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BC Science 9 CONNECTIONS

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BC Science CONNECTIONS

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BC Science Connections 9

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Whitby, ON L1N 9B6

Please quote the ISBN and title when placing your order.

ISBN-13: 978-1-25-965069-7
MHID: 1-25-965069-3

1 2 3 4 5 6 7 8 9 1 0 TCP 1 2 3 0 9 8 7 6

Printed and bound in Canada

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ELECTRONIC PAGE MAKE-UP: Pixel Hive Studio

SET-UP PHOTOGRAPHY: David Tanaka

COVER IMAGES: Background: Andrii Vodolazhskyi/Shutterstock; Band Images: left, Masterfile RF; Chris Cheadle/All Canada Photos; goodluz/Shutterstock; Jason Doiy/iStock; Masterfile RF; PhotoSky/Shutterstock

Acknowledgements

Students – We would like to thank all the students who took part in focus groups, class testing, and in sharing work and ideas.

BC and Yukon Educators – Thank you to the many teachers, consultants, curriculum writers, and administrators who actively engaged in focus groups, product feedback, and field testing, and who shared best practices.

Clam Garden Network & Hakai Institute – Thank you to Nicole Smith, Dana Lepofsky, Keith Holmes, and Denise Augustine (Director of Aboriginal Education and Learner Engagement, SD79 Cowichan Valley) for assistance with clam garden content. Thank you to the Elders who shared traditional words for clam gardens with researchers over the years (see Lepofsky et al. 2015, Deur et al. 2015 and www.clamgarden.com for more information).

Science Fair Foundation of BC – Thank you to Patti Leigh, Karen Morley, and Madeleine Guenette who have provided direction and support with our resources and participated in the McGraw Hill Education BC Science Institutes for teachers.

Elementary and Middle School Advisors – Thank you to Delyth Morgan, Bronwen Howden, Nicole Hurtubise, Jayson Ricker and Karen Appleton.

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Contents

Investigations

Features

UNIT 1

UNIT 2

UNIT 3

UNIT 4

Safety in Your Science Classroom

Safety Symbols

The following safety symbols are used in *BC Science Connections 9* to alert you to possible danger. Be sure that you understand each symbol used in an activity or investigation before you begin.

Disposal Alert
This symbol appears when care must be taken to dispose of materials properly.

Thermal Safety
This symbol appears as a reminder to be careful when handling hot objects.

Sharp Object Safety
This symbol appears when there is danger of cuts or punctures caused by the use of sharp objects.

Electrical Safety
This symbol appears as a reminder to be careful when using electrical equipment.

Skin Protection Safety
This symbol appears when the use of caustic chemicals might irritate the skin or when contact with micro-organisms might transmit infection.

Clothing Protection Safety
A lab apron should be worn when this symbol appears.

Fire Safety
This symbol appears as a reminder to be careful around open flames.

Eye Safety
This symbol appears when there is danger to the eyes and safety glasses should be worn.

Fume Safety
This symbol appears when chemicals or chemical reactions could cause dangerous fumes.

Chemical Safety
This symbol appears when chemicals could cause burns or are poisonous if absorbed through the skin.

WHMIS 2015 Symbols

Look carefully at the WHMIS (Workplace Hazardous Materials Information System) safety symbols shown here. These WHMIS symbols are used throughout Canada to identify dangerous materials. Make certain you understand what these symbols mean. When you see these symbols on containers, use safety precautions. It is also important to know that WHMIS symbols were updated in 2015. So, older textbooks or chemical containers may have the previous symbols. Those symbols are being replaced with the ones below.

Symbol	Descriptor	Meaning
	Compressed gas	For gases under pressure
	Flammable	For fire hazards
	Oxidizer	For oxidizing hazards
	Acute toxicity	Can cause death or toxicity with short exposure to small amounts
	Health hazard	May cause or be suspected of causing serious health effects
	Exclamation mark	Can cause irritation to skin and eyes
	Corrosive	For corrosive damage to metals, as well as skin and eyes
	Explosive	For explosion or reactivity hazards
	Biohazardous infectious materials	For organisms or toxins that can cause diseases in people or animals
 *	Environmental hazard	May cause damage to the environment

*Environmental hazards are not regulated under WHMIS, but are regulated by the Globally Harmonized System. This symbol may appear on products from other countries.

non-latex gloves

Safety Rules and Procedures

Become familiar with the following safety rules and procedures. Following them and your teacher's instructions will make performing the activities and investigations safe and enjoyable. Your teacher will also give you specific information about any other special safety rules that need to be followed in your school.

1 General rules

- Listen carefully to your teacher's instructions.
- Inform your teacher if you have any allergies, medical conditions, or other physical problems that could affect your work in the science classroom. Tell your teacher if you wear contact lenses or a hearing aid.
- Obtain your teacher's approval before beginning any activity you have designed.

- Know the location and proper use of the nearest eyewash station, deluge shower, fire extinguisher, fire blanket, first-aid kit, and fire alarm.
- Before starting an activity or investigation, read all of it. If you do not understand how to do a step, ask your teacher for help.
- Be sure you have checked the safety symbols and have read and understood the safety precautions.
- Begin an activity or investigation only after your teacher tells you to start.

2 Acting responsibly

- When you are told to do so, wear protective clothing, such as a lab apron and safety goggles. Always wear protective clothing when you are using materials or equipment that may be a safety problem.
- Tie back long hair, and avoid wearing scarves, ties, or long necklaces.
- Never chew gum, eat, or drink in your science classroom. Do not taste any substance.
- Handle equipment and materials carefully. Carry only one object or container at a time.
- Inform your teacher of any spills so they can be cleaned up properly.
- Wash your hands thoroughly after doing an activity or an investigation.
- Dispose of materials as directed by your teacher.
- If other students are doing something that you consider dangerous, report it to your teacher.

3 Working with sharp objects

- Always cut away from yourself and others when using a knife or scissors.
- Always keep the pointed end of scissors or any pointed object facing away from yourself and others if you have to walk with such objects.
- If you notice sharp or jagged edges on any equipment, take special care with it and report it to your teacher.
- Dispose of broken glass according to your teacher's instructions.

4 Working with electrical equipment

- Make sure your hands are dry when touching electrical cords, plugs, or sockets.
- Pull the plug, not the cord, when unplugging electrical equipment.
- Report damaged equipment, broken ground pins, or frayed cords to your teacher.
- Place electrical cords where people will not trip over them.

5 Working with heat

- Always use heatproof containers.
- Point the open end of a container that is being heated away from yourself and others.
- Do not allow a container to boil dry.
- Handle hot objects carefully. Be especially careful with a hot plate, even if you think it has cooled down.
- If you use a laboratory burner, make sure you understand fully how to light and use it safely.
- If you do receive a burn, inform your teacher, and apply cold water to the burned area immediately.

6 Working with chemicals

- If any part of your body comes in contact with a substance, wash the area immediately and thoroughly with water. Inform your teacher.
- If you get anything in your eyes, do not touch them. Wash them in the nearest eyewash station immediately and continuously for 15 minutes, and inform your teacher.
- If you are asked to smell a substance, never smell it directly. Hold the container slightly in front of and beneath your nose, and waft the fumes towards you.
- Hold containers away from your face when pouring liquids.

7 Designing and building

- Use tools safely to cut, join, and shape objects.
- Handle modelling clay correctly. Wash your hands after using modelling clay.
- Follow proper procedures when using mechanical systems and studying their operations.
- Use special care when observing and working with objects in motion.

Inquiry

Welcome to Science 9 and the Process of Scientific Inquiry

Imagine taking a walk near where you live. Maybe you are familiar with the area. Maybe it's a place you don't know very well. As you observe your surroundings, what do you notice? What kinds of things do you know? What kinds of things are you curious about? What makes you wonder?

Your wonderings about the world around you are the start of a process that leads to answers. Sometimes you can find answers easily by looking online or asking a person whose opinions and knowledge you trust. Other times you have to dig deeper by investigating and reflecting on many sources of information.

Asking questions about what you observe and wonder about is something that all scientists do. This year in science class, you will have many opportunities to observe, wonder, ask questions, and collect evidence to support the answers you develop. As you engage in this process, you will be demonstrating and developing scientific attitudes such as those shown below.

These are examples of scientific attitudes. **What other scientific attitudes can you think of, and what value do they bring to the work that you and other scientists do?**

Curiosity

Persistence

Open mindedness

Questioning

Effective communication

Flexible thinking

Humility

Objectivity

Accuracy of observations

Inventiveness

Critical mindedness

Risk taking

Scientific Inquiry

Observing, wondering, asking questions, collecting evidence, developing answers—these are all part of the process of scientific inquiry. Scientific inquiry is something that scientists do to study and propose explanations of the world, the universe. That *doing* results in a particular kind of *knowing and understanding* of the world. Although there is no single method of scientific inquiry that everyone follows, the key steps are outlined below. Since the answers to the questions we ask can always lead to new questions, the inquiry process is often depicted in the form of a cycle diagram.

Key steps in the process of scientific inquiry

Scientific Inquiry in Your Science Class

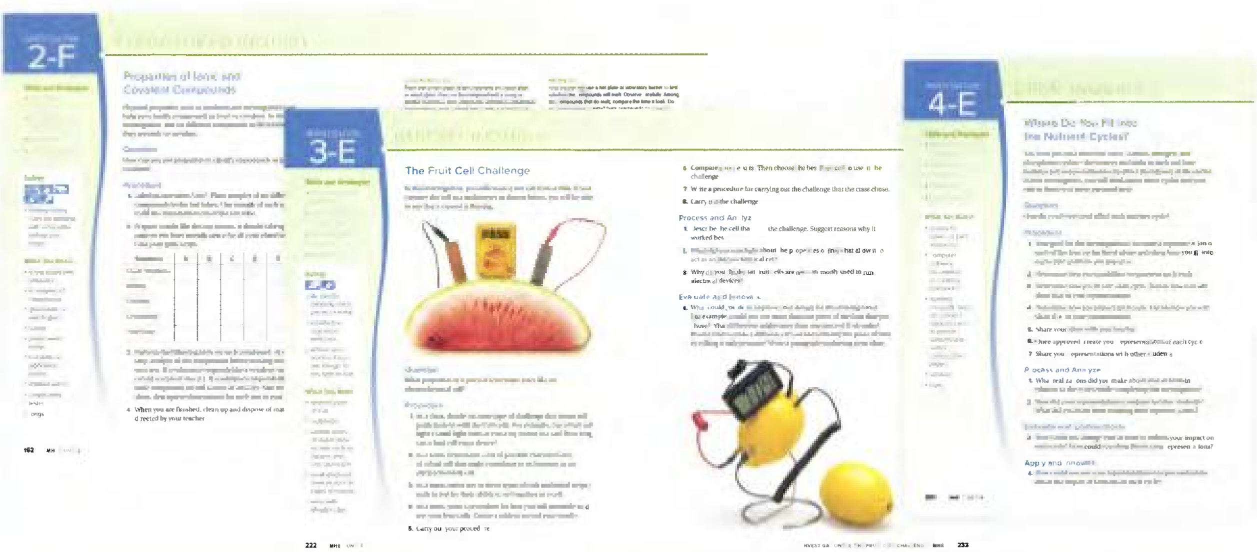
In your class, your teacher may use the table below to help you develop your skills of scientific inquiry. If you look through this textbook, you will see that the Investigations are classified as Structured, Guided, or Open Inquiries. The first column of the table below lists the most common steps for an Investigation. In each of the next three columns, you will see the terms Teacher-led or Student-led.

Notice that in a Structured Inquiry, the teacher is responsible for the first two of the common Investigation steps, and you are responsible only for the last one. Compare the responsibilities of the teacher and students in a Structured Inquiry with the responsibilities in a Guided Inquiry and an Open Inquiry. Notice that more of the responsibilities shift from the teacher to the students. This means that as you do a variety of activities and investigations this year, you will get more practice and support to develop your inquiry skills.

Investigation Types in this Textbook

Common Investigation Steps	Structured Inquiry	Guided Inquiry	Open Inquiry
Ask a question	Teacher-led	Teacher-led	Student-led
Plan and carry out a procedure	Teacher-led	Student-led	Student-led
Analyze evidence and support an answer or claim	Student-led	Student-led	Student-led

You may be wondering what this all looks like in class. The example on the next page will help give you an idea of what you do in an inquiry investigation and some of the skills you can develop.



Summary of an Inquiry: Which Laundry Detergent Cleans Better in Cold Water?

Inquiry Stage	What's Going On?
Making a Prediction The teacher posed a question and asked the class which laundry detergent cleans better in cold water: O-So-Clean, Dirt-B-Gone, or Sudsy Scrub. Shan and Tauryn were asked to make a prediction by their teacher. After some discussion, the two classmates decided that Sudsy Scrub would work best.	*Shan and Tauryn are starting an inquiry investigation by making a prediction based on what they think may happen. They will test their prediction and use the data to inform their inquiry.*
Testing a Prediction The students were then asked to test their prediction by planning and conducting an investigation. After collecting their results, they found that Dirt-B-Gone was best at removing grape juice from cotton fabric.	*The students now have some data to compare against future tests.*
Wondering and Generating Questions Their teacher asked them to write down three things they wonder about, based on their findings. Shan and Tauryn agreed on the following "I wonder" statements: • Does the type of fabric matter? • Does the type of stain matter? • Are there other detergents better than Dirt-B-Gone?	*The wondering questions help the students define variables that can be tested and controlled.*
Generating a Testable Question The students chose one wondering statement to rewrite in the form of a testable question: "Will Dirt-B-Gone be the best detergent for removing ketchup from cotton?" Next, they developed a hypothesis based on their testable question: "If we use the three detergents on three identical pieces of cotton fabric stained with ketchup, then we will be able to compare their stain-removing ability." They also included a prediction based on their hypothesis: "O-So-Clean will be best at removing ketchup from cotton fabric."	*Shan and Tauryn are going to change the variable of the stain type and record their results. They can base their hypothesis and prediction on their results from the grape juice trial.*
Answering the Question The students planned a fair test that kept everything the same as the first experiment except the type of stain. After repeating the procedure three times they determined that Sudsy Scrub was best at removing ketchup from cotton fabric.	*A fair test for any inquiry is very important. If the test isn't fair, then you can't compare the data from different trials of the investigation. Part of a fair test is ensuring that all variables but one are controlled.*
Analyzing Information Analyzing their information, the students concluded that changing the detergent made a difference. They communicated their findings with the class, stating they found Sudsy Scrub was better at removing ketchup from cotton fabric.	*Looking at their data, Shan and Tauryn were able to identify evidence to answer their question. Notice they used the data collected in the investigation to support their conclusion. (What do you think of their explanations?)*
Next Steps As they were cleaning up, Tauryn wondered what other types of stains they could compare with this type of investigation.	*Any investigation can always lead to new wonderings, new questions.*

First Peoples Perspectives in Science

First Peoples have a profound connection with the local environment built on thousands of years of experience. Here a man fishes at the Fraser River where his ancestors have fished for generations.

Science is all about understanding the natural world. In this book you are going to have the opportunity to understand the world from different perspectives.

Like all knowledge, scientific knowledge is rooted in culture. What is often called Western science is based on ideas that developed mostly within the cities and aristocracies of Europe during the 1600s. Indigenous people around the globe understand the world in different ways. Their science is based on living close to the land for thousands of years.

First Peoples scientific knowledge is based on the knowledge and experience gained from the local environment. Therefore, their knowledge is as diverse as the First Peoples themselves. However, most First Peoples share a world view that is based on a reciprocal and respectful relationship with the natural world.

The aim of First Peoples science is to live in balance with the rest of the world. The scientific perspective of First Peoples reflects an understanding that survival depends on an equal relationship with the rest of the universe.

Traditional Ecological Knowledge (TEK)

One of the most important aspects of First Peoples science is Traditional Ecological Knowledge or TEK. This is detailed local knowledge that First Peoples have gained through their relationships with the particular landscape where they live. It takes in the world view of the people. This includes relationships with their local ecosystems and the plants and animals that live there, as well as with spiritual dimensions.

The fish weir is an example of a sustainable fishing technique used for thousands of years to fish selectively for salmon returning to their spawning rivers.

The traditional knowledge of First Peoples includes understanding the lives and behaviours of plants and animals. It also includes skills and practices that people have used and developed over thousands of years to use these resources in sustainable ways. TEK embeds beliefs about the natural world and the role people play in that world. It emphasizes living in a way that respects the natural world.

Traditional Ecological Knowledge has been accumulated over many thousands of years as people interacted with the land. It is still being accumulated. TEK is learned as a result of direct contact with the local environment through observation, experience, events, and interactions. The knowledge has been passed down from generation to generation, from time immemorial.

One way that knowledge and skills are passed down is through direct experience. From a young age, children participate in the cultural activities of their ancestors. This can include helping to harvest resources from the land and participating in ceremonies and celebrations.

Another way that TEK is transmitted is through story. In the past, First Peoples lived in oral societies. Storytelling was a crucial way of passing on information, values, and beliefs. Traditional stories told today still hold the ancient teachings that speak about humans' relationships with the natural world. They often emphasize the need for respect by telling stories about people or creatures who did not show respect.

The vehicle for passing on TEK is, of course, the language of the First Peoples who hold the knowledge. There are more than 30 different languages spoken by the First Peoples of B.C. Each has its own way of speaking about the natural world through its words and phrases, grammar, and local place names.

Traditional knowledge is passed on from one generation to the next through experience and story. A reciprocal relationship with the land ensures survival for future generations.

Today, First Peoples sometimes share their Traditional Ecological Knowledge with scientists working in fields such as wildlife and environmental sciences. Their specific knowledge of animal behaviours and their relationships with the local ecosystem is a storehouse of data that is invaluable to the work of scientists.

It is necessary to remember, however, that Traditional Ecological Knowledge is the intellectual property of the people who hold it. Some of this knowledge is considered sacred and is usually not shared with outsiders. Other knowledge, such as changes in animal behaviour and properties of medicinal plants, may be shared, with the goal of contributing to wider scientific knowledge.

Recognizing First Peoples Perspectives

Much of this book deals with the natural world from the perspective of Western science. However, there are also places where you can think about the world from a First Peoples perspective of science. To do this, it is important to understand some of the foundations of First Peoples science.

We can think of these foundations by considering four related themes or ideas: interconnectedness, transformation, renewal, and connection with place.

From a First Peoples perspective everything in the universe is connected. Humans and the rest of the world are interdependent.

Interconnectedness

From a First Peoples perspective, humans are not separate from or outside the rest of nature. We are one part of the universe. This view is expressed by the idea of interconnectedness. Everything is connected; everything is related.

The idea that everything is connected goes further. Because everything is connected, everything is also interdependent. Humans depend on the rest of the natural world for our existence and our survival.

If people understand that everything is connected and interdependent, that understanding has a big impact on their relationships with the natural world. It means knowing that any action people take will affect the land and living things in some way.

Fire transforms matter and energy into new forms. For many First Peoples, fire is one of the four formative elements, along with air, water, and earth.

Transformation

Another idea understood by First Peoples science is that everything is in motion. Change is normal and to be expected. Change brings about transformation—moving from one form or state to another.

Transformation is part of interconnectedness. For example, when we eat plants and animals, our bodies transform the food. The plants and animals become part of us.

First Peoples have always understood the power of transformation. Many origin and creation stories talk about a time when the world was transformed. At the core of most First Peoples cultures is a Trickster character like Coyote or Raven. The Trickster sometimes causes chaos but ultimately brings about order to the world. This usually involves some kind of transformation.

Change and transformation also bring about creativity. The universe itself is a creative force, and First Peoples perspectives view human existence as a creative activity.

Renewal

Change often is cyclical—it moves in patterns that repeat themselves over and over again. Think of the seasons. Life changes over the year from young growth in the spring, ripening and maturing in the summer and autumn, and decay and sleep through the winter. But spring comes again, and life is renewed.

Renewal is the third big idea held in First Peoples perspectives on science. Renewal is key to maintaining the conditions people need to exist on the planet. But First Peoples knowledge understands that for nature to renew itself, ecosystems must be sustained. People have to act in a sustainable way to ensure the planet renews itself.

A new shoot renews the plant known as Devil's Club. For First Peoples, this plant offers powerful medicine, to be used only by people with specialized knowledge.

First Peoples honour the importance of renewal through important ceremonies. For example, many communities have ceremonies in the spring to mark the first berries, the first bitterroot, or the first salmon. These may be family or community events that recognize the renewal of the gifts that the natural world provides. They may include words or songs that give thanks to the plants or animals for giving up their lives to nourish humans.

Connections with Place

This brings us back to the relationship with the land. When we say land, we mean all of nature, or the universe. But First Peoples knowledge usually comes from the local territories where they live. Traditional Ecological Knowledge is scientific knowledge resulting from generations of observing and experiencing the landscape where people live.

For most First Peoples, their connections with place are a part of their identity. This goes to the heart of the idea of interconnectedness and interdependence. In every way imaginable, First Peoples feel they are an extension of the land. This is why First Peoples science aims to live in harmony with the rest of the natural world. It is crucial for all survival.

Bridging First Peoples Knowledge and Western Science

First Peoples perspectives on science, then, provide a holistic (all-inclusive) view of science. It seeks to understand how all things are connected and dependent on each other. Western science often emphasizes the study of details, looking at certain aspects of the natural word as if they are separate from it. Sometimes it is helpful to look at the world

This dual-language sign warns of rattlesnakes in English and Nsyilxcen, the Okanagan language.

in such detail. Neither view is better or worse than the other. We can benefit from both.

One way in which First Peoples scientific knowledge usually differs from Western science is the inclusion of spirituality. Because of their holistic view, because everything is connected, First Peoples include the spiritual side of life as part of their knowledge of the universe. It is important to note the difference between spirituality and religion. When we speak of First Peoples spiritual connections with the natural world, this is something quite different from the concepts of religious beliefs.

Spirit is that part of life that can't be observed and measured scientifically. It can be thought of as energy, or as the life force. One way to understand this is through different perspectives on animate and inanimate entities. Western science separates everything in the universe as animate or inanimate. Cougars and blueberries are animate: they are living. Rocks and stars are classified as inanimate. However, First Peoples perspectives see everything as animate, as alive. Rocks and stars have their own spirit or life force.

Western science does not usually include the spiritual side of life in its knowledge system. But there are interesting parallels with First Peoples perspectives. Consider the big bang theory of the universe. All matter is believed to have been created in the mysterious moments of the big bang. Immense forces created the stars. Almost all the elements that we know of in the universe were created and transformed in the heart of the stars. The stars exploded, sending particles of these elements through space. We are made from those particles. We are, in fact, star dust.

Petroglyph in Gitga'at territory. No one knows the meaning of these rock carvings, but they likely had something to do with the spiritual world. There are dozens of carvings along this beach in the Great Bear Rainforest, which is covered twice a day by the tides.

Another parallel between First Peoples science and Western science may be found in our dreams. For many First Peoples, dreams are an important part of understanding life. Some hunters dream about the animals they are going to hunt the next day. In the same way, many major scientific discoveries have been made through dreaming. For example, Niels Bohr's insights into the structure of atoms and Frederick Banting's discovery of insulin came about, in part, through dreams.

Looking at Science 9 from a First Peoples Perspective

As you study the lessons in this course, find opportunities to look at the information, concepts, and activities as First Peoples might understand them. Here are some questions you can ask to help look at the concepts in a new way:

- What can we learn from Traditional Ecological Knowledge? First Peoples have been observing and living in their local ecosystems since time immemorial.

Star trails over the Cariboo Mountains. According to Star Chief Robert Cardinal, Cree Blackfoot astrophysicist: "The light, the energy and matter are about five per cent of what the universe is made of. We have no clue what the rest is. When you know that a huge part of the universe is not understood, there's plenty of room there for spirit."

The knowledge and skills they have attained can help bring a new or additional insight to the work of Western scientists.

