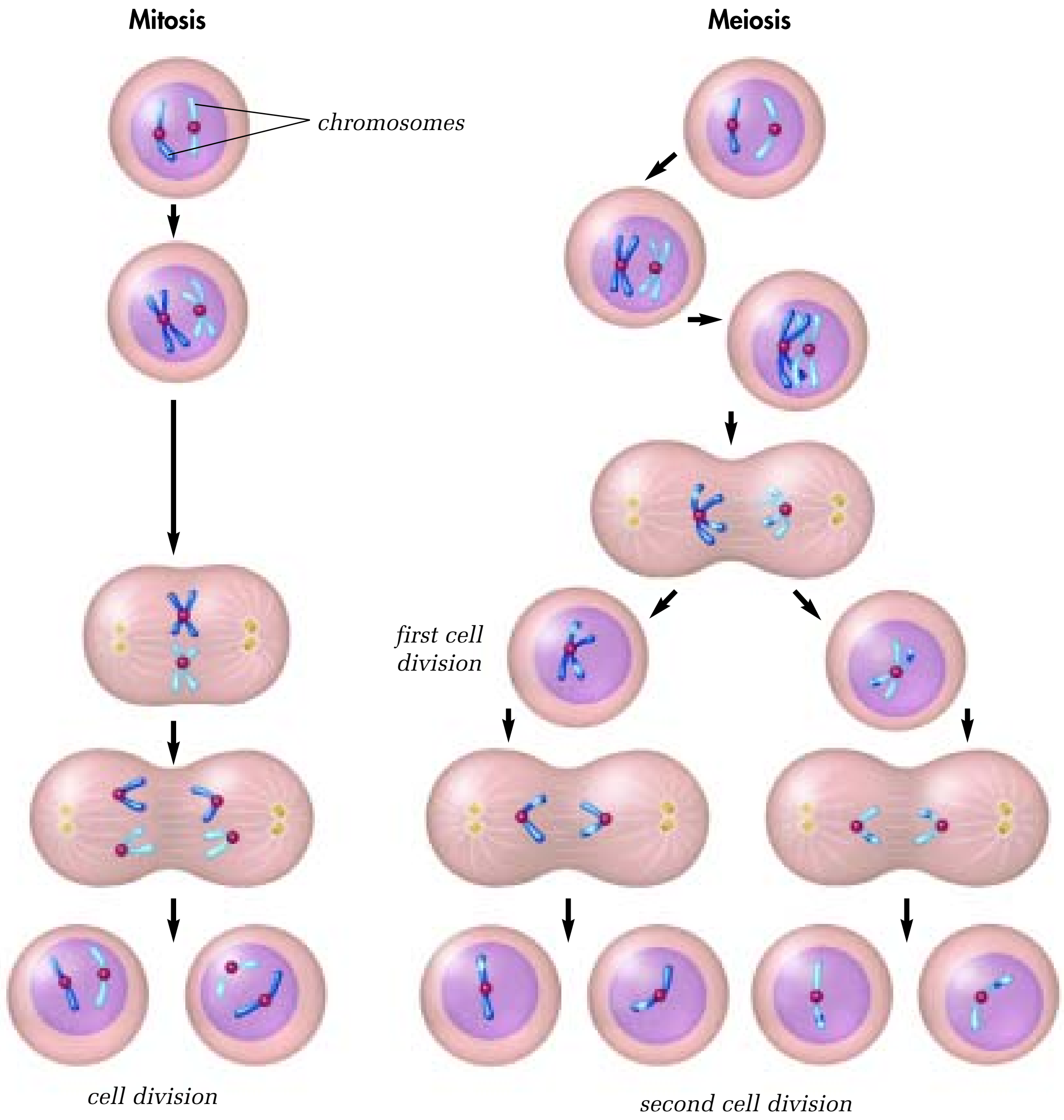

Figure 3.11 Comparison of mitosis and meiosis. Mitosis produces two offspring cells with the same number of chromosomes as the parent cell. Meiosis produces four sex cells that have *half* the number of chromosomes as the parent cell.

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?

*info***BIT**

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**.

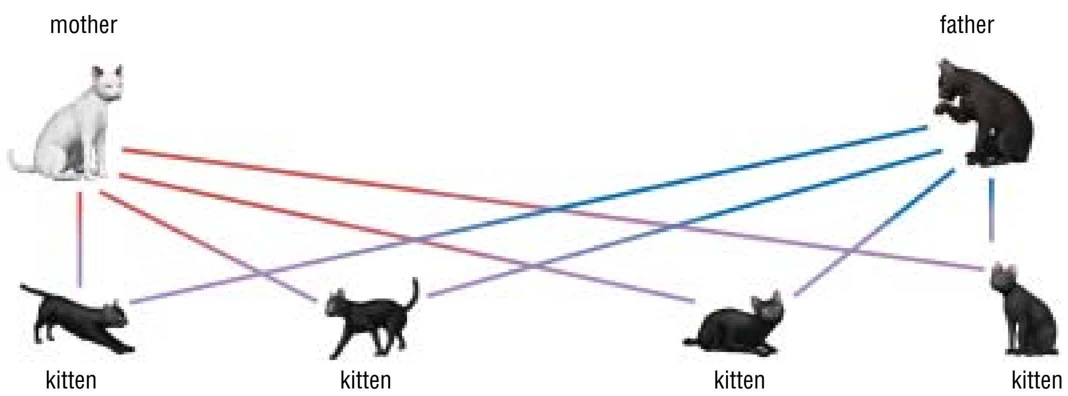

Figure 3.13 Cross between purebred white female cat and purebred black male cat. Black fur is the dominant trait.

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.

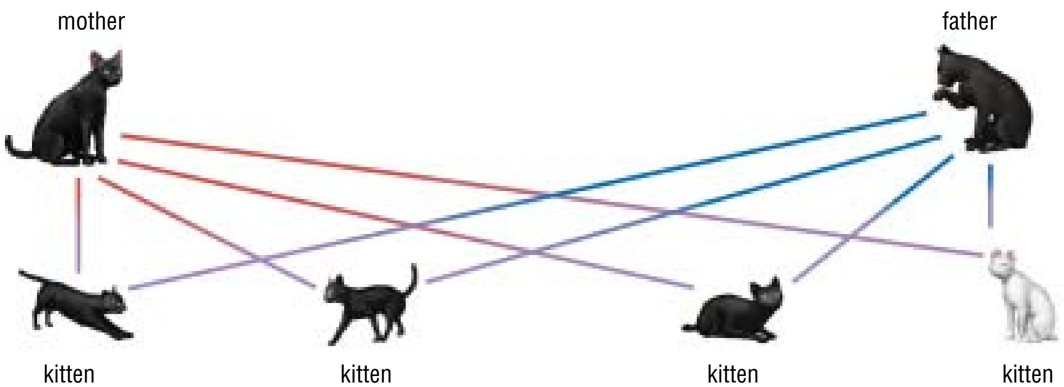

Figure 3.14 The kittens from Figure 3.13 are the parents in this cross.

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.

*re*SEARCH

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.

SECTION REVIEW

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.

*info***BIT**

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.

reSEARCH

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.

4.2 Selecting Desirable Traits

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Beefier Cows

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

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.

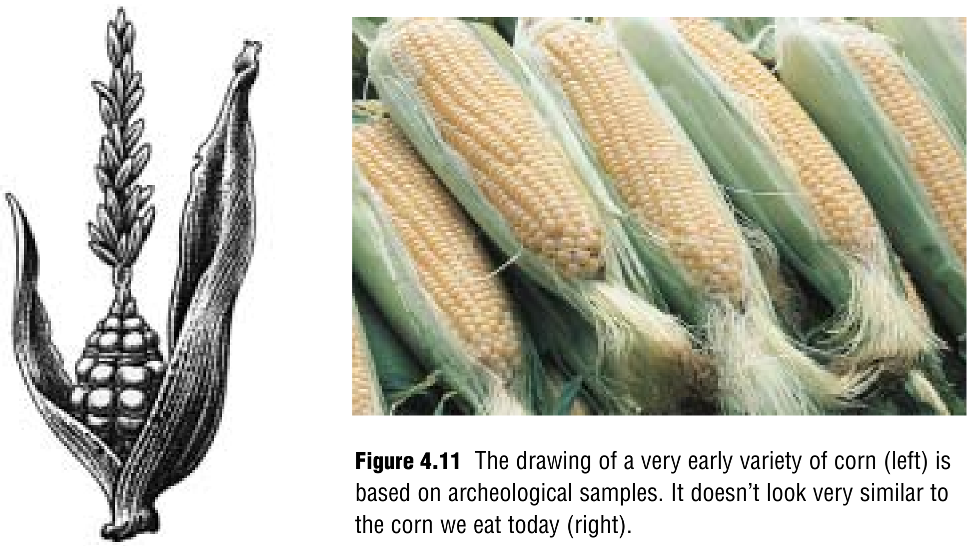


Figure 4.11 The drawing of a very early variety of corn (left) is based on archeological samples. It doesn't look very similar to the corn we eat today (right).

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.

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

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.

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.

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.

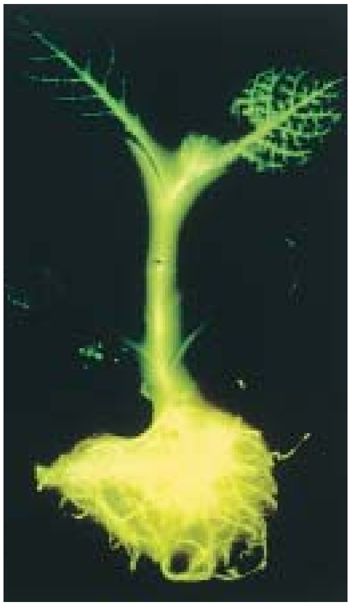


Figure 4.14 This plant was grown from cells that had a firefly gene inserted into them. When the gene is activated, the plant glows.

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

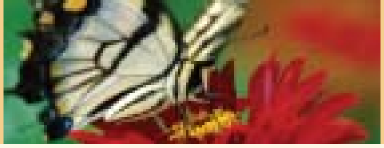
1. What is in-situ conservation? How does it preserve biological diversity?
2. Why is it important to protect networks of ecosystems and habitats? Provide an example of a species that would benefit from such protection and state why.
3. How have governments been involved in the protection of vulnerable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

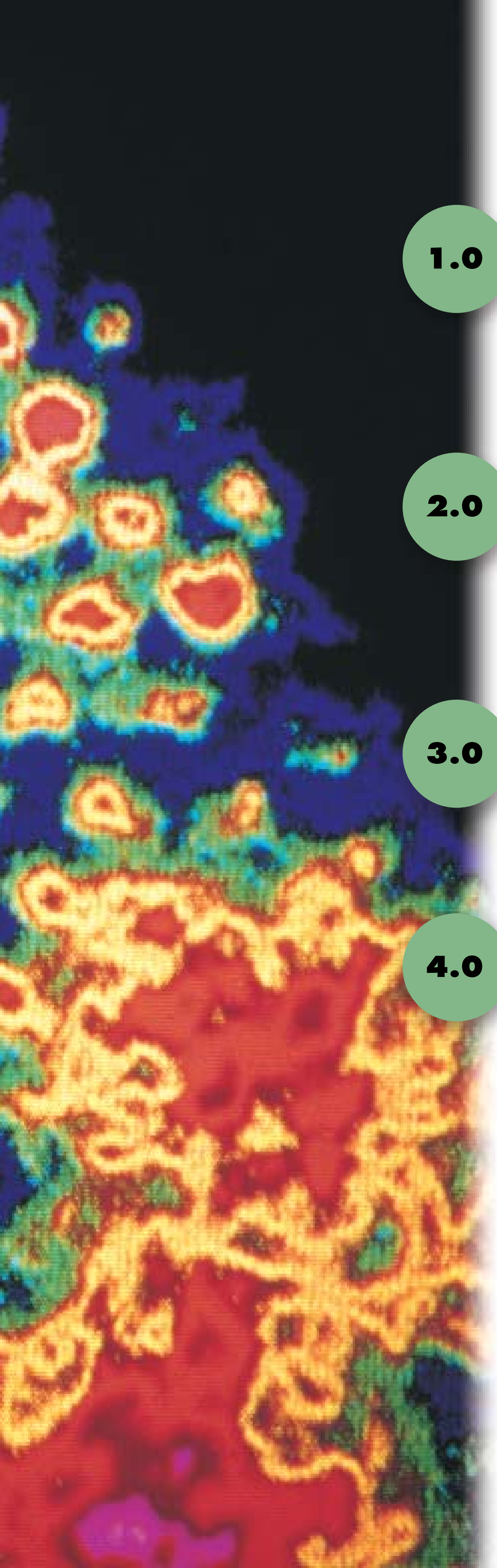
2. How is a population related to a community? Refer to a pond environment to illustrate your answer.
3. What is genetic diversity?
4. Outline the three levels of biological diversity. Give an example of each.
5. Using an example, explain how species are dependent on many other species in their environments.
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.

UNIT B

Matter and Chemical Change



In this unit, you will cover the following sections:

1.0

Matter can be described and organized by its physical and chemical properties.

1.1 Safety in the Science Class
1.2 Organizing Matter
1.3 Observing Changes in Matter

2.0

An understanding of the nature of matter has developed through observations over time.

2.1 Evolving Theories of Matter
2.2 Organizing the Elements
2.3 The Periodic Table Today

3.0

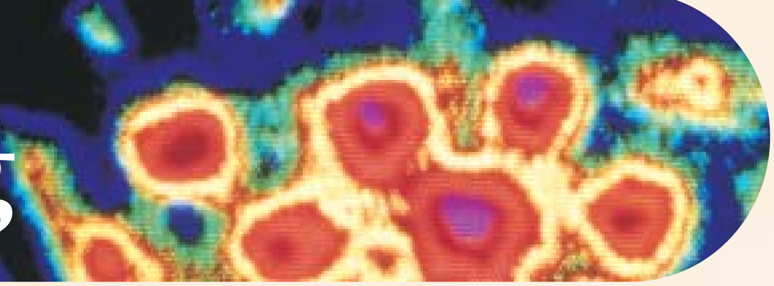
Compounds form according to a set of rules.

3.1 Naming Compounds
3.2 Ionic Compounds
3.3 Molecular Compounds

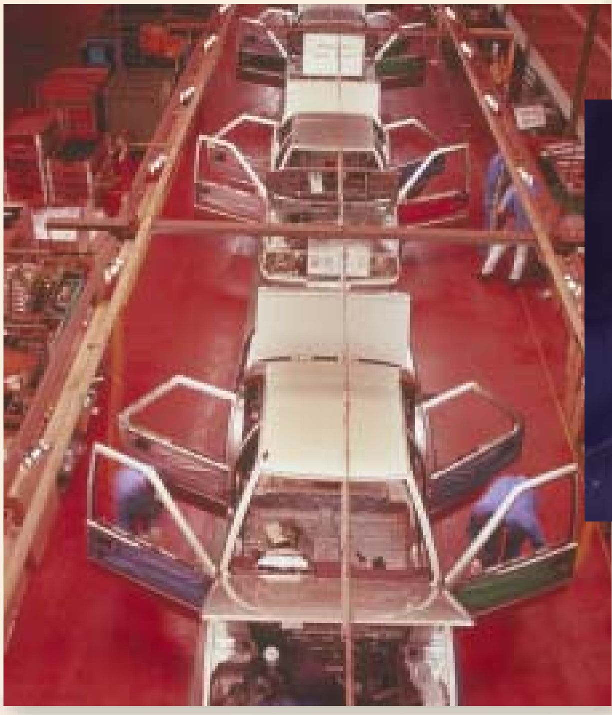
4.0

Substances undergo a chemical change when they interact to produce different substances.

4.1 Chemical Reactions
4.2 Conservation of Mass in Chemical Reactions
4.3 Factors Affecting the Rate of a Chemical Reaction



Exploring



Aluminum foam

The next time you drink pop from a can, take a good look at the container. You probably know that it's made of the metal aluminum, which is light and flexible, yet strong. These characteristics, or **properties**, make aluminum useful for holding liquids. Aluminum has many other applications as well. For example, screen doors, cars, and airplanes all use aluminum. In these applications, the metal is usually used in sheets or formed into parts. But did you know that aluminum can also be made into a foam?

Aluminum Foam

Aluminum foam is an example of combining a variety of materials to create a new material with different properties from those of the original materials. Mixing powdered aluminum with a foaming material makes aluminum foam, a substance that can be 10 times stiffer and 50% lighter than aluminum. It can also float because it has air pockets.

Engineers use this new material to create lighter, safer cars. It may sound strange that a lighter car can be a safer car. However, compared to other materials, aluminum foam is able to absorb more impact energy when a car is in a collision.

QUICKLAB

Foam in a Cup

Purpose

To observe what happens in a simple chemical reaction

Procedure

1. Pour 30 mL of corn syrup into a 250-mL beaker. Stir in 3 drops of one food colouring. Sprinkle 20 mL of baking soda on the corn syrup.
2. Tip the beaker slightly and carefully pour in 30 mL of water down one side. Add 30 mL of vegetable oil to the beaker in the same way.
3. Into a separate beaker, pour 20 mL of vinegar and add 3 drops of the other food colouring.
4. Fill the eyedropper with coloured vinegar. Squeeze 3 drops of coloured vinegar into the beaker containing the other substances. Record your observations. Repeat if necessary.
5. Push the eyedropper down to the bottom of that beaker, and release all the vinegar by squeezing the bulb of the eyedropper. Record your observations.

Questions

6. Describe how your observations were different in steps 4 and 5.
7. Work with the rest of the class to explain what is going on in the activity.

Materials & Equipment

- graduated cylinder
- 30 mL corn syrup
- two 250-mL beakers
- two different colours of food colouring
- stirring rod
- 20 mL baking soda
- 30 mL water
- 30 mL vegetable oil
- 20 mL vinegar
- eyedropper

Focus On The Nature of Science

In this unit, you will be asked to observe how matter changes and interacts with other matter. You will collect evidence of changes by:

- investigating the properties of matter
- interpreting observations and data from experiments
- creating and interpreting models

Think about the following questions while you study how our understanding of matter and its interactions has developed. The answers to these and other questions about matter will help you understand the interactions among substances.

1. **How do we determine the properties of a variety of different substances?**
2. **How do different substances interact?**
3. **What evidence can be used to indicate that an interaction between substances has occurred?**

1.0 Matter can be described and organized by its physical and chemical properties.

Key Concepts

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

- Workplace Hazardous Materials Information System (WHMIS) and safety
- substances and their properties
- elements, compounds, and atomic theory

Learning Outcomes

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

- identify and evaluate dangers of caustic materials and potentially explosive reactions
- investigate and describe properties of materials
- describe and apply different ways of classifying materials based on their composition and properties

Imagine visiting a market where all the food is displayed in big bags, like the ones shown in the photo. How could you tell what was in each bag? One way would be to look at the colour and shape of each item. You also might handle each one to see whether it is hard or soft, rough or smooth, dense or light. If these clues still weren't enough to help you identify the unknown substances, then you might have to cut them open to see their composition. In all of this, you would be doing just what a chemist does: investigating matter.

Studying the properties of matter and how matter changes is part of the science called chemistry. **Matter** is anything that has mass and occupies space. In this section, you will first learn proper science lab safety. Then you will learn about some properties of matter and how those properties can be used to identify substances and to organize matter in a useful way.

For Web links relating to 1.0, visit **www.pearsoned.ca/scienceinaction**

1.1 Safety in the Science Class

In any science activity, the safety of you, your classmates, and your teacher are of the utmost importance. It is essential that everyone in your science class act in a safe and responsible manner. Before you begin investigating chemical reactions, you should review some safety rules and basic lab skills.

SKILL PRACTICE

SAFETY IN THE SCIENCE LAB

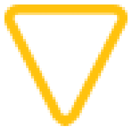
Look at Figure 1.1. Some of the students are not following proper safety procedures. Work with a partner to identify and list the problem actions in a table. Then suggest a better, safer way to perform each action. After you have finished, share your observations with the class.

Figure 1.1 Students at work in the lab

*info***BIT**

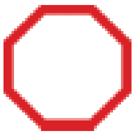
Symbol Shapes

These shapes and their colours indicate how dangerous a substance is.



caution

warning



danger

Safety Hazard Symbols

Before you do any activity in this unit, read the directions and look for "Caution" notes that will tell you if you need to take extra care. There are two areas of special consideration for people working in the lab: understanding warning labels and following safety procedures.

Some of the materials you will use in science activities are hazardous. Always pay attention to the warning labels, and follow your teacher's instructions for storing and disposing of these materials. If you are using cleaning fluids, paint, or other hazardous materials at home, read the labels for special storage and disposal advice.

All hazardous materials have a label showing a hazard symbol. You may have seen these labels on chemical substances in your kitchen or garage. For example, many kinds of window cleaner contain ammonia, which is toxic and corrosive. Car batteries contain sulfuric acid which is also toxic and corrosive, and lead which is toxic.

Each hazard symbol shows two separate pieces of information. The shape of the symbol indicates how hazardous a substance is. A yellow triangle means "caution," an orange diamond means "warning," and a red octagon means "danger." These shapes are shown in the infoBIT on this page. The second piece of information in the symbol is the type of hazard, which is indicated by the picture inside the shape. Figure 1.2 shows the common hazard warnings.

Figure 1.2 These symbols warn you of specific hazards.

WHMIS Symbols

The Workplace Hazardous Materials Information System—or **WHMIS**—is another system of easy-to-see warning symbols on hazardous materials. These symbols were designed to help protect people who use materials that might be harmful at work. Figure 1.3 shows eight WHMIS symbols.

In several activities in this unit, you will encounter the symbols for poisonous material, dangerously reactive material, and corrosive (or caustic) material. For example, hydrogen peroxide is very reactive and can burn your skin, and battery acid is corrosive. Treat both chemicals with extreme care whenever you use them.

Figure 1.3 WHMIS symbols

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MSDS

Materials and Safety Data Sheets (MSDS) are information sheets about specific chemicals. Find out what type of information is on the MSDS. Begin your search at www.pearsoned.ca/scienceinaction.

Understanding the Rules

When you perform science activities of any kind, it is very important to follow the lab safety rules shown below. Not following one or more of these rules could result in injury to you or your classmates. Your teacher will also discuss any specific rules that apply to your classroom. For more information on lab safety, see Toolbox 1.

Lab Safety Rules

1. Read all written instructions carefully before doing an activity.
2. Listen to all instructions and follow them carefully.
3. Wash your hands thoroughly after each activity and after handling chemicals.
4. Wear safety goggles, gloves, or an apron as required.
5. Think before you touch. Equipment may be hot and substances may be dangerous.
6. Smell a substance by fanning the smell toward you with your hand. Do not put your nose close to the substance.
7. Do not taste anything in the lab.
8. Tie back loose hair and roll up loose sleeves.
9. Never pour liquids into containers held in your hand. Place a test tube in a rack before pouring substances in it.
10. Clean up any spilled substances immediately as instructed by your teacher.
11. Never look into test tubes or containers from the top. Always look through the sides.
12. Never use cracked or broken glassware. Make sure you follow your teacher's instructions when getting rid of broken glass.
13. Label any container you put chemicals in.
14. Report all accidents and spills immediately to your teacher.
15. If there are WHMIS (Workplace Hazardous Materials Information System) safety symbols on any chemical you will be using, make sure that you understand all the symbols. See Toolbox 1 at the back of this book.

Keep Safety in Mind

Remember that safety in the science class begins with you. Before you start any activity:

- Follow the safety instructions outlined by your teacher and in this textbook.
- Identify possible hazards and report them immediately.
- Show respect and concern for your own safety and the safety of your classmates and teachers.
- Read Toolbox 1: Safety in the Laboratory.

Check and Reflect

(a)

(b)

(c)

(d)

Figure 1.4 Question 5. Warning labels on hazardous products.

Key Concept Review

1. Why is it important for all students to follow the safety rules while in a science class?
2. What does WHMIS stand for?
3. Why is there a need for a WHMIS program?
4. One area of special consideration for people working in a lab is understanding warning labels. What is the other special consideration?
5. What does each hazard warning label mean on the chemicals shown in Figure 1.4?

Connect Your Understanding

6. What type of WHMIS symbols would you expect to see on the following containers?
   a) a can of gasoline
   b) a tub of caustic cleaning chemical
   c) a bottle of oxygen gas
   d) a bottle of sulfuric acid
7. Explain the difference between WHMIS symbols and safety symbols used on commercial products.
8. List the steps a student should take before starting a science activity where safety is an issue.
9. Describe one problem that may occur with having different coloured safety symbols.