- How can we connect with the local First Peoples community to understand these ideas better? Can we connect with local stories and language?
- Can we learn anything new about the topic by thinking from a female or male perspective? Often women and men hold different Traditional Ecological Knowledge about certain topics.
- What is the story? Can you put the facts together to make a narrative about a topic? Does this help bring new understandings, or help you remember some ideas?
- How does this topic fit into the big picture? How can we view it holistically? Does that help us understand the problems or issues differently?
- How is this topic connected to other topics or ideas? How is it interconnected and interdependent?
- Is there evidence of transformation in this topic? Does understanding how motion and change are involved give us new ways to understand a problem?
- What is the role of renewal? Is there a question of sustainability that needs to be understood?
- How does the topic connect with you and your sense of place?

A Tour of Your Textbook

Welcome to *BC Science Connections 9*. This textbook introduces you to the wonders of how different organisms reproduce, the amazing properties of chemical elements and compounds, the exciting world of electrical energy, and the life-sustaining interconnections of Earth's spheres. Take a brief tour on the following pages to learn some key features of your textbook.

Unit Opener

There are four units of study in your science course—one for biology, one for chemistry, one for physics, and one for Earth and space science.

Each unit opens with a spread of two pages that feature a large, stunning photo.

The box in the upper left corner has

- the unit number
- the unit title
- an intro paragraph and quotation connected to the visual

The box in the lower right corner helps you to start thinking about the unit opener, the whole unit itself, and questions of your own that you can use to personalize your learning.

Connections to First Peoples Perspectives

This special icon identifies places in the textbook with a First Peoples context. The icon can appear on any page and as part of any component of the textbook—narrative text, activity, investigation, photo, illustration, and questions.

The appearance of this icon signals an opportunity to pause and reflect on ways that First Peoples Principles of Learning may be acknowledged, understood, and respected.

Unit at a Glance

The second spread provides an overview that shows you what you will learn, do, and be responsible for.

The **Essential Question** is your doorway to inquiry. It echoes the Big Idea in a form that enables you to investigate important ideas and assumptions that the Big Idea represents.

The box in the upper left corner outlines your responsibilities—what is expected of you—for the unit.

The unit is organized into **Topics**, which are like mini-chapters. Each Topic asks a question that is a smaller, more easily explored part of the Essential Question.

Some of the things that you will do and come to know in the Topic are showcased.

Topic Openers

Each **Topic** opens with a spread of two pages that have the following parts:

- the Topic number and title
- an intro paragraph that works with a large photo (sometimes with a second smaller photo added)
- a list of Key Concepts and Curricular Competencies
- activities that your teacher may choose as possible Starting Points for the Topic
- a list with Key Terms that appear in the Topic

Key Concepts are the titles of the segments that make up each Topic. (See **Concepts** below.)

Curricular Competencies tell what you are expected to be able to do. Each Topic focusses on some of the many skills and processes that you will use at school, at home, and in your communities through your whole life.

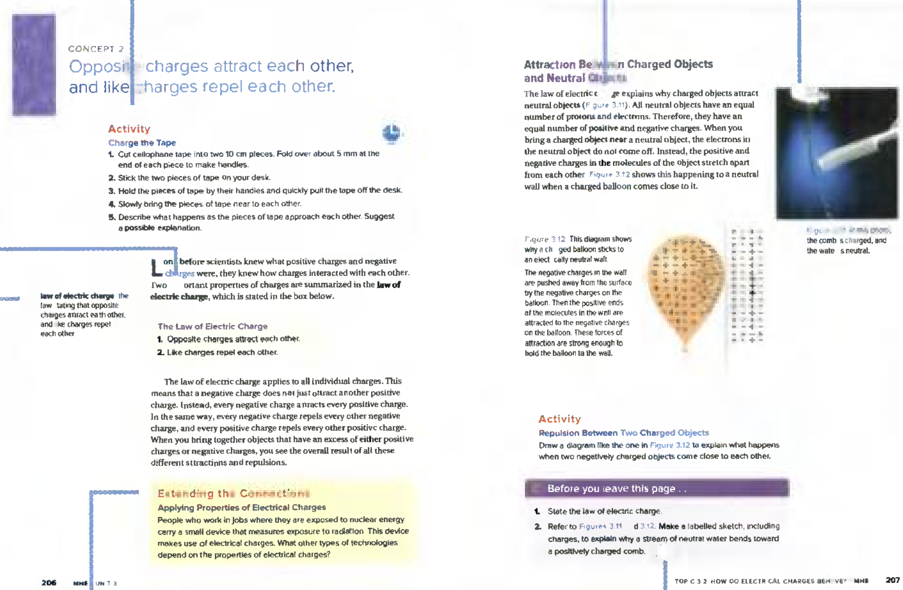
Concepts

The title of each **Concept** is an answer to the Topic-title question. Each Concept has some or all of the following parts.

An **Activity** invites you to think about or do something that is related to the Concept. Sometimes an activity may ask you to make connections to what you have learned in a previous grade or in a previous Topic.

Figures are photos, diagrams, and other visual components. Captions identify each Figure with a number and provide information about the visual. Some captions also pose questions, which appear in bold type.

Key terms are in boldface type in the narrative text. They also appear in the margin with a definition so you can find them easily. (Key terms also appear in the Glossary at the back of the book.)


CONCEPT 2
Opposite charges attract each other, and like charges repel each other.

Activity
Charge the Tape
1. Cut cellophane tape into two 10 cm pieces. Fold over about 5 mm at the end of each piece to make handles.
2. Stick the two pieces of tape on your desk.
3. Hold the pieces of tape by their handles and quickly pull the tape off the desk.
4. Slowly bring the pieces of tape near to each other.
5. Describe what happens as the pieces of tape approach each other. Suggest a possible explanation.

Long before scientists knew what positive charges and negative charges were, they knew how charges interacted with each other. Two important properties of charges are summarized in the **law of electric charge**, which is stated in the box below.

law of electric charge the law stating that opposite charges attract each other, and like charges repel each other

The Law of Electric Charge
1. Opposite charges attract each other.
2. Like charges repel each other.

The law of electric charge applies to all individual charges. This means that a negative charge does not just attract another positive charge. Instead, every negative charge attracts every positive charge. In the same way, every negative charge repels every other negative charge, and every positive charge repels every other positive charge. When you bring together objects that have an excess of either positive charges or negative charges, you see the overall result of all these different attractions and repulsions.

Extending the Connections
Applying Properties of Electrical Charges
People who work in jobs where they are exposed to nuclear energy carry a small device that measures exposure to radiation. This device makes use of electrical charges. What other types of technologies depend on the properties of electrical charges?

206 MHE UNIT 3

Attraction Between Charged Objects and Neutral Objects
The law of electric charge explains why charged objects attract neutral objects (Figure 3.11). All neutral objects have an equal number of protons and electrons. Therefore, they have an equal number of positive and negative charges. When you bring a charged object near a neutral object, the electrons in the neutral object do not come off. Instead, the positive and negative charges in the molecules of the object stretch apart from each other. Figure 3.12 shows this happening to a neutral wall when a charged balloon comes close to it.

Figure 3.11 In this photo, the comb is charged, and the water is neutral.

Figure 3.12 This diagram shows why a charged balloon sticks to an electrically neutral wall. The negative charges in the wall are pushed away from the surface by the negative charges on the balloon. Then the positive ends of the molecules in the wall are attracted to the negative charges on the balloon. These forces of attraction are strong enough to hold the balloon to the wall.

Activity
Repulsion Between Two Charged Objects
Draw a diagram like the one in Figure 3.12 to explain what happens when two negatively charged objects come close to each other.

Before you leave this page . . .
1. State the law of electric charge.
2. Refer to Figures 3.11 and 3.12. Make a labelled sketch, including charges, to explain why a stream of neutral water bends toward a positively charged comb.

TOPIC 3.2 HOW DO ELECTRICAL CHARGES BEHAVE? MHE 207

Extending the Connections offer suggestions for new or additional opportunities for discovery that you can pursue on your own, with other interested classmates, and sometimes with your whole class.

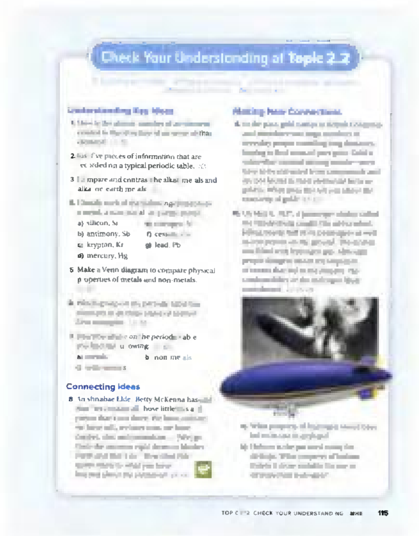
Before you leave this page is a small set of questions to help you check your understanding before you move on.

At Issue

The **At Issue** sets the scene for a matter of social, cultural, environmental, and/or scientific importance, and then hands it over to you to "Dig Deeper." You can choose one or more of the questions offered, or you can create your own adventure by pursuing a question of your own.

Check Your Understanding

A set of review questions appear at the end of each Topic. Different types of questions help you assess what you know and can do. The icons assigned to each question identify specific skills and processes that you demonstrate in answering the question.



Make a Difference

There are two types of these features.

- **Take a Stand** asks you to make an evidence-based and opinion-supported decision about an issue.
- **Take Action** asks you to become involved in a project that benefits your school or community.

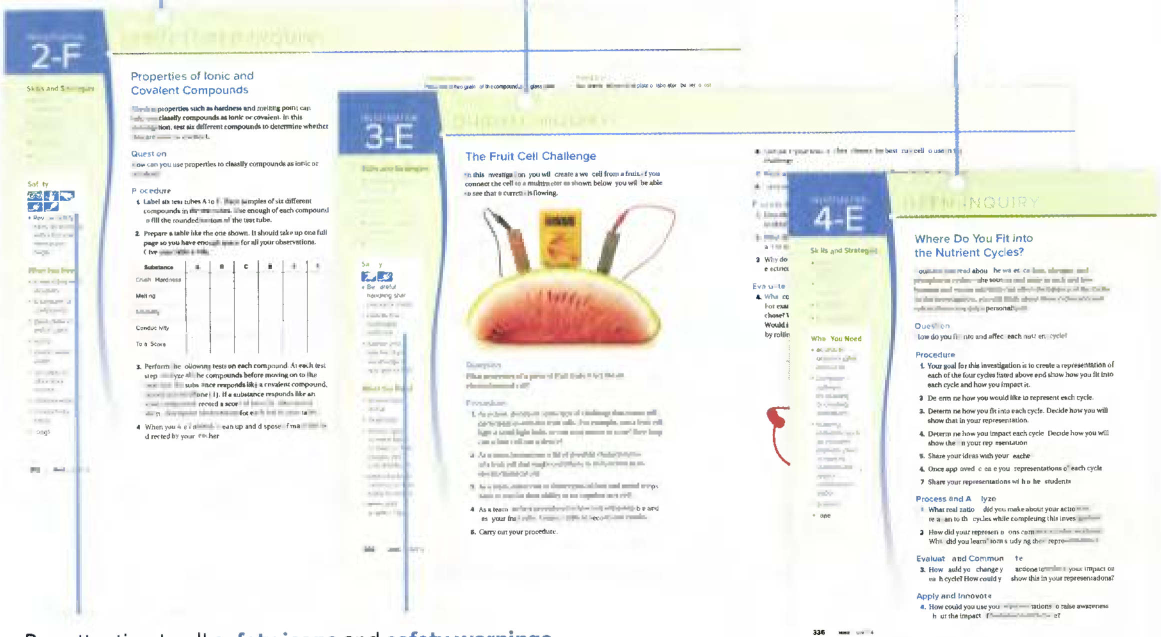
Investigations

These are hands-on and minds-on opportunities to develop your science inquiry skills and to provide practice working with laboratory equipment and materials.

In a **Structured Inquiry**, you follow a specified procedure to investigate a question that is provided to you.

In a **Guided Inquiry**, you design your own procedure to investigate a question that is provided to you.

In an **Open Inquiry**, you design your own procedure to investigate a question of your own.



Pay attention to all **safety icons** and **safety warnings** so you can maintain a safe classroom environment.

Science at Work

This feature showcases a variety of jobs and careers that you might be interested to investigate on your own.

Unit Assessment

This cutting-edge, multimedia-based, interactive activity enables you to demonstrate and apply knowledge, skills, and processes that you have been developing throughout the unit.

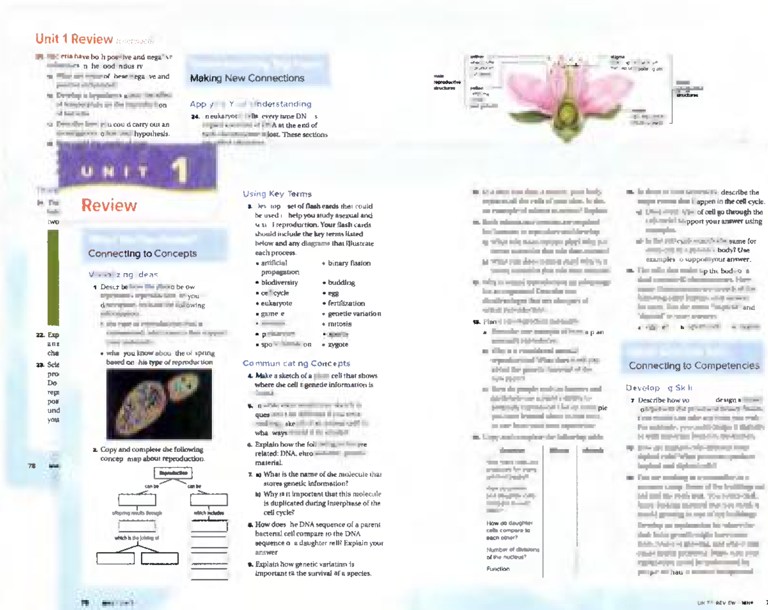
Unit Summary

This reviews the Topic titles and Concept titles from the unit, along with Key Terms that appear in each Topic.

Unit Review

At the end of each unit, these pages can help you assess...

- what you know—your recall of essential information
- what you can do—your ability to engage and apply your critical and creative thinking skills
- what you understand—your ability to apply your knowledge and skills to make new connections to yourself, to society, and to the worlds that you share with all other beings



UNIT 1

The continuity of life depends on cells being derived from cells

Apples are Canada's largest fruit crop, and B.C. contributes more than one billion of them to markets in North and Central America, Europe, and Asia. But without bees, such as the one on this apple blossom, there would be no apples—or beets, lettuce, sunflowers, and a host of other plants that provide the world's food. Bees help transfer pollen, initiating a series of cellular events that enable most flowering plants to reproduce and thus ensure the survival of their species.

"Given the estimates that over $\frac{3}{4}$ of flowering plant species rely or benefit from pollination services, these oft-neglected insects are critical components to maintaining ecosystem and agricultural sustainability."

Sheila Colla, PhD
North American Co-Coordinator of the IUCN Species Survival Commision, Bumblebee Specialist Group

- What do bees get from the flowers they visit? What do the plants get from the bees?
- Bees are not the only pollinating animals. What other animals help plants reproduce?
- What questions do you have about—this photo? the introduction? the quotation? the title for this unit? ...?

UNIT 1

At a Glance

You will demonstrate what you know, can do, and understand by being able to

- Perform investigations and use other investigative methods to explore asexual and sexual reproduction in a variety of organisms
- Develop and use models and other methods to represent and compare mitosis and meiosis
- Seek patterns and connections to compare forms of asexual and sexual reproduction
- Apply a variety of ways of knowing, including First Peoples perspectives and knowledge, to reflect on and investigate the continuity of life and its cellular basis
- Use evidence-based arguments to communicate ideas about reproduction and continuity

ESSENTIAL QUESTION

How is the reproduction of cells essential to the survival of organisms?

TOPIC 1.1:

Why is the reproduction of cells important?

Some things you will do:

- observe and ask questions about the world around you
- develop skills in the use of the microscope
- consider assumptions and bias in your and others' work

Some things you will come to know:

- general differences between asexual and sexual reproduction
- the importance of transferring genetic information in reproduction

TOPIC 1.2:

What are different ways that living things reproduce asexually?

Some things you will do:

- select and use equipment to collect and record data
- make, analyze, and interpret graphs, models, and diagrams
- analyze cause-and-effect relationships

Some things you will come to know:

- different ways that organisms reproduce asexually
- the changes that take place as a cell divides by mitosis
- how First Peoples apply their understanding of plant reproduction

TOPIC 1.3:

How do living things sexually reproduce?

Some things you will do:

- exercise healthy, informed skepticism to evaluate claims in secondary sources
- critically analyze the validity of information
- generate and introduce new or refined ideas

Some things you will come to know:

- different ways that organisms reproduce sexually
- how cell division in meiosis differs from mitosis
- cellular developments related to human reproduction

TOPIC 1.4:

How does reproduction contribute to the variety of life on Earth?

Some things you will do:

- identify questions you have about the world around you
- use knowledge of scientific concepts to draw conclusions consistent with evidence
- connect scientific explorations to careers

Some things you will come to know:

- advantages and disadvantages of asexual reproduction
- advantages and disadvantages of sexual reproduction
- how sexual reproduction contributes to Earth's diversity

TOPIC 1.1

Why is the reproduction of cells important?

Key Concepts

- Reproduction ensures that life exists beyond its present generation.
- Reproduction transfers genetic information from parents to offspring.

Curricular Competencies

- Demonstrate a sustained intellectual curiosity about a scientific topic or problem of personal interest.
- Experience and interpret the local environment.
- Ensure that safety and ethical guidelines are followed in your investigations.
- Apply First Peoples perspectives and knowledge, other ways of knowing, and local knowledge as sources of information.

The Granville Island market is a popular place for locals and tourists alike. As in other markets throughout the province, vendors display their wares in hopes of attracting hungry customers.

Take a moment to think about all the different kinds of fruits, vegetables, and meats that you could find at a market such as this. Reflect on how they differ in qualities such as size, colour, shape, and the number of their cells. Then consider this: Each began, at the very start of its life, as one, single cell. For that matter, so did you. And so did every other living thing on Earth.

Starting Points

Choose one, some, or all of the following to start your exploration of this Topic.

1. **Identifying Preconceptions** What do you remember about cells from Science 8? What is the cell theory, and what are its three statements? How do prokaryotic cells differ from eukaryotic cells?
2. **Questioning** All of us started out as a single cell. What do you think happened to the one cell you started from to make the person you are today? What do you think would happen if your body could no longer make new cells?
3. **Applying** Think about a food such as apples, which come in so many different varieties. What makes all the apples of one variety the same but different from other varieties? How are these similarities and differences achieved?
4. **Considering First Peoples Perspectives** Life renews itself through reproduction of cells. In what ways have humans affected this process of renewal? What are some ways that people can impact sustainability of plants and animals through their actions?

Key Terms

There are four key terms that are highlighted in bold type in this Topic:

- asexual reproduction
- DNA
- sexual reproduction
- chromosome

Flip through the pages of this Topic to find these terms. Add them to your class Word Wall along with their meanings. Add other terms that you think are important and want to remember.

CONCEPT 1

Reproduction ensures that life exists beyond its present generation.

Activity

Take a Nature Walk

According to cell theory, all living things are made up of cells, which are derived from previously existing cells. Following your teacher's instructions, go for a nature walk. Record, digitally or in writing, all the organisms that you observe.

1. What does it mean to you that all the life you observe is made up of cells?
2. Record your thoughts, curiosities, and questions about cells and life around your school, your home, and other places that you are a part of.
3. Think about interconnectedness. How are the parts of a plant connected to what you observe? How is the sky connected? How are you connected?

The people of the Kwantlen First Nation stand along the river banks of Fort Langley (Figure 1.1) Like their ancestors before them, like other First Peoples throughout the province, they stand to mark the start of this year's salmon run. Following traditions established since time immemorial, they welcome the returning salmon, their relatives, with respect and gratitude. In this ceremony, the people and the salmon honour promises made long ago to renew and replenish the spirit and the flesh—promises that sustain generations now and in the future.

Figure 1.1 All First Foods ceremonies reflect the spiritual dimension of First Peoples science. They also demonstrate the interconnectedness of people and the natural world, and they reinforce respect for resources of the land.

Reproduction and Sustainability

Sustainability refers to the ability of the environment and the living things it supports to endure into the future (Figure 1.2) Imagine for a moment that all living things on Earth are no longer able to reproduce—to make more of their own kind. Picture, for example, the last bear eating the last berry on the last berry bush. Or catching the last trout that moments earlier snapped up the last crayfish. Imagine this same scenario for every organism on the planet. In this grim thought experiment, it would not be long before all life on Earth starved and came to an end.

Reproduction ensures that organisms have a source of nutrients and energy to sustain their life processes. The sustainability of living things depends on reproduction.

Figure 1.2 The Western Painted Turtle is B.C.'s only native freshwater turtle. It is found mainly on the southwest coast, where it is endangered, and in the southern interior, where it is of special concern. Adults live up to 30 years, but males need 8 to 10 years to reach sexual maturity and females 12 to 15 years. **What questions can you think of about the Western Painted Turtle, interconnections, and the turtle's ability to endure into the future?**

Reproduction and Continuity

Look back at the title for this unit on page 2. When you read the phrase "cells being derived from cells," you might recall learning about the cell theory in Science 8. Part of the cell theory states that all cells come from pre-existing cells. What this means is that all cells are formed through the division of previously existing cells. In short, all cells are formed by reproduction.

Connect to Investigation 1-A on page 14

Now look at the word at the start of the unit title: *continuity*. Biologists use this word to talk about how each species (kind) of organism continues to exist over time, from one generation to another. Individual organisms grow, develop, and die. However, a species continues to exist into the future only if its individual members produce offspring. A species continues to exist into the future only if its members reproduce.

Reproduction ensures that life exists beyond its present generation. All the life you see around you, all the life in the world beyond the places that you live, all the life that provides you and other living things with food that supplies you with energy and nutrients to grow, develop, and carry out all your daily activities—all this life depends on the ability of cells to reproduce.

Connect to Investigation 1-B on page 16

Before you leave this page . . .

1. What does the word *continuity* mean in terms of reproduction?
2. How are these three terms related: *reproduction*, *sustainability*, *continuity*?

CONCEPT 2

Reproduction transfers genetic information from parents to offspring.

Every species has its own strategies for reproduction. As shown in Figure 1.3, the flowers of many plants have colours and scents that attract animals so that they can pick up and transfer pollen to other flowers (A) Many animals have courtship rituals that enable sexually mature individuals of a species to become mating pairs (B). Microbes such as bacteria reproduce on their own and form offspring by dividing in two (C)

Figure 1.3 Examples of different strategies for reproduction

Despite these differences, there are just two basic ways that living things reproduce. They may reproduce asexually or sexually. Figure 1.4 summarizes the two types of reproduction.

In **asexual reproduction**, offspring come from a single parent. Each offspring receives a copy of the parent's genetic material. As a result, offspring are genetically identical to the parent and to each other.

In **sexual reproduction**, two parents each contribute half of the offspring's genetic material. As a result, the offspring have genetic information that is different from either parent's, so the offspring are not identical to their parents or, in most cases, to each other.

In both asexual and sexual reproduction, the genetic material and the information it holds is passed on to the offspring. This information is contained within what is often called the molecule of life: DNA.

asexual reproduction reproduction that requires only one parent and produces genetically identical offspring

sexual reproduction reproduction that requires two parents and produces genetically different offspring

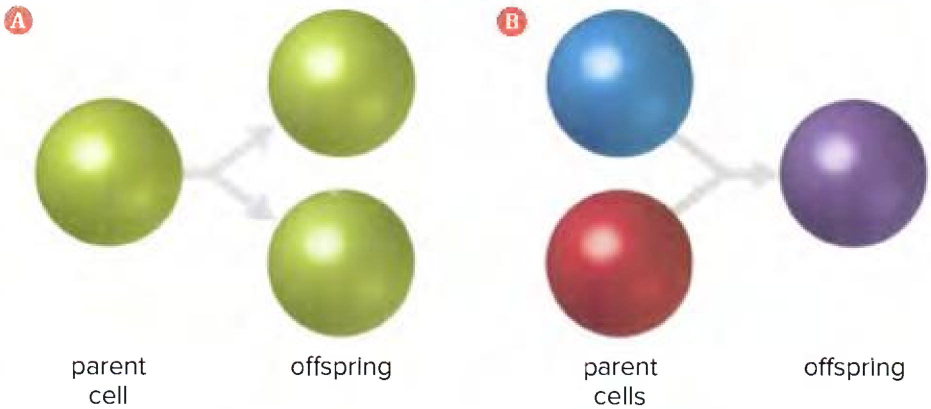


Figure 1.4 Asexual reproduction (A) results in offspring that are identical to the parent. Sexual reproduction (B) results in offspring that are different from each other and their parents.

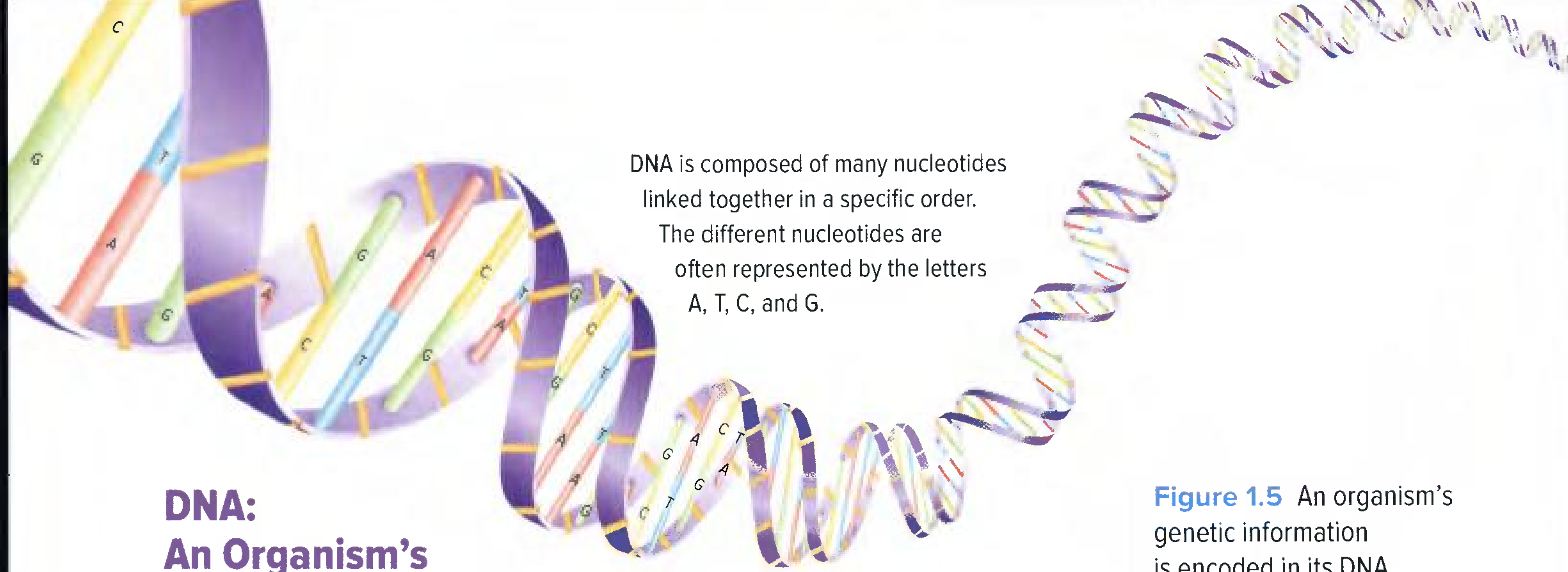


Figure 1.5 An organism's genetic information is encoded in its DNA sequence.

DNA: An Organism's Genetic Material

An organism's genetic material determines how it looks, functions, and in many cases, behaves. Genetic material carries these instructions in a molecule called DNA. **DNA** is short for *deoxyribonucleic acid*. As shown in Figure 1.5, DNA exists as two long strands shaped like a twisted ladder. It consists of many copies of four different chemical building blocks that are linked together. These building blocks are called *nucleotides*. The specific order in which they are linked together is called an organism's *DNA sequence*. It is like a code that holds the genetic information of an organism.

An organism's DNA is contained within each of its cells. To fit into such a small space, DNA molecules coil and compact into a condensed form called *chromatin*. When a cell is ready to reproduce, it is condensed even more into structures called **chromosomes**. When an organism reproduces, copies of its chromosomes, and therefore its DNA, are transferred to the offspring.

No matter how an organism reproduces, it all begins with the transfer of genetic information and the reproduction of a cell. That cell may be the organism itself or it may be the beginning of a new multicelled organism.

DNA stores the genetic information of an organism; short for deoxyribonucleic acid

chromosome genetic material that is a condensed form of DNA

Connect to Investigation 1-C on page 18

Extending the Connections

Investigating DNA

The structure and function of DNA have been studied by scientists for decades. Find out more about nucleotides and how they link together to produce the three-dimensional structure of DNA, which is so essential to life.

Before you leave this page . . .

1. What is the function of DNA?
2. How is sexual reproduction different from asexual reproduction?

TAKE a Stand

Make a Difference

Salmon Farming: Friend or Foe?

The farming of salmon is part of an industry called aquaculture. This industry is one response to the need to feed an ever-growing human population as the world's oceans are fished in ways that are unsustainable.

Salmon farming involves the raising and rearing of salmon from eggs to market. The fish are raised in net-cages, ponds, or closed containment systems. Most of the industry still uses open net-cages in the ocean.

Small-scale farms began to appear in B.C. in the 1980s. They have since grown in size and number along the coastline and play a large role in the economy. Farmed salmon is B.C.'s largest agricultural export.

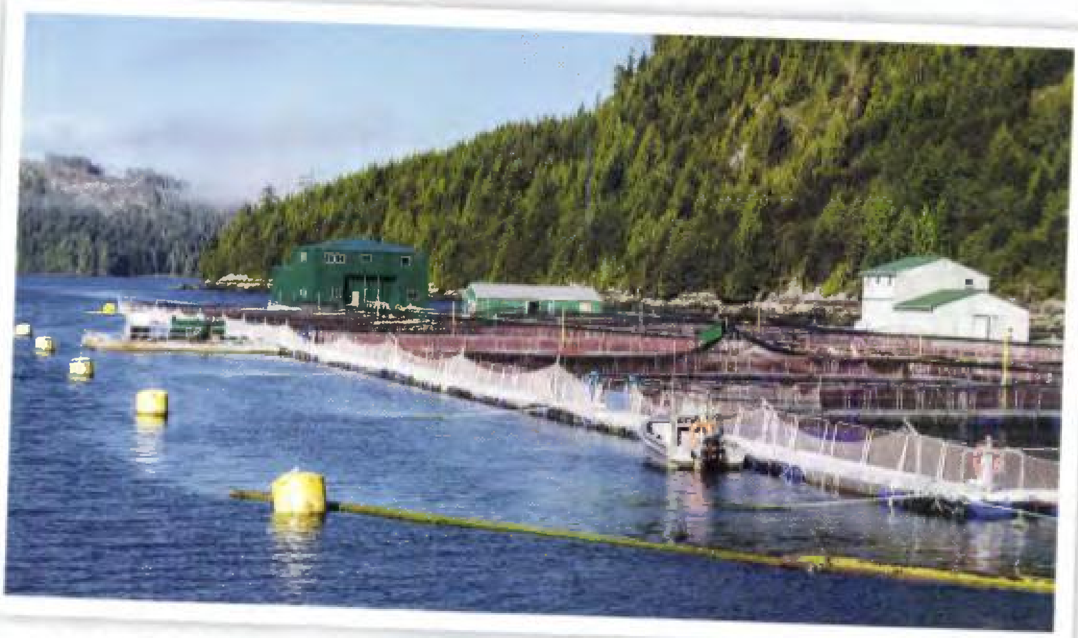
The industry has supporters and opponents from all walks of life. Where do you stand, and why?

Analyze

1. Find out about the salmon farming industry in B.C. What is its history? What types of salmon are raised? What are the risks and benefits? Who supports the industry, who opposes it, and why?
2. Investigate First Peoples perspectives on salmon farming. What are their reasons for or against the practice?

Communicate

3. Based on your research, what is your view of the industry? Are you for or against it? Give reasons to justify your opinion. Your opinion should be grounded in scientific understanding, as well as reasoned assessments of environmental, social, and other relevant issues.



An open-net fish farm

Check Your Understanding of **Topic 1.1**

QP Questioning and Predicting PC Planning and Conducting PA Processing and Analyzing E Evaluating
AI Applying and Innovating C Communicating

Understanding Key Ideas

1. Describe three ways that you depend on the reproduction of cells. AI

2. If all living things survived for only a single generation and did not reproduce, Earth would soon become a lifeless planet. Explain why. PA E

3. How are the terms *genetic material*, *DNA*, and *chromosome* connected? What role do they play in reproduction? PA C

4. Compare asexual reproduction and sexual reproduction. Use a Venn diagram to show their similarities and differences. C E

Connecting Ideas

5. Read each description below. Decide if it is an example of asexual reproduction or sexual reproduction. Support your answer in each case. PA E

a) A bacterial cell divides to form two new independent bacterial cells.

b) A female salmon lays thousands of eggs that will be fertilized by a male salmon.

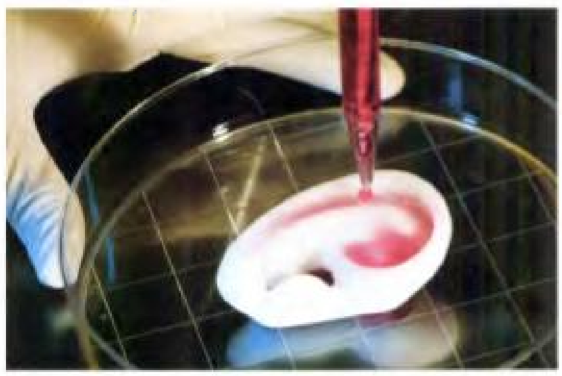
c) A structure will form on the body wall of a Hydra, shown below. This structure will grow to a miniature adult form that breaks away to be an independent organism.

6. What are some ways that reproduction involves transformation and renewal? AI

7. Is reproduction necessary for the survival of an individual? Is reproduction necessary for the survival of a species? Explain both of your answers. PA AI

Making New Connections

8. The image below shows how scientists are using ear-shaped devices and a patient's cells to develop an implant that could replace a human ear. Researchers hope this type of technology can be used to replace a variety of tissues and organs in people. PA AI QP



a) How does understanding cell reproduction allow scientists to generate organs and tissues in the laboratory?

b) Why do you think using a person's own cell to make a new organ or tissue for them will increase the chance that their body will accept the transplant?

9. Which do you think plays a bigger role in the wide variety (diversity) of life on Earth: asexual or sexual reproduction? Explain why you think so. E AI

INVESTIGATION
1-A

STRUCTURED INQUIRY

Skills and Strategies

- Processing and Analyzing
- Evaluating

Safety

What You Need

- Appendix A, Care and Use of the Microscope
- prepared microscope slides (different plant and animal cells)
- light microscope

Observing Eukaryotic Cells

Organisms with eukaryotic cells include single-celled organisms such as amoebas, paramecia, and euglena, as well as multicelled organisms such plants and animals. In this investigation, you will use a light microscope to observe different features of these cells and review how to use a microscope at the same time.

Question

What are important features of plant and animal cells?

Procedure

1. Use Appendix A at the back of this textbook to review how to care for and use a microscope.
2. Obtain a microscope and a prepared microscope slide.
3. Use the checklist below, in this order, to help you set up the microscope and view the slides.
   - ✓ Plug in the microscope and turn on the light.
   - ✓ Turn the nosepiece until the low-power lens faces the stage.
   - ✓ Put the slide on the stage so that you will be able to see what is on the slide.
   - ✓ Secure the slide with the stage clips.
   - ✓ Looking from the side of the microscope, use the coarse-adjustment knob to bring the lens as close as it will go to the stage.
   - ✓ Look in the eyepiece. Slowly turn the coarse-adjustment knob to get the image in focus.
   - ✓ Make sure that the cells you want to observe are in the field of view (centre of the circle).
   - ✓ Turn the fine-adjustment knob to get the best possible focus.
   - ✓ Looking from the side of the microscope, turn the nosepiece until the medium-power lens faces the stage. Look through the eyepiece again. Focus using only the fine-adjustment knob.

✓ Looking from the side of the microscope, turn the nosepiece until the high-power lens faces the stage. Look through the eyepiece again. Focus using only the fine-adjustment knob.

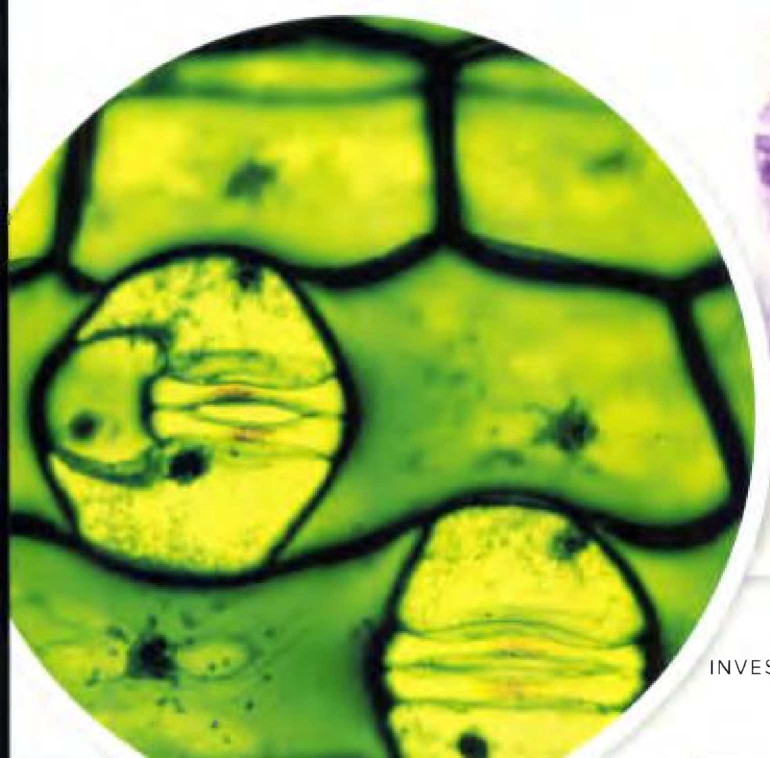
4. Observe a plant cell under the microscope at high power. Sketch the cell. Identify and label the cell wall, the nucleus, and any other features that you recognize.
5. Using Care and Use of a Microscope in Appendix A as a reference, calculate the size of the cell you viewed.
6. Repeat steps 4 and 5 with at least one type of animal cell.

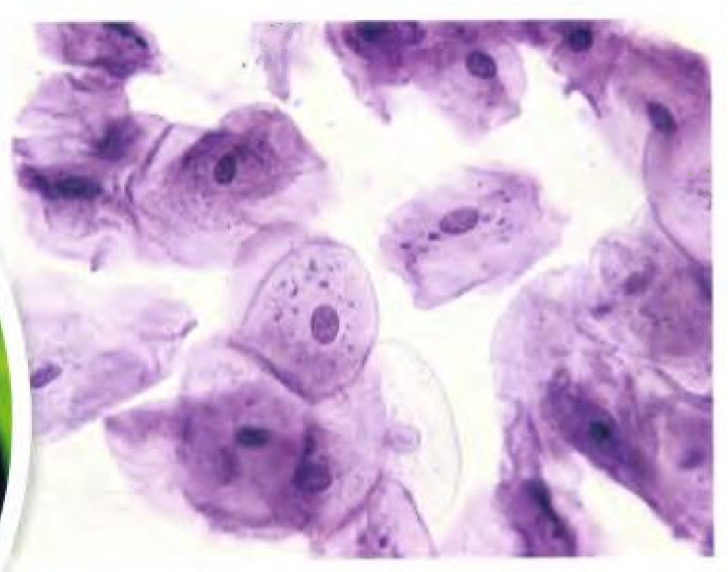
Process and Analyze

1. What features in each of the cell types were you able to see using the light microscope?
2. Compare the plant and animal cells that you viewed. How are they the same? How are they different?

Conclude and Evaluate

3. Find a group of students who viewed the same type of animal or plant cell as your group. How are your drawings similar to and different from theirs? How can you account for differences in your drawings?
4. Find a group that viewed a type of animal cell or plant cell that was different from the one that your group viewed. How are your drawings similar to and different from theirs? How can you account for differences in your drawings?





INVESTIGATION
1-B

OPEN INQUIRY

Skills and Strategies

- Questioning and Predicting
- Planning and Conducting
- Processing Information
- Evaluating
- Applying and Innovating
- Communicating

What You Need

- computer with Internet access
- print resources
- Appendix A, How To Do a Research-Based Project

British Columbia's Agriculture Resources

Agricultural activities in B.C. include cattle ranching, dairy farming, poultry raising, and fish farming, as well as growing tree fruits, vegetables, berries, grapes, and many types of ornamental flowers and shrubs. This success is completely dependent on continual reproduction of the plants and animals involved and following good practices for maintaining these natural resources.

In this investigation you will research the role of reproduction in the sustainable development of an agricultural resource of your choice.

Procedure

1. The chart below lists examples of agricultural products grown or raised in B.C. Choose one of these to investigate.

asparagus	eggs	crabs
beans	milk	oysters
corn	cheese	shrimp
lettuce	seaweed	prawns
apples	yoghurt	chicken
berries	cod	turkey
cherries	halibut	bison
grapes	salmon	beef
peaches	trout	lamb
pears	clams	pork

2. Write out questions you have that could guide your research. Here are some examples to get you started.
   - How is reproduction involved in developing and maintaining the crop or animal that you chose? What are some technologies that are used to help?
   - How can Traditional Ecological Knowledge be applied to sustainable farming techniques?
   - What, if any, issues are there? (Issues related to agriculture are often environmental and/or ethical, for example.)

3. Develop a research plan that you will follow. Also, choose a format for how you want to present the results of your research. Other considerations include the following.
   - What types of resources will have the most relevant information?
   - Will you need to find print resources or use only online information?
   - What resources are reliable? What makes a resource reliable?
   - How will you organize your data as you collect it?
   - In what way can you use figures, graphs, and photographs to convey some of the information?
4. Have your teacher approve your questions, research plan, and presentation format.
5. Carry out your plan once your teacher has approved it.

Evaluate

1. Were you able to find answers to all of your questions? If not, why not? What information was missing?
2. Based on your research, do you have any concerns about how your chosen agricultural product is developed or raised? Why or why not?

Apply and Innovate

3. The agriculture industry is more than just growing and raising plants and animals. It is also made up of all the people who contribute to the safe production, processing, and transportation of food products to consumers.
   a) Come up with a list of 10 careers or jobs that are related to helping meet these needs.
   b) Share your list with your teacher, who will combine the class's ideas. What does this list tell you about the importance of the agriculture industry to the social and economic well-being of B.C.?

INVESTIGATION
1-C

STRUCTURED INQUIRY

Isolating DNA

To study DNA, scientists must first isolate it from the rest of the material of the cell. This can be done by breaking open the cell and the nucleus, and then isolating the DNA. In this investigation, you will isolate DNA from the cells of a banana.

Skills and Strategies

- Processing and Analyzing Data
- Evaluating
- Communicating

Safety

- Handle the glass rod carefully.
- Dispose of materials as directed by your teacher.

What You Need

- small piece of ripe banana
- small resealable plastic bag
- graduated cylinders
- 10 mL 0.9% table salt in water
- 3 mL dishwashing liquid
- cheesecloth
- 250 mL beaker
- large test tube
- test tube rack
- ice-cold isopropanol
- stirring rod

Question

How can DNA be isolated from plant cells, and what does it look like?

Procedure

1. Work with a partner. Place about one quarter of a ripe banana in a small resealable plastic bag. Seal the bag, and use your fingers to squash the banana until no visible chunks remain.
2. Use a graduated cylinder to measure 10 mL of the table salt solution, and add it to the bag. Mix thoroughly by gently squeezing the contents of the bag.
3. Use a graduated cylinder to measure 3 mL of dishwashing liquid, and add it to the bag. Mix gently so that you do not create any bubbles.
4. Lay a piece of cheesecloth over a beaker. One partner will hold the cloth steady. The other partner should pour the banana mixture onto the cloth, over the beaker.
5. Allow any liquid to pass through into the beaker. Wrap the cheesecloth around the banana mixture that remains and gently squeeze out any remaining liquid into the beaker. Dispose of the banana residue as your teacher instructs.
6. Transfer 2 mL of the liquid to a large test tube.
7. Use a graduated cylinder to measure 8 mL of ice-cold isopropanol.
8. Tilt the test tube. Gently pour the isopropanol down the inside of the tube. The isopropanol layer should "float" on the banana liquid.
9. Let the solution sit for 2–3 minutes. You will see a white substance forming where the two layers meet. This is the DNA.

10. Carefully insert a glass stirring rod and swirl it slowly in the alcohol layer to collect the DNA and remove it from the test tube.
11. Record your observations.
12. Dispose of all materials according to your teacher's instructions.

Process and Analyze

1. The DNA appeared as a white solid, called a precipitate, when it came in contact with the rubbing alcohol. What physical property of DNA does this step in the procedure depend on?
2. Soaps interact with and disrupt cell membranes. Why is it necessary to disrupt the cell membrane in this investigation?
3. Do you think the process of isolating DNA would be very different if you were to use a vegetable, animal cells, or a different fruit? Explain why or why not.

Conclude and Communicate

4. Describe the appearance of the DNA collected. Is it what you expected? Explain your answer.
5. The photo below shows purified DNA. Do you think the DNA you isolated is pure, or are there other components of the cell mixed in? Explain.

DNA from a laboratory sample

TOPIC 1.2

What are different ways that living things reproduce asexually?

Key Concepts

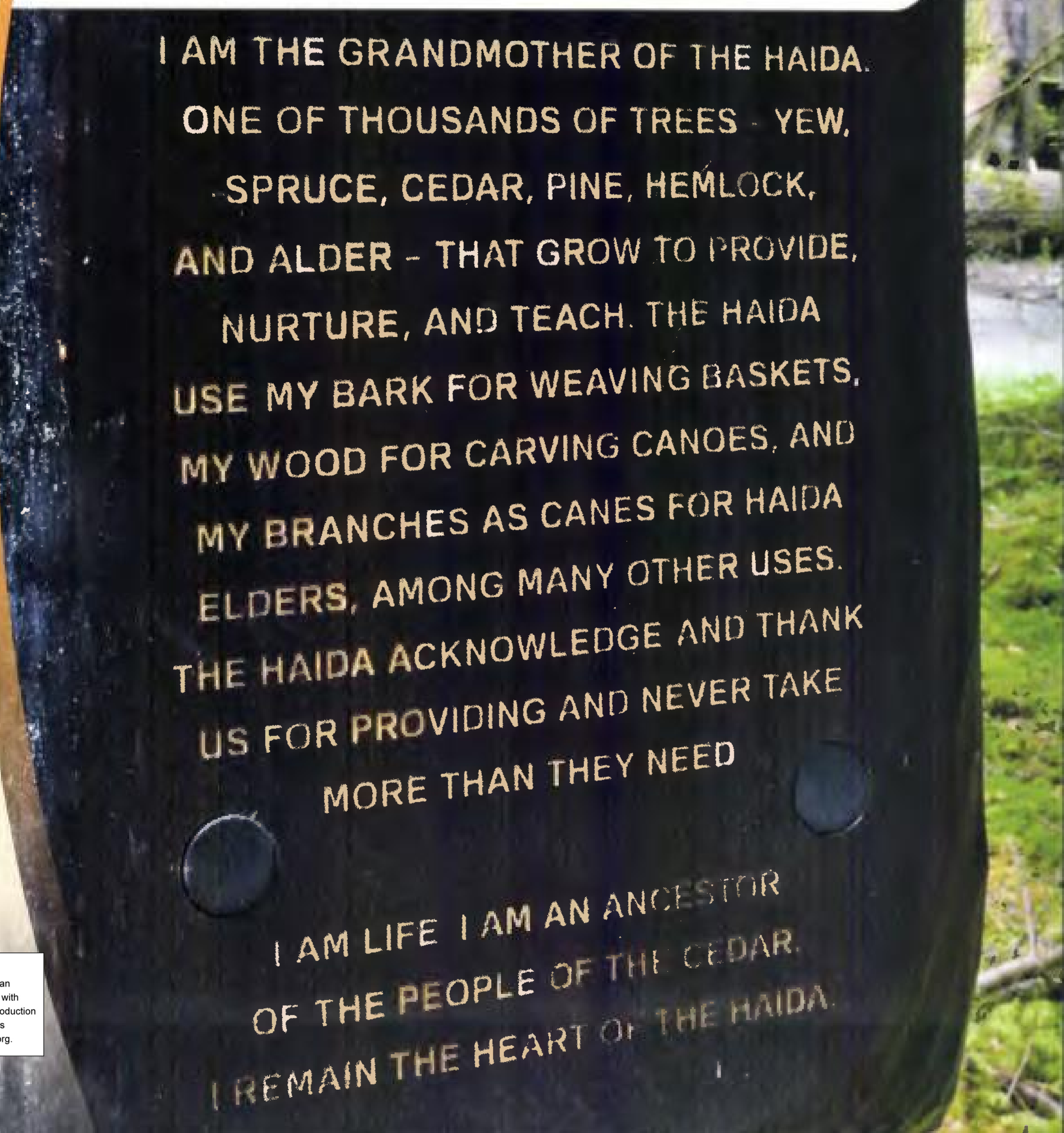
- Bacteria reproduce by binary fission.
- All eukaryotic cells reproduce by the cell cycle.
- Yeasts reproduce by budding.
- Moulds reproduce using spores.
- Plants have many ways to reproduce asexually.