Extend Your Understanding

10. Divide the lab safety rules given on page 95 among members of your class. Have each person or group make a poster illustrating the rule. Display your safety posters in your classroom to remind everyone of the importance of following these rules.
11. What additional lab safety rules would you add to the list on page 95?

1.2 Organizing Matter

Matter exists as a solid, liquid, or gas. These are called the **states** of matter. The state of a substance—solid, liquid, or gas—depends on temperature.

Specific terms are used to describe changes of state in substances. A change from a solid to a liquid is **melting**. A change from a liquid to a gas is **evaporation** (also known as vaporization). A change from a gas to a liquid is **condensation** and from a liquid to a solid is **freezing**. A solid can also change directly into a gas; this process is called **sublimation**. A gas can change directly to a solid. This is called **deposition.**

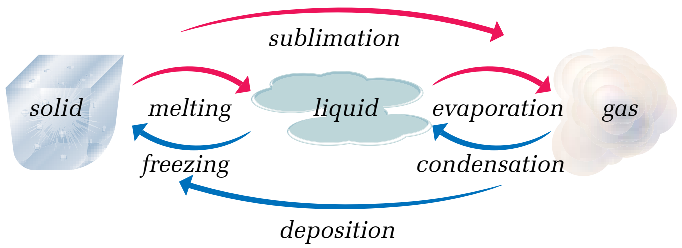

Figure 1.5 Changes in states of matter

To understand how substances differ, you need to observe their properties. **Properties** are characteristics that can be used to describe a substance. All matter has two types of properties: physical and chemical.

***info*BIT**

Plasma

A fourth state of matter is the *plasma* state. Examples of plasmas are found in lightning, neon signs, and stars such as our Sun. Plasmas result when a large amount of energy is added to a gas.

*QUICK*LAB

Organizing the Properties of Matter

Purpose

To describe and classify materials by their properties

Materials & Equipment

- paper
- pencil
- scissors

Procedure

1. Cut a sheet of notepaper into eight equal pieces. These are your summary cards.
2. Your teacher will give you samples of the following materials: copper wire, vinegar, salad oil, aluminum foil, granite, graphite, rock salt, lemonade, and baking soda. At the top of each summary card, write the name of one of the materials (one card per material).
3. Study each material sample in turn, and write a short description of the material. Refer to as many different properties as you can to describe the material so you can show how it differs from the other materials you study.
4. Divide the materials into groups having similar properties. You should have at least four groups. Determine a name that best describes each of these groups, or classifications.

Questions

5. Compare your classification system with that of your classmates. What similar properties did everyone use? What different properties did everyone use?

Some Physical Properties of Matter

- colour
- lustre
- melting point
- boiling point
- hardness
- malleability
- ductility
- crystal shape
- solubility
- density
- conductivity

Physical Properties of Matter

A variety of **physical properties** can be used to identify matter. Two examples are colour and lustre (shininess). The temperature at which a substance melts is also a physical property. It's important to remember that when a substance undergoes a **physical change**, such as melting, its appearance or state may be altered, but its composition stays the same. Melted chocolate ice cream has the same composition as frozen chocolate ice cream. The table on page 99 lists several of the key physical properties used to describe matter.

Figure 1.6 This ice cream has undergone a physical change. Even though it has melted, its composition hasn't changed.

*QUICK***LAB**

Observing a Physical Change

Purpose

To investigate a physical change and the factors that influence the rate of change

Procedure

1. Fill the two glasses about two-thirds full with soda pop.
2. Into one glass, drop a piece of the mint candy. Watch what happens in both glasses and record your observations.
3. Identify one variable you could manipulate to increase the rate of change that occurs.
4. Write a procedure to perform this test. Identify your control, the manipulated variable, and the responding variable. Also decide how you will measure your responding variable.
5. Ask your teacher to approve your procedure. Then, carry out the test.
6. Record your results.

Questions

7. Adding a candy to the pop causes a physical change to occur. The candy reduces the surface tension in the liquid, allowing gas to be released faster. Does the composition of the candy change after it is added to the pop?
8. Why were you required to fill two glasses with pop in step 1, but to add candy to only one glass in step 2?
9. What factors influenced the rate at which the gas was released from the pop? What data did you collect to support your answer?

Materials & Equipment

- soda pop
- 2 glasses (or large test tubes)
- chewy mint candy such as Menthos
- pencil and notebook

Some Physical Properties of Matter

Melting point	The melting point of a substance is the temperature at which it changes from a solid to a liquid. The melting point of ice is 0°C. At this temperature, it changes into water. Other substances have different melting points. For example, table salt melts at 801°C, and propane melts at −190°C.
Boiling point	The boiling point of a substance is the temperature at which its liquid phase changes to the gas phase. At sea level, water's boiling point is 100°C. Table salt boils at 1413°C, and propane boils at −42°C.
Hardness	Hardness is a substance's ability to resist being scratched. Hardness is usually measured on the Mohs' hardness scale from 1 to 10. The mineral talc is the softest substance on the scale (1). Diamond is the hardest (10). Figure 1.7 shows the scale.
Malleability	A substance that can be pounded or rolled into sheets is said to be **malleable**. Metals such as gold and tin are malleable. Aluminum foil is an example of a product made from a malleable substance.
Ductility	Any solid that can be stretched into a long wire is said to be **ductile**. The most common example of a ductile material is copper.
Crystal shape	The shape of a substance's crystals can help identify it. Silicon crystals, for example, are diamond shaped. Salt crystals form cubes.
Solubility	**Solubility** is the ability of a substance to be dissolved in another. For example, sugar is soluble in water, but cooking oil is not.
Density	**Density** is the amount of mass in a given volume of a substance. The density of water is 1 g/mL. The density of gold is 19 g/cm^3.
Conductivity	**Conductivity** is the ability of a substance to conduct electricity or heat. A substance that conducts electricity or heat is called a conductor. A substance with little or no conductivity is an insulator.

1	2	3	4	5
Talc	Gypsum	Calcite	Fluorite	Apatite

6	7	8	9	10
Feldspar	Quartz	Topaz	Corundum	Diamond

Figure 1.7 Mohs' hardness scale

Activity B-1

Inquiry

Identifying Mystery Substances

The Question

How can the properties of a substance be used to identify it?

Materials & Equipment

- salt, baking soda, corn starch, sodium nitrate, sodium thiosulfate
- black paper
- hand lens
- water
- 5% acetic acid or 5% hydrochloric acid
- iodine solution
- wax paper or spot plate
- disposal containers

Figure 1.8 Step 7

Procedure

Part 1—Examining Five Substances

1. Copy the table shown on the next page into your notebook.
2. Collect five substances from your teacher.
3. Perform the tests described below to identify the properties of the substances. You do not have to do the tests in the order shown below, but you must do all of them.
4. Make sure the data table is completely filled in before you begin part 2 of the activity.

Test 1—Appearance

5. Use one sheet of black paper for all your samples. Place a small amount of each powder in different places on the same sheet of black paper. Make sure that your powder samples are not touching each other.
6. Describe the appearance of each powder. Record your observations in the data table.

Test 2—Crystal shape

7. Use a hand lens or microscope to examine the grains of each powder. Record your observations in the data table.
8. Dispose of the powders and the black paper in the container provided.

Test 3—Behaviour in water

9. Use one large sheet of wax paper or a spot plate for all your samples. Place a small amount of each powder on the wax paper or spot plate.
10. Add a drop of water to each powder. Record your observations in the data table.
11. Dispose of the powders and the wax paper in the container provided. Clean the spot plate.

Test 4—Behaviour in acid

12. Place a small amount of each powder on a new sheet of wax paper or a clean spot plate.
13. Add a drop of 5% acetic acid solution or 5% hydrochloric acid solution to each powder. Record your observations in the data table.
14. Dispose of the powders and the wax paper in the container provided. Clean the spot plate.

Test 5—Behaviour in iodine

15. Place a small amount of each powder on a new sheet of wax paper or a clean spot plate.
16. Add a drop of iodine solution to each powder. Record your observations in the data table.
17. Dispose of the powders and the wax paper in the container provided. Clean the spot plate thoroughly.

Part 2—Identifying Unknown Substances

18 Collect an unknown sample from your teacher. Record the letter or number of the sample in the data table next to the word "unknown."

19 Determine the properties of the unknown sample by repeating the five tests above, and record your observations in the data table.

Analyzing and Interpreting

20 For each substance, one or two tests clearly identified it as being unique from the other substances. What were those tests for each of the white powders?

21 Were some tests more useful than others? Explain your answer.

22 Were the results of some of the tests confusing? Explain your answer.

23 What substance or substances were in your unknown sample?

Forming Conclusions

24 Describe how you inferred what substance or substances were in your unknown sample. Use your data to support your conclusions.

Applying and Connecting

Knowing the properties of a substance is essential to finding practical uses for it. For example, corn starch can be used to make glue. If corn starch is cooked with an acid, a sticky, adhesive substance is produced. A similar substance can be produced from the solid materials that form after acid is added to milk. This substance is called *casein*. Casein can be mixed with a basic solution to form a strong glue.

Substance	State	Appearance	Crystal Shape	Behaviour in Water	Behaviour in Acid	Behaviour in Iodine
salt						
baking soda						
corn starch						
sodium nitrate						
sodium thiosulfate						
unknown						

Chemical Properties of Matter

Chemical Properties of Matter—Examples

- reaction with acids
- ability to burn
- reaction with water
- behaviour in air
- reaction to heat

A **chemical property** describes how a substance interacts with other substances such as acids. Chemical properties are observable only when a chemical change occurs. A **chemical change** always results in the formation of a different substance or substances. For example, if you make pancakes, you mix together flour, milk, baking powder, sugar, and other ingredients, each with its own set of physical properties. When you cook them, however, they form a completely new substance—a pancake. The pancake has different properties from those of its ingredients.

Figure 1.9 Cooking the pancake ingredients changes them into a different substance.

Pure Substance or Mixture?

All matter is either a pure substance or a mixture. Physical and chemical properties show us whether a substance is "pure" or a mixture.

Types of Pure Substances

A **pure substance** is made of only one kind of matter and has a unique set of properties that sets it apart from any other kind of matter. Mercury and sugar are two examples. A pure substance may be either an element or a compound.

- An **element** is a material that cannot be broken down into any simpler substance. Elements are the basic building blocks for all compounds. Later in this unit, you will learn how elements are organized into a **periodic table** according to their properties. Each element has its own symbol. For example, hydrogen is H, carbon is C, and oxygen is O.
- When two or more elements combine chemically—that is, in specific, fixed proportions—they form a **compound**. When the elements hydrogen and oxygen are combined in specific proportions, they form the compound water. Carbon and oxygen chemically combined form the compound carbon dioxide, the gas that is used to create the "fizz" in carbonated drinks. Later in this unit, you will learn that compounds have chemical names and formulas. For example, water is H_2O and carbon dioxide is CO_2.

The structural composition of elements and compounds is discussed further in Section 2.0.

Types of Mixtures

A **mixture** is a combination of pure substances. However, the substances in a mixture do not combine chemically as happens when a compound is formed. They remain in their original, pure form, even though they are not always easy to see distinctly once the mixture is made. There are four main types of mixtures:

- In a **mechanical mixture**, the different substances that make up the mixture are visible. Soil is an example of a mechanical (or *heterogeneous*) mixture. So is a package of mixed vegetables.
- In a **solution**, the different substances that make it up are not separately visible. One substance is dissolved in another, creating what looks like one *homogeneous* substance. Examples of solutions are shown in the table below.

Type of Solution	Example
Solid dissolved in liquid	sugar in hot coffee
Liquid dissolved in liquid	acetic acid in water (to create white vinegar)
Gas dissolved in liquid	carbon dioxide gas in water (to create carbonated pop)
Gas dissolved in gas	oxygen and smaller amounts of other gases in nitrogen (in the atmosphere)
Solid dissolved in solid	copper in silver (to create sterling silver)

Figure 1.10 You use many different kinds of mixtures and solutions each day.

Chemists call a substance dissolved in water an **aqueous solution**. Examples include fresh water, vinegar, and cleaning solvents.

- A **suspension** is a cloudy mixture in which tiny particles of one substance are held within another. Tomato juice is an example of a suspension. These particles can be separated out when the mixture is poured through filter paper.
- A **colloid** is also a cloudy mixture, but the particles of the suspended substance are so small that they cannot be easily separated out from the other substance. Milk and ketchup are examples of colloids.

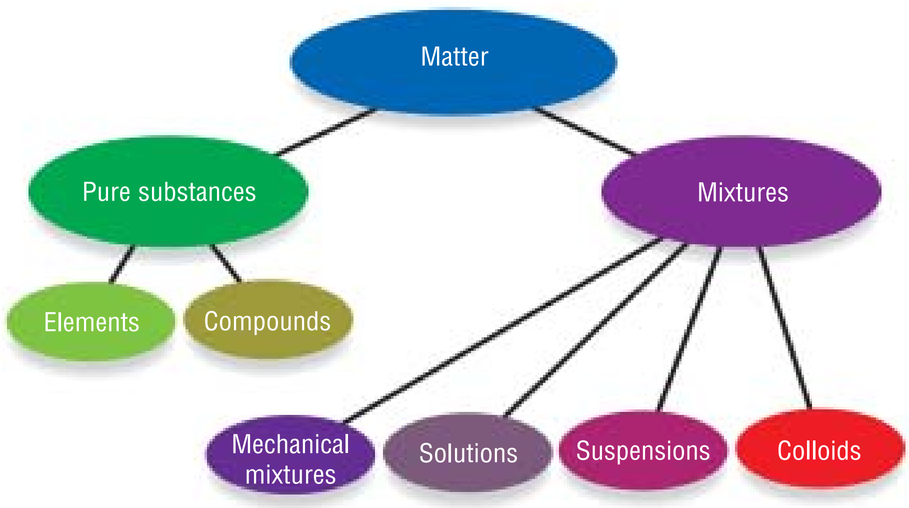

Figure 1.11 Classifying matter

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Other Types of Mixtures

Gels are colloids used in beauty products. Find out how these types of mixtures are created, and how they are used in various applications. Begin your search at www.pearsoned.ca/scienceinaction.

Check and Reflect

Key Concept Review

1. What physical properties could be used to describe a substance?
2. Give two examples to illustrate the difference between a physical and a chemical property.
3. How is an element different than a compound? Give an example of each.
4. What is the difference between a pure substance and a mixture?
5. How is a suspension different from a colloid?

Connect Your Understanding

6. The melting and boiling points of five chemical substances are shown in the table below. What state of matter does each exist in at room temperature (about 20°C)?

Substance	Melting Point (°C)	Boiling Point (°C)	State at Room Temperature
water	0	100	
oxygen	−218	−183	
ammonium nitrate	170	210	
ethanol	−117	79	
mercury	−39	357	

7. What physical property is described by each of the following statements?
   a) Solid oxygen melts at −218°C.
   b) A penny cannot scratch glass.
   c) Silver is shiny.
   d) Gold can be made into thin sheets.
   e) Both aluminum and copper can be used for making wire.
8. Classify the following substances as an element, compound, or mixture:
   a) Pop is composed of water, sugar, and carbon dioxide.
   b) Graphite in a pencil is composed of carbon.
   c) Carbon dioxide is composed of carbon and oxygen.
9. Someone sprinkles dilute acetic acid over your French fries. Are they safe to eat? Explain your answer.

Extend Your Understanding

10. Create a concept map to illustrate the different categories of matter. Use the following terms: matter, solution, element, homogeneous mixture, heterogeneous mixture. Include an example of each in your map.
11. Find out how mixtures can be modified to meet human needs. For example, a substance obtained from the sea weed carrageen is added to many brands of ice cream as a thickener.

1.3 Observing Changes in Matter

Think about the changes in matter you have observed in nature and elsewhere. For example, in the spring, you can see ice—solid water—become liquid water. At home, you can heat water in a kettle and watch it vaporize as steam. These changes are easy to see, but others are not. For example, the hemoglobin which carries oxygen in your blood changes colour when carbon dioxide and oxygen are exchanged in your lungs.

As you learned in section 1.2, changes in matter are classified as physical or chemical. A **physical change** is one in which a material changes from one state to another. The material can also physically change back into its original state. When frozen apple juice is thawed, it melts from a solid to a liquid. If you refreeze the juice, it will turn back into a solid. Its composition will remain the same in all states.

A **chemical change** occurs when two or more materials react and create new materials. The new materials have completely different properties from the original substances. How can you tell when a chemical change is underway or has taken place? The main pieces of evidence to look for are changes in colour, odour, state, or thermal energy during, or as a result of, the reaction between the original substances. Examples are shown below:

Evidence of Chemical Change	Example
Change in colour	When bleach is added to the dye on a denim jacket, a noticeable colour change occurs.
Change in odour	When a match is struck, the substances in the match head react and give off a distinctive odour.
Formation of a solid or gas	When vinegar (a liquid) is added to baking soda (a solid), carbon dioxide gas is formed.
Release or absorption of heat energy	When gasoline burns in a car engine, heat is released.

Sometimes, it can be unclear whether a material's change in state means that a chemical or a physical change has occurred. In such situations, chemical analysis in the lab is required to confirm the nature of the change.

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Detecting Changes in Blood

Canadian scientist Imant Lauks invented a device called the I-Stat. In 2 min, this device can perform 12 different tests to identify changes that have occurred in a person's blood. This process used to take hours or days.

SKILL PRACTICE

Identifying Physical and Chemical Changes

For each example in Figure 1.12, identify the change shown as either a physical change or chemical change. If you are not sure what type of change is happening, note that. Review all the examples again when you have finished working through this section.

Figure 1.12(a–e)

(a) (b) (c) (d) (e)

Activity B-2

Inquiry

Investigating Physical and Chemical Changes

Materials & Equipment

- sodium carbonate
- 250-mL beaker
- dilute hydrochloric acid
- aluminum foil
- sugar
- candle
- Plasticine
- matches
- wooden clothespin or tongs
- 3 test tubes
- sodium carbonate solution
- copper(II) sulfate solution
- 5-mL measuring spoon
- test-tube holder
- copper(II) sulfate (solid)
- water
- stirring rod

Caution!
Make sure long hair and loose clothing are tied back.

Caution!
Copper(II) sulfate is poisonous and can stain your clothes and skin.

The Question

What are some characteristics of physical changes and chemical changes?

Procedure

1. You will investigate four different reactions described below.
2. Copy the data table shown on the next page into your notebook. Fill it in as you complete each test.

Test 1—Sodium carbonate and hydrochloric acid

3. Put a pea-sized pile of sodium carbonate into a small beaker or plastic cup. In your data table, describe the appearance of the sodium carbonate.
4. Observe the dilute hydrochloric acid. If you are unable to see inside the container, use a clear eyedropper to remove a small sample of the acid. Record your observations.
5. Predict what you think will happen when you add the dilute hydrochloric acid to the sodium carbonate.
6. Add 5 to 8 drops of dilute hydrochloric acid to the sodium carbonate. Record your observations.

Test 2—Sugar and heat

7. Use a piece of aluminum foil to make a small cup shape. Put a pea-sized pile of sugar into the centre of the aluminum cup. In your data table, describe the appearance of the sugar.
8. Predict what you think will happen when the sugar is heated.
9. Stand a candle securely in some Plasticine, and light the candle.
10. Using tongs or a wooden clothespin, hold the aluminum cup containing the sugar over the candle's flame. Slowly move the cup back and forth over the flame to heat the sugar. Record your observations.
11. When you are finished, place the aluminum cup in a safe place to cool.

Test 3—Copper(II) sulfate and sodium carbonate

12. Place 5 mL of copper(II) sulfate solution in a test tube. Place 5 mL of sodium carbonate solution in another test tube. In your data table, describe the appearance of each solution.
13. Record your prediction of what will happen when the two solutions are combined.
14. Combine the two solutions and record your observations.
15. When you are finished, dispose of the solution as directed by your teacher.

Test 4—Copper(II) sulfate and water

16 Place a pea-sized pile of copper(II) sulfate in a clean test tube and place the test tube in a holder. In your data table, record the substance's appearance.

17 Record your prediction of what will happen when water is added to the copper(II) sulfate.

18 Add 15 mL of water and record your observations. Use a stirring rod to mix the water and copper(II) sulfate. Record your observations.

Figure 1.13 Test 4

Analyzing and Interpreting

19 Which of the changes that you observed were physical?

20 What observations helped you identify a physical change?

21 Which of the changes that you observed were chemical?

22 What observations helped you identify a chemical change?

Forming Conclusions

23 Create a summary, chart, or picture to illustrate the observations you might make to describe the characteristics of a chemical change and a physical change.

Change	Observations before Change	Predictions	Observations during Change	Observations after Change	Type of Change (Physical or Chemical)
Station 1: Sodium carbonate and dilute hydrochloric acid					
Station 2: Sugar and heat					
Station 3: Copper(II) sulfate and sodium carbonate					
Station 4: Copper(II) sulfate and water					

Controlling Changes in Matter to Meet Human Needs

In our everyday life, there are many examples of how understanding and controlling changes in matter help us meet our basic needs. One example you might be interested to read about is the freeze-drying of foods. Freeze-drying is a way to preserve foods so that they can be eaten months—and sometimes even years—later. As well, freeze-drying makes foods easy to prepare—all you have to do is add hot water.

In the freeze-drying process, the food is first frozen to convert the water content in the food to ice. The frozen food is then put in a pressure chamber and the pressure is reduced until the ice sublimes (changes from a solid to a gas). The result is that about 98% of the water in the original food item is removed. This leaves a food that is about 10% its original mass and that, once packaged, doesn't have to be refrigerated. When it's time to eat, all you do is stir in hot water!

Figure 1.14 If you've ever kayaked, you know the importance of keeping your supplies as light as possible. Freeze-dried foods weigh little and take only minutes to prepare.

Figure 1.15 A highly magnified photo of a "freeze-fractured" cell. In this process, plant or animal tissue is rapidly frozen. The ice formed within each cell is then removed by various evaporation techniques. The result is a clearly revealed cell structure: nucleus, pores, and membrane.

The technique of freeze-drying is also used by biologists to study tissue samples and by restoration experts to rescue important documents that are water damaged.

Another process, developed by the U.S. Army, makes freeze-dried food even more convenient. Instead of having to be heated over a fire or portable stove, the "Meal, Ready to Eat" (also referred to as an MRE) is heated in a special package called a "Flameless Ration Heater." This makes MREs especially useful for soldiers, astronauts, and mountain climbers. To be warmed up, the freeze-dried MRE is placed in the Flameless Ration Heater pouch. The pouch contains magnesium, iron, and salt. When a little water is added to these chemicals, the resulting chemical change releases heat—enough to warm the freeze-dried contents.

From Corn to Nail Polish Remover and Plastic Wrap?

Scientists are also able to change common materials into other useful products. For example, chemicals made from corn can be used to make soda pop bottles, remove paint or nail polish, and fuel some cars. Corn is put through a chemical change called fermentation. Once this chemical process is complete, the new substances are recovered, purified, and made into biodegradable plastics, solvents, and gasohol. Corn-based biodegradable plastics such as bottles and plastic wrap are better for the environment because they can be decomposed by bacteria. Corn-based solvents for removing paint and nail polish are not as harmful to the environment as other types of solvents. Gasohol provides a renewable type of fuel for automobiles.

reSEARCH

What Makes a Match Light?

When a match burns, the wood or paper undergoes combustion, but how does the match ignite? Find out about the chemical reactions that occur when a match is lit. Begin your research at www.pearsoned.ca/scienceinaction.

Check and Reflect

Key Concept Review

1. What is the difference between a chemical change and a physical change?
2. Copy the following table into your notebook and fill in the blanks:

Event	Changes in Matter	
	Observable Changes	Type of Change
Baking bread		
Burning wood		
Freezing water		
Mixing sugar and water		

Connect Your Understanding

3. Describe three indicators of a chemical change. Include examples of each.
4. An unknown white solid is heated for 1 min. It is observed that (a) the solid disappears, leaving a colourless liquid; and (b) after the liquid cools, a white solid appears. What kind of change is this? Explain the reason for your choice.
5. Describe an example of how humans control changes in matter to meet their basic needs.

Extend Your Understanding

6. Find one example of a physical change and one of a chemical change not discussed in this section. Share your findings with the class.
7. Is popping popcorn a physical or chemical reaction? Explain your answer.

Section Review

Assess Your Learning

Key Concept Review

1. Define matter.

2. What do the following symbol shapes represent?

3. Why does everyone working with hazardous materials use WHMIS?

4. Create a diagram illustrating the different states of matter. Name the process that makes the change in state possible.

5. Name at least six properties of matter that can be used to describe a substance.

6. Identify each of the following as either a physical or a chemical change:
   a) Acid is dropped on limestone and bubbling occurs.
   b) Snow turns into rain just before it reaches the ground.
   c) A strip of magnesium is ignited, and it burns brightly.
   d) Solid carbon dioxide, or dry ice, sublimes into carbon dioxide gas.