Curricular Competencies

- Collaboratively and individually plan, select, and use appropriate investigative methods to collect reliable data.
- Seek and analyze patterns, trends, and connections in data.
- Construct, analyze, and interpret graphs, models, and/or diagrams.
- Analyze cause-and-effect relationships.
- Consider the role of scientists in innovation.

For 300 years, it stood. The lone 50 m Sitka spruce glowed golden from amidst a stand of emerald-coloured trees on the banks of Haida Gwaii's Yakoun River. Sacred among the Haida, who know it as K'iid K'iyaas (Ancient Tree), it is also called more popularly the Golden Spruce.

Today you cannot see the tree in the place where it once stood. In 1997, an activist cut K'iid K'iyaas to the ground as a misguided logging protest. But you can walk the Golden Spruce trail near Port Clements and see signs such as the one shown here. Meanwhile, sheltered in a corner of the UBC Botanical Garden, the Golden Spruce does live on, thanks to the natural ability of plants to reproduce asexually.



Starting Points

Choose one, some, or all of the following to start your exploration of this Topic.

1. **Identifying Preconceptions** The Golden Spruce growing in the UBC Botanical Gardens is a clone of K'iid K'iyaas. What do you think of when you hear the word *clone*? What do you think the word means?
2. **Questioning** Brainstorm what you know about bacterial cells. Come up with some ideas about how these organisms might reproduce. What does a new bacterial cell need to live?
3. **Applying** Which cells in your body do you think reproduce asexually? How often do they do so? Why might they need to do so? What other questions about cells and asexual reproduction do you have?
4. **Considering First Peoples' Perspectives** Think about interconnectedness and interdependence. In what ways do we depend on organisms that reproduce asexually?

Key Terms

There are six key terms that are highlighted in bold type in this Topic:

- binary fission
- cell cycle
- budding
- spore
- vegetative propagation
- clone

Flip through the pages of this Topic to find these terms. Add them to your class Word Wall along with their meanings. Add other terms that you think are important and want to remember.

This photo shows K'iid K'iyaas, the Golden Spruce, before it was cut down.

CONCEPT 1

Bacteria reproduce by binary fission.

From the surface of your desk, to the inside of our bodies, and in extreme environments of the planet, bacteria are all around us (Figure 1.6) Bacteria are micro-organisms that exist as single prokaryotic cells. Even though you cannot see an individual bacterium, it behaves just like any other living thing. To survive, it must be able to make more of its own kind. It must be able to reproduce. Bacteria reproduce asexually by a process called binary fission, which is discussed on the next page.

Figure 1.6 Bacteria are in, on, and all around us.

Bacteria are used to make foods such as cheese and yoghurt.

Bacteria can be found in extreme conditions such as Canada's second-largest hot springs near Liard River in northern B.C.

Bacteria can harm health by rotting teeth.

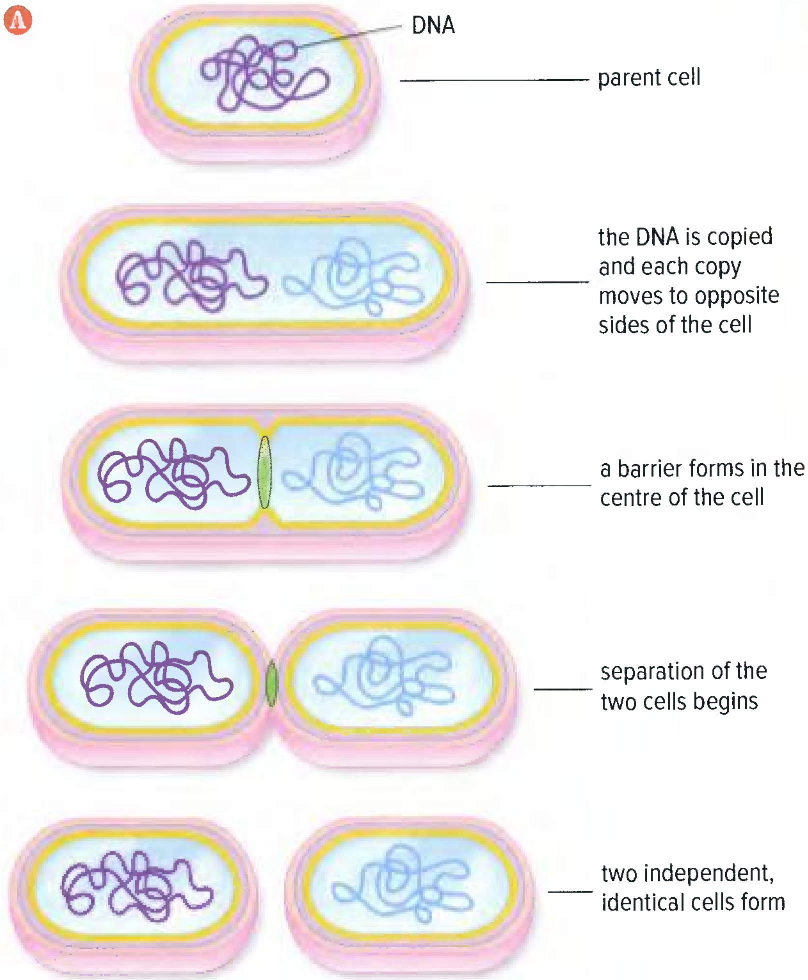
Certain diseases, such as strep throat, are caused by bacteria.

Reproduction by Binary Fission

Figure 1.7 shows what happens during **binary fission**. In this process, a *parent cell* produces two individual, identical cells. The identical cells that form from the parent cell are called *daughter cells*, and they contain the same DNA. (The term "daughter cells" is a convention that biologists use. It doesn't mean that the cells are female.)

binary fission a type of asexual reproduction in which a cell splits into two daughter cells that have identical genetic information (DNA)

A



B

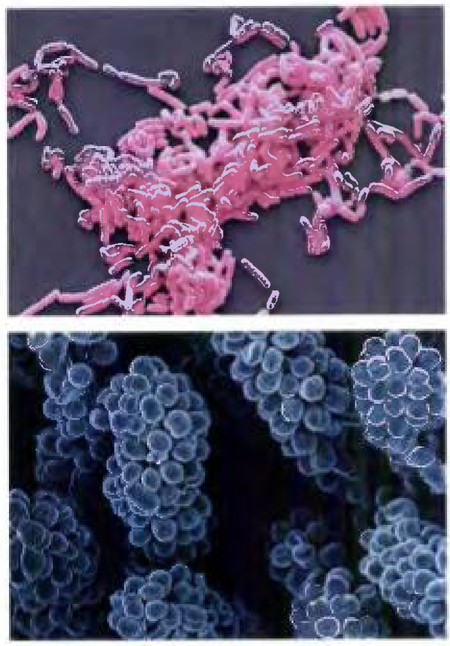


Figure 1.7 A In binary fission, two cells that have identical DNA form from the parent cell. B Many types of bacteria are found as clusters or chains.

Connect to Investigation 1-D on page 36

Activity

The Power of Doubling

After each cycle of binary fission, the number of cells doubles. The time for many bacteria to double (called *doubling time*) is 20 to 30 min, so a small population can grow quickly to millions under the right conditions. What conditions do you think affect bacterial growth, and how do they affect it?

Before you leave this page . . .

1. What key piece of evidence tells you that bacteria reproduce asexually?

AT ISSUE How does bacterial reproduction affect food safety?

What's the Issue?

Have you ever had food poisoning? Do you know someone who has? According to Health Canada, 1 in 8 Canadians is affected by food poisoning each year. More than 11 000 people will wind up in the hospital, and more than 200 will die from it. There are more than 30 types of microbes that cause food poisoning. These include bacteria such as *Salmonella* and certain strains of *Escherichia coli* (or *E. coli*, for short).

Bacteria that cause food poisoning are all around us, including at low levels in our food and the food products we buy. However, when conditions are right, the bacteria can reproduce in a very short amount of time—with populations doubling in size in minutes. This means that within a few hours, a very small population of bacteria can grow to millions—becoming a threat to health.

Dig Deeper

Collaborate with your classmates to explore one or more of these questions—or generate your own questions to explore.

1. What are common symptoms of food poisoning? How are they treated?
2. Why can food poisoning be dangerous or even deadly?
3. What can people do at home to reduce or prevent food poisoning?
4. Companies that make prepared foods such as those sold at grocery stores must follow strict guidelines. Identify one company that is involved in food processing or packaging. What measures do they take to ensure that their products are safe for consumers?

CONCEPT 2

All eukaryotic cells reproduce by the cell cycle.

Activity

How Many Times Have You Shed Your Skin?

A snake sheds its skin all at once, but you are always shedding cells from the outer layer of your skin. This happens because older cells are constantly being pushed to the surface by new cells that are reproducing below them. In about 28 days, your entire outer layer of skin is replaced by new cells. Use the equation below to determine the number of times that you have changed your skin in your lifetime.

$$\text{Number of times you have changed your skin} = \frac{\text{your age} \times 365 + \text{number of days since your last birthday}}{28}$$

365: number of days in a year

28: number of days your skin takes to replace itself completely

Right now, cell reproduction is taking place in your body as it produces thousands of new cells. Different types, such as red blood cells, skin cells, and cells that line your digestive tracts, are continually being made to replace older cells.

Cell reproduction is also needed for the body to heal. Imagine you fall and scrape your skin. You might have a wound like the one shown in Figure 1.8. The wound heals because your body can make new skin cells to replace those that were damaged.

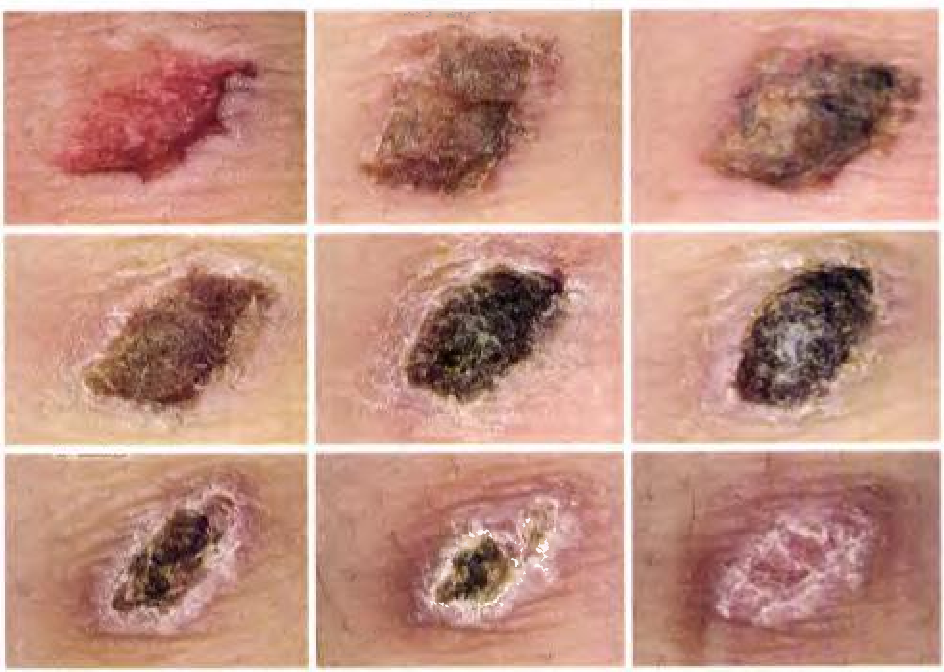


Figure 1.8 A scab forms as some of the remaining skin cells beneath the wound reproduce repeatedly to form a new skin layer to replace what was scraped away. **What clues help you know what sequence to follow to interpret this image?**

Reproduction and the Cell Cycle

First Peoples Perspectives
Create a story about the cell cycle. How does it help you understand what happens or remember the process better?

Replacing damaged cells is not the only reason eukaryotic cells must reproduce. It is an essential part of an organism's life cycle. For single-cell eukaryotes such as amoebas, the process of making new cells is how they produce new offspring. For you and other multicellular eukaryotes, different cells of the body have different life spans. For example, cells of the colon live for a few days. Skin cells live a few weeks. Red blood cells last for a few months, and some white blood cells last more than a year.

However, eukaryotic cells share this in common: They reproduce by a series of events called *interphase*, *mitosis*, and *cytokinesis*. See Figure 1.9.

1 Interphase

- The cell grows and the number of organelles increases.
- The DNA in the nucleus is copied.

2 Phase 1 of mitosis (prophase)

- The nuclear membrane begins to disappear.
- DNA condenses into duplicated chromosomes. Each contains two copies of the same DNA.

3 Phase 2 of mitosis (metaphase)

- Structures called spindle fibres guide chromosome movement.
- Chromosomes line up along the middle of the cell.

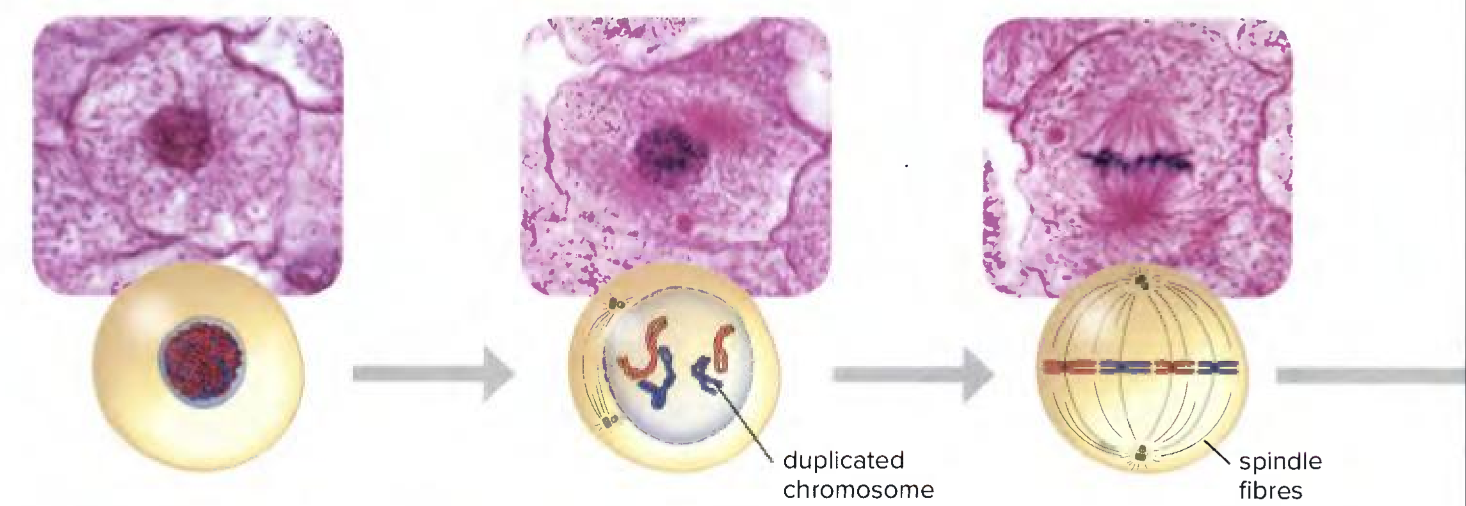


Figure 1.9 Cell reproduction by mitosis results in daughter cells that are genetically identical to each other and to the parent cell.

Activity

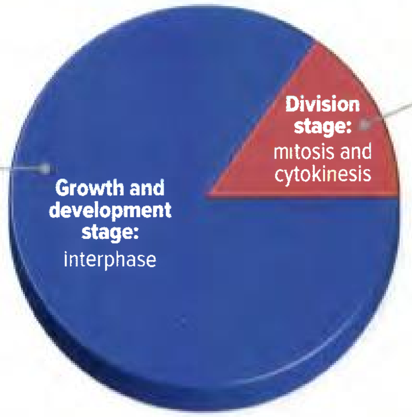
Mitosis Flip Book

Make a mitosis flip book to show the changes that happen at each phase of mitosis. Design your flip book on paper, or develop a digital one for a computer or hand-held device. Compare your completed flip book with others in the class.

The events in Figure 1.9 are part of what is called the **cell cycle**. The cell cycle is made up of two stages: (1) a growth and development stage, and (2) a cell division stage. See Figure 1.10.

cell cycle a series of events in the life cycle of a cell

1. The growth and development stage of the cell cycle is called interphase. The cell grows and prepares for division by copying its DNA and organelles.



2. The cell division stage of the cell cycle involves mitosis, during which DNA is distributed between the two developing daughter cells, and cytokinesis, when those cells separate into independent daughter cells.

Figure 1.10 The cell cycle involves growth, development, and then division. **In which stage does a cell spend most of its life?**

4 Phase 3 of mitosis (anaphase)

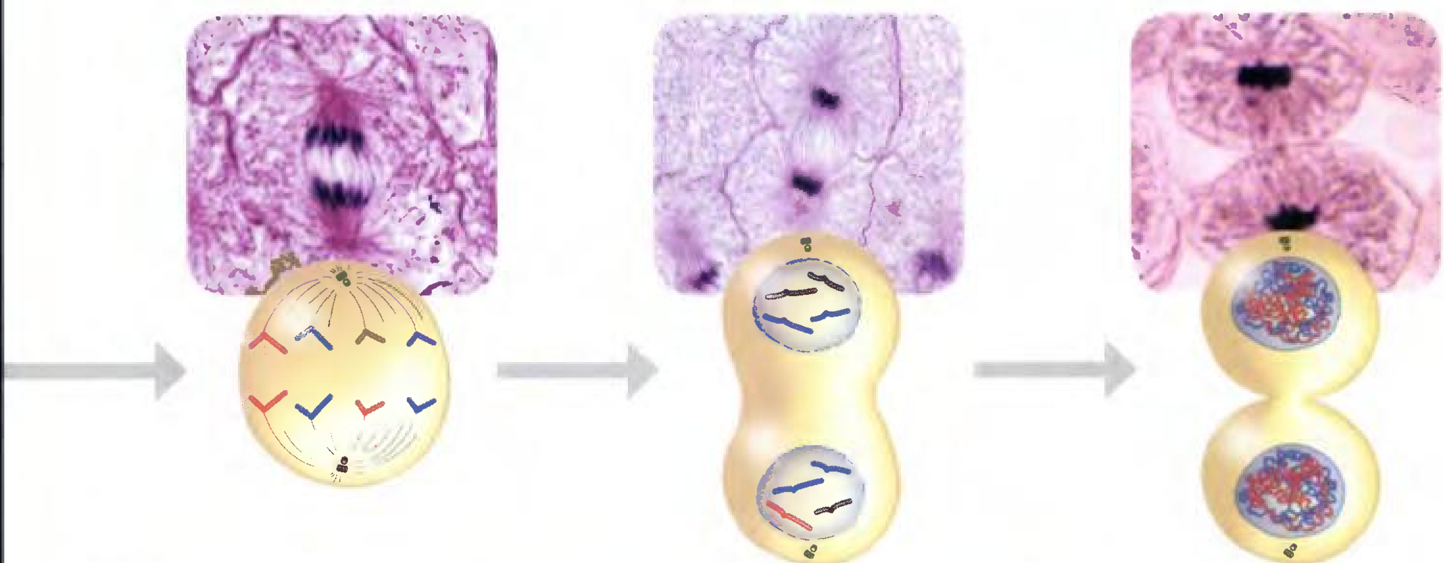
- The copies of DNA are separated and go to each end of the cell.

5 Phase 4 of mitosis (telophase)

- Two nuclei form and each nucleus contains a complete copy of the cell's DNA.

6 Cytokinesis

- The cytoplasm and organelles are divided, and two separate cells form.
- The cells then begin interphase.



Before you leave this page . . .

1. What happens to the DNA in a cell during interphase? Why is this step important for the reproduction process?
2. In two or three sentences, describe what the cell cycle is.

Connect to Investigation 1-E on page 38

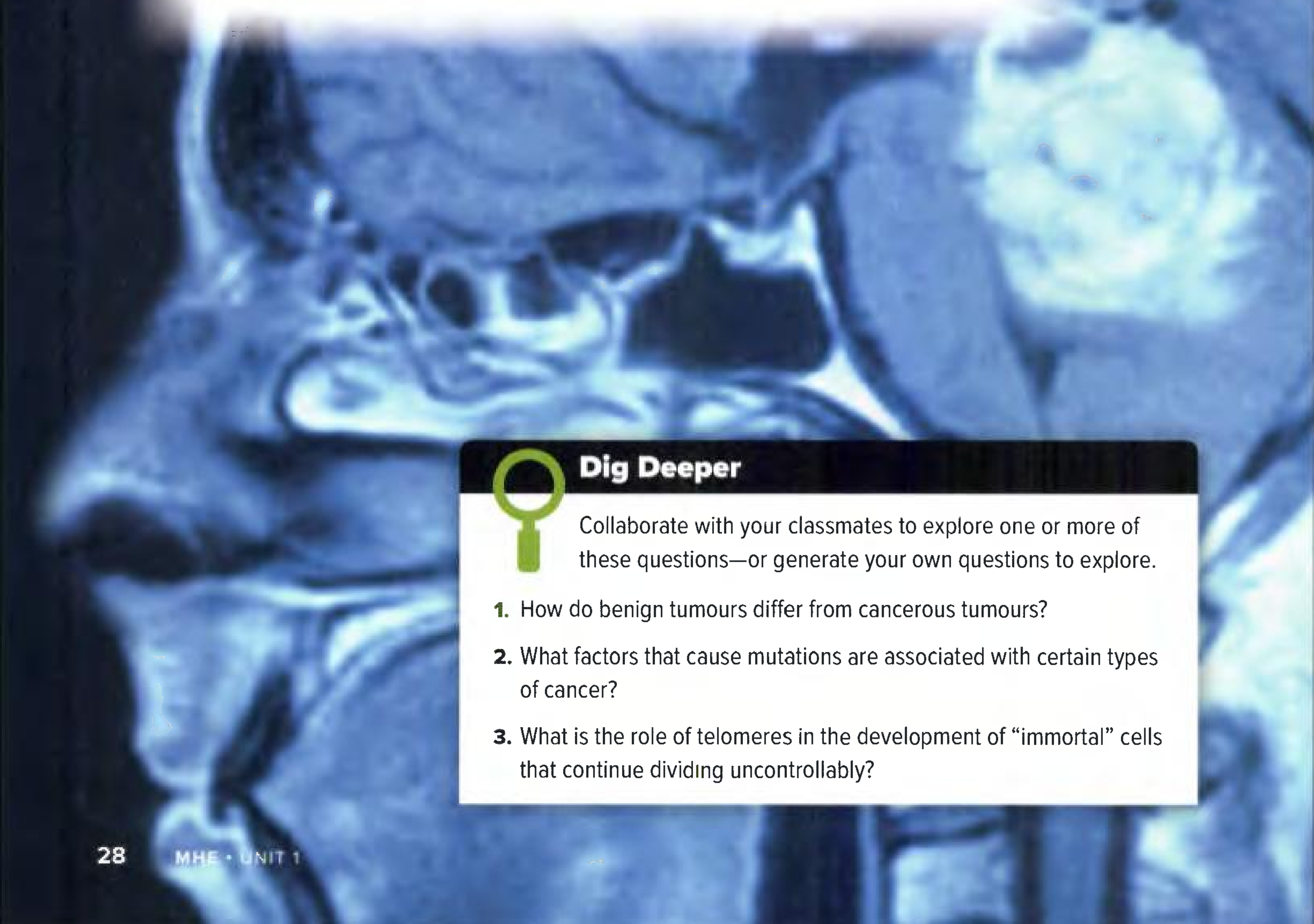
AT ISSUE What happens when cell division is out of control?

For a body to function properly, cell division must be controlled. Think about cells dividing to heal a wound. At some point, dividing cells must be sent a signal that the wound is healed so that the repair can stop.

There are points in the cell cycle at which a cell "checks" its growth. During these checkpoints, molecules that act as chemical signals determine whether cell division should or should not occur. For example, if the DNA of a cell has been damaged, the cell is marked for death.

What's the Issue?

If a cell ignores a signal to stop dividing, over time the newly divided cells form a mass called a tumour. Why do some cells ignore these signals? The answer lies in mutations, which are changes to a cell's DNA. These changes can affect how a cell responds to signals that indicate if cell division should occur.



Dig Deeper

Collaborate with your classmates to explore one or more of these questions—or generate your own questions to explore.

1. How do benign tumours differ from cancerous tumours?
2. What factors that cause mutations are associated with certain types of cancer?
3. What is the role of telomeres in the development of "immortal" cells that continue dividing uncontrollably?

CONCEPT 3

Yeasts reproduce by budding.

Activity

Yeast in Action

With a partner, empty a package of yeast into a 125 mL Erlenmeyer flask or large test tube that has about 20 mL of warm water. Add about 5 g of sugar and mix by gently swirling the flask. Place a balloon around the neck of the flask and watch for 10 min. How can you explain what you observe? Develop one or more questions about what is happening that could be investigated.

Connect to Investigation 1-F on page 40

Although yeasts are too small to see without a microscope, you are probably familiar with them from the products that these micro-organisms are used to make. These include dough for pizza and bread, pretzels, soy sauce, cheese, and vinegar.

Like bacteria, yeasts are unicellular organisms. Unlike bacteria, yeasts are eukaryotes. The most common way that yeast cells reproduce is by a type of asexual reproduction called **budding** (Figure 1.11) Since yeast cells are eukaryotic, their reproduction involves the cell cycle. However, a yeast cell will grow a bud that pinches off to become a separate cell. This new cell is smaller than the original cell at first. It eventually grows to the same size as other yeast cells.

budding a type of asexual reproduction that involves the formation of an outgrowth, or bud, from a parent cell

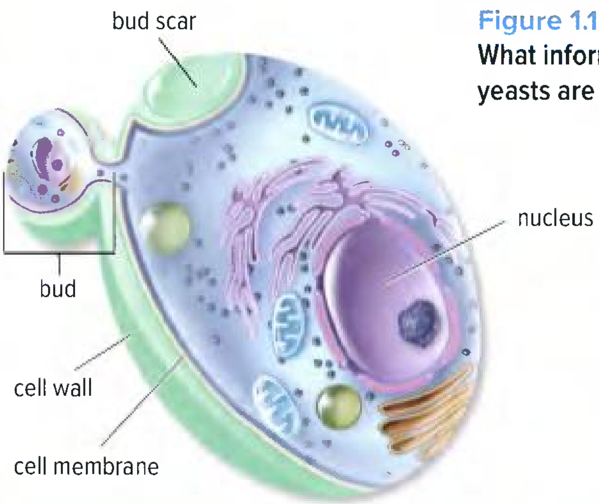


Figure 1.11 Yeasts reproduce asexually by budding. **What information in this diagram tells you that yeasts are eukaryotic cells?**

Before you leave this page . . .

1. In what ways is reproduction in yeasts and bacteria similar? In what ways is it different?
2. Why is a daughter yeast cell identical to the parent cell?

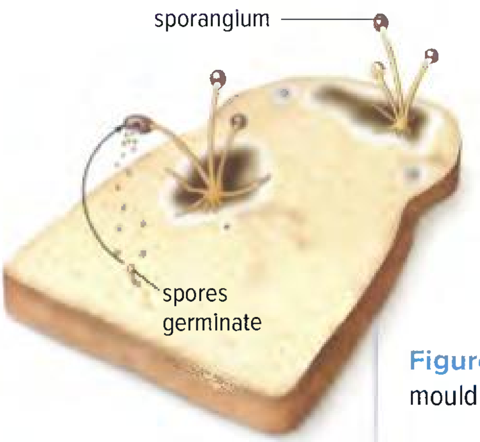
CONCEPT 4

Moulds reproduce using spores.

Activity

What's the Fuzz?

Perhaps you have experienced a situation like this. One day at school, you don't have time to finish your sandwich at lunch. You decide to save the rest of it for later. After wrapping it in plastic wrap, you put it in your locker—and forget about it. A week later, you find it in the back of your locker. But it is now covered with black fuzzy-looking material. How did this happen?



The fuzzy material that grew on the sandwich is a type of *mould*. It is composed of many eukaryotic cells. This type of mould has a fuzzy or hairy appearance because of how the long thread-like cells weave together.

Mould can break down food to use as nutrients. It also has structures that help to anchor it to the food. But what did the mould grow from? The answer is shown in Figure 1.12.

Figure 1.12 Moulds reproduce using spores that grow into a new mould by mitosis. **Why is this a type of asexual reproduction?**

The most common way that moulds reproduce is by the formation of spores that are genetically identical to the mould cells they come from. The **spores** are released into the air from a structure called a *sporangium*. When a spore lands in a favourable environment—such as a piece of bread in a warm, moist environment—it begins to grow and divide by mitosis and cytokinesis and eventually produces more mould.

spore a structure that produces a new organism by asexual reproduction

Extending the Connections

A Mouldy Inquiry

Moulds are used to make food products, but they can also be found growing in dark, damp places in schools and homes. Their spores can cause sickness. Develop three questions you have about moulds. Then plan how you can answer your questions.

Before you leave this page . . .

1. What role do spores play in the asexual reproduction of mould?

CONCEPT 5

Plants have many ways to reproduce asexually.

Plants can reproduce both sexually and asexually. Asexual reproduction in plants is called **vegetative propagation**. New plants grow from a portion of the roots, stems, or leaves of an existing plant. Figure 1.13 shows some common examples. Because the new plants are formed by asexual reproduction, they are copies, or **clones**, of the parent plant.

vegetative propagation asexual reproduction of a plant from a part of its roots, stems, or leaves

clone an exact copy of a cell or organism

Figure 1.13 Through the process of vegetative propagation, new plants can grow from the stems, roots, or leaves of a plant.

If you look closely at a field of strawberry plants, you will see smaller plants growing near a larger plant. These smaller plants are new plants that grow along runners. Runners are like stems that grow horizontally, above the ground, from a full-grown plant. Eventually runners die, leaving independent, identical plants.

Camas grows from bulbs and has long been used by First Peoples of the Pacific Northwest as an important staple food. Roots grow out of the base of the bulb, and other bulbs grow from them. Other plants that grow from bulbs include onions and daffodils.

A plant commonly called “the piggyback” is native to B.C. As its name suggests, new plants develop from the leaves of the parent plant. Eventually the weight of the new plants causes the leaves to bend over and touch the soil. The new “piggyback” then develops roots and develops into an independent plant.

Potatoes are enlarged underground stems called tubers. You may have seen the white root structures on store-bought potatoes that have been kept for a long time. New roots and shoots grow from the eyes of the potato. If you plant a potato with this new growth, a potato plant will develop.

Artificial Vegetative Propagation

Farmers, gardeners, and people who work in plant nurseries use artificial vegetative propagation to produce plants with specific characteristics. This method uses a plant's natural ability to asexually reproduce. It allows people to produce a large number of plants, consistently and quickly, to meet specific needs. Some common methods are shown in Table 1.1.

Table 1.1 Examples of Artificial Vegetative Propagation Techniques

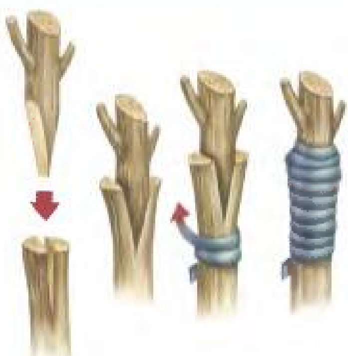
Propagation	What It Looks Like	Plants Used	Uses
Splitting A plant is split into two or more pieces, each containing intact shoots and roots.		• bulbs such as tulips and daffodils • plants such as peonies and hostas	• used in landscaping to thin out plants that have spread over a large area, or to help older plants continue to bloom
Grafting A bud, portion of the stem, or section of the root is cut from one plant and joined to another.		• fruit trees such as apple and pear • nut trees such as walnut and almond • grapevines	• used to produce orchard trees with desirable characteristics, such as high-quality fruit or resistance to disease, and to cultivate a new variety of fruit
Cutting Part of a leaf, stem, or root is cut from a plant and placed in water with nutrients or potting soil. Cells near the cut surface develop into roots or shoots. The new roots supply water and nutrients, and each shoot forms a new plant		• herbs such as sage, oregano, basil, and thyme • trees such as pine, spruce, poplar, willow, and elm • grapevines • flowering bushes such as rose and lilac • chrysanthemums • carnations	• used to produce large numbers of plants that are purchased by plant-related industries and that are popular with consumers • used by flower growers to start plants in a greenhouse during the winter

Table 1.1 Examples of Artificial Vegetative Propagation Techniques (continued)

Propagation	What It Looks Like	Plants Used	Uses
Simple Layering A section of stem is bent to touch the ground. Then a cut is made in it to promote the growth of roots. The cut part of the stem is buried in the ground. Once a new root system develops, the stem is cut away from the parent plant.		• climbing roses • grapevines • honeysuckle • junipers • willows • hydrangeas	• used in landscaping to grow new plants in a short period of time • used by nurseries to grow trees
Air Layering A strip of outer bark is removed and moss is packed around the stem. Plastic is wrapped around the moss to prevent water loss. Once a new root system has developed, the stem is cut away from the parent plant and planted in soil.		• tropical plants such as rubber trees • magnolias • holly • lilacs • fruit trees such as apple, pear, and orange • nut trees such as pecan	• used by nurseries to grow houseplants • used in landscaping to grow plants that are difficult to root using other techniques
Tissue Culture An individual cell or a small piece of plant is placed in or on nutrients that promote shoot and root growth. Tiny plantlets develop and these are planted in soil.		• a variety of ferns and ornamental plants • variety of trees	• used by nurseries to produce large quantities of plants • allows crops to be bred in the laboratory for desirable features and then be made available to growers in massive amounts • used in forestry for the regeneration of tree plantations

Before you leave this page . . .

1. Describe an example of vegetative propagation.
2. Why are new strawberry plants that form from runners identical to the parent plant?

Connect to Investigation 1-G on page 42

AT ISSUE How do First Peoples apply their understanding of plant reproduction?

What's the Issue?

TEK (Traditional Ecological Knowledge) includes sophisticated resource management methods that have been used for thousands of years. One of these methods is to use the reproductive properties of plants. Root plants such as camas, riceroot, silverweed, and bitterroot were important sources of starches in the past. Camas meadows like this one near Victoria were cultivated and harvested for their nutritious bulbs. Traditional pit cooking made them sweeter and easier to digest. One way that First Peoples managed these and similar plants was to replant small, living sections of the harvested roots. Some First Peoples continue with these techniques today, while others are renewing the ancient practices.

The bulb of the northern riceroot, for example, has small bulblets that look like rice. At the centre is a small sprout that can be replanted. The Kwakwaka'wakw word for it means "grandfather," showing an understanding of reproductive continuity from one generation to another. This is just one technique First Peoples have used to manage their resources. Others include improving landscapes by controlled burning and modifying beaches to create clam gardens. All require a depth of scientific knowledge that can only be learned from generations of experience with local ecosystems.

Dig Deeper

Collaborate with your classmates to explore one or more of these questions—or generate your own questions to explore.

1. First Peoples like the Squamish and Kwakwaka'wakw have projects to restore riceroot habitats and harvest it for food. What might be the benefits of reviving traditional plant management techniques?
2. Investigate some other traditional resource management techniques used by First Peoples. What scientific knowledge or principles do they employ?

Check Your Understanding of **Topic 1.2**

QP Questioning and Predicting PC Planning and Conducting PA Processing and Analyzing E Evaluating
AI Applying and Innovating C Communicating

Understanding Key Ideas

1. What are the two main stages of the cell cycle? What happens in each? PA C

2. Compare binary fission and budding. How are they the same? How are they different? PA E

3. Describe how mould forms on bread by asexual reproduction. PA C

4. What is vegetative propagation? Describe an example of how it occurs in nature and one example of how it is used by an industry. PA AI

Connecting Ideas

5. The cell cycle diagram in Concept 2 is designed in a linear fashion to help you focus on each stage and phase of the process. However, it is called the cell cycle for a reason. Make a summary diagram to show the process as an actual cycle. Your diagram should include
   - the names of the two stages and a brief description of what happens in each
   - the part of the cycle that involves mitosis, along with the names of the phases of mitosis
   - the part of the cycle that involves cytokinesis
   - a representation of the parent cell and daughter cells showing what changes, if any, occur to the genetic material PA C

6. Raspberry plants can produce root sprouts. A new plant will grow from the root sprout.
   a) Explain how this represents asexual reproduction.
   b) Is the new plant identical to the parent plant? Explain why or why not. QP PA

7. Bacteria can live and reproduce in the laboratory on plates of jelly-like material called agar. The material contains nutrients that they need to survive. The photo below shows what happens when bacteria are placed in a 37°C environment overnight. Each circle-shaped mass on the plate is called a colony.

   a) What do you think a colony is composed of—a few bacteria or closer to millions of bacteria? How do you know?
   b) Each bacterium in a colony is a clone. What does that tell you about each bacterium within a colony?
   c) What does the fact that each colony represents clones of bacteria tell us about the type of reproduction that they undergo? PA E

Making New Connections

8. Some organisms have the ability to grow a new organism from a piece of the parent. This process is called regeneration.
   a) Why is this an example of asexual reproduction?
   b) Some organisms, such as sea stars sponges, hydras, salamanders, and newts, can regrow missing legs or other lost body parts. Even humans can regenerate some damaged parts, such as skin. Is this type of regeneration an example of reproduction? Why or why not? QP AI

INVESTIGATION

1-D

STRUCTURED INQUIRY

Skills and Strategies

- Processing and Analyzing
- Evaluating
- Communicating

What You Need

- Appendix A, Scientific Notation

Bacteria Population Growth

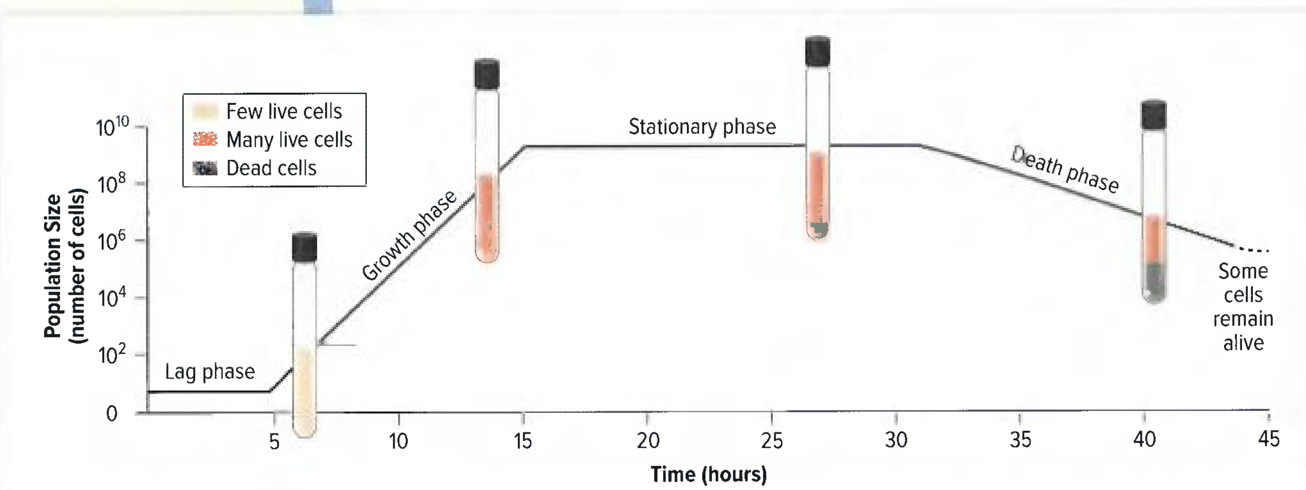
Studies of the growth of a bacteria population can be done in the laboratory. The growth of the population is monitored by measuring the number of cells over time. In this investigation, you will analyze the results of one of these studies.

Question

How does the growth of a population of bacteria change over time in a controlled environment?

Procedure

1. A scientist set up an experiment in a laboratory using this procedure.
   - A small number of bacteria were added to a liquid medium that contains nutrients for the microbes to grow and reproduce. The medium is sterile, which means that the only bacteria present are the ones added for the study.
   - The test tube containing the medium and bacteria was placed in an incubator. The incubator keeps the temperature stable at 37°C and provides the conditions bacteria need to reproduce.
   - Every hour, a small sample of the bacteria in liquid was removed and the number of cells was determined. This was done for 45 hours.
   - A graph was drawn, plotting number of live cells versus time. The graph, called a growth curve, is shown below.



Process and Analyze

1. Study the graph on the previous page. Think about the shape of the graph at different times and the images of the test tubes and what they represent. Copy the table in your notebook. Complete it by interpreting what is happening to the bacteria population at the lag, growth, stationary, and death phases that are labelled on the graph.

Phase of Growth	Time Period (hours)	Interpretation
Lag Phase		
Growth Phase		
Stationary Phase		
Death Phase		

2. During which phases are bacteria actively reproducing? Which phase has the greatest number of bacteria reproducing? Explain your answers.
3. What is happening during the stationary phaase? Why does it occur?
4. Why does a death phase occur?

Apply and Communicate

5. Compare the number of daughter cells produced to the number of parent cells after each round of reproduction.
6. Think about the time it takes for the bacteria population to grow from approximately 100 cells to 10^{10} (or 10 000 000 000) cells.
   a) How would this relate to the importance of keeping foods refrigerated to avoid food spoilage and food poisoning?
   b) What is a situation where rapid bacterial growth might be helpful or beneficial? Explain your answer.

INVESTIGATION
1-E

STRUCTURED INQUIRY

Skills and Strategies

- Processing and Analyzing Data
- Evaluating
- Communicating

What You Need

- prepared microscope slides of whitefish embryo cells showing phases of mitosis, interphase, and cytokinesis
- light microscope
- Appendix A, Care and Use of the Microscope

Observing the Cell Cycle in Animal Cells

In the cell cycle, a precise sequence of events leads to the production of new cells. In this investigation, you will observe and compare the stages of the cell cycle using prepared slides of whitefish embryo cells. An embryo is the stage in an organism's development in which a fertilized cell has divided into many cells that continue to grow and divide. Whitefish embryos are in a period of rapid growth.

Question

How can the features of a cell be used to identify the different phases of mitosis?

Procedure

1. Use Appendix A at the back of this textbook to review how to care for and use a microscope
2. Obtain a microscope and a prepared microscope slide of whitefish embryo cells.
3. Identify one cell in each of the following stages.
    - interphase
    - prophase
    - metaphase
    - anaphase
    - telophase
    - cytokinesis

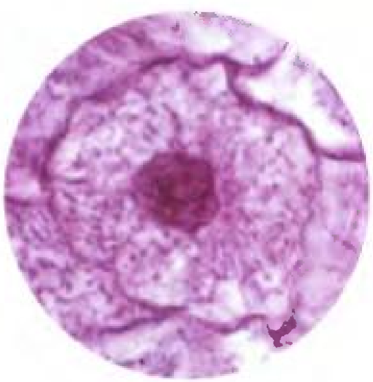
   Use the images on the opposite page to help you identify the correct stage of the cell cycle.
4. Look again for an area of dividing cells on your slide. Move the slide until you are viewing about 100 cells. Record how many cells are dividing and how many are not dividing within your field of view.

Process and Analyze

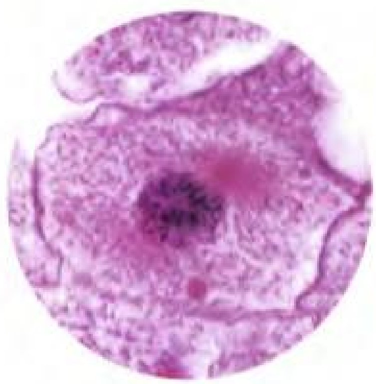
1. Explain how you decided whether a cell was dividing.
2. Were most of the cells you examined in step 4 dividing or not dividing? Explain your observation.
3. Draw a pie graph to show the relative number of cells dividing and not dividing. How does your pie graph compare with Figure 1.10 in this Topic?

Apply and Communicate

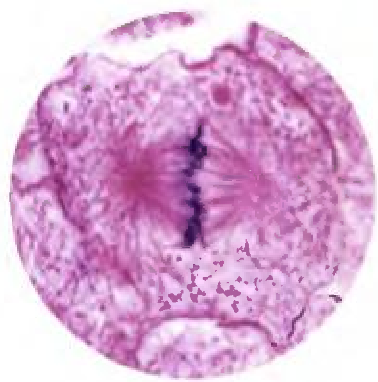
4. In this investigation, you observed cells from a whitefish embryo. Why do you think embryo cells were used instead of cells from an adult whitefish?
5. Assume that you repeat this investigation using plant cells. Do you think plant cells go through the same phases of the cell cycle? Why or why not? How would the plant cells appear different from the cells you viewed in this investigation?



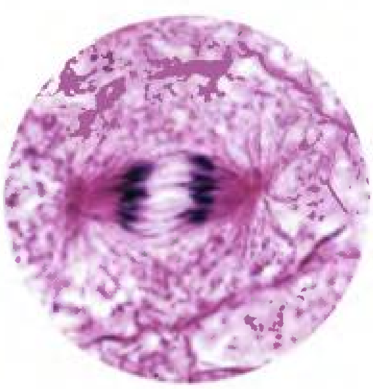
interphase



prophase



metaphase



anaphase

telophase

cytokinesis

INVESTIGATION

1-F

STRUCTURED INQUIRY

Skills and Strategies

- Planning and Conducting
- Processing and Analyzing Data
- Evaluating

Safety

- Wash your hands well before and after this Lab.
- Dispose of all materials as directed by your teacher.

What You Need

- Appendix A Care and Use of the Microscope

Part B:

- warm tap water
- test tube
- 1 g sugar
- 0.5 g yeast
- microscope, slide, cover slip, paper towel, and dropper

What You Need

Part C:

- 80 mL tap water
- Erlenmeyer flask
- 5 g sugar
- 4 g yeast
- balloon
- masking tape
- string
- ruler
- water baths (ice water, 35°C, and 65°C)
- thermometer

Yeast Reproduction

Yeast get energy from food using fermentation, which converts sugar to carbon dioxide gas and other products. You will observe the effect of temperature on yeast reproduction by monitoring carbon dioxide production.

Question

How does temperature affect yeast reproduction?