7. Define the terms physical change and chemical change. Include the words *water*, *baking soda*, *sugar*, and *vinegar* in your definitions.

8. Describe the four main types of mixtures that can be formed.

9. Explain the difference between deposition and freezing.

10. List three examples of physical changes you have observed today.

Connect Your Understanding

11. Describe two occupations in which knowledge of WHMIS is important.

12. What safety symbol would appear on the following?
   a) an aerosol can of hair spray
   b) an agar plate of bacteria culture
   c) a 4-L jug of bleach
   d) a gasoline can

13. What WHMIS symbol would be used in each case listed in question 12?

14. Compare and contrast physical properties with chemical properties.

15. What physical properties could be used to identify the following?
   a) copper metal
   b) water

SECTION REVIEW

16. Using the classification of matter chart as a guide (Figure 1.11), create a classification system for the following substances: chocolate chip cookies, coffee with milk in it, aluminum foil, potting soil, a gold medal, pizza, sugar, and garbage. Be sure to list the properties you used to guide your classification.
17. Explain the difference between a suspension and a colloid.

Extend Your Understanding

18. Why are there two different sets of safety symbols for labelling chemicals?
19. Your class is going to be doing a chemistry experiment with a grade 1 class. You are partnered with two students from the younger class. What would you tell them about safety before the activity begins?
20. You are given three unlabelled containers, each with a white powder. Your teacher tells you that the powders could be baking soda, corn starch, or sodium nitrate. Describe the chemical tests you need to perform to identify each powder.

Focus On THE NATURE OF SCIENCE

The goal of science is to develop knowledge about our natural world. This includes knowledge about the nature of substances, how they interact to form new substances, and how these interactions can be controlled and used in a practical way. Working with a partner or the whole class, consider the following questions:

1. Identify an example of a physical change. How do you know a physical change has occurred? What evidence do you have?
2. Identify an example of two or more substances interacting to produce a chemical change. How do you know a chemical change has occurred? What evidence do you have?
3. Describe several chemical changes that you think are useful either to you personally or to society in general. What characteristics or properties of each of these reactions make them useful?

2.0

An understanding of the nature of matter has developed through observations over time.

Key Concepts

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

- substances and their properties
- elements, compounds, and atomic theory
- periodic table

Learning Outcomes

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

- distinguish between observation and theory, and provide examples of how models and theoretical ideas are used in explaining observations
- demonstrate understanding of the origins of the periodic table, and relate patterns in the physical and chemical properties of elements to their positions in the periodic table
- use the periodic table to:
  - identify the number of protons and electrons in each atom, as well as other information about each atom
  - describe the relationship between the structure of atoms in each group and the properties of elements in that group

Humans have been warming themselves around campfires for thousands of years. You may have sat around a campfire and enjoyed the heat. You may even have cooked over a fire. What do you think early humans might have wondered about this mysterious flame that gives off heat and light? Some of them likely puzzled over why fire turns wood black or makes it smell different. Maybe they would have wondered what happened to the wood after the fire had burned out. By being curious about the world around them, these people were the first to try to learn more about substances and how they behave.

In this section, you will learn how our understanding of matter has changed over time. As you read, you will begin to appreciate how asking questions is a key first step we use in making sense of our world. Then, from our observations and experiments, we develop theories and build models to predict and explain what we see. We test these, adjust them, try out new ideas, and eventually reach what seems to be the reasonable answers to our questions. It all begins with curiosity.

For Web links relating to 2.0, visit www.pearsoned.ca/scienceinaction

2.1 Evolving Theories of Matter

As people observe the natural world around them, they try to make sense of their observations by suggesting explanations. They develop theories to explain what they see. Over time, the theories are modified as new evidence is discovered. The understanding of the structure of matter grew in this way.

Stone Age Chemists

The first chemists lived before 8000 B.C. in an area now called the Middle East. This period is known as the Stone Age because humans used only simple stone tools at the time. Metals had not been discovered.

Once these first chemists learned how to start and control fire, they learned how to change a range of substances to their advantage. For example, they could cook their food, fire-harden mud bricks to strengthen them, and make tougher tools. Eventually this ability to control fire led to the production of glass and ceramic material.

Figure 2.1 Humans in the Stone Age could make only simple stone and bone tools like these. Stone Age people improved their lives when they discovered how to start and control fires. They used fire mainly for cooking and warmth.

GIVE IT A TRY

Creating a Time Line Story of Matter

In this subsection, you will be learning how our understanding of the structure of matter has developed through history.

1. Make a time line that shows when the key ideas were proposed and who proposed them. Start your time line at 8000 B.C. and add to it as you read through the subsection. For each idea, be sure to include the observations the person made that led to the new theory.
2. Beneath your time line, sketch the model that resulted from the key idea.
3. Mark the final point in your time line "Today." Draw a diagram beneath this that shows your own understanding of the structure of matter.

EARLY INTEREST IN METALS AND LIQUID MATTER

Between 6000 B.C. and 1000 B.C., early chemists investigated only materials that had a high value to humans. Many of these materials were metals, such as gold and copper. Gold became highly valued because of its properties. It had attractive colour and lustre, and it didn't tarnish. Its softness made it easy to shape into detailed designs, form into wire, and beat into sheets. Because it is so soft, however, gold could not be used for tools or weapons.

Figure 2.2 The earliest use of gold was in jewellery, but it later became very important in the making of coins.

Copper became valuable because it could be used to make pots, coins, tools, and jewellery. It was early chemists asking questions that led to an understanding of copper's properties and how the material could be controlled. A piece of natural, untreated copper is brittle—that is, it breaks easily. In that state, therefore, it isn't a useful material for making things. However, when copper is heated, it becomes very useful because it can be rolled into sheets or stretched into long wires.

The original discovery of the effect of heat on copper was possibly accidental. A chunk of copper may have fallen into a fire and whoever picked it out may have asked: Has the copper changed because it was heated? Testing it would have revealed how much softer it was and that it was less likely to shatter when hammered. Later experimenting with copper (about 4500 B.C.) led to the creation of a hard, strong material known as bronze, which is produced when copper and tin are heated together.

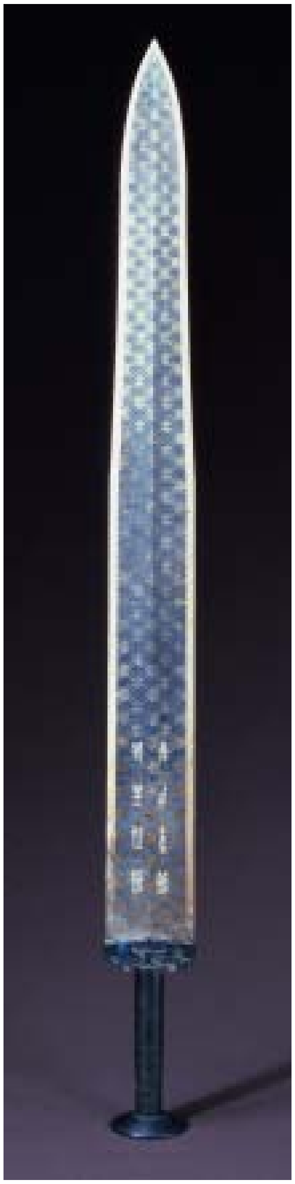


Figure 2.3 An ornate bronze sword dating from about 600 B.C.

Figure 2.4 The discovery of copper's usefulness (such as in these copper spearheads) is a good example of how asking questions leads to scientific and technological development.

Around 1200 B.C., a group of people in the Middle East called Hittites discovered how to extract iron from rocks and turn it into a useful material. The Iron Age began. Eventually, people learned to combine iron with carbon to produce an even harder material—steel. Steel meant sharper blades could be fashioned for hunting and stronger armour could be built to protect soldiers in battle.

Metals were not the only form of matter that early people wanted to learn more about. Many cultures investigated the ways of extracting and using different types of liquids. Juices and oils were especially important both in everyday life and in rituals. (In fact, the word "chemistry" may be derived from the Greek word *khemeia*, meaning juice of a plant.) In ancient Egypt, human bodies were preserved after death by being wrapped in cloths soaked in natural pigments and resins from the juniper tree. Figure 2.6 shows a mummy preserved with this technique.

Figure 2.5 The knowledge and ability to process iron and use it to make stronger tools and weapons changed human society greatly.

Figure 2.6 The ancient Egyptians developed techniques for extracting and purifying juices and oils to use in mummifying bodies.

*re*SEARCH

Discovering Different Metals

Other metals besides gold and copper have also been long known. Find out when tin, silver, lead, and mercury were discovered and how they were first used. Begin your research at www.pearsoned.ca/scienceinaction.

*info***BIT**

Thinking About Matter

The first people who developed theories about the structure of matter were philosophers. Philosophers are people who think about the world and humans' place in it. Rather than performing experiments on the nature of matter, early philosophers just thought about the structure of matter. Their explanations and theories were based on their ideas, not on experimental evidence.

Emerging Ideas About the Composition of Matter

The idea that all matter is made up of particles started with the Greek philosophers about 2500 years ago. They observed that a rock could be broken into smaller and smaller pieces until it became a powder. But, they asked, how many times could you continue to break the particles of powder down until they couldn't be broken down any more? In about 400 B.C., the Greek philosopher Democritus used the word *atomos* to describe the smallest particles that could not be broken further. *Atomos* means "indivisible."

Democritus stated that each type of material was made up of a different type of *atomos*. These different particles, he believed, gave each material its own unique set of properties. By mixing different *atomos*, you could make new materials with their own unique properties. However, in about 350 B.C. another Greek philosopher, Aristotle, supported a different hypothesis. He stated that everything was made of earth, air, fire, and water. Because Aristotle was well known and well respected, his description of matter was preferred over Democritus's description for 2000 years.

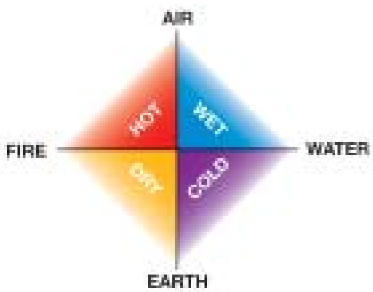


Figure 2.7 Until about A.D. 1600, most people believed Aristotle's view that matter was made up of earth, air, fire, and water. Each of these elements had two main features. For example, water was wet and cold, and earth was dry and cold.

From Alchemy to Chemistry

For the next 2000 years after Democritus's time, experiments with matter were mainly carried out by alchemists, people who were part magician, part scientist. (The word "alchemy" comes from the Arabic word *al-kimiya*, which translates as "the chemist.") Today, the study of alchemy would be called a pseudo-science (an activity that is not a real science because it includes the use of magic). Alchemists believed that it should be possible to change metals into gold. They were not interested in understanding the nature of matter.

Figure 2.8 Alchemists continued in their search for a way to make gold until about 1600.

Even though they weren't real scientists, alchemists performed some of the first chemistry experiments. In doing so, they invented many useful tools that we still use in labs today, such as beakers and filters. They also made practical discoveries. For example, the Arab alchemist al-Razi discovered what we now call plaster of Paris—a material that today's doctors still use to hold broken bones in place until they heal. In 1597, the German alchemist Andreas Libau published *Alchemia*, a book describing the achievements of alchemists. In it, however, Libau also explained how to prepare chemicals such as hydrochloric acid. This type of information made his book the first chemistry text ever printed.

Figure 2.9 Plaster of Paris is a white, powdery combination of chemical substances that, when mixed with water, becomes a quick-hardening paste.

New Interest in Atoms

From the late 1500s on, people investigating the world around them became more like scientists today. They had a greater interest in understanding the nature of matter and change than the alchemists had. And, unlike the philosophers, they based their theories on observations and experimentation.

In the 1660s, Robert Boyle experimented with the behaviour of gases. He was interested in what happened when gases were placed under pressure. He was also interested in determining the composition of gases and other substances. Through his experiments and observations, Boyle became convinced that matter was made up of tiny particles, just as Democritus had suggested in about 400 B.C.

Boyle believed that the tiny particles, existing in various shapes and sizes, would group together in different ways to form individual substances. Boyle felt that the purpose of chemistry was to determine the types of particles making up each substance.

Figure 2.10 Robert Boyle was an Irish aristocrat living in London. He devoted his life to scientific inquiry.

Chemistry Develops as a New Science

In the 1770s, the French scientist Antoine Laurent Lavoisier studied chemical interactions. By the late 1780s, he had developed a system for naming chemicals. This was significant, for now all scientists could use the same words to describe their observations. That made it easier to compare the results of their experiments. Using his naming system, Lavoisier defined some of the substances discovered to that time, including hydrogen, oxygen, and carbon.

Because of his experimental and theoretical work, Lavoisier is called the "father of modern chemistry." Unfortunately, he supported the losing side during the French Revolution and was executed by guillotine in 1794. After his death, Lavoisier's wife, Marie, continued his work. She had worked with him as his lab assistant.

Figure 2.11 Antoine Laurent and Marie Lavoisier worked together conducting scientific investigations into chemical interactions.

An Atomic Theory Takes Shape

In 1808, English scientist John Dalton used the observations from his experiments to develop his own theory of the composition of matter. Dalton suggested that matter was made up of elements. He was the first to define an element as a pure substance that contained no other substances. Gold, oxygen, and chlorine are examples.

Dalton also put forward the first modern theory of atomic structure. He stated that each element is composed of a particle called an **atom**. All atoms in a particular element, he said, are identical in mass, and no two elements have atoms of the same mass. For instance, all oxygen atoms have the same mass, which is different from the mass of chlorine atoms. Dalton's model is sometimes called the "billiard ball model" because he thought of the tiny atoms as solid spheres. While some of Dalton's ideas were later modified based on new evidence, his basic description of the structure of an element was correct.

Figure 2.12 In John Dalton's theory, atoms are like solid billiard balls. The atoms of each element have a different mass than atoms in other elements.

Adding Electrons to the Atomic Model

Dalton's work on the structure of the atom was continued by British physicist J.J. Thomson. He is credited with being the first person to discover a subatomic particle (a particle smaller than an atom). Thomson, experimenting with cathode rays, concluded that the rays were made up of streams of negatively charged particles. He showed that these particles were much smaller in mass than even a hydrogen atom. He named them **electrons**. Although Thomson inferred that these invisible electrons were part of atoms, many people did not agree with him at first. They believed that atoms were the smallest particle of matter and could not be broken down further.

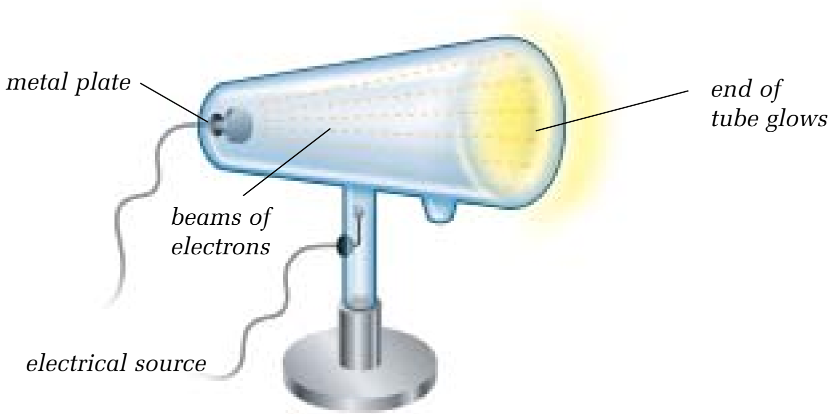


Figure 2.13 Cathode rays are produced when a piece of metal is heated at one end of a tube containing a gas. The heated metal sends out a stream of electrons toward the opposite end of the tube, causing the end of the tube to glow. Early scientists used a simple tube like the one shown here. Cathode ray tubes are now used in electrical devices such as televisions.

In 1897, Thomson proposed what is called the "raisin bun model" of the atom. He described the atom as a positively charged sphere in which negatively charged electrons were embedded like raisins in a bun. Figure 2.14 shows one way of representing this model. The negative electrons balance the positive sphere, so the whole atom has no electrical charge.

In 1904, the Japanese physicist Hantaro Nagaoka refined the model of the atom further. In his model, the atom resembled a miniature solar system (Figure 2.15). At the centre of the atom was a large positive charge. The negatively charged electrons orbited around this charge like planets orbiting around the Sun. Most scientists of the day did not agree with this model because existing theories could not explain it.

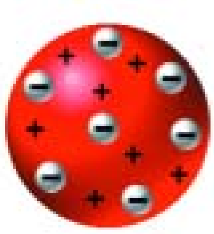


Figure 2.14 J.J.Thomson's model was the first one that described particles smaller than atoms. This model represented the atom as a positive sphere with electrons scattered throughout it—like raisins mixed in a baked bun.

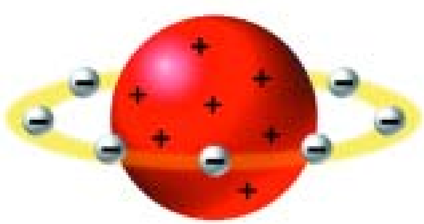


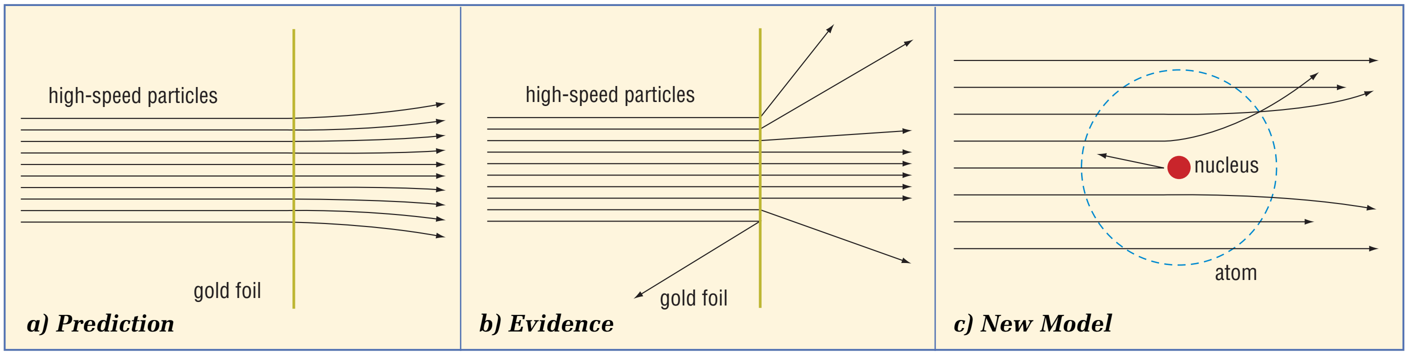
Figure 2.15 Hantaro Nagaoka's model showed the atom as a positive sphere around which electrons orbited in a ring, like Earth orbiting the Sun.

A Canadian Contribution to Atomic Theory

Support for the Nagaoka model and the idea of a central nucleus came from the British scientist Ernest Rutherford. Rutherford won a Nobel Prize in 1908 for his work in radioactivity, which he carried out at McGill University in Montreal from 1898 to 1907. This work contributed to the development of his model of the atom.

Using Thomson's model, Rutherford conducted experiments in which he shot positively charged particles through thin gold foil. He predicted that all the high-speed particles would pass straight through the foil without being affected by the gold atoms (Figure 2.16a). Instead, the results showed that while most particles did behave as predicted, some were greatly deflected (Figure 2.16b). To explain why this might happen, Rutherford proposed a new model. He suggested that atoms were mainly empty space through which the positive particles could pass, but at the core was a tiny positively charged centre. This he called the **nucleus** (Figure 2.16c). He also calculated that the nucleus was only about 1/10 000th the size of the atom—like a green pea in a football field.

Figure 2.16 From experiments with high-speed particles, Ernest Rutherford was able to infer the existence of an atom's nucleus.



Bohr's Model

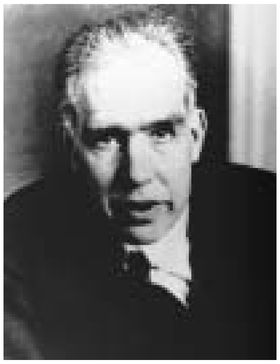


Figure 2.17 Niels Bohr was only 28 when he published his theory of the atom in 1913. In 1922, he won the Nobel Prize in physics.

It was Danish researcher Niels Bohr who, working with Rutherford, suggested that electrons do not orbit randomly in an atom. Bohr said that they move in specific circular orbits, or **electron shells**, as shown in Figure 2.18. He believed that electrons jump between these shells by gaining or losing energy. For his work in studying the atom, Bohr won the Nobel Prize in physics in 1922.

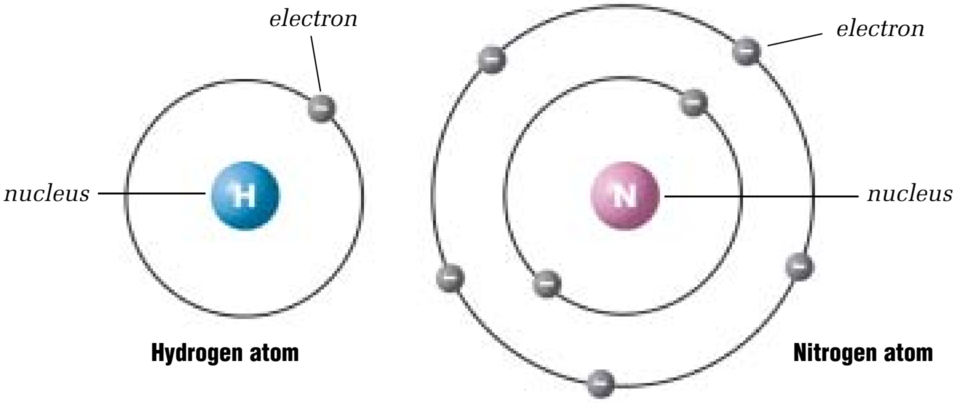


Figure 2.18 Bohr's model of the atom. Electrons orbit the nucleus in a regular pattern.

*re*SEARCH

The Quantum Atom

Find out more about the quantum nature of the atom. Use print and electronic resources to learn about orbitals and electron clouds. Begin your research at www.pearsoned.ca/scienceinaction.

Bohr's model was readily accepted, though with further refinements, by James Chadwick, another British physicist. Chadwick discovered that the nucleus contained positively charged particles called **protons**, and neutral particles called **neutrons**. The neutron has about the same mass as the proton but carries no electrical charge. An electron has only 1/1837th the mass of either a proton or a neutron.

Today, most people still use the Bohr model to describe the particles that make up the atom. However, further research in the area of quantum mechanics has found that the structure of the atom is different again from that model. The quantum mechanics model of the atom describes electrons as existing in a charged cloud around the nucleus, shown in Figure 2.19.

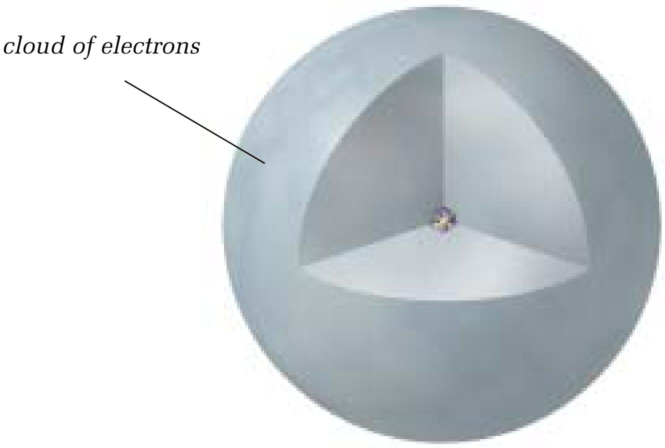


Figure 2.19 Today's quantum mechanics model describes the atom as a cloud of electrons surrounding a nucleus.

Check and Reflect

Key Concept Review

1. Gold and copper were the first forms of matter investigated by humans. Explain why.
2. Where did the word "chemistry" come from?
3. How did Democritus define the atom?
4. Why is Antoine Laurent Lavoisier considered to be the "father of chemistry"?
5. Name four examples of matter other than gold and copper that have been studied because of their value.

Connect Your Understanding

6. Describe one practical example of alchemists' work.
7. Explain the difference between J.J. Thomson's model of the atom and Ernest Rutherford's model.
8. Draw a diagram of Niels Bohr's atom, labelling the position of the three subatomic particles.
9. What was the significance of the work done by Andreas Libau?
10. What made Robert Boyle's study of matter different from the previous work done by philosophers?
11. What changes were made to Thomson's "raisin bun model"? What ideas of his remained the same?