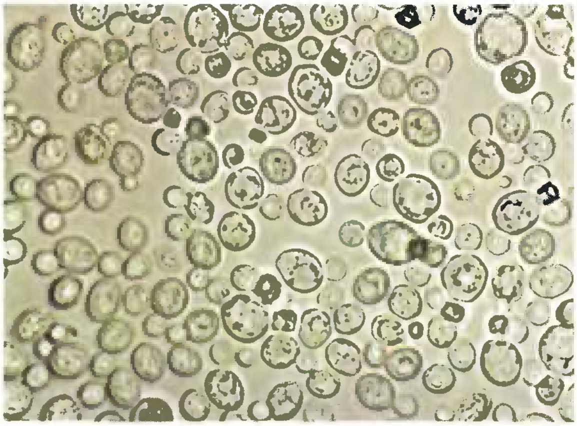
PROCEDURE A: WET MOUNT SLIDE

1. Read through Care and Use of the Microscope in Appendix A. Then carry out the exercise on how to view a wet mount slide that is given in that section.

PROCEDURE B: VIEWING YEAST

1. Add about 10 mL of warm tap water to the test tube.
2. Dissolve 1 g of sugar in the test tube.
3. Add 0.5 g of yeast to the test tube, and gently shake to mix.
4. Allow this mixture to sit on your bench for about 10 min. While you are waiting, set up a light microscope.
5. Place a drop of yeast mixture on the microscope slide (A) Hold a cover slip by the edges, on an angle. Lower it until one edge touches the slide surface at the edge of the drop (B). Slowly lower the rest of the cover slip over the drop. If bubbles form, ask your teacher for help. Gently blot away excess liquid with a paper towel (C)

6. Observe the yeast under high power. Use the diaphragm below the stage to adjust the amount of light if necessary. You should see many circle-shaped yeast cells. Look for small bumps, which are buds. Draw what you observe.



PROCEDURE C: EFFECTS OF TEMPERATURE

1. Predict how temperature will affect yeast reproduction.
2. Each group will test one of four temperatures: ice water, room temperature, 35°C, or 65°C. Your teacher will assign a temperature to your group. Your teacher also will set up stations where you will obtain water samples. Record the temperature of your sample and the classroom.
3. Design a table to collect and organize your data.
4. Determine the volume of carbon dioxide gas produced by a yeast population by measuring the circumference of a balloon that is placed over the top of a flask that contains the yeast. To do this:
   - Add 80 mL tap water to a flask
   - Dissolve 5 g of sugar in the water.
   - Place the flask at the temperature to be studied for 5 min.
   - Add 4 g of yeast to the flask and swirl the flask to mix the contents.
   - Place a balloon over the mouth of the flask. Secure it tightly with masking tape.
   - Every 2–3 min, swirl the flask to stir the contents. Record your observations.
   - After 15 min, measure the circumference of the balloon by wrapping a piece of string around the widest part. Measure the length of that section of string.
   - Remove the balloon very carefully to prevent foam from spilling over.
5. Report the circumference of the balloon to your teacher to share with the class.
6. Clean up your work station. Dispose of your sample as instructed by your teacher.

Analyze and Interpret

1. What is the relationship between the circumference of the balloon and the level of yeast reproduction in a population?
2. What are the dependent and independent variables in this investigation?
3. How did your data compare with other groups? Account for any differences. How could this investigation be improved?

Conclude and Communicate

4. What condition was the most favourable for yeast reproduction?

Applying

5. Plan and write a procedure to study the effects of the amount of a nutrient, such as sugar, on yeast reproduction. Predict what you expect to see. Use your prediction to write a hypothesis.

INVESTIGATION
1-G

STRUCTURED AND GUIDED INQUIRY

Skills and Strategies

- Processing and Analyzing Data
- Evaluating

Safety

- Wash your hands well before and after handling plants and plant chemicals, especially hormone products.
- Take care when using sharp utensils such as scissors. Report any accidental cuts to your teacher.

What You Need

- African violet (for leaf cutting)
- geranium (for stem cutting)
- primrose (for root cutting)
- sharp scissors
- paper towel
- potting soil or compost
- pots
- masking tape
- marker
- large test tube in a rack
- water
- metric ruler

Vegetative Propagation Techniques

Different types of vegetative propagation are used by gardeners, nurseries, and foresters as an easy way to produce plants with desirable characteristics. In this investigation, you will study the use of leaf cutting, stem cutting, and root cutting for propagating new plants.

Question

How can vegetative propagation be used to produce new plants?

PROCEDURE

1. Read the whole investigation before you begin.

Part A (Structured Inquiry):

2. Your teacher will assign you to a group. You will be cultivating two of the following: a leaf cutting, a stem cutting, or a root cutting.
3. Using sharp, clean scissors, take two cuttings from the appropriate parts of the plants. Clean the scissors and dry them well before taking each cutting.
4. Choose from one of the steps below:
   a) For a root cutting, place one cutting horizontally in a pot of soil. Cover it with a thin layer of potting soil or compost.
   b) For a stem cutting, place one cutting in a test tube half-filled with water. (The cut end should be in the water.)
   c) For a leaf cutting, place one cutting in a pot with potting soil.

5. Put all cuttings in a well-lit area of the classroom.
6. Clean and return all equipment. Dispose of any waste as instructed by your teacher.
7. Thoroughly wash your hands.

Part B (Guided Inquiry):

1. Make a plan for how you will quantitatively measure the progress of your cuttings and any differences in growth between the two cuttings. Remember to control as many variables as possible so that any differences between the cuttings result from the difference in method of propogation and not differences in growing conditions.
2. Decide how you will record and organize your results. Keep in mind that you will need to graph your results. Identify the dependent and independent variables that you will graph.
3. Have your teacher approve your plan before you begin monitoring the growth of your cuttings.
4. Observe the progress of your cuttings over the next several days. Record your observations. Water the cuttings as needed.

Process and Analyze

1. Create a line graph to analyze your results. Place the results from both cuttings on the same graph.
2. Between the two cuttings, which showed the best results? Suggest a reason why.

Apply and Communicate

3. Compare your procedure and results with those of other groups. Did other groups have similar results as your group? Why or why not?
4. If you had to propagate plants for a nursery, which method would you use? Explain your reasoning.
5. Assess the data you collected and the methods you used to collect the information. How do you think this investigation could be improved?

TOPIC 1.3

How do living things sexually reproduce?

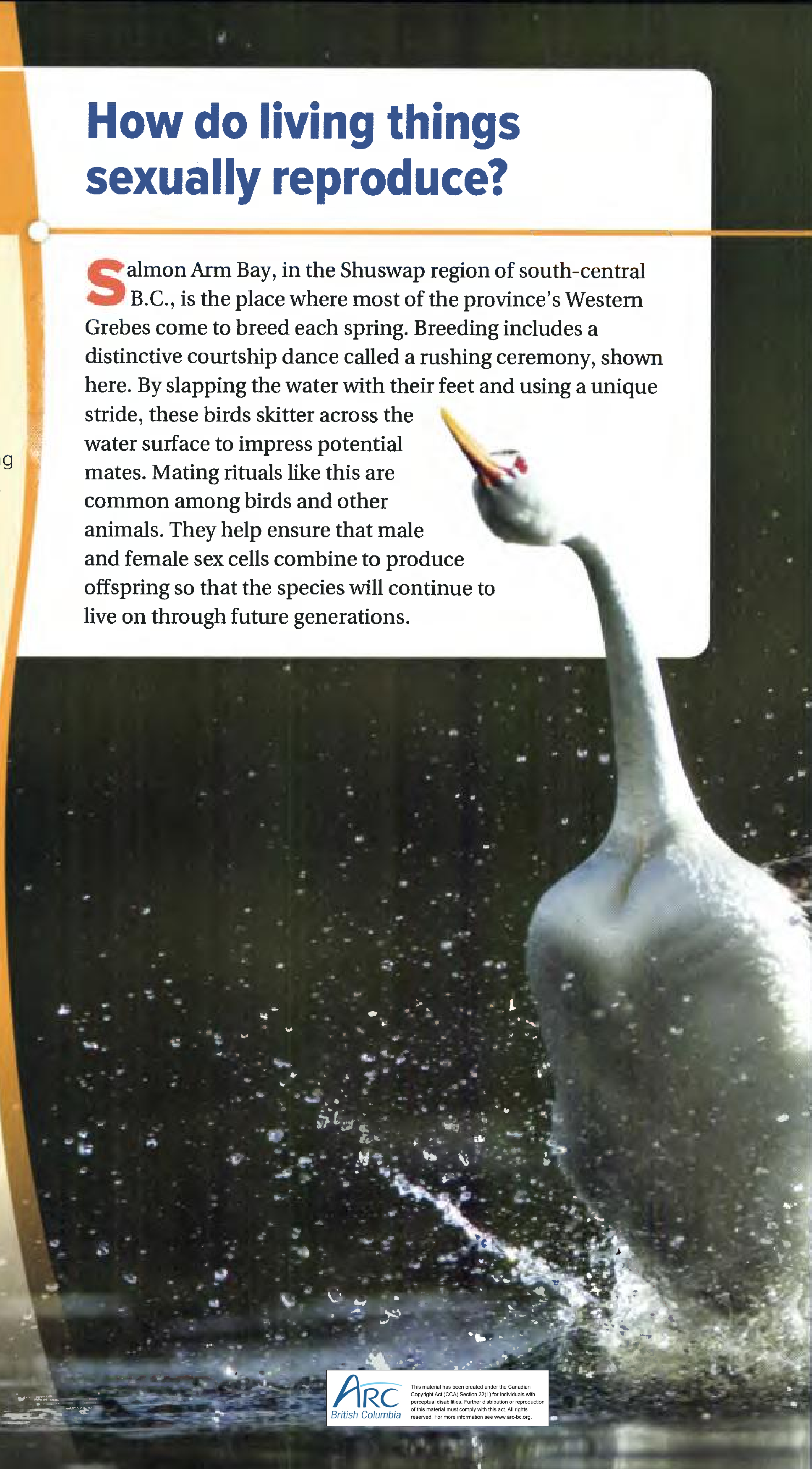
Key Concepts

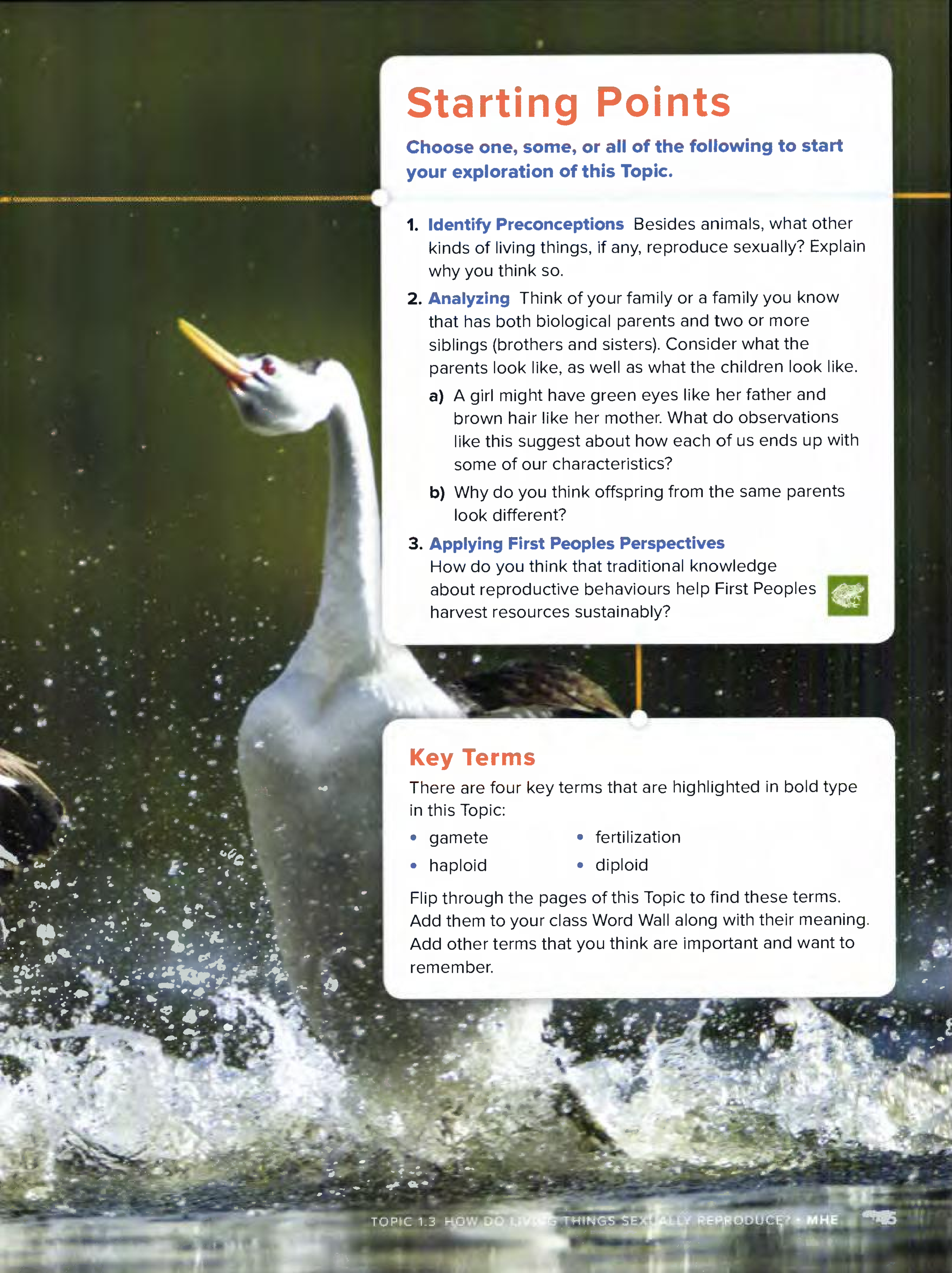
- Male and female reproductive cells combine to produce a zygote.
- Reproductive cells are formed by a cell-dividing process called meiosis.
- Development of the human zygote occurs in stages.
- Sexual reproduction takes many different forms.

Curricular Competencies

- Construct, analyze, and interpret graphs, models, and/or diagrams.
- Use knowledge of scientific concepts to draw conclusions that are consistent with evidence.
- Consider social, ethical, and environmental implications of findings from investigations.
- Generate and introduce new or refined ideas.

Salmon Arm Bay, in the Shuswap region of south-central B.C., is the place where most of the province's Western Grebes come to breed each spring. Breeding includes a distinctive courtship dance called a rushing ceremony, shown here. By slapping the water with their feet and using a unique stride, these birds skitter across the water surface to impress potential mates. Mating rituals like this are common among birds and other animals. They help ensure that male and female sex cells combine to produce offspring so that the species will continue to live on through future generations.





Starting Points

Choose one, some, or all of the following to start your exploration of this Topic.

1. **Identify Preconceptions** Besides animals, what other kinds of living things, if any, reproduce sexually? Explain why you think so.
2. **Analyzing** Think of your family or a family you know that has both biological parents and two or more siblings (brothers and sisters). Consider what the parents look like, as well as what the children look like.
   a) A girl might have green eyes like her father and brown hair like her mother. What do observations like this suggest about how each of us ends up with some of our characteristics?
   b) Why do you think offspring from the same parents look different?
3. **Applying First Peoples Perspectives** How do you think that traditional knowledge about reproductive behaviours help First Peoples harvest resources sustainably?

Key Terms

There are four key terms that are highlighted in bold type in this Topic:

- gamete
- fertilization
- haploid
- diploid

Flip through the pages of this Topic to find these terms. Add them to your class Word Wall along with their meaning. Add other terms that you think are important and want to remember.

CONCEPT 1

Male and female reproductive cells combine to produce a zygote.

Activity

Why Do Offspring Look Different?

Unless they are identical twins, children from the same parents look different. Differences can include features such as eye colour, hair colour, ear shape, and height.

You and a partner will be given two paper bags that contain many different coloured beads. Each bag represents a parent, and the beads represent features that the parents can pass on to their children.

1. Open the *Male Parent* bag and, without looking, remove three beads. Record the colours of the beads that you pulled out.
2. Open the *Female Parent* bag and, without looking, remove three beads. Record the colours of the beads you pulled out.
3. The combination of male and female beads represents a child from those parents. Record the six-bead colour combination, which represents the child produced by your selections. Your teacher will collect this information from all groups in the class.
4. Compare your group's child (that is, the six-bead colour combination) with the other groups. How many different offspring did the class produce from the same parents? How do you think this activity is related to sexual reproduction?

Perhaps you have seen a litter of kittens or puppies like the one shown in Figure 1.14. One or more offspring might look like one parent, but others might look like the other parent. Still others might look like a combination of both parents. This happens because animals—and many other types of living things—reproduce sexually. Half of an offspring's DNA (genetic information) is from the male parent, and the other half is from the female parent.

Figure 1.14 In sexual reproduction, each of the two parents contributes characteristics to the offspring. **What do you think the male and female parents of this litter might look like? What is your reasoning?**

Sex Cells

In sexual reproduction, two cells and their genetic material combine to produce a cell that eventually develops into an offspring. The cells that combine are called *sex cells*, or **gametes**. The male parent contributes one gamete, which is the *sperm cell*. The female parent contributes the other gamete, called the ovum or *egg cell* (Figure 1.15) In humans, sperm are produced in the testes, and eggs are produced in the ovaries.

gamete male or female reproductive cell

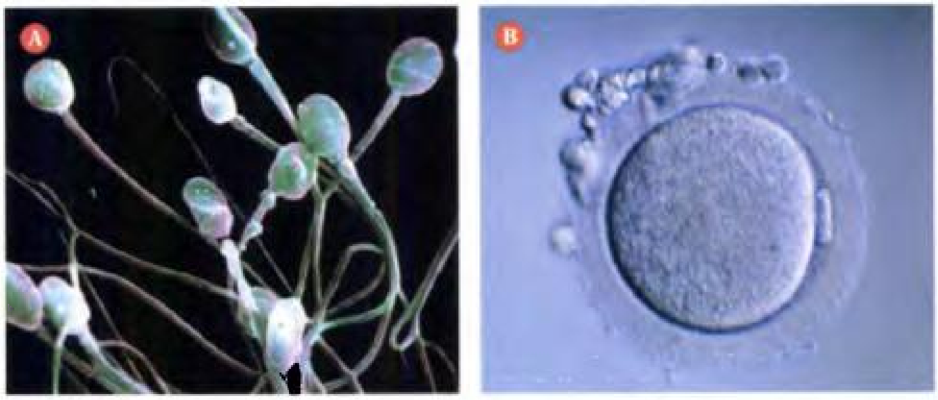


Figure 1.15 A Sperm cells have a unique look, with their long "tails" or flagella. B Egg cells are much bigger than sperm cells and lack flagella. **What does the presence or absence of flagella on sex cells tell you about their mobility?**

Contact between sperm and egg is the central event of sexual reproduction (Figure 1.16) At that moment, reproductive processes in two different individuals join together to create a single cell that will develop over a period of time into a new organism.

Figure 1.16 Of the many sperm that approach and surround an egg, only one can fertilize the egg.

Fertilization

fertilization the combining of male and female reproductive cells

The process in which male and female gametes combine is called **fertilization**. The nuclei of the two gametes fuse together to produce a single cell called a *zygote* (Figure 1.17) The zygote is the first cell that develops into a new organism containing genetic information from both the sperm cell and the egg cell.

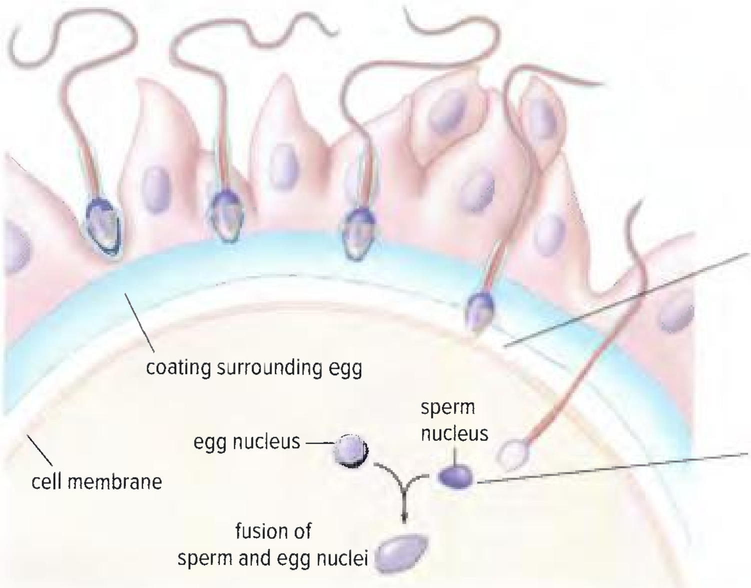


Figure 1.17 When a sperm cell fertilizes an egg cell, the two nuclei fuse and a zygote forms.

Activity

Internal and External Fertilization

For some organisms, fertilization occurs inside the body. Males have structures, such as a penis, that deposit sperm near the egg or eggs. Other organisms reproduce by means of external fertilization, which occurs outside the bodies of both parents. The female deposits unfertilized eggs and males release sperm over the eggs.

1. Name one organism that carries out internal fertilization and one organism that carries out external fertilization.
2. How is internal fertilization an advantage over external fertilization?
3. Why do you think organisms that reproduce using external fertilization release a large number of eggs and sperm?

Before you leave this page . . .

1. How does the process of fertilization occur?
2. What is needed for fertilization to occur?

CONCEPT 2

Reproductive cells are formed by a cell-dividing process called meiosis.

Activity

Halves of a Whole

Humans have 46 chromosomes in cells that make up the body. For fertilization to occur, the genetic material in male and female gametes combines to form a single cell. What does that tell you about the number of chromosomes in human gametes? Explain why mitosis of body cells could not produce gametes.

Each species has a particular number of chromosomes in its cells. Humans have 46 chromosomes that are organized into 23 pairs. Chromosomes that are paired are called *homologous chromosomes* (Figure 1.18) They have similar features and carry similar genetic information. During fertilization, each parent contributes one chromosome of each pair.

Because gametes combine in sexual reproduction, each must have half the number of chromosomes of other body cells. This ensures the correct number of chromosomes in each offspring and from one generation to the next (Figure 1.19)

Figure 1.18 In a pair of homologous chromosomes, the female parent contributes one chromosome, and the male parent contributes the other.

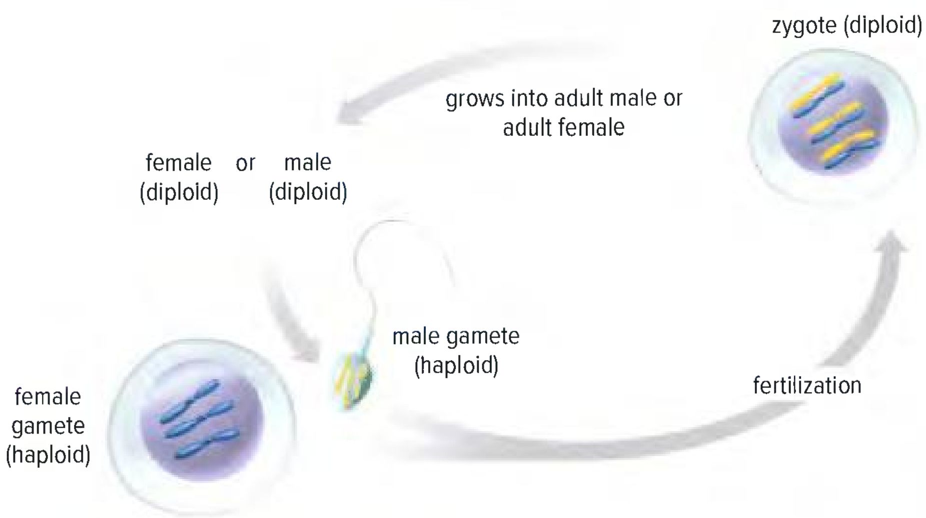


Figure 1.19 When haploid gametes combine together, they form the diploid zygote. **How many chromosomes are in a human gamete?**

Cells with half the normal number of chromosomes, such as gametes, are called **haploid** cells. Our body cells, which have a full number of chromosomes, are called **diploid** cells. How do diploid organisms produce haploid gametes? The answer involves a type of cell division called meiosis.

haploid a cell with half the number of chromosomes as the parent cell

diploid a cell with a complete set of chromosomes

Meiosis Produces Unique Gametes

Connect to Investigation 1-H on page 58

Special cells that produce gametes undergo a similar cell cycle to the one that you saw in Topic 1.2. However, instead of cell division by mitosis, these cells undergo meiosis. *Meiosis* involves a diploid cell dividing twice to produce four haploid cells (Figure 1.20)

Offspring are genetically different from their parents and from one another because the gametes that a parent produces are not all genetically the same.

prophase I

- The nuclear membrane begins to disappear.
- DNA condenses into duplicated chromosomes and homologous chromosomes are paired.

metaphase I

- Spindle fibres guide chromosome movement.
- Homologous chromosome pairs line up along the middle of the cell.

anaphase I

- Homologous chromosome pairs separate and go to each end of the cell.

telophase I

- Two nuclei form and each nucleus contains a complete copy of the cell's DNA.
- The cell divides.