Extend Your Understanding

12. Do you agree or disagree with the statement "In prehistoric times, people understood very little about matter"? Explain your answer.
13. Imagine you had interviewed one of the philosophers, alchemists, or scientists responsible for developing our understanding of the structure of matter. Write a one-page interview with that person.
14. Compare Boyle's model of the atom with Rutherford's model. Use a diagram and a brief description to support your comparison.
15. Scientists, like most people, have lives outside their work. Select one of the scientists discussed in this subsection and write a short biography about his or her life outside of science. Be prepared to read your biography to the class.
16. Innuit peoples are believed to have been using copper long before Europeans arrived in North America. Find out more about the Copper Inuit and present your findings to the class.

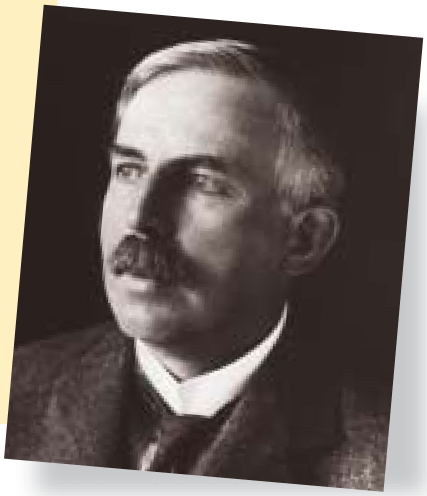


Figure 2.20 Ernest Rutherford proposed his nuclear theory of the atom in 1911.

*info*BIT

Choose Your Carbon

Some elements exist in different forms as a solid. Carbon can be a soft black substance called graphite. Or it can be a hard, clear substance called diamond.

2.2 Organizing the Elements

Looking for patterns and classifying scientific information helps us bring order to unorganized ideas. It can also help us interpret what the information means. As you reviewed in section 1.2, matter can be organized in several different ways. It can be classified as solids, liquids, or gases; and, in any of those states, it can be classified as pure substances (elements or compounds) or mixtures (mechanical mixtures, solutions, suspensions, or colloids).

*QUICK***LAB**

Meet the Elements

Purpose

To create a table of properties for a range of elements

Procedure

1. Draw a table in your notebook with the following properties listed across the top: colour, state, appearance, hardness, magnetism, and electrical conductivity. List the samples down the left side.
2. Your teacher will put out samples of different elements in the classroom, as well as the equipment you will need to make some of your assessments. Examine each element and fill in the table with the information you gather about the properties of each one. The guidelines below will help you in your investigation:

   Colour
   Record the colour of each element. If the element has no colour, call it colourless.

   State
   Record what state the element is in at room temperature.

   Appearance
   Describe the appearance of each element. Use words such as "lustre" (shine) and "texture."

   Hardness
   Determine the hardness of each solid element.

   Magnetism
   Use a magnet to determine whether the element is magnetic.

   Electrical Conductivity
   Test electrical conductivity with a simple electrical circuit and a light bulb. If the light bulb goes on when you touch the two wires to the element, the element is a conductor. If the light bulb does not go on, the element is an insulator.

Questions

3. Sort the elements into groups that have the same or similar properties.
4. For each of the groups that share similar properties, suggest a collective name to describe the elements.
5. List these elements under their collective group headings.

Organizing the elements in a meaningful way was a goal of many early chemists. In this subsection, you will learn about that effort and the origins of the periodic table. As well, you'll learn how important advances in this classification approach not only revealed trends in the properties of known elements, but also allowed scientists to predict the existence of elements not then known. To date, scientists have identified 112 elements. Several of the common ones have been mentioned in this unit already, including gold, copper, oxygen, hydrogen, nitrogen, and carbon. The characteristics of some of the common elements are listed in Toolbox 12 at the end of this textbook.

Looking for Patterns

Early chemists used symbols of the Sun and planets to represent the seven metallic elements known at the time. The definition of element that we use today was developed in the late 1700s. By the early 1800s, more than 30 elements had been identified, including oxygen, lead, and mercury. As the science of chemistry developed, more and more elements were identified. To help in the study of elements and compounds, chemists tried to group elements according to their properties. But this became confusing because different scientists organized elements in different ways. A new organization was needed so that everyone would be using the same system.

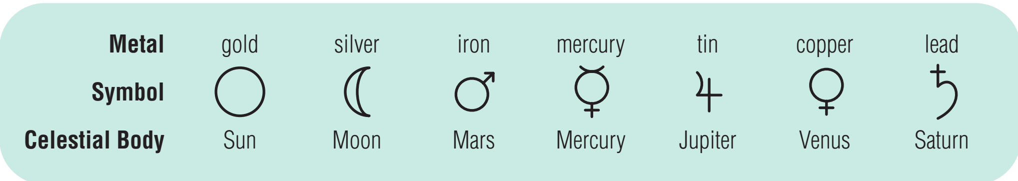


Figure 2.21 The symbols for the Sun and planets closest to Earth have long been used to represent the seven metals known from ancient times.

One of the first attempts by a scientist to create a better system for organizing the elements was made by John Dalton, an English chemist. In the early 1800s, he developed a new set of symbols for elements, as shown in Figure 2.22.

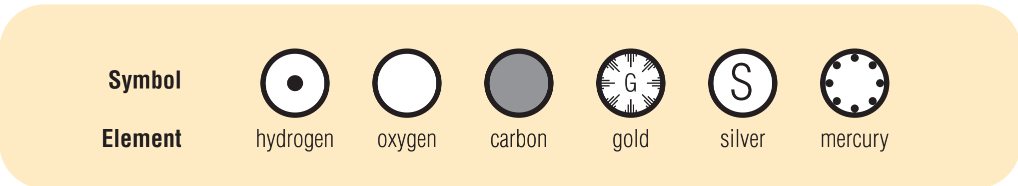


Figure 2.22 The element symbols devised by John Dalton, who lived from 1766 to 1844, were designed to improve communication between chemists.

Dalton's symbols were later modified by Swedish chemist Jöns Jacob Berzelius. In 1814, Berzelius suggested using letters rather than pictures to represent each element. The first letter (capitalized) of an element would become the symbol. For elements with the same first letter, such as hydrogen and helium, a small second letter would be added. Thus, "H" came to stand for hydrogen and "He" for helium. The new system—which remains the one used today—enabled scientists to communicate with each other in a precise and understandable manner. The next challenge was to find a way of putting the elements into an order that made sense.

*re*SEARCH

New Elements

Use electronic and print resources to find out about new elements that have been discovered or named in the past few years. Share this information with your class, using your choice of media. Begin your research at www.pearsoned.ca/scienceinaction.

An Order for the Elements

It was soon realized that the elements could be listed in order of increasing atomic mass. **Atomic mass** is the mass of one atom of an element. Scientists were able to determine the average mass of an atom of other elements by comparing it with the mass of a carbon atom (which is 12.0). Atomic mass is measured by *atomic mass unit* (amu).

In 1864, the English chemist John Newlands recognized a pattern when elements were listed by increasing atomic mass. He noticed that properties of elements seemed to repeat through this list at regular intervals. He called this pattern the "law of octaves," as the pattern was similar to the octave scale on a piano or other musical instrument. Many other scientists thought this law was silly and refused to accept the idea.

Not until 1869 did a clearer understanding of how to arrange the elements emerge. Russian chemist Dmitri Mendeleev was able to organize the elements in a way that reflected the patterns in the properties of the elements.

Finding a Pattern

Mendeleev collected the 63 elements known to exist in his time (the mid-1800s). These included lithium, carbon, nitrogen, oxygen, fluorine, sodium, silicon, phosphorus, sulfur, and chlorine. He then wrote down the properties of each element on a card, such as melting point, density, and colour. Using these cards, he tried to sort the elements into a pattern based on their properties. He also wanted to find a pattern that would allow him to predict the properties of elements not yet discovered. He felt that the ability to predict properties of new elements would prove that his pattern accurately reflected nature.

Mendeleev liked to play a form of the card game solitaire. In that game, a person looks for patterns in the layout of the cards. Mendeleev used his element cards like playing cards, laying them out and searching for patterns. Eventually, he found a pattern that seemed to work. It showed that the properties of elements vary periodically with increasing atomic mass. Figure 2.23 shows the chart that Mendeleev developed.

			Ti = 50	Zr = 90	? = 180.
			V = 51	Nb = 94	Ta = 182.
			Cr = 52	Mo = 96	W = 186.
			Mn = 55	Rh = 104,4	Pt = 197,4
			Fe = 56	Ru = 104,4	Ir = 198.
			Ni = Co = 59	Pl = 106,6	Os = 199.
H = 1			Cu = 63,4	Ag = 108	Hg = 200.
	Be = 9, 4	Mg = 24	Zn = 65,2	Cd = 112	
	B = 11	Al = 27,4	? = 68	Ur = 116	Au = 197?
	C = 12	Si = 28	? = 70	Su = 118	
	N = 14	P = 31	As = 75	Sb = 122	Bi = 210
	O = 16	S = 32	Se = 79,4	Te = 128?	
	F = 19	Cl = 35, 5	Br = 80	I = 127	
Li = 7	Na = 23	K = 39	Rb = 85,4	Cs = 133	Tl = 204
		? = 45	Sr = 87,5	Ba = 137	Pb = 207
		?Er = 56	Ce = 92		
		?Yt = 60	La = 94		
		?In = 75, 5	Di = 95		
			Th = 118?		

Figure 2.23 Dmitri Mendeleev's original data for the periodic table

Predicting New Elements

Mendeleev noticed some gaps in his chart of the elements, yet was convinced that his organization of the elements was correct. He predicted that new elements would be discovered that would have the properties and atomic mass needed to fit into the gaps. Many scientists didn't agree with Mendeleev's ideas and criticized his work. Within 16 years, however, the gaps were filled through the discovery of new elements that had the properties Mendeleev had predicted.

Figure 2.24 Dmitri Mendeleev, a Russian scientist, discovered a useful way of organizing the elements.

Check and Reflect

Key Concept Review

TOOLBOX

1. What is the basic building block of all compounds?
2. a) Define the term atomic mass.
   b) Why is an understanding of atomic mass important to a person trying to organize elements?
3. List five properties used in describing an element.
4. Using Toolbox 12 as a guide, identify the elements in the following common substances:
   a) Aspirin
   b) battery acid
   c) MSG food additive
   d) vitamin C

Connect Your Understanding

5. What two properties make oxygen different from copper?
6. What properties did Dmitri Mendeleev use to identify patterns in the elements? Were any properties of greater value than others in helping him find patterns?
7. Why was it important for Mendeleev to predict the properties of elements not yet discovered?

Extend Your Understanding

8. How were the patterns in the elements that Mendeleev recognized different from the patterns that John Newlands recognized?

*info***BIT**

A New Element

One of the newest elements to be discovered is ununbium. Scientists worked steadily for 24 days to find just two atoms of ununbium.

2.3 The Periodic Table Today

Dmitri Mendeleev's periodic table included the 63 known elements of his time. Since then, many more elements have been discovered. Today, about 112 elements are known (Figure 2.25).

One of the first important finds using Mendeleev's table was the element gallium. Discovered in 1875, gallium fit into one of the positions in the periodic table where Mendeleev had placed a question mark. It matched almost exactly his prediction of the properties of an element that would fit in that position.

Another question mark in the table wasn't filled until 1939 when the element francium was discovered by the French chemist Marguerite Perey. This element also matched Mendeleev's prediction almost exactly. This proved once again that the periodic table was a useful tool for organizing the elements.

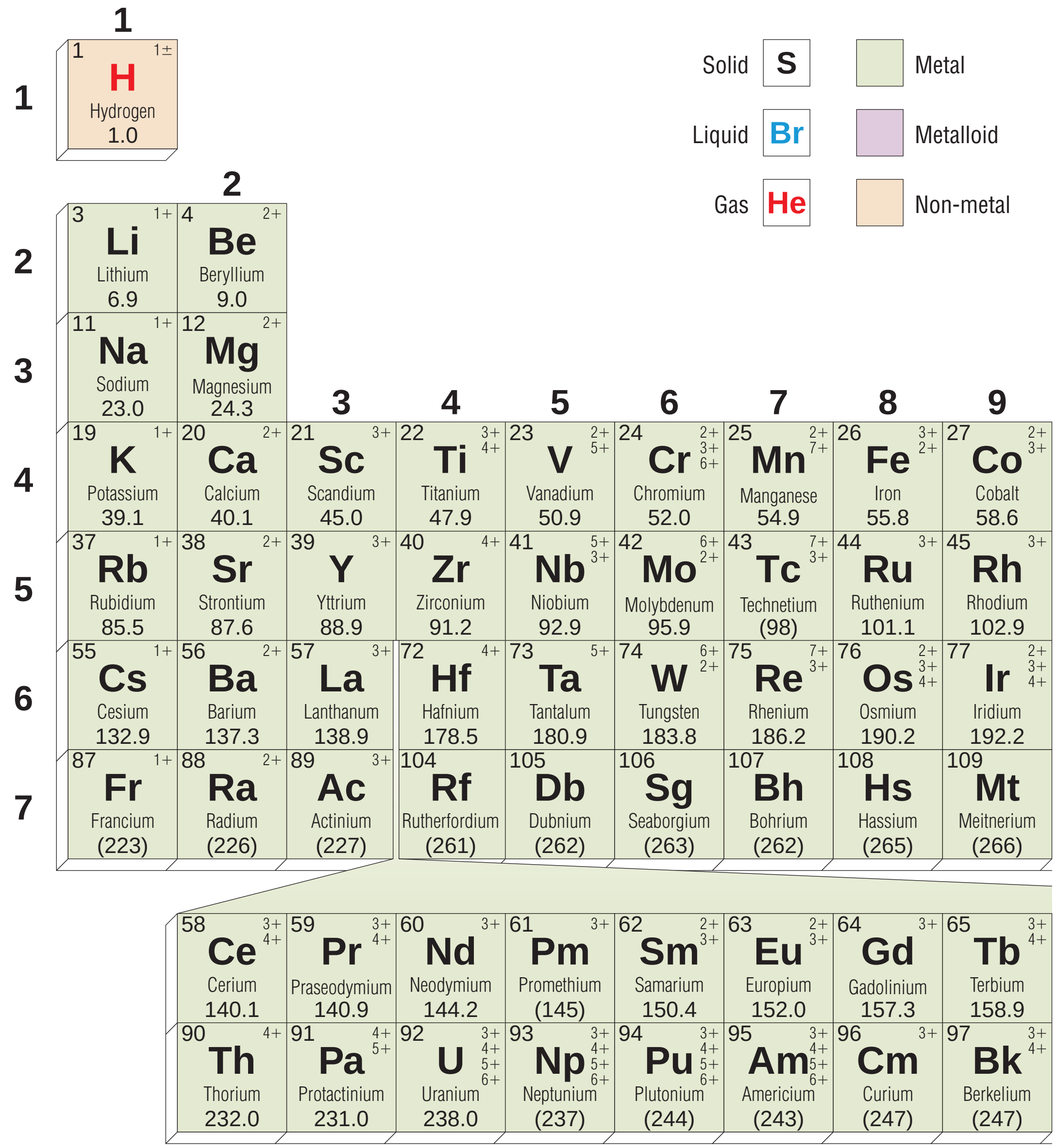
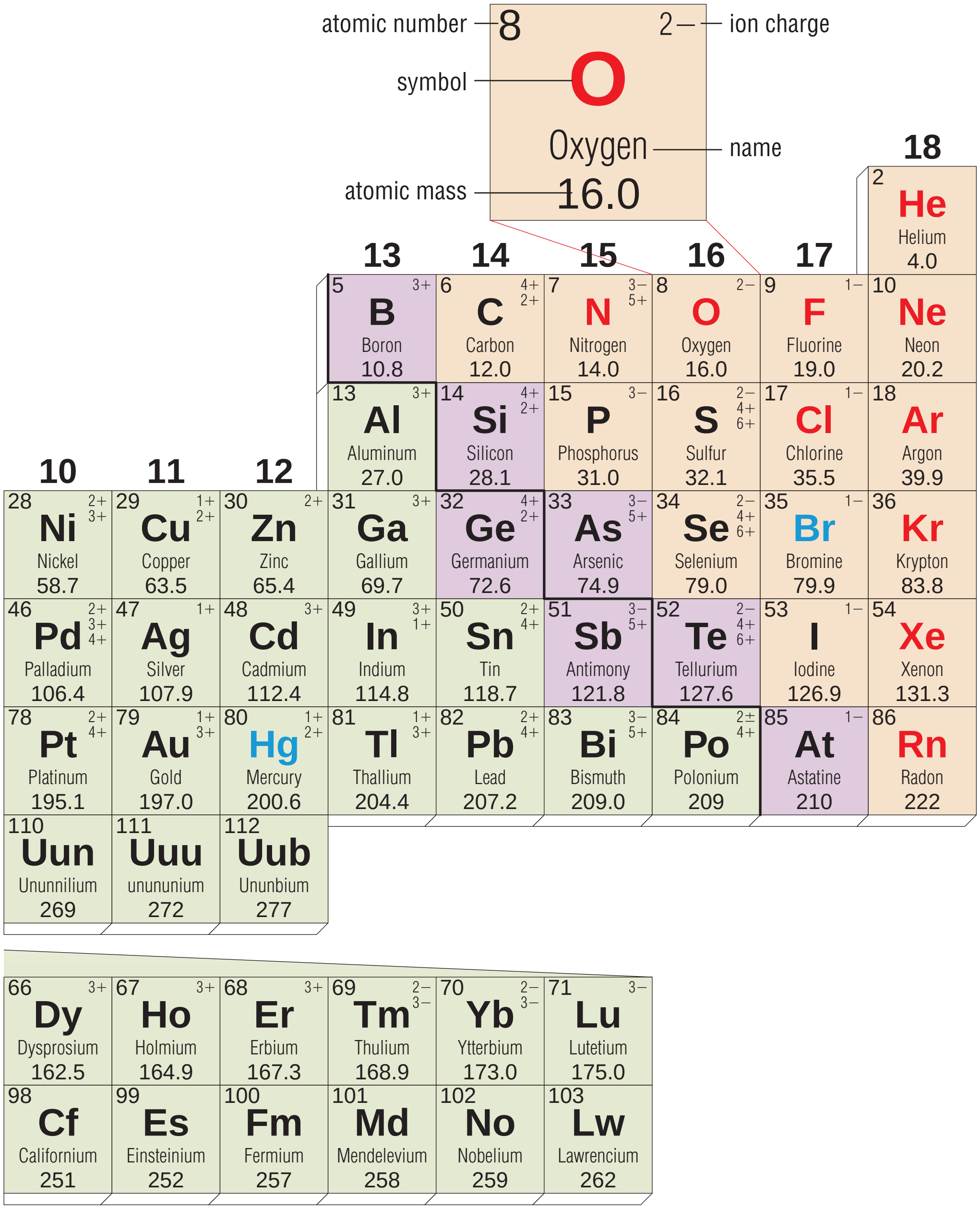


Figure 2.25 The periodic table. The element oxygen is shown as an example of the information that the periodic table provides for each element.

Today, more new elements are being discovered, but many of these are not stable. They have been created in laboratories with special equipment and have never been found in nature. Still, no matter how the elements are identified, they all have their place in the periodic table.

Understanding the Periodic Table

Notice that the periodic table is a series of boxes in rows and columns. Each horizontal row is called a **period** (numbered from 1 to 7). Each vertical column forms a **group**, or **family**, of elements (numbered from 1 to 18). These groups have similar chemical properties. Every box in the table contains several useful pieces of information.



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A Different Version of the Periodic Table

Scientists continue to organize the elements in different ways. One recent example is the three-dimensional periodic table shown here.

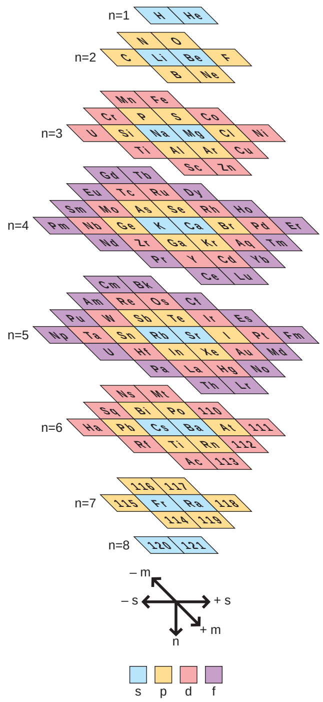


Figure 2.26 Not all scientists who contribute to the understanding of elements are recognized. Canadian Harriet Brooks is a case in point. One of her subjects of study was the radioactive element thorium. Brooks was able to measure the mass of what was thought to be a gas being given off by thorium. She showed that this "gas" was in fact a new element, and it was given the name radon.

Photo Miss Harriet Brooks, Nuclear Physicist, Montreal QC, 1898/Notman Photographic Archives/McCord Museum of Canadian History, Montreal/II-123880

Useful Information on Each Element

Element Symbol and Name

The large letter or letters in each box show the symbol for the element. In Figure 2.25, you can see that oxygen's symbol is O. For most elements, the symbol is an abbreviation derived from the element's modern chemical name. For example, the symbol for silicon is Si, and the symbol for manganese is Mn. However, there are exceptions. For example, the symbol for gold is Au, which is from *aurum,* the Latin word for gold. The symbol for iron is Fe, which is from *ferrum,* the Latin word for iron. The table below shows the word origin for several common elements.

Modern Name	Symbol	Latin Name
antimony	Sb	*stibium*
copper	Cu	*cuprum*
gold	Au	*aurum*
iron	Fe	*ferrum*
lead	Pb	*plumbum*
mercury	Hg	*hydrargyrum*
potassium	K	*kalium*
silver	Ag	*argentum*
sodium	Na	*natrium*
tin	Sn	*stannum*
tungsten	W	*wolfram*

Other Names for Elements

Not all elements are named for Latin words. Some elements are named after the location in which they were first discovered. For example, californium was discovered in 1950 at the University of California. Other elements are named after scientists who made important contributions to their field of study. For example, einsteinium, fermium, and curium are named after Albert Einstein, Enrico Fermi, and Marie Curie.

Atomic Number

The number above the element's symbol on the left is the **atomic number**. It shows how many protons are in the nucleus of one atom of the element. An oxygen atom, for example, always has eight protons. If you found six protons in an atom, the periodic table would show you that you were looking at carbon. Because atoms are neutral, the number of protons equals the number of electrons. Therefore, the atomic number also tells you how many electrons are in an atom of a particular element.

Notice that the atomic number increases by one for each element as you read across the periodic table from left to right.

Atomic Mass

The number below the element's name is the atomic mass. The atomic mass tells you the total mass of all the protons and neutrons in an atom. (Electrons are so tiny that they have very little effect on the total mass of the atom.) Recall that this is the average mass of the element's atoms. Not all atoms in an element have exactly the same mass: some have slightly higher values than others, and some have slightly lower values. This difference occurs because of the different number of neutrons from atom to atom. Atomic mass is measured by **atomic mass unit** (amu). One amu is defined as 1/12th the mass of a carbon-12 atom.

Associated with atomic mass is **mass number**. It represents the sum of the number of protons and neutrons in an atom. For example, the most common form of carbon atom has six protons and six neutrons. Its mass number is therefore equal to 12.

Not all carbon atoms are carbon-12, however. About 1% of carbon atoms have seven neutrons. The mass number of each of those atoms is 13. There is also one more naturally occurring form of carbon atom, and its mass number is 14. How would you find out how many neutrons it has? Subtracting the atomic number (6) from the mass number (14) shows you there are 8 neutrons in the nucleus of this type of carbon atom:

mass number (14) − atomic number (6) = number of neutrons (8)

Carbon-14 is present in nature in very low concentrations. That's good, because carbon-14 is *radioactive*, which means the atom is unstable and falls apart easily in a mini-nuclear reaction, releasing energy. Carbon-14 is present in small amounts in all living things. Scientists use it to find the age of biological materials, such as animal fossils. This technique is called carbon dating.

Element	Atomic Mass (amu)	Mass Number of Most Common Type of Atom of the Element	Mass Number of Second Most Common Type of Atom of the Element
hydrogen	1.0	1	2
carbon	12.0	12	13
bromine	79.9	79	81
iron	55.8	56	54
titanium	47.9	48	46
lead	207.2	208	206
uranium	238.0	238	235

SKILL PRACTICE

USING THE PERIODIC TABLE

Use the periodic table to find out how many protons, electrons, and neutrons are in each of the following elements. The mass number is shown beside each element in parentheses. Make a table in your notebook to record your results.

a) vanadium (51)
b) nickel (58)
c) phosphorous (31)
d) bromine (79)
e) beryllium (9)
f) argon (40)
g) magnesium (24)
h) uranium (238)
i) silicon (28)
j) chromium (52)
k) titanium (48)

ACTIVITY B-3

Inquiry

BUILDING A PERIODIC TABLE

The Question

How can you use a model to represent the patterns in the periodic table?