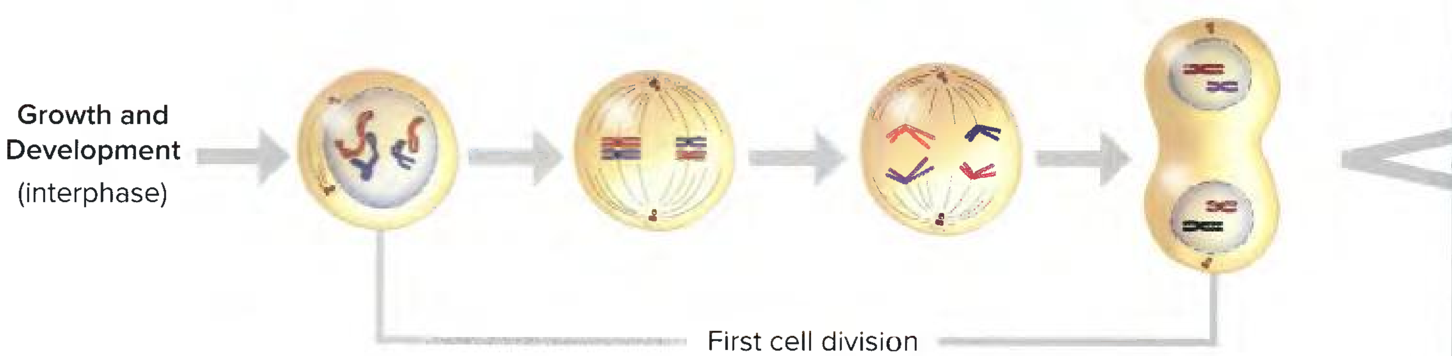


Figure 1.20 Meiosis produces four haploid cells from one diploid cell. These haploid cells are the gametes that take part in sexual reproduction.

Activity

It's in the Cards

Your teacher will provide you and a partner with a shuffled deck of cards. Each card contains an image of a phase in mitosis or meiosis. Arrange the cards in a sequence showing the steps that occur during mitosis and a separate sequence showing the steps that occur during meiosis.

Extending the Connections

Meiosis and Diversity

As a general rule, the number of possible unique gametes is given by the term 2^n, where n is the number of pairs of chromosomes in the cell. Since humans have 23 pairs of chromosomes, 2^{23} different gametes are possible. That is 8 388 608 unique gametes that each person could produce! Find out how meiosis produces unique gametes and how this affects the diversity of offspring from sexual reproduction.

Connect to Investigation 1-I on page 60

prophase II

- The nuclear membrane begins to disappear.
- DNA exists as chromosomes.

metaphase II

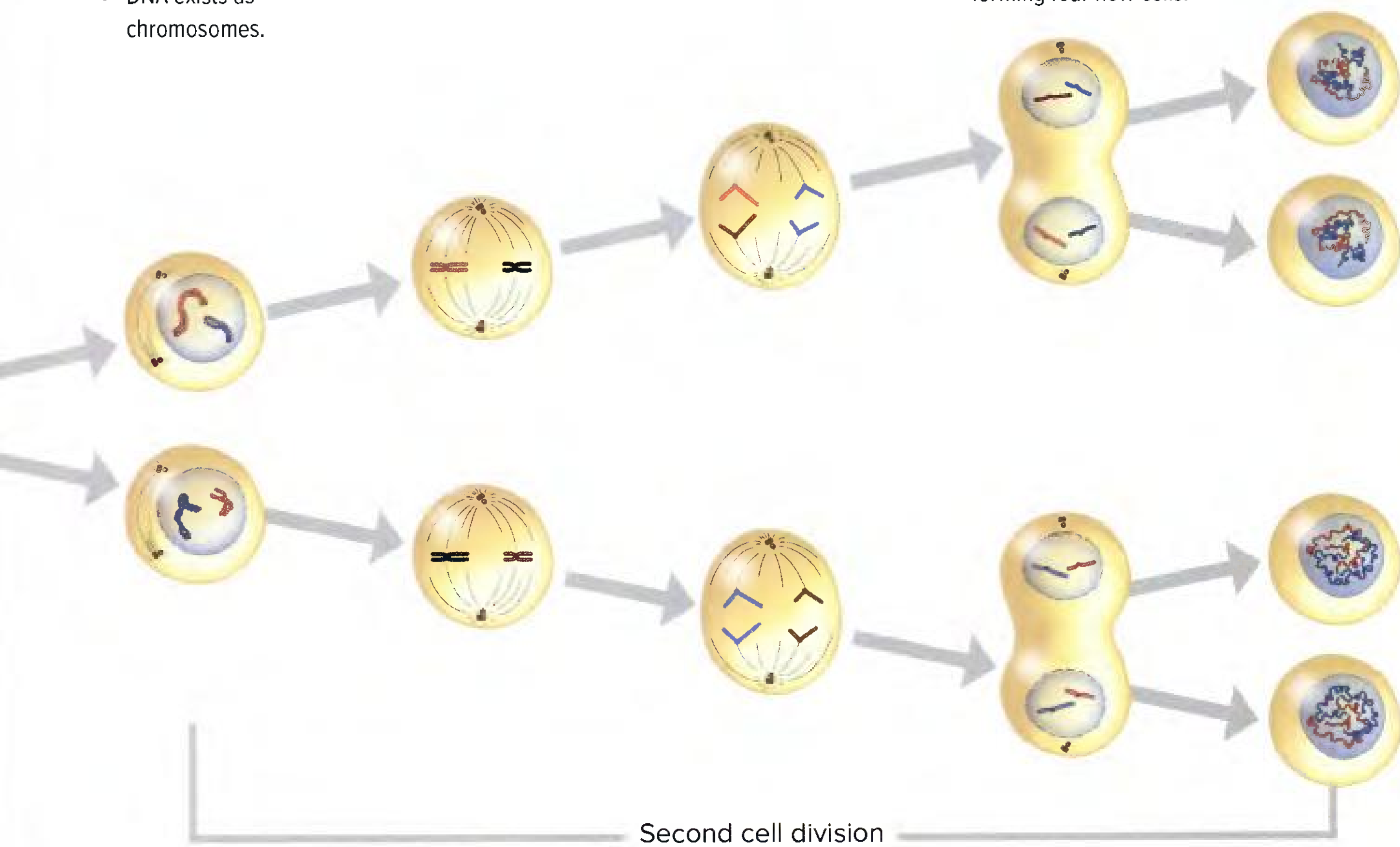
- The chromosomes line up along the middle of the cell.

anaphase II

- The copies of DNA are separated and go to each end of the cell.

telophase II

- Four nuclei form.
- The cells divide, forming four new cells.



Before you leave this page . . .

1. What role does meiosis play in sexual reproduction?
2. Use a graphic organizer to show how meiosis is similar to and different from mitosis.

CONCEPT 3

Development of the human zygote occurs in stages.

Human prenatal (before birth) development begins as soon as the egg is fertilized. Within about 30 hours of this event, the zygote divides by mitosis for the first time. Cell division continues at such a fast rate that there is no time for the early cells to increase in size between divisions (Figure 1.21) After several rounds of division, the spherical mass of actively dividing cells travels to and implants in the lining of the uterus, where development will continue.

Figure 1.21 In the first stages of cell division, the overall size of the zygote stays the same.

Over a period of about 38 weeks, a zygote undergoes a complex sequence of changes as it multiplies, develops, and grows to form the many billions of cells that make up the infant human body (Figure 1.22)

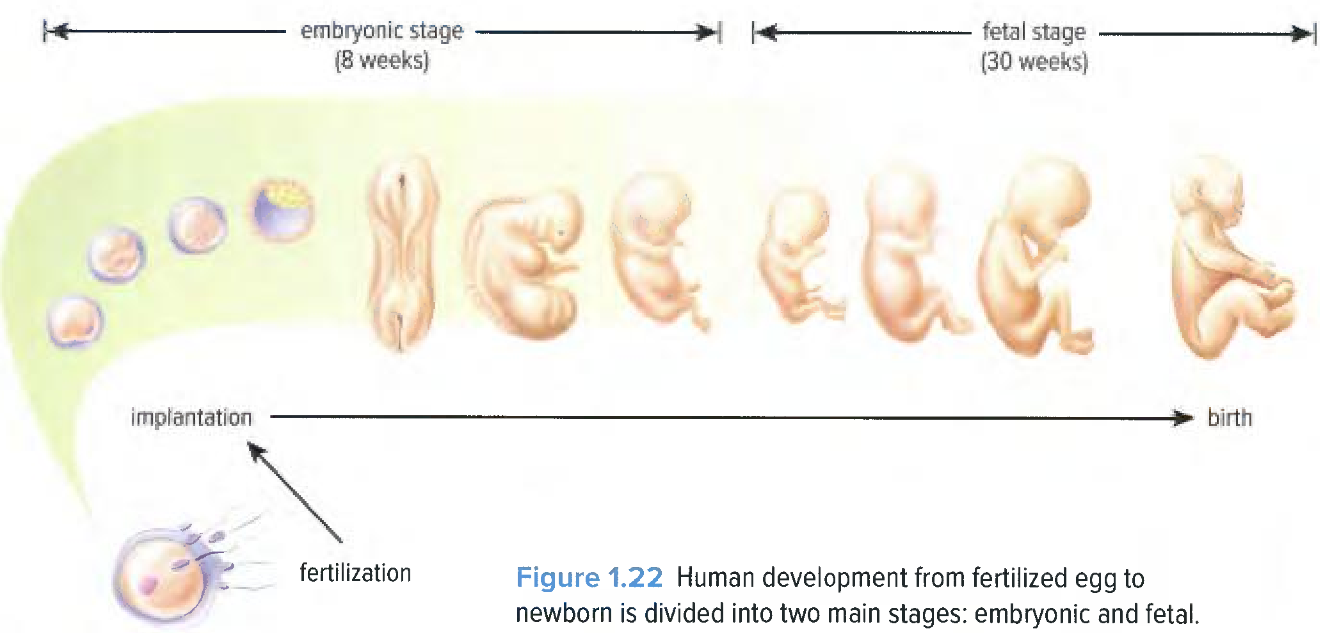


Figure 1.22 Human development from fertilized egg to newborn is divided into two main stages: embryonic and fetal.

Prenatal Development

Some of the major events that occur in prenatal development are described in Table 1.2.

Table 1.2 Human Prenatal Development

Month	Mass at End of Month (g)	Some Key Developments
1	< 1	• Spinal column and central nervous system start to form • Appendages are represented by small limb buds • Heart begins beating (around day 22)
2	1	• Eyes form, but eyelids are fused shut • Brain waves are detectable • Limb buds form paddle-like hands and form ridges
3	30	• Eyes are well developed, but eyelids are fused • Limbs are well-formed, with nails on fingers and toes • Fetus moves but too weakly for mother to feel it
4	100	• Face looks more distinctly human • Heartbeat can be heard with a stethoscope • Scalp begins to grow hair
5	200–450	• Body covered with fine hair (lanugo) • Mother can feel fetal movements • Fetus is now bent forward into "fetal position"
6	500–800	• Eyes are open • Skin is wrinkled, pink, and translucent
7	1100–1350	• Fetus turns to an upside-down position • Fetus can usually survive if born prematurely
8	2000–2300	• Fetus has a "babyish" appearance, with less wrinkled skin
9	3200–3500	• More fat deposits • Nails extend to or beyond fingertips • Birth is imminent

Activity

Show Development

Plan and create a multimedia presentation to show prenatal development from a fertilized egg until just before birth.

Before you leave this page . . .

1. During which parts of human development are cells dividing by meiosis? by mitosis?

2. On page 52, the words *divides* and *multiplies* are both used in describing prenatal development. Explain why this isn't as confusing as it might seem at first.

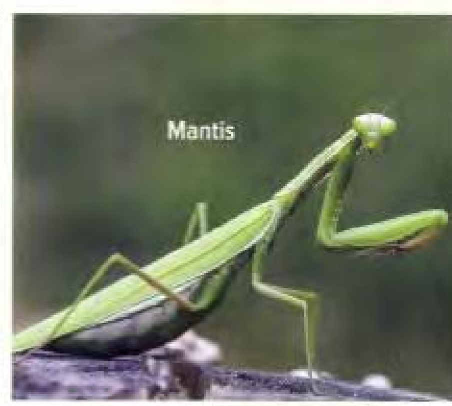
CONCEPT 4

Sexual reproduction takes many different forms.

So far, you have learned about what happens in sexual reproduction in humans. However, many kinds of organisms reproduce sexually. Of those that do, many have very different reproductive behaviours, methods of fertilization, and ways that offspring develop. The organisms shown in Figure 1.23 on these two pages represent just a few examples. All of them can be found right here in B.C.

Development from fertilized egg to offspring of most mammals occurs inside the female, who is also the source of nourishment.

Reproduction in insects is usually sexual. In some insects, such as bees, eggs can develop without fertilization. Unfertilized eggs develop to become males and fertilized eggs develop to become females. The female mantis sometimes bites off the head of the male she mates with.



Fungi such as yeasts and moulds can reproduce sexually as well as asexually. Sexual reproduction in fungi is different from that in other organisms.

Figure 1.23 A wide diversity of organisms sexually reproduce.

For some animals, such as fish, frogs, and birds, fertilized eggs develop into offspring outside the female's body. Offspring are released when the eggs hatch.

Plants sexually reproduce in different ways. Those that grow from seeds require pollination for fertilization to occur. Pollen can be transferred by the wind or by animals, such as bees and birds.

Extending the Connections

What's the Story?

Find or create a transformation story about a species that interests you. How does the story help you understand the reproduction in that species?

Activity

How Do They Reproduce?

Find out about reproduction in one species from Figure 1.23. For example:

- Are there mating rituals or behaviours?
- What cellular processes are involved?
- How long do offspring take to develop?

Before you leave this page . . .

1. Identify three ways that sexual reproduction differs in different organisms.
2. What do all forms of sexual reproduction have in common?

AT ISSUE How can technology help reproduction?

Over the past 200 years, our knowledge about cells and DNA has changed as new tools and technologies related to reproduction have been developed. For example, we are now able to invent new types of foods, develop new treatments for disease, and assist people to have babies. These examples are part of an area of study called *reproductive technology*.

What's the Issue?

Despite its benefits, reproductive technology invites controversy. People ask questions such as:

- Is it ethical to manipulate life?
- Can we foresee all the consequences?
- Are the technologies available to everyone?

Dig Deeper

Collaborate with your classmates to explore one or more of these questions—or generate your own questions to explore.

1. Below are just a few types of reproductive technologies. Choose one of these or another from your own research. Decide if you want to learn about a technology that applies to people or to animal breeding.
   - artificial insemination
   - selective breeding
   - in vitro fertilization
   - assisted hatching
   - intracytoplasmic sperm injection (ICSI)
   - cloning
2. What are the advantages and disadvantages of this technology? Does one outweigh the other? What assumptions and biases are involved?

Check Your Understanding of **Topic 1.3**

QP Questioning and Predicting   PC Planning and Conducting   PA Processing and Analyzing   E Evaluating
AI Applying and Innovating   C Communicating

Understanding Key Ideas

1. How are the terms *gamete*, *fertilization*, and *zygote* related? AI C

2. Each body cell of a cat has 38 chromosomes.
   a) How many chromosomes will be in each sperm cell of a male cat? Explain why it is this number.
   b) How many chromosomes will be in a zygote of a cat? Explain your answer. PA QP

3. Why is meiosis important? E

4. Copy and complete the following table in your notebook by answering the questions about meiosis. QP C

Question	Result of Meiosis
How many cells are produced for every cell that undergoes meiosis?	
How do parent and daughter cells differ genetically?	
How do daughter cells compare to each other?	

Connecting Ideas

5. A breed of dog called a labradoodle was developed from the mating of a Labrador retriever and a poodle. Use this example and your knowledge of sexual reproduction to explain why this can happen. AI E

6. The word *twins* refers to two offspring being produced in the same pregnancy. In humans, twins can be identical or fraternal. As their names imply, identical twins are genetically identical and, therefore, they are the same sex. Fraternal twins are not genetically identical and can be different sexes. AI C

   a) One type of twin forms when two eggs are individually fertilized. Another type of twin forms when a single fertilized egg divides into two separate bodies in the first few days of embryo development. Identify which represents fraternal twin development and which represents identical twin development. Explain your answer.
   b) Fraternal twins are called dizygotic twins and identical twins are called monozygotic twins. Why are those names appropriate? Hint: Think of the meanings of the prefixes *mono-* and *di-* and the meaning of the word *zygote*.

Making New Connections

7. Some plants can self-pollinate. This means pollen, which contains sperm cells, is transferred from the male reproductive structure to the eggs in the female reproductive structure within the same flower. In your opinion, is this sexual or asexual reproduction? Why? PA AI

INVESTIGATION

1-H

GUIDED INQUIRY

Modelling Mitosis and Meiosis

Skills and Strategies

- Planning and Conducting
- Processing and Analyzing Data
- Evaluating
- Communicating

Safety

- Take care when using sharp utensils, such as scissors. Report any accidental cuts to your teacher.

What You Need

Suggested materials:

- pool noodles (to represent chromosomes in a play)
- crafts supplies such as
  - clay
  - pipe cleaners
  - string
  - glue
  - coloured paper
  - markers
  - scissors
  - yarn

During cell reproduction, changes occur to the chromosomes. These are necessary for the new cells to have the correct genetic material. In this investigation, you will develop models that show what happens to the chromosomes of a parent cell with four chromosomes when daughter cells form by mitosis and by meiosis.

Question

How can you model the movement of chromosomes in meiosis and mitosis?

Procedure

1. Your teacher will assign groups. As a group, make a list of the important features of mitosis and meiosis that you will need to show in your models.
   - What features will you need to include to be able to show what happens to the chromosomes?
   - How can your models show important differences between mitosis and meiosis?
2. Based on your list in step 1, develop a plan for how to make models to represent chromosome movement in mitosis and meiosis.

   Be creative—for example, your group could build a clay model, create a computer simulation, or perform a play. Make a list of your ideas, and decide on the type of model you will use.
3. Make a list of the materials you will need.
4. Have your teacher approve your plan and materials list before you start to develop your models.
5. Carry out your plan.
6. As a class, display your models. Any group that has chosen to do a play should perform the play for the class.

Analyze and Interpret

1. What is the difference between chromosomes in cells at the beginning and end of mitosis? at the beginning and end of meiosis?
2. How did your models represent the similarities between mitosis and meiosis? How did they represent differences?
3. Compare your models with what you saw from other groups. Would you change something about your models after seeing the others? Why or why not?

Conclude and Communicate

4. How did this modelling investigation help you better understand mitosis, meiosis, and the similarities and differences between the two processes?
5. In what ways is meiosis suited to the production of gametes, but not to the production of identical daughter cells? How is mitosis better suited for this purpose? Explain your answer using your model as a reference.
6. What are some limitations of your models?

INVESTIGATION

1-I

OPEN INQUIRY

Skills and Strategies

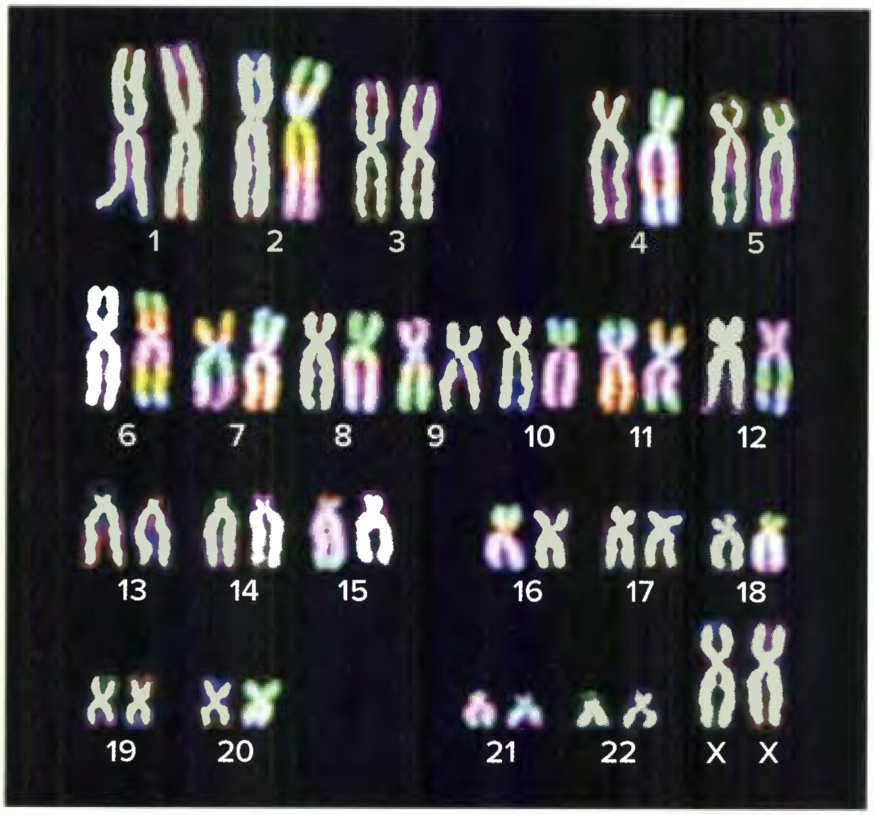
- Questioning and Predicting
- Planning and Conducting
- Processing Information
- Evaluating
- Applying and Innovating

What You Need

- computer with Internet access
- print resources, as needed

Errors in Meiosis and Human Genetic Disorders

A photo of the chromosomes in a human body cell is shown below. This is called a karyotype. It shows the 46 chromosomes organized into 23 pairs. The chromosomes are placed in order of decreasing size, and numbered. One pair is the sex chromosomes, which determine the biological gender of the individual. The two X chromosomes indicate this is the karyotype of a female.



During meiosis, errors can occur. Many of these errors result in gametes that do not survive. However, some gametes do survive. If they are fertilized, they will produce a zygote. Since every cell in an offspring is produced from the one zygote cell, all of the cells in the offspring will contain the error. One type of error that occurs during meiosis in humans results in the zygote not having 23 pairs of chromosomes. In this investigation, you will find out more about a human genetic disorder due to this type of error.

Procedure

1. Do research on genetic disorders that are the result of a change in chromosome number. Develop a list of questions you have or topics that interest you about some of these disorders. Choose an example of a genetic disorder that interests you and that you want to learn more about.
2. Decide which questions you will investigate.
3. As part of your research, find out answers to the following:
   - What is the error and how does the error occur?
   - What are the symptoms that a person who has the disorder experiences?
   - What treatments are available?
   - How does the disorder affect a person's lifestyle and the lives of their family members?
4. Develop a plan for how you will research the topic, and how you will collect and organize the information about it. Choose a format for presenting the information to the class.
5. Have your teacher approve your chosen topic, research plan, and presentation format.
6. Carry out your plan once your teacher has approved it.
7. Present the information to the class.

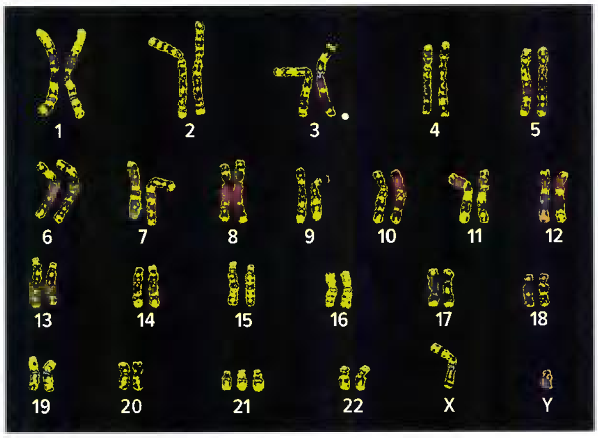
Evaluate

1. Did you determine the answers to your questions? If so, what are they? If not, why were you not able to?
2. Do you have any new questions that were not part of your presentation but you are now curious about? What can you do with these questions?