Procedure

Part 1—Classifying Nuts and Bolts

Materials & Equipment

- 24 assorted nuts and bolts in a bag
- 1 extra nut or bolt
- 2 large sheets of paper
- balance
- element cards
- graph paper

1. Your teacher will give you a bag that contains 24 nuts and bolts. Take the nuts and bolts out of the bag and examine them.
2. Your bag originally contained 25 nuts and bolts, but your teacher removed one of them. Determine whether a nut or a bolt was removed, and provide as much detail as you can about the missing piece.
3. Share your ideas with your class. How were your ideas similar to your classmates? How were they different?
4. Collect the missing nut or bolt from your teacher. How close was your description to the missing object?
5. In step 2, each group probably used a slightly different method of classifying their nuts and bolts to help them identify the missing one. For step 6, everyone will use the same classification.
6. On a large sheet of paper, make a grid with five equal-size columns and five equal-size rows. Make sure the boxes are large enough to hold your largest nut or bolt. Number the boxes 1 to 25 starting on the top left at number 1 and working across the row from left to right. The first box in the second row should be number 6.

Figure 2.27 Step 7

7. Place the smallest bolt at number 1 and the largest nut at number 25. Now organize the rest of your nuts and bolts on the grid.
8. Measure the mass of each nut and bolt and record that information on your grid.

Part 2—Classifying Elements

9. Your teacher will give you a card that describes an element. Find classmates who have element cards that describe elements with properties similar to yours.
10. Tell the class about the properties that the members of your group all share. If the class agrees with your grouping, your teacher will assign your group a number.
11. After everyone in the class has been assigned to groups, arrange all the students in the class in order of atomic mass.
12. Make another five-by-five grid, as you did in step 6. Fill it in using the order of the elements in the class. In your grid, include the atomic mass for each element.

Analyzing and Interpreting

13. Using the data you collected in part 1, make a graph of nut or bolt mass (responding or dependent variable) versus nut or bolt number (manipulated or independent variable). (The number of each nut or bolt is the number of the box in the grid where the nut or bolt was placed.)
14. What patterns do you notice in this graph? Record your observations.
15. Using the data on the elements from part 2, make a graph of atomic mass versus atomic number. What patterns do you notice in this graph? Record your observations.
16. Compare the two graphs you made. What similarities do you see?
17. What similar patterns do you see between the two grids you made in parts 1 and 2?

Forming Conclusions

18. Using the periodic table in Toolbox 12, compare your arrangement of elements with the arrangement of elements in the periodic table. Describe their similarities and their differences.

Applying and Connecting

As the infoBIT on page 127 says, different versions of the periodic table have been developed in the past and are still being developed today. Find examples of these other periodic tables and present your findings to the class.

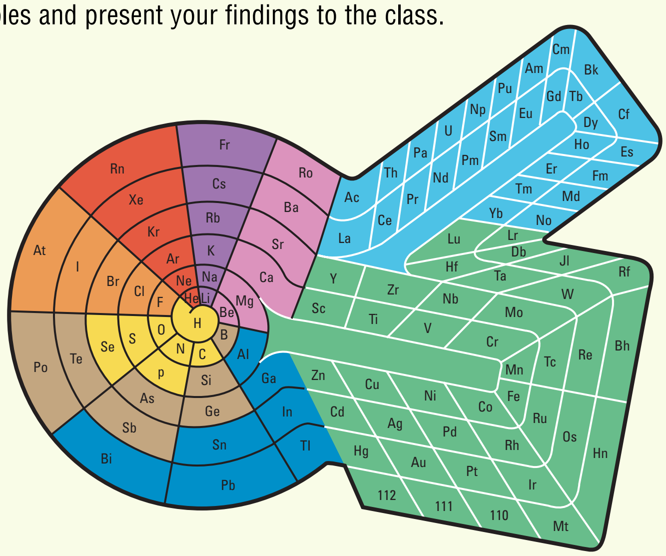


Figure 2.28 This is another version of the periodic table, created by Dr. Theodor Benfey, an American chemist.

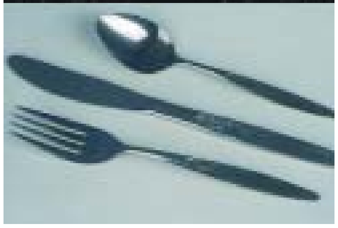


Figure 2.29 Nickel is widely used in solution with other metals to create *alloys*. Some coins are made of copper-nickel alloys. Stainless steel is made of iron, nickel, and other elements.

Figure 2.30 Palladium is used in dental crowns, surgical instruments, and watch parts.

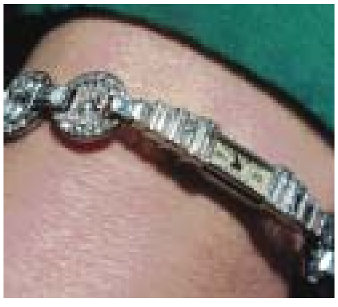


Figure 2.31 Platinum, highly valued as a precious metal, is more expensive than gold. It is also used in industry as a powder that enables chemical reactions to work better.

Patterns of Information in the Periodic Table

The periodic table contains a wealth of information related to the elements, in addition to their atomic number and atomic mass. By noticing where elements appear in the periodic table, you can tell something about their general nature.

Notice that a large part of the periodic table on pages 126–127 is green. All the elements in this area are metals. **Metals** are shiny, malleable, and ductile. They also conduct electricity. The elements in the orange area on the right are non-metals. **Non-metals** can be a solid or a gas. Solid non-metals are dull, brittle elements. Non-metals, except carbon, do not conduct electricity. Because they don't conduct electricity, they are called insulators. The diagonal purple row of elements between the metals and the non-metals contains elements called metalloids. **Metalloids** have both metallic and non-metallic properties.

Groups

Recall that Mendeleev arranged the periodic table to show a variety of patterns. The 18 columns in the table contain groups or families of elements with similar chemical properties.

These groups are numbered from 1 to 18 and are usually referred to by the first element in the column. For example, group 10 is the nickel group of elements because nickel is the first element at the top of that column. The other elements in that group are palladium and platinum. They have properties that are similar to those of nickel. There are a few exceptions to this pattern. Group 1 is divided into two parts—hydrogen and the alkali metals (see page 133). Hydrogen is considered to be a unique element, and in some periodic tables it is placed in a separate spot away from the other elements.

Periods

The rows in the periodic table, called periods, are numbered 1 to 7. The number of elements may vary from period to period. The first period has two elements. Periods 2 and 3 have eight elements, and periods 4 and 5 have 18 elements. You may have also noticed periods 6 and 7 have an additional 14 elements. These elements are placed separately at the bottom of the periodic table. This makes it easier to print a periodic table on a standard-sized page.

As you move from left to right across a period, you will notice that the properties of the elements change. Within the periods, there is a pattern. From left to right, the elements gradually change from metals to non-metals. So the first element in a period, on the far left, is a metal. The last element in a period, on the far right, is a non-metal. For example, if you look at period 4, you'll see that potassium (K) is a metal and krypton (Kr) is a non-metal. The most reactive metals start on the left. As you move right, the metals generally become less reactive.

Other Interesting Patterns

Group 1 elements, not including hydrogen, are called the **alkali metals**. These are the most reactive of the metals. They react when exposed to air or water. As you move down the group, starting with lithium, the reactivity increases. Group 2 elements are called the **alkaline-earth metals**. They react when exposed to air and water as well, but their reactivity is not as strong as that of the alkali metals.

Group 17 elements are called the **halogens**. They are the most reactive non-metals. For example, fluorine can etch glass, chlorine is commonly used to sterilize the water in swimming pools, and bromine gas is so corrosive it can burn skin. These elements are reactive and can combine with other elements to form new substances with useful properties. Sodium, for instance, can be highly reactive with fluorine, producing sodium fluoride—a chemical found in toothpaste.

Group 18 elements are the **noble gases**, the most stable and unreactive elements. In fact, it was long believed that noble gases could never combine with other elements. It wasn't until 1962 when that idea was proved incorrect. Canadian chemist Neil Bartlett and his colleagues at the University of British Columbia synthesized the first noble gas compound, combining xenon, platinum, and fluorine to create a new substance.

reSEARCH

Investigate an Element

Select an element from the periodic table and find as much information as you can about its properties and uses. Create a poster or Web page to illustrate your information. Begin your research at www.pearsoned.ca/scienceinaction.

SKILL PRACTICE

EXPLORING PATTERNS IN THE PERIODIC TABLE

TOOLBOX

Use the periodic table in Toolbox 12 to answer the following questions.

1 a) How many elements are gases at room temperature (20°C)? Write their chemical names and symbols.
b) How many elements are liquids at room temperature (20°C)? Write their chemical names and symbols.

2 What element is found in group 2, period 3?

3 a) What is the symbol of the element with the atomic number 82?
b) What is the atomic number of arsenic?

4 a) What is the symbol of the element with the atomic mass of 238?
b) What is the atomic mass of silver?

5 Use the atomic number, atomic mass, and symbol of the elements to indicate the number of subatomic particles in an atom of the following elements:
a) electrons in oxygen
b) electrons in Li
c) protons in Na
d) protons in helium

6 Two of the most recent elements to be discovered are ununbium and ununquadrium. Ununbium has an atomic number of 112 and an atomic mass of 277. Ununquadrium has an atomic number of 114 and an atomic mass of 289. What do you think the atomic mass of the element with atomic number 113 will be?

Check and Reflect

Figure 2.32 High-energy subatomic particles leave telltale tracks in an experimental cloud chamber.

Key Concept Review

1. What is the difference between the atomic number and the atomic mass of an element?
2. If tin's mass number is 119 and its atomic number is 50, how many neutrons are in the nucleus of an atom of tin?
3. Correct the following statements about the periodic table.
   a) Neon has 11 protons.
   b) The symbol for sodium is So.
   c) Beryllium has 4 neutrons.
   d) Boron and aluminum are metals.
   e) Chlorine has 16 electrons.
4. Match the elements in the list below with one of the following two descriptions:
   i) shiny, ductile conductor of electricity OR
   ii) dull, brittle insulator
   a) P b) W c) Cu d) F e) Hg f) K
5. Match the term on the left with the description on the right.

a) alkali metal	i) a combination of two or more elements
b) halogen	ii) an unreactive non-metal
c) element	iii) very reactive metal
d) compound	iv) a pure substance of the same atoms
e) noble gas	v) very reactive non-metal

Connect Your Understanding

TOOLBOX

6. Use the periodic table in Toolbox 12 to answer the following questions:
   a) What two elements are liquids at room temperature?
   b) What element has the symbol K?
   c) What element has 50 protons?
   d) What element has a mass of 183.8 amu?
7. Hydrogen is considered to be a unique element. Describe three atomic properties that make it different from the other elements.
8. Why isn't atomic mass used to classify an element?

Extend Your Understanding

9. Three containers each hold a different "mystery" element. Four of their properties are shown below. Identify which element is (a) a non-metal, (b) an alkali metal, and (c) a noble gas.

	Colour	State at Room Temperature	Reactivity	Conductivity
Element X	green-yellow	gas	high	no
Element Y	colourless	gas	none	no
Element Z	silver-white	solid	high	yes

Careers and Profiles

Quality Control Analyst

Sona Arslan is a quality control analyst at a large pharmaceutical company.

A quality control analyst tests products to make sure that they meet manufacturing specifications before they are released to consumers. Quality control analysts use a variety of equipment during testing. For example, a quality control analyst testing medicines would use chromatographs, microscopes, lasers, pH meters, and other devices to test the properties of the substances. They also use many different computer applications to analyze the data. Sona Arslan is a quality control analyst for a major pharmaceutical company. Pharmaceutical companies make the wide range of medicines we use, from headache pills to chemotherapy treatments.

Q: Why did you choose the career of quality control analyst?

A: In high school, I liked and did well in chemistry, so I wanted to pursue a career in this field. Quality control analysts work in all types of industries. While at university, I became interested in working in the pharmaceutical industry. In 1998, after I graduated from university with an Honours B.Sc. in chemistry and physics, I obtained a one-year internship at Glaxo Wellcome Inc., one of the largest pharmaceutical manufacturing companies in the world. When I completed the internship, I was offered a position with the company to continue working as a quality control analyst.

Q: What types of skills are required in your work?

A: Some of the skills required are accuracy, attention to detail, organizational skills, and good computer, troubleshooting (problem-solving), and team-work skills.

Q: What do you enjoy most about your work?

A: I enjoy most the "hands on" aspect of my job, as well as the variety of work and challenges that are present. What I do on any given day depends on what test or tests I am working on. There is usually a lot of preparation work that is done before starting a test: glassware and reagents must be gathered, test solutions must be made, and instruments calibrated before testing can begin.

Q: Can you give an example of how a product is tested?

A: Here's what happens when we test an ointment. First, I conduct a physical examination to confirm the colour and consistency of the product. Next, I do a chromatography analysis to confirm that the ointment is homogeneous. This also confirms the identity and amount of the main active ingredient present in the product. Finally, I do a microscopic examination to make sure there is no foreign matter in the product. The test results are reviewed by a senior analyst and then signed off by a manager. The completed test results are sent to the Quality Assurance department. Staff there review the quality control test results before releasing the product for sale. If the sample fails the quality control test, an investigation is conducted to determine whether the failing result is related to analyst or instrument error, or to the product. If it is product related, the batch is rejected. According to Canadian law, no products can be released to market without first passing quality testing.

Q: What advice do you have for someone thinking about a career like yours?

A: You need a B.Sc., preferably in chemistry. It's also very helpful to obtain related work experience during the summer or through a co-op program.

1. Why do you think it's important for a quality control analyst to have a strong knowledge of the properties of matter?
2. What do you think quality control analysts would test for in the following industries?
   - candy making
   - soft drink production
   - synthetic fibre manufacturing (e.g., for clothing and furniture)
3. If you were a quality control analyst, what part of the job would you find most interesting?

SECTION REVIEW

Assess Your Learning

Key Concept Review

1. What is considered to be one of the first series of events in the study of chemistry? Explain why this was an important event.
2. How did an early understanding of gases lead to a better understanding of the atom?
3. What properties could you use to distinguish metals from non-metals?
4. Explain how knowing the boiling point and melting point of a substance can help you identify it.
5. For each statement below, explain why you think it describes an element or a compound.
   a) An odourless, colourless gas produces water and carbon dioxide when it burns.
   b) A shiny, ductile solid cannot be broken into smaller components.
   c) An odourless, colourless liquid can be broken into two different gases when electricity is passed through it.
   d) A toxic, green gas is very reactive with other metals and some non-metals.
6. What is the difference between a group and a period in the periodic table?

Connect Your Understanding

7. Human history is divided into ages. How did an understanding of matter help humans move from the Stone Age to the Iron Age?
8. Describe the atomic model developed by each of the following people:
   a) Democritus
   b) Nagaoka
   c) Bohr
   d) Chadwick
9. The diagram in Figure 2.33 is a box from the periodic table. Label each item of information in the box. What does each item tell you about the element?
10. Copy the picture of the atom shown in Figure 2.34 into your notebook. Use the models of the atom developed by Ernest Rutherford and James Chadwick to label its parts.
11. While making a dessert in your kitchen, you realize that the salt, baking soda, and cornstarch are in unlabelled containers. What properties could you use to identify each substance? No tasting allowed!

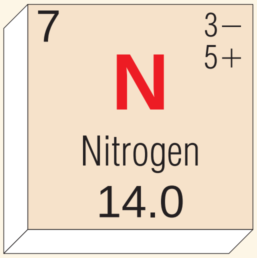


Figure 2.33 Question 9

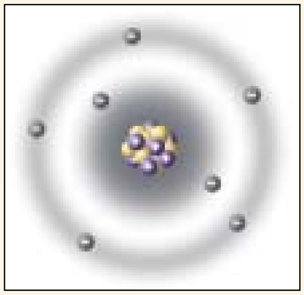
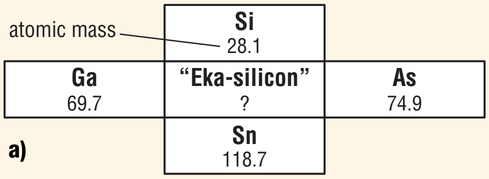


Figure 2.34 Question 10

Extend Your Understanding

12. Mendeleev believed that one of the gaps in his first periodic table would eventually be filled by an element he called *eka-silicon* (Figure 2.35a). Such an element had not yet been discovered. In 1871, he predicted what the properties of this undiscovered element would be. In 1886, he was proven correct.



b)

Some Properties of Selected Elements		
Element	**Colour**	**Atomic Mass**
Silicon	steel grey	28.1
Gallium	grey-black	69.7
Eka-silicon		
Arsenic	silver to grey-black	74.9
Tin	grey-white	118.7

Figure 2.35 Question 12

Use the information in Figure 2.35b to answer the following questions:

a) Which of the four elements in Figure 2.35b would you use to predict the properties of Mendeleev's new element? Explain your reasoning.
b) What atomic mass would you predict for *eka-silicon*?
c) What colour would you predict *eka-silicon* to be?
d) What do we now call *eka-silicon*?
e) Why do you think Mendeleev did not use the atomic number in his work?

Focus On THE NATURE OF SCIENCE

An idea, such as the description of the structure of an atom, develops through the contributions of many people over a long period of time. This is a common process for developing ideas in science. By sharing and collaborating with people all over the world, scientists make and investigate discoveries. Consider the following questions and, if possible, use examples from this section to support your answers.

1. What conditions or factors were necessary for ideas on the structure of the atom to be shared?

2. What is the value of sharing your discoveries with others?

3. Why would some people consider not sharing their discoveries with others?

3.0 Compounds form according to a set of rules.

Key Concepts

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

- periodic table
- elements, compounds, and atomic theory
- chemical nomenclature

Learning Outcomes

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

- distinguish between ionic and molecular compounds, and describe the properties of some common examples of each
- read and interpret chemical formulas for compounds of two elements, and give the IUPAC name and common name of these compounds
- identify/describe chemicals commonly found in the home, and write the chemical symbols
- identify examples of combining ratios/number of atoms per molecule found in some common materials, and use information on ion charges to predict combining ratios in ionic compounds of two elements
- assemble or draw simple models of molecular and ionic compounds

All the signs above tell you that this is where you can get gas for your car. If you were travelling in France, you would look for a sign that said "Gaz." If you were travelling in Britain, you would have to watch for a sign that said "Petrol." Even though Britain and Canada are both English-speaking countries, sometimes we use different words for the same things. For example, in England, potato chips are called "crisps" and the trunk of your car is called the "boot." If you travel to a non-English-speaking country, words can be even more confusing if you don't speak the local language.

Scientists studying the nature of matter encountered similar problems. At first, there was no common way of naming compounds. How could scientists understand each other's work if they weren't sure from the terminology what materials were being used? To help reduce the confusion, scientists have agreed on a common set of rules for naming compounds. Using these rules, a person can identify and describe any compound in the world—and be clearly understood by others. In this section, you will investigate how compounds are formed and how they are named.

 For Web links relating to 3.0, visit **www.pearsoned.ca/scienceinaction**

3.1 Naming Compounds

Earlier in this unit, you learned how our understanding of the structure of the atom has gradually developed. At first, people thought the atom was the smallest particle possible (atom, you'll recall, comes from the Greek word *atomos*, meaning indivisible). Today we know that the atom is made of several much smaller particles.

infoBIT

How Big Are Atoms?
Five-hundred-million gold atoms lined up side-by-side would form a line as long as a $10 bill.

Combining Elements to Make Compounds

Look around your home and you'll be amazed at the variety of chemicals in your cupboards and on your shelves. In the bathroom, you'll find water, soap, shampoo, and toothpaste—all chemicals. In the basement or garage, you may find cleaning products, such as ammonia and bleach, and perhaps painting and gardening products. In your kitchen, you'll likely find table salt, baking soda, and baking powder. Each of these compounds has a chemical name and a **chemical formula**. The formula identifies which elements, and how much of each, are in the compound. So, for example, table salt's chemical name is sodium chloride and its formula is NaCl. Baking soda's chemical name is sodium bicarbonate and its chemical formula is $NaHCO_3$.

Figure 3.1 Most homes contain a range of chemical compounds, such as the ones shown here.

SKILL PRACTICE

Make a Model of an Atom

Your teacher will give you some of the following materials: paper, bingo chips, coins, Plasticine, and rubber magnetic strips. Your task is to choose an element from the first 18 in the periodic table and construct a model of what you think that element's atom would look like. Remember to consider the information you learned in subsection 2.1 about the atom and evolving ideas about its structure.

Your model should clearly show the structure of the atom and should include the correct number of protons, neutrons, and electrons.

When you have completed your model, show it to your class. Compare your model with other models.

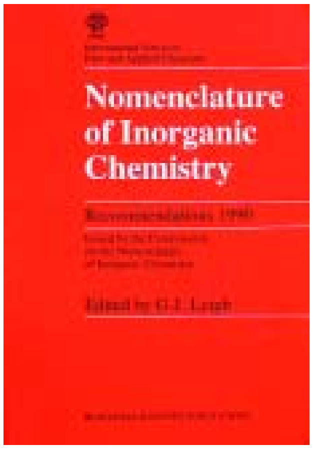


Figure 3.2 The IUPAC book contains the rules for naming chemical compounds.

Naming Chemical Compounds

Until the 18th century, no standardized system existed for naming chemicals. This created confusion because the names for chemical compounds varied from country to country and scientist to scientist. For example, hydrochloric acid and muriatic acid refer to the same thing. If you didn't know that, you might think they were two different chemicals. Today, some compounds are better known by their common name. Bleach, for instance, is almost always used instead of the chemical name aqueous sodium hypochlorite.

In 1787, a French chemist named Guyton de Morveau created a naming system, or nomenclature, for compounds. He decided to use the chemical name for each element in the compound, always putting the metal element first. For example, zinc and oxygen combine to form zinc oxide. Since 1920, the International Union of Pure and Applied Chemistry (IUPAC) has been the body responsible for agreeing on the appropriate name for every chemical compound discovered.

*QUICK***LAB**

Common Chemicals in Your Home

Purpose

To learn about the chemical formulas of compounds by "buying" common household substances with "element money"

Procedure

1. Your teacher will give your group a selection of element cards and an information sheet. The cards are your element money. The information sheet tells you how to interpret the chemical formula for each item.
2. At the front of the class are several common items with labels. Each item can be purchased from the storekeeper (your teacher) with the correct amount of element money. Each group will have an opportunity to purchase an item.
3. You may purchase any of these items with the cards you have. For example, one of the components of toothpaste has the chemical formula NaF. If you want to buy some toothpaste, you need one sodium card (Na) and one fluorine card (F).
4. Note that each item has a value. Compounds made of two or more elements are more valuable than items made of one element.
5. When you have bought all your items, your group may trade any remaining cards with other groups.
6. Calculate the total value of the items you purchased.

Questions

7. What was the cost for each item you bought?
8. Were some materials easier to purchase than others? Explain your answer.
9. Describe any patterns you observed between the chemical formula and the "cost." (Hint: Using the periodic table might help you with your answer.)

Interpreting Chemical Names and Formulas from Compounds

If you know only the formula of a chemical compound, you can determine its chemical name. If you know only its name, you can determine its formula. Table salt's chemical name, sodium chloride, indicates that the compound is made of one atom of sodium and one atom of chlorine (Figure 3.3). Its chemical formula, NaCl, indicates this too.

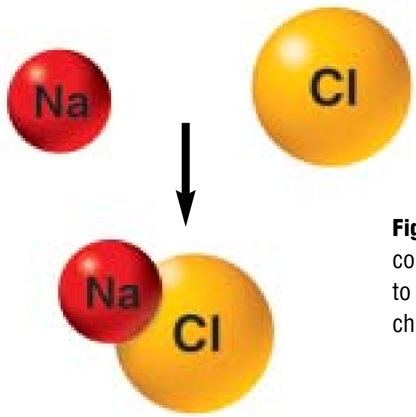


Figure 3.3 One sodium atom combines with one chlorine atom to form the compound sodium chloride, which we call table salt.

Now look at the formula for the compound water: H_2O. Notice that next to the H is a small 2 as a subscript. ("Sub" means below.) The 2 indicates that there are two atoms of hydrogen to go with every atom of oxygen in water. Figure 3.4 shows how the atoms in water are arranged. Subscript numbers in a chemical formula indicate the number of atoms of the elements that must combine to form the compound. No subscript number indicates that only one atom of that element is needed.

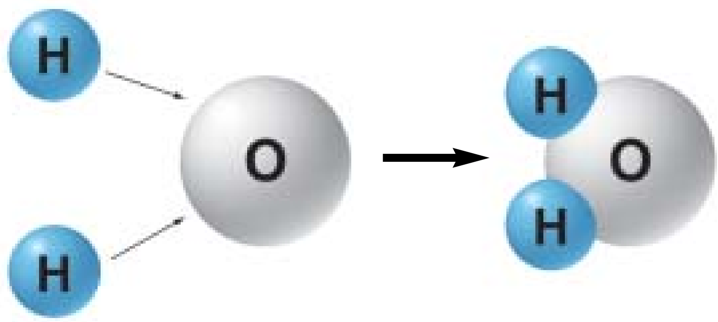


Figure 3.4 In water, two hydrogen atoms join with each oxygen atom.

Compound	Chemical Formula	Elements	No. of Atoms of Each	Total No. of Atoms
sodium chloride	NaCl	• sodium • chlorine	1 1	2
water	H_2O	• hydrogen • oxygen	2 1	3

reSEARCH

Chemical Formulas of Household Products

Many household chemicals have a common name rather than a chemical formula. Find the chemical formula for some of these household chemicals. Begin your search at www.pearsoned.ca/scienceinaction.

Indicating the Physical State of a Compound

Another common notation added to chemical compounds indicates the state of the chemical at room temperature. After the chemical formula, a subscript *s* for solid, *l* for liquid, or *g* for gas is shown in parentheses. For example, sodium chloride is written as $NaCl_{(s)}$, water is written as $H_2O_{(l)}$, and natural gas (methane) is written as $CH_{4(g)}$. For aqueous solutions (substances dissolved in water), a subscript *aq* in parentheses is added to the formula. So, if sodium chloride was dissolved in water, the resulting aqueous solution would be written as $NaCl_{(aq)}$.

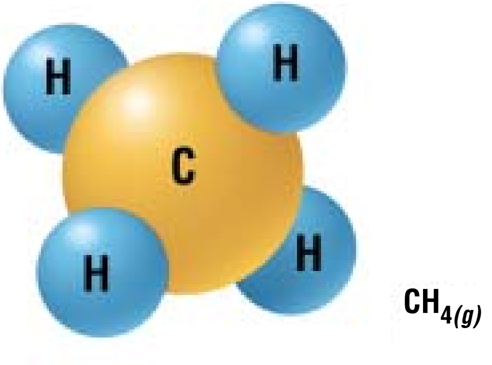


Figure 3.5 In methane, four hydrogen atoms combine with one carbon atom.

SKILL PRACTICE

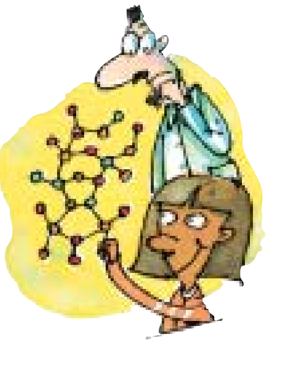
Working with Compounds

Referring to the compounds listed in the table below, complete the following.

- List the elements present in the compound.
- State the number of atoms of each element in the compound.
- In your notebook, draw what this compound would look like. Refer to Figures 3.3, 3.4, and 3.5 for your drawings. If time permits, create a model of each compound. Use materials of your own choosing.

Create a table like the one below to record your answers. Be sure to leave enough room to draw the compound in the far right column.

Compound	Elements in Compound	No. of Atoms in Each Element	Drawing of Compound
$CaO_{(s)}$			
$CaCl_{2(s)}$			
$Al_2O_{3(s)}$			
$Na_2O_{(s)}$			
$AlCl_{3(s)}$			
$KCl_{(s)}$			
$NaOH_{(s)}$			



Check and Reflect

Key Concept Review

1. What information can you determine from a chemical formula?
2. Identify the elements in each of the following compounds.
   a) $HF_{(g)}$
   b) $Li_2O_{(s)}$
   c) $K_3P_{(s)}$
   d) $Ni_2O_{3(s)}$
   e) $HgCl_{2(s)}$
3. How many atoms are indicated in the formula of each of the following compounds?
   a) Silver chloride—$AgCl_{(s)}$
   b) Calcium oxide—$CaO_{(s)}$
   c) Magnesium nitride—$Mg_3N_{2(s)}$
   d) Aluminum oxide—$Al_2O_{3(s)}$
   e) Scandium sulfide—$Sc_2S_{3(s)}$

Connect Your Understanding

4. Write the chemical formula for each of the following compounds:
   a) sodium sulfide, which has two atoms of sodium and one atom of sulfur
   b) aluminum fluoride, which has one atom of aluminum and three atoms of fluorine
   c) oxygen gas, which has two atoms of oxygen
   d) glucose, which has six carbon atoms, 12 hydrogen atoms, and six oxygen atoms

Extend Your Understanding

5. Acetylsalicylic acid, commonly called Aspirin, has the chemical formula $C_9H_8O_{4(s)}$. Urea, also called carbamide, has the formula $H_2NCONH_{2(s)}$. Compare and contrast the two formulas in terms of total elements and atoms.

3.2 Ionic Compounds

(a) (b) (c)

Figure 3.6 Sodium, shown in (a), is a metal. Sodium combines with chlorine gas in a violent reaction (b). The product is table salt, $NaCl_{(s)}$ (c).

Most people are familiar with common table salt and know that it is a white substance composed of tiny crystals. You might be surprised to learn that table salt is formed when a very reactive metal—sodium—is placed in a container with a poisonous, green non-metal—chlorine gas. When the two chemical elements are combined, the sodium metal explodes in a bright yellow flame. As the sodium burns, a white, coarse-grained powder is produced. That powder is table salt, or what you now know is sodium chloride ($NaCl_{(s)}$).

Sodium chloride is called an **ionic compound**. Ionic compounds are pure substances formed as a result of the attraction between particles of opposite charges, called ions. Table salt is formed from positively charged sodium ions and negatively charged chloride ions. Other properties of ionic compounds include their high melting point, good electrical conductivity, and distinct crystal shape.

All ionic compounds are solids at room temperature. In fact, table salt will not melt until it is heated to 801°C. When an ionic compound is melted or dissolved in water, it will conduct electricity. This property of ionic compounds led to the study of electrochemical cells (cells that either convert chemical energy into electrical energy or electrical energy into chemical energy). And that work in turn eventually led to the invention of batteries.

This new technology allowed scientists to investigate the structure of matter in greater depth.

How does an ionic compound actually form? When the ions are combined, they form a crystal.

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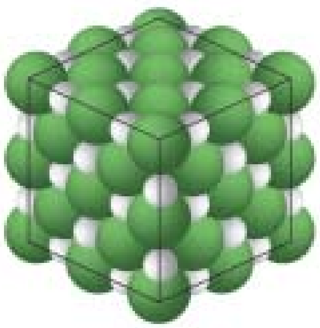
"Ion" Origin

The word "ion" comes from a Greek word meaning "to go" or "wander."

Figure 3.7 The crystals in this table salt are held together by ionic bonds.



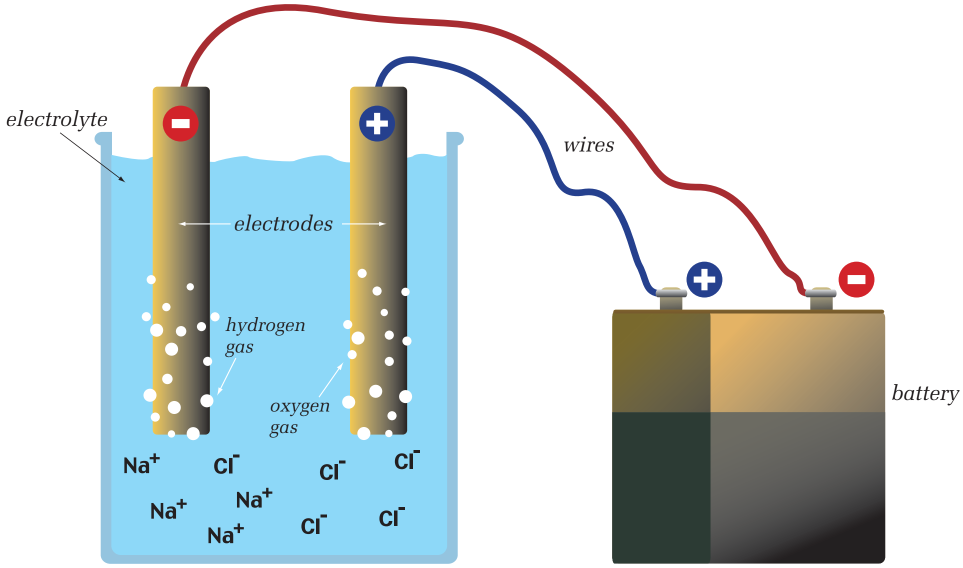


Figure 3.8 Two electrodes are placed in an electrolyte, water containing a little $NaCl_{(s)}$ forming $NaCl_{(aq)}$. The salt helps the electrical charge flow through the solution. At the negative electrode, positively charged hydrogen forms hydrogen gas. At the positive electrode, negatively charged oxygen forms oxygen gas. Chlorine gas may also be formed. In school laboratories, $Na_2SO_{4(s)}$ is used instead of $NaCl_{(s)}$.

QUICKLAB

Using Batteries to Investigate a Chemical Reaction

Purpose

To investigate the behaviour of ions

(Note: Your teacher may demonstrate this activity on the overhead projector.)

Procedure

1. Fill a Petri dish about two-thirds full with water. Add two to four drops of universal indicator.
2. Attach the end of one wire to the graphite at one end of a pencil. Attach the other wire to the second pencil in the same way. Make sure both ends of the pencils are sharpened so that the graphite is exposed. Attach the other ends of the wire to the battery.
3. Place the other sharpened ends of the pencils into the Petri dish, keeping the ends well apart. Record your observations.
4. Remove the pencils and place them in a safe spot.
5. Add several crystals of sodium sulfate to the Petri dish and stir until dissolved.
6. Repeat step 3. Do you observe any additional changes if you add a little more sodium sulfate?

Questions

7. What changes did you observe after the sodium sulfate was added to the Petri dish?
8. What evidence was there of a chemical change?
9. What do you think would happen if you added a non-ionic compound such as sugar to the Petri dish?

Materials & Equipment

- clear Petri dish
- water
- universal indicator
- 2 pencils sharpened at both ends
- 2 wires with alligator clips
- 9-V battery
- sodium sulfate ($Na_2SO_{4(s)}$)

reSEARCH

Ions and the Body

Metal ions such as Na^+, K^+, Mg^{2+}, Sn^{2+}, and Ca^{2+} are important in enabling our bodies to function properly. Find out the role of these ions in the human body. Begin your search at www.pearsoned.ca/scienceinaction.

When the ionic compound is dissolved in water, the metal and non-metal form an aqueous solution of **ions**. An ion is an atom or a group of atoms that has become electrically charged through the loss or gain of electrons. The table below shows some examples of ion charges for various elements.

Element	Ion Charge	Ion Notation
Hydrogen	1+	H^+
Lithium	1+	Li^+
Nitrogen	3−	N^{3-}
Oxygen	2−	O^{2-}
Fluorine	1−	F^-
Sodium	1+	Na^+
Magnesium	2+	Mg^{2+}
Aluminum	3+	Al^{3+}
Sulfur	2−	S^{2-}
Iron	2+ or 3+	Fe^{2+} or Fe^{3+}
Copper	1+ or 2+	Cu^+ or Cu^{2+}
Lead	2+ or 4+	Pb^{2+} or Pb^{4+}

Ion Charges

To indicate ions in written notation, a plus sign (+) or a minus sign (−) is placed to the upper right of the element symbol. This is a superscript position (*super*- means "above"). For example, a sodium ion is written as Na^+ and a chlorine ion as Cl^-.

Some ions can also form when certain atoms of elements combine. These ions are called **polyatomic ions** (*poly*- means "many"). Polyatomic ions are a group of atoms acting as one. For example, one atom of carbon and three atoms of oxygen form the polyatomic ion called carbonate or CO_3^{2-}. When carbonate reacts with calcium ions, the product is calcium carbonate, or limestone ($CaCO_{3(s)}$). Other examples of compounds with polyatomic ions include copper(II) sulfate ($CuSO_{4(s)}$) and sulfuric acid ($H_2SO_{4(aq)}$).

Naming Ionic Compounds

When naming an ionic compound, there are two rules to remember. First, the chemical name of the metal or positive ion goes first, followed by the name of the non-metal or negative ion. Second, the name of the non-metal negative ion changes its ending to *ide*. This is the reason that the chemical name for $NaCl_{(s)}$ is not sodium chlorine, but sodium chloride.

There is one exception to these naming rules. Where negative ions are polyatomic ions, the name remains unchanged. Limestone's chemical name therefore remains calcium carbonate.

You'll notice in the table above that iron, copper, and lead have more than one ion charge. Some elements have this property. To show clearly which ion is being used in a chemical name, a Roman numeral is added. For example, iron(II) oxide is a compound containing the Fe^{2+} ion. Iron(III) oxide contains the Fe^{3+} ion.

Using Ion Charges and Chemical Names to Write Formulas

Once you know the ion charge and the chemical name of a substance, you can determine its chemical formula. The following steps will help you write the formulas for ionic compounds.

Step 1 Print the metal element's symbol with its ion charge. Next to it, print the non-metal element's symbol with its ion charge.	Ca^{2+} Cl^{1-}
Step 2 Balance the ion charges. The positive ion charge must balance the negative ion charges. In our example, this means that there must be two chlorine atoms each with an ion charge of 1− to balance the 2+ ion charge of one calcium atom. Now you know how many atoms of each element you need to include in the formula.	Ca^{2+} Cl^{1-} Cl^{1-}
Step 3 Write the formula by indicating how many atoms of each element are in it, as shown. Do not include the ion charge in the formula. Place the number of atoms of each element in a subscript after the element's symbol. If there is only one atom, no number is used.	$CaCl_{2(s)}$

Ion Charges and the Periodic Table

Take a moment to look at the periodic table in section 2.3 and the common ion charge. Do you see a pattern? The first group of elements on the left side of the table is the alkali group of metals—lithium and sodium. They each have an ion charge of 1+. The halogens, on the right of the table—fluorine and chlorine—have an ion charge of 1−. Generally, all the elements in a group form ions with the same charge. This pattern is the most consistent at either end of the periodic table. Figure 3.9 illustrates the ion charges of the elements that follow this pattern the best.

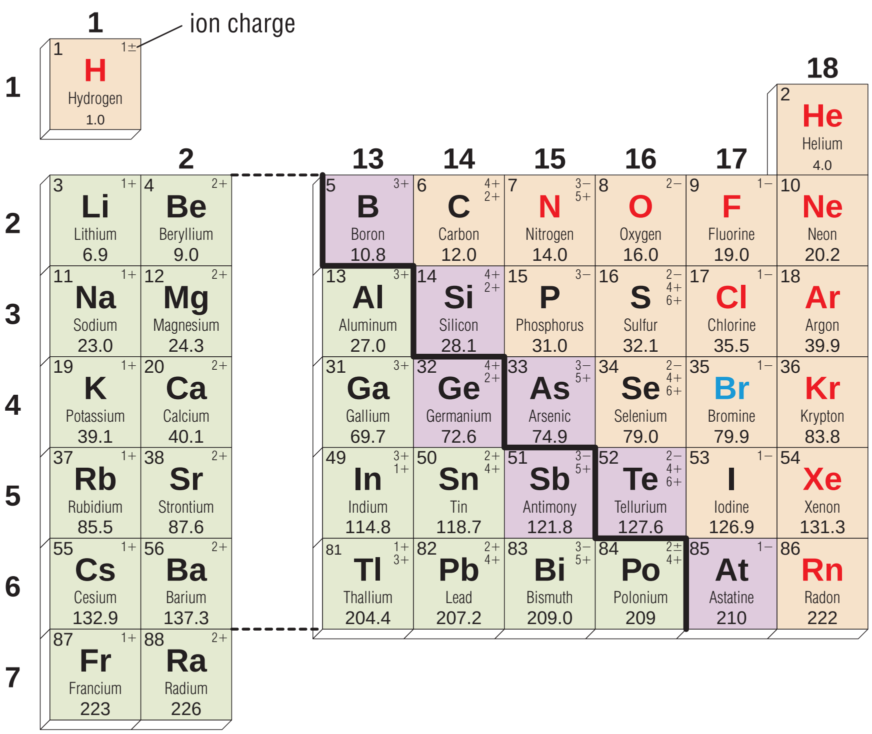


Figure 3.9 Ion charges of some of the groups in the periodic table

Activity B-4

Inquiry

Modelling Ionic Compounds

The Question

How can you create a model to illustrate an ionic compound?

Materials & Equipment

- marshmallows, marbles, Styrofoam balls, egg cartons, or a molecular model kit
- glue
- large sheet of paper
- felt pens

Figure 3.10 Step 4

Procedure

1. Working with a partner, select one metal and one non-metal element from the periodic table. Your task is to create a model illustrating the ionic compound that forms from combining these two elements. This type of ionic compound is called a binary compound because it consists of just two elements.
2. Determine how you will represent the atom of each element.
3. Decide which materials you will use to build your model.
4. Build your model to show one formula unit.
5. State the appropriate name for your compound, write out its chemical formula, and describe its combining ratio.
6. Repeat steps 1 to 5 to create three additional ionic compounds. Ensure that at least one of them is an example of a metal with multiple ion charges.
7. When you are finished, share your models with the class.

Analyzing and Interpreting

8. What did your models have in common with other models?
9. How were your models different from other models?

Forming Conclusions

10. Describe how you created models that illustrate ionic compounds.

Check and Reflect

Key Concept Review

1. What is an ionic compound?
2. List three properties of all ionic compounds.
3. How is an ion formed?
4. What is the difference between Fe^{2+} and Fe^{3+} ?
5. If an element has more than one ionic charge, how is that piece of information represented in a chemical name?

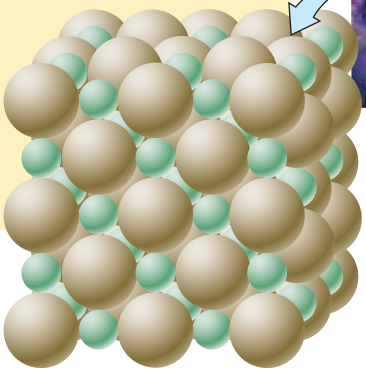
Connect Your Understanding

6. Outline the steps for writing the chemical formula of an ionic compound.
7. Write the formula for the following compounds:
   a) sodium fluoride
   b) magnesium sulfide
   c) lithium oxide
   d) iron(III) chloride
   e) copper(II) phosphide
   f) magnesium iodide
   g) iron(II) phosphide
   h) aluminum nitride
8. Write the chemical name for the following formulas:
   a) $LiCl_{(s)}$
   b) $Ca_3P_{2(s)}$
   c) $AlBr_{3(s)}$
   d) $PbS_{2(s)}$
   e) $Fe_2O_{3(s)}$
   f) $Na_2O_{(s)}$
   g) $CaS_{(s)}$
   h) $CuSO_{4(s)}$

Extend Your Understanding

9. What ion charge patterns are there in the periodic table?

sodium chloride crystals



Na^+ ions and Cl^- ions arranged in a crystal of sodium chloride

Figure 3.11 Each substance has a different crystal shape. Knowing the type of crystal a substance forms can help in identifying it. Pictured here are sodium chloride crystals.

infoBIT

Carbon Compounds
Scientists have discovered more than 10 million compounds. At least 9 million are molecular compounds containing the element carbon.

3.3 Molecular Compounds

When non-metals combine, a pure substance called a **molecule** or a **molecular compound** is formed. Molecular compounds differ from ionic compounds in several ways. They can be solids, liquids, or gases at room temperature. They tend to be insulators, or poor conductors of electricity. They also have relatively low melting and boiling points because the forces between the molecules are weak. Examples of molecular compounds include sugar, acetylene, and water.

Figure 3.12 Sugar ($C_{12}H_{22}O_{11(s)}$) is a common molecular compound.

QUICKLAB

Ionic or Molecular Compound?

Purpose

To determine through experimentation whether a substance is an ionic compound or a molecular compound

Procedure

1. Set one of the 100-mL beakers in the dish or large bowl.
2. Using tongs, place several pieces of solid air freshener into the beaker.
3. Put the watch glass or Petri dish on top of the beaker and cover with ice.
4. Pour hot water into the dish to a depth of 2 cm. The water does not have to be boiling, but must be above 45°C (use the thermometer if necessary).
5. Record your observations every 5 min for 30 min.
6. In a second beaker containing water, place another piece of air freshener. Record your observations.
7. Test the conductivity of the air freshener.

Questions

8. From your observations, do you think the air freshener is an ionic compound or a molecular compound?
9. Did you collect any evidence that seemed to contradict the conclusion drawn in question 8?

Materials & Equipment

- two 100-mL beakers
- dish or large bowl
- tongs or forceps
- several small pieces of solid air freshener
- watch glass or Petri dish
- ice
- hot water
- thermometer
- pencil and notebook

Caution!
Handle the air freshener with tongs, not directly with your fingers. Do not directly inhale the vapour.

ACTIVITY B-5

Inquiry

MODELLING MOLECULAR COMPOUNDS

The Question

How can you create a model to illustrate a molecular compound?

Materials & Equipment

- marshmallows, Styrofoam balls, egg cartons, or a molecular model kit
- glue
- large sheet of paper
- felt pens

Procedure

1. Working with a partner, select two non-metal elements from the periodic table. Your task is to create a model illustrating a molecular compound that forms from combining these two elements.
2. Determine how you will represent the atom of each element.
3. Decide which materials you will use to build your model.
4. Build your model.
5. State the appropriate name for your compound, write out its chemical formula, and describe its combining ratio.
6. Repeat steps 1 to 5 to create three additional molecular compounds.
7. When you are finished, share your models with the class.

Analyzing and Interpreting

8. What did your models have in common with other models?
9. How were your models different from other models?

Forming Conclusions

10. Describe how you created models that illustrate molecular compounds.

Figure 3.13 Step 4

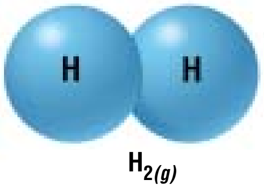


Figure 3.14 In a molecule of hydrogen gas, two hydrogen atoms combine to form the molecule. The formula is $H_{2(g)}$.

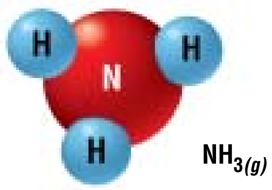


Figure 3.15 In a molecule of ammonia, each hydrogen atom is attached to the nitrogen atom. The formula is $NH_{3(g)}$.

Writing Formulas for Molecular Compounds

Writing formulas for molecular compounds is similar to writing formulas for ionic compounds, except that no ions are present and the ion charge is not used in the formulas. This makes it hard to predict how non-metals combine. However, the formulas still clearly show what elements are present, and how many of each type of atom make up the molecule. For example, hydrogen gas is usually found as H_2. Each molecule has two atoms of hydrogen connected to each other.

For ammonia ($NH_{3(g)}$), the situation is similar. Three hydrogen atoms combine with the nitrogen atom.

Naming of Molecular Compounds

Many molecular compounds are often known by their common names. Two compounds you have encountered in this section are water and ammonia. The names of these compounds do not give any indication of the elements they are made from. All molecular compounds, except those containing hydrogen, can be named using the following rules. Common names are used for molecular compounds containing hydrogen.

1. The first element in the compound uses the element name—just like ionic compounds.
2. The second element in the compound has the suffix 'ide'—just like ionic compounds.
3. When there is more than one atom in the formula, a prefix is used which specifies the number of atoms. Some prefixes are listed below.
4. An exception to rule 3 is when the first element has only one atom, the prefix *mono* is not used.

Number of Atoms	Prefix
1	mono
2	di
3	tri
4	tetra
5	penta

Using the above rules, molecular compounds are named using this format:

Prefix + First Element **Prefix** + Second Element (with 'ide' ending)

Here are some examples: (Note that the coloured numbers in the formula correspond to the prefixes in the name.)

CO_2	carbon **di**oxide
N_2O	**di**nitrogen **mono**xide
N_2O_3	**di**nitrogen **tri**oxide
NF_3	**ni**trogen **tri**fluoride
CCl_4	carbon **tetra**chloride
PF_5	phosphorus **penta**fluoride

reSEARCH

Bonding Forces

Use your library and the Internet to find out about other types of forces that create bonds between atoms. Begin your research at www.pearsoned.ca/scienceinaction.

Comparing Ionic and Molecular Compounds

The table below and the one on the next page list the melting and boiling points for some common ionic and molecular compounds. By comparing the information in these tables, you will see several differences between the two types of compounds. For example, baking soda, an ionic compound, boils at 1550°C. Carbon dioxide, a molecular compound, boils at −78.5°C.

Figure 3.16 Examples of ionic compounds

Ionic Compound	Formula	Melting Point (°C)	Boiling Point (°C)
lye	$NaOH_{(s)}$	318°	1390°
silver nitrate	$AgNO_{3(s)}$	212°	440° (decomposes)
baking soda	$NaHCO_{3(s)}$	455°	1550°
salt	$NaCl_{(s)}$	801°	1413°

Molecular Compound	Formula	Melting Point (°C)	Boiling Point (°C)
carbon dioxide	$CO_{2(g)}$	(changes directly from solid to gas)	−79°
water	$H_2O_{(l)}$	0°	100°
sugar	$C_{12}H_{22}O_{11(s)}$	185°	(decomposes)
rubbing alcohol	$C_3H_8O_{(l)}$	−90°	82°

Figure 3.17 Examples of molecular compounds

Check and Reflect

Key Concept Review

1. Define a molecular compound and give an example of one.
2. List three properties of a molecular compound.
3. Draw a simple model to show a molecule for each of the following:
   a) chlorine gas ($Cl_{2(g)}$)
   b) phosphorus trichloride ($PCl_{3(g)}$)
   c) nitrogen monoxide ($NO_{(g)}$)
   d) iodine bromide ($IBr_{(g)}$)
4. Describe one test that can be performed to determine whether a substance is ionic.

Connect Your Understanding

5. Which of the following compounds are molecular?
   a) $H_2O_{(l)}$
   b) $NaCl_{(s)}$
   c) $NH_{3(g)}$
   d) $F_{2(g)}$
   e) $CuCl_{2(s)}$
   f) $CCl_{4(l)}$
6. Write the chemical formula for the following molecular compounds:
   a) dinitrogen trioxide
   b) sulfur trioxide
   c) carbon tetrachloride
   d) phosphorus pentachloride
   e) carbon disulfide

Extend Your Understanding

7. Create a Venn diagram that compares the properties of a molecular compound with those of an ionic compound.

Assess Your Learning

Key Concept Review

1. Explain the two rules to follow when naming an ionic compound.

2. For each substance below, name the elements and indicate the number of each kind of atom present in one formula unit.
a) $HgF_{(s)}$
b) $O_{2(g)}$
c) $Na_2S_{(s)}$
d) $B_2O_{3(s)}$
e) $FeCl_{3(s)}$

3. When an ionic compound forms, what must be the sum of the ionic charges?

4. What kind of elements form molecular compounds?

5. Identify how many atoms of each element are present in the following compounds:
a) glucose: $C_6H_{12}O_{6(s)}$
b) ethanol: $C_2H_5OH_{(l)}$
c) hydrogen peroxide: $H_2O_{2(l)}$
d) rust remover: $H_3PO_{4(aq)}$
e) fatty acid: $C_{17}H_{35}COOH_{(aq)}$

6. Which of the following compounds are ionic and which are molecular?
a) $PbO_{(s)}$
b) $Al_2S_{3(s)}$
c) $F_{2(g)}$
d) $H_2O_{(l)}$
e) $NH_{3(g)}$

7. What is the formula for the ionic compounds with the following combinations of elements?
a) potassium and bromine
b) barium and oxygen
c) aluminum and selenium
d) calcium and nitrogen
e) copper and phosphorous

8. Write the formula for the following molecular compounds:
a) carbon monoxide
b) carbon dioxide
c) nitrogen dioxide
d) dinitrogen monoxide
e) disulfur dichloride

Connect Your Understanding

9. Describe a pattern of ion charges in the periodic table.

10. Write the formula for the following ionic compounds:
a) magnesium bromide
b) sodium phosphide
c) lithium fluoride
d) nickel(II) chloride
e) lead(IV) nitride
f) copper(I) sulfide
g) silver oxide
h) nickel(III) oxide

11. In terms of ion charges and chemical change, what is the difference between $CuF_{(s)}$ and $CuF_{2(s)}$?
12. Sketch simple models to show the following molecular compounds:
    a) sulfur and oxygen (SO_2)
    b) nitrogen and chlorine (NCl_3)
    c) oxygen and bromine (OBr_2)
    d) carbon and fluorine (CF_4)

Extend Your Understanding

13. Which of the following formulas is/are not correctly written?
    a) Li_3O
    b) CuO
    c) Mg_3O_2
    d) $HgCl_2$
    e) $FeCl$
14. Using the periodic table, find the elements iron, mercury, and bromine. Make a chart to answer the following questions as related to each element.
    a) Is it a metal or non-metal?
    b) What is the common ion charge?
    c) Will it conduct electricity?
    d) What state will it be in at room temperature?
    e) What state will it be in at room temperature if it combines with a non-metal?
15. An unknown ionic compound is formed with the formula $Z_2S_{3(s)}$.
    a) What is the common ion charge of element Z?
    b) What would be the new chemical formula of the unknown compound if the S (sulfur) was replaced with fluorine?
    c) What would be one property of these two compounds?

Focus On THE NATURE OF SCIENCE

Scientific ideas can be difficult to represent in a way that is easily understandable. To help explain their ideas, scientists often use models. In this section, you investigated and developed models to explain how atoms form compounds. Answer the following questions, using examples from your work in this section to support your answers.

1. How can a model help explain your observations?
2. Can a model be used to predict future observations?
3. Why is it important to understand chemical symbols, and to ensure that everyone uses these symbols correctly?

4.0 Substances undergo a chemical change when they interact to produce different substances.

Key Concepts

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

- endothermic and exothermic reactions
- reactants and products
- conservation of mass
- factors affecting reaction rates

Learning Outcomes

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

- identify conditions under which properties of a material are changed, and critically evaluate if a new substance has been produced
- observe and describe evidence of chemical change in reactions between familiar materials
- distinguish between materials that react readily and those that do not
- observe and describe patterns of chemical change
- describe familiar chemical reactions, and represent these reactions by using word equations and chemical formulas and by constructing models of reactants and products

Fireworks burst into the night sky in brilliant patterns caused by chemical reactions. The different colours that we see result from reactions between different substances within the fireworks. For example, barium compounds create green fireworks, strontium compounds create red ones, copper creates blue ones and sodium yellow. Fireworks are also launched by the chemical reaction that results from the fuse being lighted. The heat of the fuse ignites the chemicals that propel the fireworks into the sky.

In this section, you will investigate a variety of chemical reactions and how different factors affect the rate of these reactions. Think about safety as you do each activity.

4.1 Chemical Reactions

At first it may seem that the launch of a space shuttle and the activation of air bags in a vehicle have very little in common. In fact, both of these events require a **chemical reaction** to work. A chemical reaction takes place when two or more substances combine to form new substances. A chemical change in a substance results from a chemical reaction.

The chemical reaction occurring in launching a space shuttle involves almost 1 500 000 L of liquid hydrogen and 545 000 L of liquid oxygen combining to form water. During this reaction, enough energy is released to put the shuttle into orbit around Earth. In a vehicle equipped with air bags, the chemical reaction occurs on a smaller scale, but the results are also dramatic. Air bags, packed inside the frame of a vehicle, contain the explosive chemical sodium azide ($NaN_{3(s)}$). When the vehicle is in a collision, the sodium azide reacts and forms large volumes of nitrogen gas and sodium. The sodium quickly reacts with another compound in the air bag to make less dangerous compounds. Fifty grams of sodium azide can produce 30 L of nitrogen gas in milliseconds—a reaction that releases a burst of energy. The nitrogen gas inflates the air bags instantly, cushioning the impact of the collision for the driver and front-seat passenger.

*info*BIT

Dr. John Polanyi
In 1986, Canadian Dr. John Polanyi won the Nobel Prize in chemistry for his work investigating the properties of chemical reactions.

*QUICK*LAB

ROCKET SCIENCE

Purpose

To use a chemical reaction to create a film canister rocket

Procedure

1. Half fill the film canister with water.
2. Place a quarter tablet of Alka-Seltzer in the canister and quickly snap on the lid.
3. Place the canister upside down on the ground and stand at least 5 m back. CAUTION: If the rocket does not launch after about 1 min, slowly approach it and kick it over with your foot. If the lid doesn't come off, carefully remove the lid, keeping the canister pointed **away** from everyone.
4. Record your observations.
5. Try changing the variables to make the rocket go as high as possible. For example, change the amount of water, the amount of Alka-Seltzer, or the position of the canister on the ground. Record your observations each time.

Questions

6. How did you make a film canister rocket?
7. Did a chemical reaction occur inside the film canister? Provide evidence to support your answer.
8. What combination of materials made the rocket go the highest?

Materials & Equipment

- plastic film canister with inside snapping lid
- water
- Alka-Seltzer tablet, cut into quarters
- pencil and notebook

Figure 4.1 The reactants potassium iodide and lead(II) nitrate are both clear. The chemical reaction that takes place when they are combined results in a colour change in the product.

The materials at the start of a reaction are called the **reactants**. Think of a campfire. The burning wood undergoes a combustion reaction. In this case, the reactants, or substances being combined in the reaction, are wood and oxygen. The new materials produced by the reaction are called **products**. In a campfire, the products are carbon dioxide and water, formed while energy is released.

This chemical reaction can be written as a chemical word equation, as shown below. Note that in such equations, the reactants always appear to the left of the arrow and the products to the right.

$$\text{wood} + \text{oxygen} \longrightarrow \text{carbon dioxide} + \text{water} + \text{energy released}$$

Plus signs separate the reactants from each other and the products from each other. The arrow indicates the direction in which the reaction is most likely to occur. When you take more advanced science courses, you will learn about situations where the reaction can occur in either direction.

Recall from section 1.3 that when a chemical reaction occurs, a new substance forms and evidence of the reaction may include one or more of the following:

- a colour change
- the formation of an odour
- the formation of a solid or a gas
- the release or absorption of heat

While colour change and formation of an odour are usually good indicators that a chemical reaction has taken place, care must be taken in interpreting some of the other types of evidence. For example, the formation of bubbles in a solution doesn't always mean that a new gas is being produced in a chemical reaction. The bubbles may simply mean that the solution has begun to boil. Evidence of heat being released or absorbed may also indicate a physical change rather than a chemical change. Some solids, for example, release heat when they are dissolved.

GIVE IT A TRY

IDENTIFY THE REACTION

Below are three different reactions. Identify the reactants and products for each reaction. Write out the chemical word equation.

Reaction 1. When hydrogen peroxide is left out in the sun, it changes to water and oxygen gas.

Reaction 2. A silver spoon is exposed to air. Over time, it turns a dark brown colour.

Reaction 3. Sodium and bromine react explosively to produce sodium bromide.

ACTIVITY B-6

Inquiry

OBSERVING CHEMICAL REACTIONS

Materials & Equipment

- 3 test tubes
- test-tube holder
- 5% or 1.0 mol/L sulfuric acid
- magnesium ribbon
- matches
- splint
- 2% or 0.2 mol/L copper(II) sulfate
- steel wool
- stirring rod
- 3% or 0.2 mol/L iron(III) chloride
- 3% or 0.8 mol/L sodium hydroxide
- 5 g baking soda
- vinegar
- 500-mL beaker
- thermometer

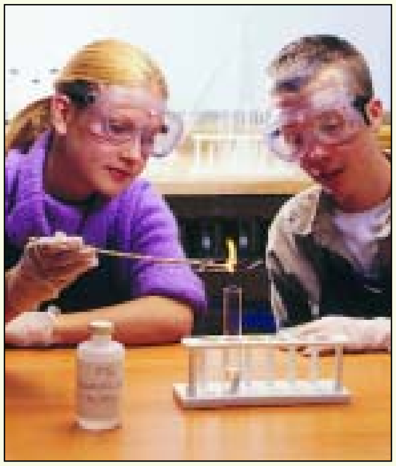


Figure 4.2 Step 4

The Question

How will different materials react with each other?

Procedure

1. Before you start, your teacher will review the safety guidelines with you.
2. Draw a table in which to record your observations.

Reaction 1—Sulfuric acid and magnesium ribbon

3. Place a test tube in the test-tube holder. Pour the dilute sulfuric acid into the test tube to a depth of about 3 cm.
4. Add a 2-cm strip of magnesium ribbon to the dilute sulfuric acid in the test tube.
5. Light a splint and hold it so that the burning end is in the test tube. Make sure the test tube is pointing away from you and your classmates. Record your observations in the table.

Reaction 2—Copper(II) sulfate and steel wool

6. Place a clean test tube in the test-tube holder. Pour the copper(II) sulfate solution into the test tube to a depth of about 3 cm.
7. Add a small piece of steel wool to the copper(II) sulfate solution. You may need to use a stirring rod to push the steel wool down into the solution. Record your observations.

Reaction 3—Iron(III) chloride and sodium hydroxide

8. Place a clean test tube in the test-tube holder. Pour the iron(III) chloride solution into the test tube to a depth of about 3 cm.
9. Add a similar amount of the dilute sodium hydroxide solution to the test tube. Record your observations.

Reaction 4—Baking soda and vinegar

10. Pour 40 mL of vinegar into a 500-mL beaker. Measure and record the temperature of the vinegar.
11. Slowly add 5 g of baking soda to the vinegar. Measure and record the temperature.

Caution!
Be sure to wear your safety goggles, apron, and gloves. Iron(III) chloride is a strong irritant, and is corrosive and toxic. Sulfuric acid and sodium hydroxide are corrosive.

Analyzing and Interpreting

12. For each combination of materials you investigated, identify whether a chemical or physical change took place. Explain your answers.
13. For each chemical reaction, describe the evidence that you used to determine if new products were formed.

Forming Conclusions

14. Look back at the question at the beginning of this activity. Write a conclusion that answers that question by describing what you did, why you did it, and what you found.

reSEARCH

Changing Chemical Bonds

Endothermic and exothermic reactions involve the forming or breaking of chemical bonds. Find out how energy is used to form or break these bonds, and give examples. Begin your research at www.pearsoned.ca/scienceinaction.

Endothermic and Exothermic Reactions

A chemical reaction that releases heat energy is called an **exothermic reaction**. When you burn an object in the presence of oxygen, energy in the form of heat is given off. Heat is also emitted when your body metabolizes food.

A chemical reaction that absorbs heat energy is an **endothermic reaction**. If you observed the chemical reactions in Inquiry Activity B-6, you noticed that the temperature in the baking soda and vinegar reaction dropped during and just after the reaction. Chemical cold-packs found in first aid kits are another example of where an endothermic reaction occurs. The reactants in the cold-packs must be crushed together to start the reaction. As the chemical change occurs and new products form, energy is absorbed from the liquid in the bag, and the bag becomes very cold.

Chemical Changes Involving Oxygen

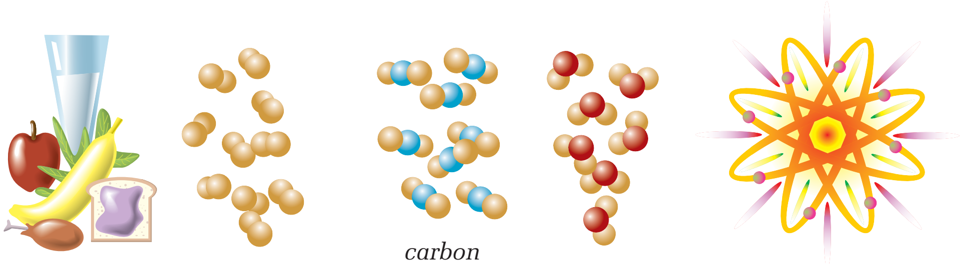
Chemical changes occur because some substances react with each other when they come into contact. Among the most common types of chemical reactions are those involving oxygen. Three examples of reactions in which oxygen reacts with other substances are combustion, corrosion, and cellular respiration.

Figure 4.3 This fire triangle shows the three factors that keep a fire going. If any one of them is missing, the fire will not continue burning.

Combustion is a chemical reaction that occurs when oxygen reacts with a substance to form a new substance and give off energy. Fire is a common example of a combustion reaction. In burning, wood reacts with oxygen to give off heat and light and produce carbon dioxide and water. Recall that earlier in this unit you read about the significance of early humans discovering how to start fires. Combustion could be considered the first chemical reaction used by humans. Today, it is still one of the most important chemical reactions we use.

Corrosion is the slow chemical change that occurs when oxygen in the air reacts with a metal. A common example of corrosion is rusting. Rusting occurs when iron reacts with oxygen to form iron oxide.

Cellular respiration is a chemical reaction that takes place in the cells in your body. Food (glucose) reacts with oxygen to produce energy, water, and carbon dioxide. Figure 4.4 shows the word equation for cellular respiration.



food ($C_6H_{12}O_{6(s)}$) + *oxygen* (O_2) → *carbon dioxide* (CO_2) + *water* (H_2O) + *energy that can be used by living things*

Figure 4.4 The word equation for cellular respiration

ACTIVITY B-7

Experiment **on your own**

REACTIONS FOR UPSET STOMACHS

Before You Start

Many different types of medications are available to soothe an upset stomach. A common one is antacid. Antacids can be solid tablets or liquids.

For this activity, you will use an Erlenmeyer flask containing 75 mL of dilute hydrochloric acid and 3 drops of methyl orange indicator. This is a model of an upset stomach. You will add antacids to the model stomach. When the orange colour disappears, the stomach is no longer upset. In this reaction, carbon dioxide gas is produced. To capture the gas, you can place a balloon over the flask.

In this activity, you will determine which antacid works best and the most effective way to take it. You may wish to use Toolbox 2 to help you plan your experiment.

Figure 4.5 Adding antacid to an Erlenmeyer flask containing hydrochloric acid

The Question

Which antacid medication works best? What is the most effective way to take it?

Design and Conduct Your Experiment

1 Write a hypothesis about the most effective method for taking antacid medication.
2 Decide what materials you will need to test your hypothesis.
3 Plan your procedure. Ask yourself questions such as:
   a) How will I determine which antacid is best?
   b) How will I determine what is the best way to take this antacid?
   c) What type of chart will I need to record data?
   d) Is the test I've designed fair? How do I know?
   e) What are the variables in my experiment? Which is the manipulated variable? Which is the responding variable? Which variables will I control?
   f) How long do I have to complete my experiment?
4 Write up your procedure. Show it to your teacher before continuing.
5 Carry out your experiment.
6 Compare your results with your hypothesis. Did your results support your hypothesis? If not, suggest possible reasons for this.
7 Share and compare your experimental plan and findings with your classmates. Did anyone plan an experiment exactly like yours or similar to yours? How do your results compare with theirs?

CHECK AND REFLECT

Key Concept Review

1. What is the difference between a chemical reaction and a physical change?
2. How are reactants different from products in a chemical reaction?
3. Describe three observations you might make when a chemical change occurs.
4. Chemical fire starter ignites as a result of from the following reaction:

$$2\ CH_3OH_{(l)} + 3\ O_{2(g)} \longrightarrow 2\ CO_{2(g)} + 4\ H_2O_{(g)}$$

   a) What are the reactants?
   b) What are the products?
   c) What could be one observation you could make to conclude a chemical reaction has occurred?

Figure 4.6 Question 6

5. What is the difference between an exothermic reaction and an endothermic reaction?
6. How are the reactions in the items shown in Figure 4.6 useful to humans?

Connect Your Understanding

7. a) In what ways are combustion and corrosion similar?
   b) In what ways are they different?
8. Write the chemical word equations for the following reactions:
   a) Zinc and hydrochloric acid are added together. A bubbling reaction creates hydrogen gas and zinc chloride.
   b) When sugar and sulfuric acid are combined, carbon, water, and sulfur dioxide are formed.
   c) Rust is formed when iron reacts with oxygen.
9. Rewrite the following chemical reactions into chemical equations using the appropriate chemical formulas.
   a) Magnesium and sulfur combine to form magnesium sulfide.
   b) When calcium is added to chlorine gas, calcium chloride is formed.
   c) Water is formed when hydrogen and oxygen are combined.

Extend Your Understanding

10. Create a step-by-step procedure describing how to write a chemical equation.
11. Compare and contrast combustion, corrosion, and cellular respiration.

4.2 Conservation of Mass in Chemical Reactions

In a chemical reaction, products are formed when the reactant (or reactants) undergoes a change. These products usually look very different from the reactants. However, the total mass of these products is always the same as the total mass of the reactants. This law is called the **conservation of mass**. It states that matter is not created or destroyed in a chemical reaction. For example, combining 24.3 g of magnesium and 32.1 g of sulfur creates a new substance called magnesium sulfide. The law of conservation of mass predicts that the mass of the product will be the sum of these two masses: 56.4 g. Careful experiments have been made on this and many other reactions. These experiments have been done in **closed systems**, where no additional material is allowed to enter or leave. The result? No exceptions to this law have ever been found in any chemical reaction.

$$\underset{24.3\text{ g}}{Mg_{(s)}} \quad + \quad \underset{32.1\text{ g}}{S_{(s)}} \longrightarrow \underset{56.4\text{ g}}{MgS_{(s)}}$$

$$\underset{\textit{iron}}{Fe_{(s)}} \quad + \quad \underset{\textit{sulfur}}{S_{(s)}} \longrightarrow \underset{\textit{iron sulfide}}{FeS_{(s)}}$$

Figure 4.7 The total mass of the reactants and the total mass of the products are equal.

Some reactions may not seem to follow the principle of the conservation of mass. For example, adding 10 g of Alka-Seltzer to 100 g of water in a beaker causes carbon dioxide gas to be given off. When the reaction is complete, the mass of the products left in the beaker is only 106 g, not 110 g. This doesn't mean that mass was not conserved. The carbon dioxide gas was also one of the products of the reaction, but it escaped from the open beaker into the air. This is an example of an **open system**. If it had been trapped, it would have been found to have a mass of 4 g.

infoBIT

Einstein, Matter, and Energy

In a nuclear reaction, some of the mass is converted to energy, as Albert Einstein expressed in his famous $E = mc^2$ relation.

mathLink

Two reactants undergo a chemical reaction and produce one product. The mass of one of the reactants is 20 g and the mass of the product is 45 g. Write an algebraic equation representing this reaction, and solve the equation to find the mass of the second reactant.

Activity B-8

Inquiry

Conserving Mass

The Question

Does the mass of reactants and products change during a reaction?

Materials & Equipment

- balance
- 4 g baking soda
- 4 g calcium chloride
- large self-sealing plastic bag
- 5-mL measuring spoon
- 5 mL water
- 5 mL bromothymol blue
- film canister

Procedure

1. Put the baking soda and calcium chloride in the self-sealing plastic bag.
2. Put the water and bromothymol blue in the film canister.
3. Place the canister in an upright position in the bag. Carefully seal the bag. Measure and record the mass of the bag.
4. Predict what you think will happen when all the substances mix together. Record your prediction.
5. Without opening the bag, tip the canister over and allow the liquids and solids to mix. Record as many observations as you can while the reaction is occurring. Be sure to hold the bag to observe the temperature changes.
6. When the reaction is complete, measure and record the mass of the bag.
7. When you have finished the activity, clean up and return the materials as instructed by your teacher.

Caution!
If the bag seems ready to burst, open it up.

Analyzing and Interpreting

8. What evidence do you have that a chemical reaction occurred?
9. How did the mass before the reaction compare with the mass after the reaction?
10. Was the reaction exothermic, endothermic, or both?

Forming Conclusions

11. Use your observations and the data collected during this investigation to answer the question posed at the beginning of the activity.

Figure 4.8 Step 3

reSEARCH

Chemical Reaction Laws

In addition to the law of conservation of mass, two other laws apply to chemical reactions. Find out what the law of definite composition and the law of multiple proportions are. Begin your search at www.pearsoned.ca/scienceinaction.

Check and Reflect

Key Concept Review

1. Define the law of conservation of mass.
2. What is a closed system in terms of a chemical reaction? Give an example.
3. What is an open system in terms of a chemical reaction? Give an example.
4. If you were to compare (i) the mass of a car with a full tank of gas to (ii) the mass of the same car with an empty tank of gas *plus* the mass of the exhaust fumes produced while the car burned the gas, would mass (i) and mass (ii) be different or would they be equal? Explain your answer.

Connect Your Understanding

5. A solid mass of 25 g is mixed with 60 g of a solution. A chemical reaction takes place and a gas is produced. The final mass of the mixture is 75 g. What was the mass of gas released?
6. If 100 g of one substance reacts with 70 g of another substance, what will be the mass of the products after the reaction?
7. A student adds 15 g of baking soda to 10 g of acetic acid in a beaker. A chemical reaction occurs and a gas is given off. After the reaction, the mass of the products remaining in the beaker is 23 g. Has mass been conserved in this reaction? Explain your answer.

Extend Your Understanding

8. Select a chemical reaction you have read about or observed in this section. Use the chemical formulas of the reactants and products to prove the law of conservation of mass.
9. Does a glass of pop have a greater, smaller, or identical mass after it has sat out on the table overnight? Explain your answer.
10. Is Earth a closed system or an open system? Explain your answer.

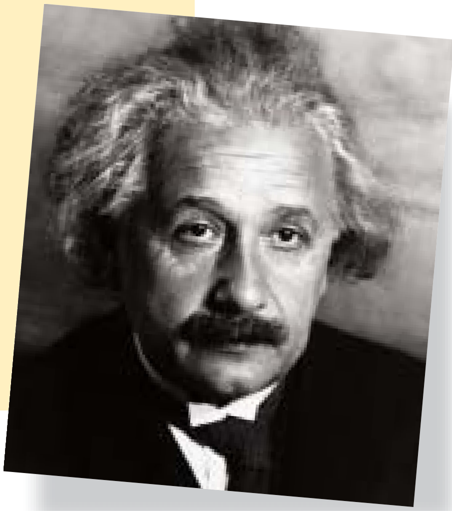


Figure 4.9 Albert Einstein was the first person to propose that in a nuclear reaction, some mass is converted into energy.

4.3 Factors Affecting the Rate of a Chemical Reaction

Figure 4.10 Chemicals can be used to change hair colour.

You may know someone who tried to change his or her hair colour, but the process didn't quite work out as planned. Colouring hair is the result of a chemical reaction. If the reaction is not controlled properly, unintended effects can occur, such as unexpected hair colours or burning of the scalp. Another common example of a chemical reaction is making a cake. It's important to use the right amount of each ingredient. If you add too much baking powder, for example, you can end up with a batter that rises more than it should.

It is important to understand how a chemical reaction works and the factors that affect the rate of the reaction. The four factors that can affect the rate of a chemical reaction are:

- the presence of a catalyst
- the concentration of the reactants
- the temperature of the reactants
- the surface area of the reactants

CATALYSTS

Catalysts are substances that help a reaction proceed faster. They are present with the reactants of a reaction, but they are not consumed during the reaction. Chemical reactions involving catalysts can be found in both living and non-living things. The most common example in living things is in your body. Many reactions, such as the breaking down of food, require a catalyst called an **enzyme**. Without enzymes, many reactions would require much higher temperatures—a situation that would be deadly to the human body.

Enzymes can help get rid of poisons in the body quickly. For example, one product of reactions in cells is hydrogen peroxide (H_2O_2). Hydrogen peroxide is poisonous. An enzyme called *catalase*, which is found in many different types of animal and plant cells, speeds up the breakdown of hydrogen peroxide into harmless oxygen and water. Figure 4.11 shows a model of how an enzyme like catalase functions.

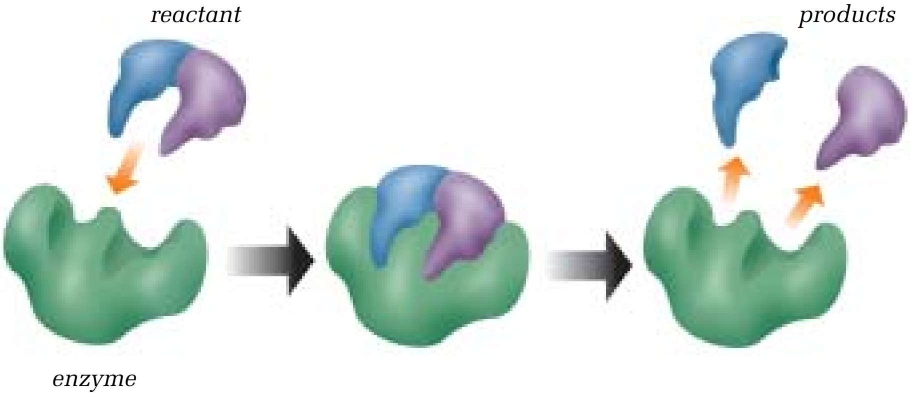


Figure 4.11 The shape of the enzyme molecule helps the reactant molecule break down.

QUICKLAB

Hydrogen Peroxide and the Catalyst Manganese(IV) Oxide

(Teacher Demonstration)

Like catalase, the catalyst manganese(IV) oxide ($MnO_{2(s)}$) also speeds up the reaction that breaks down hydrogen peroxide and produces a gas. To test if the gas is present, a glowing splint is placed in the test tube holding the reaction.

Purpose

To observe the effects of a catalyst on the rate of a chemical reaction

Procedure

1. Pour hydrogen peroxide into a test tube to a depth of 4 cm. Wait 30 s.
2. Light a wooden splint. After 5 s, blow it out. Immediately hold the glowing splint in the test tube. Record your observations.
3. Add 1 g of the catalyst manganese(IV) oxide ($MnO_{2(s)}$) to the hydrogen peroxide in the test tube.
4. Observe the test tube for 30 s.
5. Light another wooden splint and blow it out after 5 s. Immediately place the glowing splint into the test tube. Record your observations.

Questions

6. Describe how the catalyst manganese(IV) oxide affects the rate of reaction in this demonstration.
7. What gas was given off by the reaction? What evidence do you have to support your answer?
8. If a piece of fresh liver is dropped into hydrogen peroxide, a similar reaction occurs. What can you infer about the chemicals found in liver?
9. If you were to cool the hydrogen peroxide before you added the catalyst, what do you think would happen to the rate of reaction? Explain your answer.

Materials & Equipment

- hydrogen peroxide
- test tube
- wooden splint
- matches
- manganese(IV) oxide

***info*BIT**

Fuel Cells

Fuel cells use a platinum catalyst to generate electricity from the reaction of hydrogen and oxygen. These cells can now be found in cars and other devices.

ACTIVITY B-9

Inquiry

RATES OF REACTION

The Question

What factors can be changed to increase the rate of a reaction?

Materials & Equipment

- graduated cylinder
- water
- 500-mL beaker
- 15-mL plastic measuring spoon
- copper(II) chloride
- stirring rod
- thermometer
- aluminum foil

Procedure

Part 1—Investigating the Reaction

1. Using the graduated cylinder, measure 50 mL of water and place it in the beaker.
2. Measure 15 mL of copper(II) chloride.
3. Add the copper(II) chloride to the water and stir until the solid has dissolved. Record your observations of the solution.
4. Measure the temperature of the solution.
5. Crumple a piece of aluminum foil so that it will fit into the beaker. Using the stirring rod, push the aluminum foil into the solution. Observe and record any changes.
6. Record the temperature (in °C) every 30 s until the temperature begins to drop.

Figure 4.12 Step 6

Part 2—Changing the Rate of the Reaction

7. In this part of the activity, you will design a procedure using only the materials you used in part 1. Your task is to create a reaction that will give you the highest temperature as quickly as possible.
8. Working with your lab partner, design your procedure and write it down. Remember that you will have to measure the temperature every 30 s as in step 6 in part 1.
9. Have your teacher approve your procedure.
10. Carry out your plan and record your results.

Analyzing and Interpreting

11. What evidence do you have that a chemical change occurred when aluminum was added to the copper(II) chloride?
12. Graph the temperatures you measured in part 1 against the time that you measured them. On the same graph, graph the temperatures you measured in part 2. Use a different colour for your second graph.
13. What products do you think were produced from the reaction?
14. What factors did you change to increase the rate of the reaction?
15. Was there a difference in the highest temperatures you measured in parts 1 and 2? Why do you think this occurred?
16. If the challenge was to create the lowest temperature possible, what factors would you change?

Forming Conclusions

17. Describe how you would create a reaction to get the highest temperature as quickly as possible, given the materials you used in this activity.

OTHER FACTORS AFFECTING THE RATE OF REACTION

A catalyst is one factor that can affect the rate of a reaction. Three other factors are concentration, temperature, and surface area.

Concentration

The greater the concentration of the reactants, the faster the reaction. The increased concentration of the reactants means that there are more atoms of each reactant available to react. For example, adding more aluminum to a copper(II) chloride solution will cause the reaction between the two substances to proceed faster.

Temperature

The temperature of the reactants can also affect the rate of a reaction. The more heat added to the reactants, the faster the reaction. The added heat causes the atoms of each reactant to move faster, which increases the chances of their colliding with each other. For example, if you were investigating the copper(II) chloride–aluminum reaction, you could heat the copper(II) chloride solution to make the reaction proceed more quickly.

Surface area

Increasing the surface area of the reactants is another factor that can increase the rate of a reaction. The greater surface area of the reactants means that more area is available for reaction. In the copper(II) chloride and aluminum example, cutting the aluminum foil into tiny pieces would increase the surface area, causing the reaction to proceed faster.

Figure 4.13 This grain elevator blew up when the extremely fine grain dust in the air was ignited accidentally. The fine dust means a large surface area of grain was available for the combustion reaction.

reSEARCH

Controlling Industrial Reactions

Find examples of industrial chemical reactions that require the rate of the reaction to be controlled. Begin your search at www.pearsoned.ca/scienceinaction.

Check and Reflect

Key Concept Review

1. What is an enzyme?
2. Explain how an enzyme is different from other catalysts.
3. What are four factors that can affect the rate of reaction?
4. Give one example, not discussed in the book, of a reaction where the rate was increased because of changes in the four factors mentioned above.

Connect Your Understanding

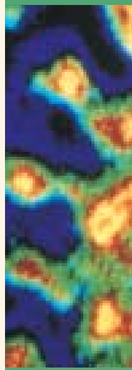
5. What is the purpose of storing food in a cooler with ice when you go camping or on a picnic? Explain your answer in terms of rate of chemical reaction.
6. Why does chewing your food make it easier to digest?
7. Why should batteries be stored in the fridge when they are not being used?
8. For each of the following reactions, how could the rate of chemical change be increased?
   a) a block of wood burns slowly
   b) an Alka-Seltzer tablet fizzes slightly
   c) ice-cold hydrochloric acid reacts slowly with powdered zinc

Extend Your Understanding

9. The catalyst manganese(IV) oxide is able to increase the rate at which hydrogen peroxide decomposes into oxygen and hydrogen. The enzyme catalase is found in animal livers and can perform the same function. If the hydrogen peroxide is heated to 60°C first, the catalase doesn't work. Why?
10. Plan and write a procedure to test how the concentration of yeast will affect the rising of bread.

Figure 4.14 Dyeing a shirt to create the varying colour tones shown here requires controlling the reaction rate of the various chemical dyes used.

Section Review



Assess Your Learning

Key Concept Review

1. Define a chemical reaction and give an example.
2. Create a chemical word equation using the following: reactants, products, $\longrightarrow$
3. Which of the following observations would not be evidence of a chemical reaction?
   a) precipitate (solid) formed
   b) heat released
   c) substance melted
   d) colour changed
4. How does the fire triangle describe the chemical reaction called combustion?
5. Define the law of conservation of mass in your own words.
6. What is the difference between an open and a closed system?

Connect Your Understanding

7. Write the following reactions as chemical word equations.
   a) Calcium and water combine to form calcium hydroxide and hydrogen.
   b) Hydrogen gas and sulfur are products created when hydrogen sulfide decomposes or breaks down.
   c) Methane and oxygen react to produce carbon dioxide, water, and energy.
   d) If there is not enough air for all the methane to react in c), carbon and water are formed.
8. How can you determine if a reaction is exothermic?

Extend Your Understanding

9. A reaction occurs in a closed system. The mass of the products is 25 g. What was the mass of the reactants? How do you know?

Focus On The Nature of Science

At the start of this unit, you were introduced to the idea that the goal of science was to develop knowledge about our natural world. This knowledge includes how substances interact to form new substances. Now that you are at the end of this unit, work with your partner or your class to consider the following questions.

1. Identify an example of two or more substances interacting to produce a change. How do you know a change has occurred?
2. Describe several chemical changes or reactions that you consider useful. What are some characteristics or properties of each of these reactions that make them useful?
3. Describe two chemical changes or reactions where it is important to control the rate of the reaction. Why is this important in each case?
4. Review your answers in Section 1.0, Focus on the Nature of Science. How has your understanding of matter and its interactions changed over time?

Key Concepts	Section Summaries
1.0 • Workplace Hazardous Materials Information System (WHMIS) and safety • substances and their properties • elements, compounds, and atomic theory	**1.0 Matter can be described and organized by its physical and chemical properties.** • Recognition of WHMIS symbols is important to lab safety. • Matter can be organized in different ways. One way is as solids, liquids, and gases. Another way is as mixtures and solutions. • Physical properties of matter such as colour, hardness, boiling point, and density are used to identify substances. Chemical properties describe how a substance interacts with other substances.
2.0 • substances and their properties • elements, compounds, and atomic theory • periodic table	**2.0 An understanding of the nature of matter has developed through observations over time.** • Human understanding of matter grew as people suggested explanations for their observations of the natural world. Theories were confirmed or rejected as people learned more about matter. • The Greek philosopher Democritus stated that matter was made up of tiny indivisible particles called *atomos*. This theory was not widely accepted for 2000 years. • Investigations by scientists, such as Robert Boyle, in the 1600s confirmed that matter is made up of tiny particles. Further investigation by researchers gradually developed the understanding we have today that matter is made up of atoms. Each atom has a nucleus containing protons and neutrons. Electrons orbit the nucleus. • Elements are pure substances made up of only one type of atom. The periodic table organizes the elements according to their atomic number and atomic mass. The atomic number is the number of protons in the nucleus. The atomic mass is the average mass of an atom of an element. • Patterns of information on the periodic table include groupings of metals, metalloids, and non-metals.
3.0 • periodic table • elements, compounds, and atomic theory • chemical nomenclature	**3.0 Compounds form according to a set of rules.** • Every chemical compound has a chemical formula and chemical name. The chemical formula identifies the elements in the compound and their proportions. • An ion is an atom or a group of atoms that has become electrically charged through the loss or gain of electrons from one atom to another. • Ionic compounds form between atoms of metals and non-metals. • Molecular compounds form between atoms of non-metals.
4.0 • endothermic and exothermic reactions • reactants and products • conservation of mass • factors affecting reaction rates	**4.0 Substances undergo a chemical change when they interact to produce different substances.** • A physical change may change the appearance or state of a substance but not its composition (e.g., melting). A chemical change results in the formation of one or more different substances. • Reactions involving oxygen are some of the most common types of chemical reactions. These include combustion, corrosion, and cellular respiration. • A chemical reaction occurs when substances called reactants interact to produce different substances called products. • According to the principle of the conservation of mass, the mass of the products in a chemical reaction equals the mass of the reactants. • An exothermic reaction gives off energy. An endothermic reaction takes in energy. • The rate of reaction can be affected by the addition of a catalyst, or an increase in the concentration, temperature, or surface area of the reactants.

Metal Contamination of the Environment

Equipment operators must wear special protective gear when cleaning up contaminated soil.

The Issue

Humans have many uses for metals. Copper for wire, aluminum for pop cans, and lead for batteries are just a few examples. Some metals, such as lead, are poisonous to humans if exposure occurs over a long period of time. This exposure may result from metals finding their way into the groundwater or from unsafe storage. In many cases, the people or companies responsible for the contamination are no longer present to take responsibility for the cleanup. The problem of metal contamination in the environment leads to several questions.

What should be done with contaminated soil?

When metals from factories, mines, and dumps contaminate soil, the area is closed to human access. This prevents immediate harm to people. However, the soil must be made safe for the future. There are two common options for cleaning up contaminated soil. The first option involves removing the top layer of contaminated soil. However, the contaminated soil must then be cleaned or stored in another area. The second option is to cover the contaminated soil with a thick layer of clean soil. In theory, the new layer seals the contaminated soil from the environment.

How much of the contaminated soil needs to be cleaned up?

Cleaning up a contaminated site is costly. Some people suggest that only toxic sites where people may live or work should be cleaned up. Others suggest that only areas where people live should be cleaned. To save money, only a partial cleanup of the workplace is necessary. Other people feel that all toxic areas should be cleaned, as it is hard to predict where people will live or work in the future.

Who should be responsible for the cleanup?

Cleaning a contaminated area may require removal of soil, buildings, and trees, and the addition of clean soil. This is an expensive process. Since many of these waste sites have been abandoned, it is difficult to determine who should be responsible for cleaning them up. All levels of government—municipal, provincial, and federal—have a role in determining how these sites should be rehabilitated.

Go Further

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

- Look on the Web: Check the Internet for information on examples of metal contamination in Alberta and what is being done about them.
- Ask the Experts: Try to find an expert on metal contamination, such as a chemical engineer or an environmental geologist. Experts can be found in various places: city hall, universities, environmental consulting companies, and government agencies.
- Look It Up in Newspapers and Magazines: Look for articles about metal contamination.

Analyze and Address the Issue

Summarize your opinion of what should be done about cleaning up contaminated soil and who should do it as one of the following:

- a newspaper article for your local or school newspaper
- a speech to be presented at a public forum on the issue

PROJECT

WHAT'S IN THE BOTTLE?

You can use the well in a spot plate for a micro-scale reaction.

Getting Started

There's a problem in the science lab. A bottle containing an unknown solution has been found. Because the contents are unknown, it is difficult to determine how to dispose of it.

Your Goal

In this activity, you will perform a variety of micro-scale reactions to gather information about how various solutions react. You will then use this information to identify an unknown sample.

What You Need to Know

Micro-scale reactions occur when very small amounts of reactants are used. Usually the reaction takes place in a small depression or well on a spot plate. By filling the well half full with one solution or solid reactant and then adding a second reactant, you can observe if a reaction has occurred.

The following observations can help you determine that a reaction has occurred:

- bubbles form or a gas is given off
- the colour changes
- a solid substance called a precipitate forms

If the spot plate is clear and colourless, you may need to put a piece of white paper under the plate. This will help you observe any reaction that occurs.

Steps to Success

Part 1—The Tests

1 Collect the necessary equipment for this activity:
- 1 spot plate
- bottles of solutions labelled A, B, C, D, E, F
- paper towel

2 Combine two solutions in all possible ways, using the table below as your guide.

3 Record your observations in a table like this one.

A	B	C	D	E	F	Unknown
A						
	B					
		C				
			D			
				E		
					F	
						Unknown

Part 2—The Identification of the Unknown

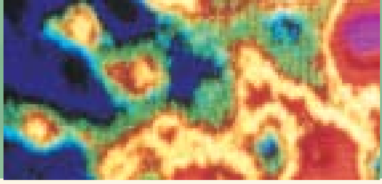
4 Your teacher will give you an unknown solution.

5 Using a clean spot plate, combine each of the known solutions with the unknown solution. Record your results in each case.

How Did It Go?

6 Using your data from part 1, determine what you think the unknown sample in the bottle is. Remember to support your answer with your data.

7 Write your conclusion in a short paragraph. Make sure it answers the following questions:
- What did you do in this activity?
- Why did you do this activity?
- What did you find?
- What is one new thing you learned?



UNIT REVIEW: MATTER AND CHEMICAL CHANGE

Unit Vocabulary

1. Define the following terms in full sentences using your own words.
   WHMIS
   matter
   elements
   periodic table
   atomic mass
   atomic number
   ion charge
   ionic compound
   molecular compound
   exothermic
   endothermic
   law of conservation of mass

Key Concept Review

1.0

2. Match the WHMIS symbol to the following descriptions.

(i)

(ii)

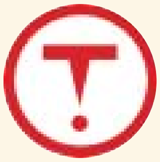
(iii)

(iv)

(v)

(vi)

(vii)



(viii)

   a) poisonous and infectious causing other toxic effects
   b) corrosive material
   c) dangerously reactive material
   d) flammable and combustible material
   e) oxidizing material
   f) biohazardous infectious material
   g) poisonous and infectious causing immediate and serious toxic effects
   h) compressed gas

3. If you had to describe an unknown green solid, what properties could you use?

4. What is the difference between a physical change and a chemical change?

5. Create a chart or picture to illustrate the differences among a pure substance, a mechanical mixture, and a solution. Include examples in your chart or picture.

2.0

6. Why must copper be heated before it can be made into something?

7. What was Ernest Rutherford's contribution to the understanding of the atom?

8. How are metals and non-metals organized in the periodic table?

9. What is the difference between a family and a period in the periodic table?

3.0

10. a) Explain what "ion charge" means.
    b) How can the ion charge be used to determine the chemical formula of compounds?

11. Name the elements in the substances below.
   a) $LiCl_{(s)}$
   b) $Al_2S_{3(s)}$
   c) $AgF_{(s)}$
   d) $ZnO_{(s)}$
   e) $Br_{2(l)}$

12. Which of the following compounds are ionic and which are molecular?
   a) beryllium oxide
   b) lithium phosphide
   c) water
   d) sodium fluoride
   e) carbon dioxide
   f) copper(I) chloride

13. Write the chemical formula for each compound in question 12.

4.0

14. Rewrite the chemical reactions below as word equations.
   a) A solid piece of sodium metal is placed in water, and it reacts explosively to form sodium hydroxide and hydrogen gas.
   b) Hydrogen peroxide is placed in sunlight and reacts slowly to form oxygen and water.
   c) Iron(II) chloride is formed when iron and chlorine gas are combined.
   d) When aluminum is exposed to oxygen, aluminum oxide forms.

15. For each reaction in question 14, suggest a different method for increasing the rate of reaction.

16. How is cellular respiration similar to combustion? How is it different?

17. Is there a difference between a catalyst and an enzyme? Explain your answer.

Connect Your Understanding

18. What contribution to the field of chemistry was made by:
   a) alchemists
   b) Robert Boyle
   c) John Dalton
   d) J.J. Thomson

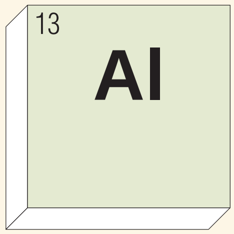
19. Compare Democritus's understanding of the atom with Niels Bohr's understanding.

20. Why was Dmitri Mendeleev's periodic table accepted as a useful way to organize the elements?

21. Explain how J.J. Thomson's "raisin bun model" of the atom is different from Niels Bohr's model of the atom.

22. Describe two patterns found in the periodic table.

23. Below is a box from the periodic table that is missing information. Copy the box into your notebook and fill in the missing information.



24. Copy the following table into your notebook. Use the periodic table to fill in the blanks.

Element	Mass Number	Protons	Electrons	Neutrons
H	1			
	166	82		
Ca	41			
Ag	109			
U	238			
	4			2
	21		10	

25. Write the name for the following formulas, including the correct Roman numerals where necessary:
   a) $MgBr_{2(s)}$
   b) $Ba_3N_{2(s)}$
   c) $FeP_{(s)}$
   d) $PbI_{4(s)}$
   e) $Cu_2S_{(s)}$
26. Why do we use kindling (small sticks of wood) to help start a fire?

Extend Your Understanding

27. How were the first "chemists" in the Stone Age different from "chemists" in the Iron Age?
28. Give three examples of how an understanding of the properties of a type of matter has benefited humans.
29. How can the periodic table be used to determine the ion charge of elements?
30. What is the chemical symbol of the element that has 14 neutrons in its nucleus?

Practise Your Skills

31. Create a mnemonic or "safety slogan" that can be used to remind people of the proper techniques for handling and disposing of laboratory materials.
32. In the following reactions, calculate the mass of the unknown product.
   a) How much water is produced when a spark creates an explosive reaction between 4 g of hydrogen and 32 g of oxygen?
   b) In a 100-g beaker, a student added 25 g of lead(II) nitrate to 15 g of sodium iodide. In her notebook, she recorded the mass of reactants as 40 g. During the chemical rection between the two materials in the beaker, the student noted a colour change but no gases being given off. When she weighed the products of the reaction, she found the total mass to be 140 g. Did this reaction conserve mass? Explain your answer.

Self Assessment

33. Scientific investigations usually require many people to work together as a team. Why is collaboration an important part of scientific work?
34. In this unit, you investigated many different questions and issues related to chemistry. Describe one idea that you would like to find out more about. Explain why you want to learn more about it.

Focus On — The Nature of Science

In this unit, you investigated the nature of science related to matter and chemical change. Consider the following questions.

35. Scientific knowledge results from the shared work of many people over time. Describe the development of an idea in this unit that resulted from the work of many people over time.
36. Was an alchemist really a scientist? Explain your answer.
37. It is often said that science cannot provide complete answers to all questions. Describe a situation in this unit where you felt this statement was true.
38. Reread the three questions on page 91 about the nature of science related to matter and chemical change. Use a creative way to demonstrate your understanding of these questions.