Apply and Innovate

3. How has performing this investigation changed how you view people with a genetic disorder and/or the families who are affected by such disorders?

A



This karyotype is from a person with Down syndrome. Notice there is an extra copy of chromosome 21. The X and Y chromosomes indicate the person is male.

B

People with Down syndrome have distinctive facial features. Many also have heart defects and other medical conditions.

TOPIC

1.4

How does reproduction contribute to the variety of life on Earth?

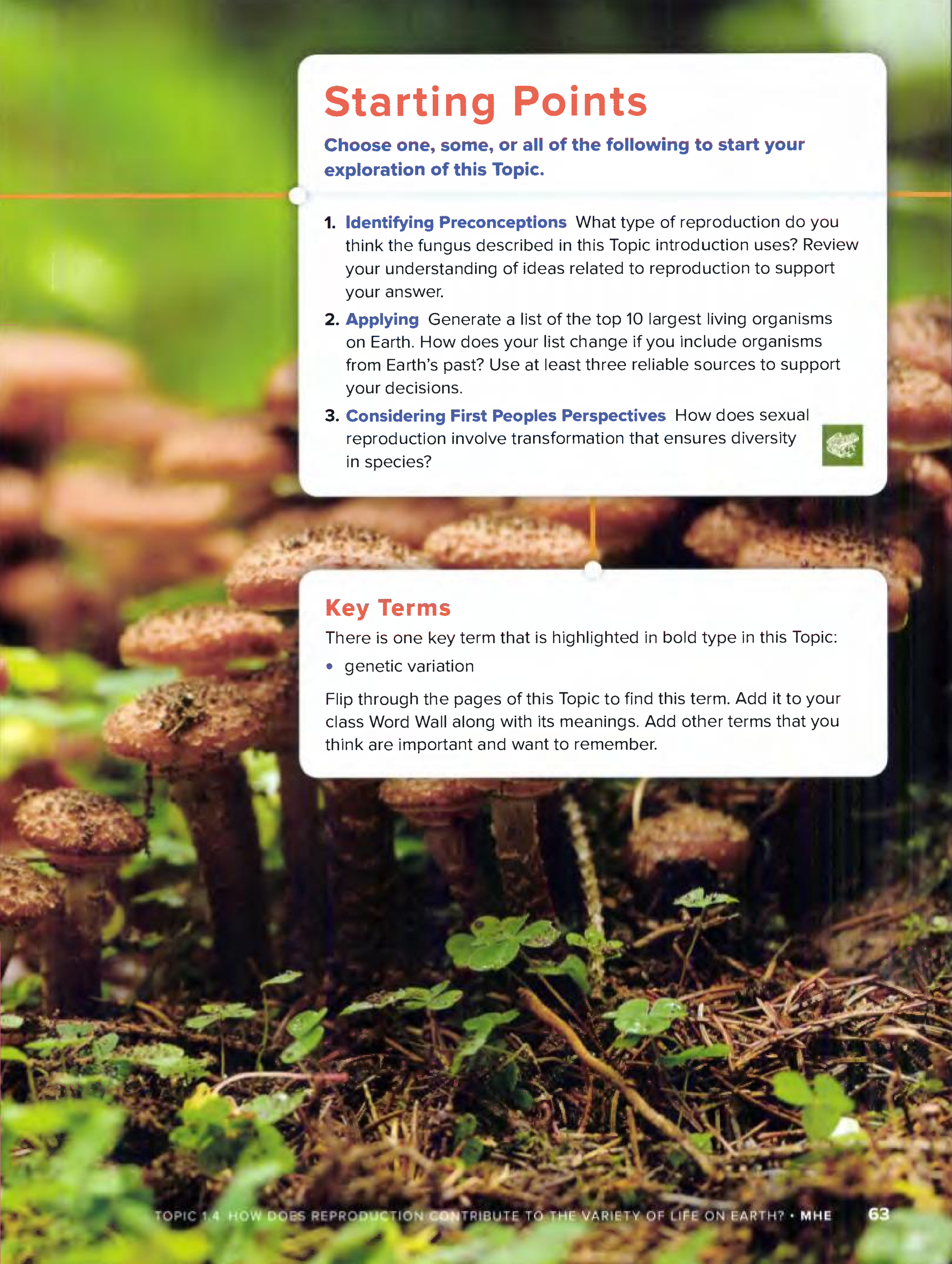
Key Concepts

- Asexual reproduction results in many genetically identical offspring in a short amount of time.
- Sexual reproduction results in genetically varied offspring.

Curricular Competencies

- Make observations aimed at identifying your own questions about the natural world.
- Assess risks and address ethical, cultural, and/or environmental issues associated with proposed methods of investigation.
- Critically analyze the validity of information in secondary sources, and evaluate the approaches used to solve problems
- Contribute to care for self, others, community, and world through individual or collaborative approaches.

Imagine a living thing so large that it covers almost 1000 hectares. That's an area that would hold more than 1700 football fields. This photo shows a *very* tiny part of the world's largest known organism: a type of honey mushroom (*Armillaria solidipes*) that lives in the Blue Mountains of Oregon. The vast majority of this huge fungus lies beneath the ground surface. Only small portions of it, like this, are visible to the eye. The parts that we see are actually the reproductive structures of the fungus, called fruiting bodies, which produce and release spores.



Starting Points

Choose one, some, or all of the following to start your exploration of this Topic.

1. **Identifying Preconceptions** What type of reproduction do you think the fungus described in this Topic introduction uses? Review your understanding of ideas related to reproduction to support your answer.
2. **Applying** Generate a list of the top 10 largest living organisms on Earth. How does your list change if you include organisms from Earth's past? Use at least three reliable sources to support your decisions.
3. **Considering First Peoples Perspectives** How does sexual reproduction involve transformation that ensures diversity in species?

Key Terms

There is one key term that is highlighted in bold type in this Topic:

- genetic variation

Flip through the pages of this Topic to find this term. Add it to your class Word Wall along with its meanings. Add other terms that you think are important and want to remember.

CONCEPT 1

Asexual reproduction results in many genetically identical offspring in a short amount of time.

In 2016, a huge population of algae—an algal bloom—formed along the west coast of North American (Figure 1.24) Plant-like algae reproduce mainly asexually. Blooms occur when conditions such as temperature and nutrient availability enable algae to multiply quickly.

Algal blooms can pollute shellfish, making them toxic. First Peoples have always used careful observation to make sure clams and other shellfish are safe to eat. They check the colour of the water and watch to see if animals like crows and mink eat the clams safely.

Advantages of Asexual Reproduction

Asexual reproduction provides a number of advantages.

- Only one parent is needed. Since there is no need to find a mate, the organism can start to reproduce as soon as it is ready and conditions are suitable.
- The process occurs quickly. As a result, each organism can produce many offspring.
- The formation of mature offspring takes a short amount of time. As a result, offspring can start to reproduce soon after being produced.
- The offspring are genetically identical to the parent. As long as environmental conditions stay the same, offspring are likely to live in and interact with their environment with the same success as their parent.

Figure 1.24 Algal blooms are a common sight along the Pacific coast any time of year but especially in the summer. **Why would algal blooms be especially common in summer?**

A Lack of Genetic Diversity

All of the advantages of asexual reproduction help an organism become established quickly and successfully in the conditions provided by its environment. But what happens if those conditions change?

For example, many farms that grow food crops use plants that are produced by asexual reproduction (Figure 1.25) New plants can be grown quickly and in large numbers when they are produced this way. The plants, and the food that comes from them, also have predictable qualities that consumers expect. However, what can happen if there is no rain for a long time, or if the plants are invaded by a disease-causing organism (Figure 1.26)? Because all the plants are genetically identical, they will all respond the same way—they will become diseased and may die.

The lack of diversity within a population means all individuals in the population are equally vulnerable to change. Sometimes these changes can cause an entire population to be wiped out.

Figure 1.25 Apples are one kind of crop plant that is grown using techniques that rely on asexual reproduction.

Figure 1.26 If the conditions change or a disease occurs, it may cause a crop to die or the yield of produce to be severely reduced.

Activity

Reflecting on Advantages and Disadvantages

Choose a species of organism you have learned about that reproduces asexually. Describe a situation in which asexual reproduction is an advantage for that organism. Then, describe a condition in which its lack of genetic diversity is a disadvantage.

Before you leave this page . . .

1. Describe one advantage and one disadvantage of asexual reproduction.

CONCEPT 2

Sexual reproduction results in genetically varied offspring.

Activity

Family Features

Think back to what you learned about gametes and sexual reproduction. Use this to explain why people have some features that are similar to those of their family members and yet they remain unique individuals.

genetic variation variation in the DNA sequences of each individual of a species

There is variation in the genetic make-up of humans and all other species. **Genetic variation** makes members of a species unique due to small differences in the DNA sequences of each individual. These differences result from sexual reproduction.

This is true even for people within the same family. The brothers and sisters shown in Figure 1.27 look similar, but they are not copies of each other. Each sibling inherited half their DNA from each parent, but they did not inherit the same DNA. Different DNA means that each offspring has a different set of features. Over many generations, as new people contribute their DNA to a family, a greater diversity of individuals within that family develops.

Figure 1.27 Although members of this family share similar traits, their different genetic material makes them unique individuals.

The Value of Genetic Diversity

Because of genetic variation, there are slight differences among individuals within a population. If the environment changes, some individuals within that population might now be less successful in living and reproducing. They may even die. Others may have certain features that enable them to live in the new conditions more easily. Genetic diversity may allow at least some individuals to survive. If surviving members of the population reproduce, their genetic information is passed on—and a new generation lives on.

Disadvantages of Sexual Reproduction

Despite the value of genetic diversity, there are disadvantages to sexual reproduction.

- The search for a mate might expose individuals to predators, disease, or harsh environmental conditions. This can delay reproduction and an organism's ability to become established in its environment.
- Fewer offspring tend to be produced. This means it takes longer for a population to grow, even under suitable conditions.
- Offspring often take longer to reach maturity before they can produce sex cells and reproduce themselves.
- In many cases, offspring require a substantial amount of time and energy to raise until they are independent from the protection of one or both parents.

Extending the Connections

The Many Faces of Biodiversity

The term *biodiversity* refers to the variety (diversity) of all species of living things, the genetic information stored in their cells, and the environments in which they live and interact. In other words, biodiversity has three components: species diversity, genetic diversity, and ecosystem diversity. Find out how the interactions and relations among these components result in Earth's rich and diverse life.

Before you leave this page . . .

1. Describe one advantage and one disadvantage of sexual reproduction.

Connect to Investigation 1-J on page 72

Biology Connections

Obstetrician

Veterinarian

Arborist

Food Technologist

Animal Behaviourist

What kinds of jobs are there for people interested in the reproduction of living things?

Midwife

Is the wail of a newborn baby music to your ears? Midwives hear this "music" on a regular basis as part of their job to observe, educate, and care for women and their babies throughout pregnancy, labour, and birth.

Horticulturist

As the green thumbs of the scientific world, horticulturist use their knowledge of plant reproduction and cultivation to help farmers grow better crops and landscapers create beautiful parks.

Pathologist

While pathology is literally "the study of disease," many people in this profession consider themselves detectives. They investigate cells for clues to identify diseases that affect people, other animals, or crops.

Questions

1. What other jobs and careers do you know or can you think of that involve the reproduction of living organism?
2. Research a job or career related to Unit 1 that interests you. Explain what attracted you to it. What kinds of things do you have to know, do, and understand for this job or career?

Check Your Understanding of **Topic 1.4**

Questioning and Predicting · Planning and Conducting · Processing and Analyzing · Evaluating · Applying and Innovating · Communicating

Understanding Key Ideas

1. Using a table or other format of your choice, summarize the advantages and disadvantages of asexual reproduction.
2. Explain the meaning of the term *genetic variation*. What might cause a lack of genetic variation in a species, and how might this affect the species' ability to survive?
3. How does sexual reproduction lead to variations in the genetic diversity seen in a family over the course of many generations?

Connecting Ideas

4. Plants are very successful organisms that can be found in just about every environment. How does their ability to reproduce both asexually and sexually contribute to this success?
5. Is reproduction required for the survival of an individual? Is reproduction required for the survival of a species? Explain each of your answers.
6. The length of time between fertilization and the birth of an offspring is called the gestation period. Gestation periods can vary a great deal. The gestation period for a mouse is 21 days. For humans it is 266 days, and elephants require about 600 days—almost two years. Fertilization cannot occur during pregnancy. Explain why a long gestation period is a disadvantage of sexual reproduction.
7. Is one type of reproduction is better than another, or are they equal? Support your answer with valid reasons.

Making New Connections

8. The white-coated Kermode or Spirit Bear of B.C.'s north coast is sacred to First Peoples and celebrated more generally as the province's official animal. It is a subspecies of black bear. About 1 out of every 10 bears has white or cream-coloured fur.

a) Explanations for the white colouring from a First Peoples perspective include stories told by the Tsimshian Peoples. Find out about these stories. What do they communicate about the Spirit Bear?

b) Explanations for the white colouring from a Western science perspective include information that comes from fields of genetics and population studies. Find out about this information. What does it communicate about the Spirit Bear?

c) In what ways are First Peoples and Western science accounts similar? In what ways are they different? In your opinion, how significant are the differences?

TAKE Action

Make a Difference

How can we deal with invasive species?

Many species have been introduced to North America, either on purpose or by accident. In some cases, these invasive species compete with native species for resources such as food, water, sunlight, and shelter. Often, the invasive species is able to out-compete native species. As a result, they reproduce more often and more successfully. Over time, the native species may die out or become at risk of doing so.

Spotted knapweed (*Centaurea biebersteinii*) was introduced into North America from Europe in the late 1800s. It is very difficult to remove.

Parrot's feather (*Myriophyllum aquaticum*) is an aquatic garden plant that can grow to become so dense that it chokes out other aquatic plants. It can also cause pools of standing water, which is the preferred environment for mosquitos to breed.

Developing An Invasive Species Attack Plan

Your task is to develop and carry out a public awareness campaign about how to prevent the introduction or spread of invasive species. Research the different invasive species in your region, how they were introduced, and how their reproductive strategies have helped them get established. Find out how they affect your region and ways that governments and communities have been dealing with this issue.

Here are some questions to consider when developing your plan.

- Who will your target audience be: people in your neighbourhood? students in your school? anyone else?
- What type of plan will you propose? For example, one idea is to develop an information bulletin that can be distributed. What other ideas do you have?
- What information do you need to find and provide? For example, what safety precautions should people take if they come across an invasive species?
- How will you get people to participate?
- How will you assess the success of your plan?

Analyze and Evaluate

1. Do you consider your plan a success? What is your evaluation based on?
2. Describe any challenges you had with developing or running the plan. What would you do differently if you were to run such a campaign again?

Apply and Innovate

3. Suppose your local town or community council has heard about the plan you developed and is thinking about expanding it. They have asked you to present the information in a meeting with council members. Develop a presentation for the council that informs them about the issue and how your plan can be expanded to reach a wider audience.

Even plants and animals, such as the American bullfrog (*Lithobates catesbeianus*), which started as pets or aquarium plants, have become invasive species by being released into the environment.

The largemouth bass (*Micropterus salmoides*) is native to eastern North America, but it is an invasive species in many lakes and rivers in B.C. Its presence has caused severe reduction in the numbers of native fish.

INVESTIGATION

1-J

GUIDED INQUIRY

Advantages and Disadvantages of Sexual and Asexual Reproduction

Skills and Strategies

- Questioning and Predicting
- Planning and Conducting
- Processing Information
- Evaluating
- Applying and Innovating

What You Need

- computer with Internet access
- print resources, as needed

There is a wide range of strategies that organisms use to reproduce. In this investigation you will study two organisms that have different reproductive strategies and identify the advantages and disadvantages of each.

Question

What are the advantages and disadvantages of how an organism reproduces?

Procedure

1. Your teacher will provide a list of organisms that reproduce sexually, asexually, or both asexually and sexually. You and your partner should choose two organisms that reproduce differently.
2. Do research to find out about the reproductive strategies of each organism that you chose.
3. As part of your research, find out answers to the following:
   - What are the physical characteristics of the organism (for example, is it a prokaryote or eukaryote; single-celled or multicellular; complex or simple body structure)?
   - What type of environment does the organism tend to live in?
   - What mating behaviours are associated with reproduction?
   - What type of reproduction does it undergo? If fertilization occurs, how and where does it occur? Are the offspring clones of the parent or is there genetic variation?
   - If an organism can reproduce both sexually and asexually, under what conditions does it perform each type?
   - What is the gestation period, and what are the stages of zygote development to form offspring?
   - How many offspring are in each reproductive cycle, and how many reproductive cycles within a year occur?

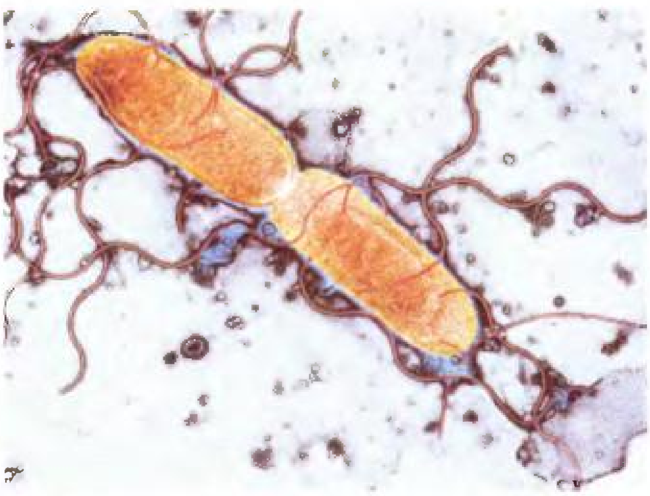
4. Develop a plan for how you will research the topic, and how you will collect and organize the information about it. Choose a format for presenting the information to the class.
5. Have your teacher approve your chosen organisms, research plan, and presentation format.
6. Carry out your plan once your teacher has approved it.
7. Present the information to the class.

Analyze and Interpret

1. In a table format, list the advantages and disadvantages of each reproductive strategy.
2. Describe how the reproductive strategies are similar and how they are different.

Conclude and Communicate

3. Provide your reasons for deciding which feature of an organism's reproductive strategy is an advantage or a disadvantage.
4. Do you think one reproductive strategy is better than the other? Provide reasons that support your opinion.




UNIT 1

Summary

ESSENTIAL QUESTION

How is the reproduction of cells essential to the survival of organisms?

TOPIC 1.1:

Why is the reproduction of cells important?

- Reproduction ensures that life exists beyond its present generation.
- Reproduction transfers genetic information from parents to offspring.

Key Terms

asexual reproduction
sexual reproduction
DNA
chromosome

TOPIC 1.2:

What are different ways that living things reproduce asexually?

- Bacteria reproduce by binary fission.
- All eukaryotic cells reproduce by the cell cycle.
- Yeasts reproduce by budding.
- Moulds reproduce using spores.
- Plants have many ways to reproduce asexually.

Key Terms

binary fission	cell cycle	budding
spore	vegetative propagation	clone

TOPIC 1.3:
How do living things sexually reproduce?

- Male and female reproductive cells combine to produce a zygote.
- Reproductive cells are formed by a cell-dividing process called meiosis.
- Development of the human zygote occurs in stages.
- Sexual reproduction takes many different forms.

Key Terms

gamete
fertilization
haploid
diploid

TOPIC 1.4:
How does reproduction contribute to the variety of life on Earth?

- Asexual reproduction results in many genetically identical offspring in a short amount of time.
- Sexual reproduction results in genetically varied offspring.

Key Term

genetic variation

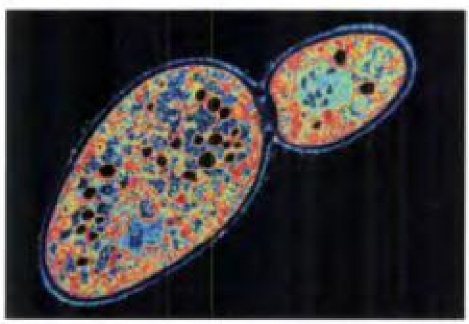
UNIT 1

Review

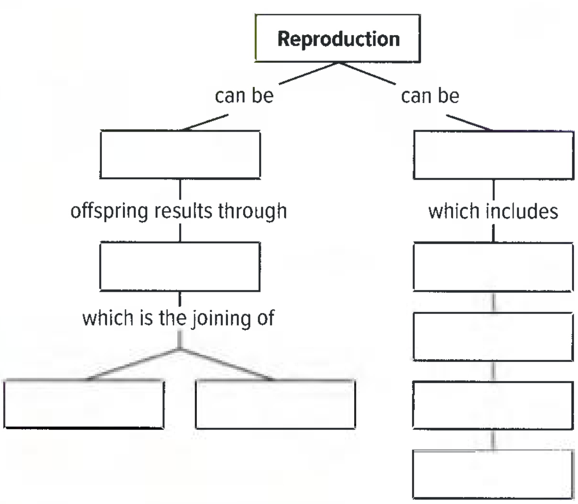
What Do You Know?
Connecting to Concepts

Visualizing Ideas

1. Describe how the photo below represents reproduction. In your description, include the following information:
   - the type of reproduction that is represented, with reasons that support your statement
   - what you know about the offspring based on this type of reproduction



2. Copy and complete the following concept map about reproduction.



Using Key Terms

3. Develop a set of flash cards that could be used to help you study asexual and sexual reproduction. Your flash cards should include the key terms listed below and any diagrams that illustrate each process.
   - artificial propagation
   - binary fission
   - biodiversity
   - budding
   - cell cycle
   - egg
   - eukaryote
   - fertilization
   - gamete
   - genetic variation
   - meiosis
   - mitosis
   - prokaryote
   - sperm
   - spore formation
   - zygote

Communicating Concepts

4. Make a sketch of a plant cell that shows where the cell's genetic information is found.
5. In what ways would your sketch in question 4 be different if you were making a sketch of an animal cell? In what ways would it be similar?
6. Explain how the following terms are related: DNA, chromosome, genetic material.
7. a) What is the name of the molecule that stores genetic information?
   b) Why is it important that this molecule is duplicated during interphase of the cell cycle?
8. How does the DNA sequence of a parent bacterial cell compare to the DNA sequence of a daughter cell? Explain your answer.
9. Explain how genetic variation is important to the survival of a species.

10. In a little less than a month, your body replaces all the cells of your skin. Is this an example of mitosis in action? Explain.

11. Both mitosis and meiosis are required for humans to reproduce and develop.
   a) What role does meiosis play? Why is it better suited for that role than mitosis?
   b) What role does mitosis play? Why is it better suited for that role than meiosis?

12. Why is sexual reproduction an advantage for an organism? Describe two disadvantages that are also part of sexual reproduction.

13. Plants can reproduce asexually.
   a) Describe one example of how a plant asexually reproduces.
   b) Why is it considered asexual reproduction? What does it tell you about the genetic material of the new plant?
   c) How do people such as farmers and gardeners use a plant's ability to asexually reproduce? Use an example you have learned about in this unit, or one from your own experience.

14. Copy and complete the following table.

Question	Mitosis	Meiosis
How many cells are produced for every cell that begins?		
How do parent and daughter cells compare to each other?		
How do daughter cells compare to each other?		
Number of divisions of the nucleus?		
Function		

15. In three or four sentences, describe the major events that happen in the cell cycle.
   a) Does every type of cell go through the cell cycle? Support your answer using examples.
   b) Is the cell cycle exactly the same for every cell in a person's body? Use examples to support your answer.

16. The cells that make up the body of a duck contain 80 chromosomes. How many chromosomes are in each of the following cells? Explain your answer for each. Use the terms "haploid" and "diploid" in your answers.
   a) egg cell b) sperm cell c) zygote

What Can You Do?
Connecting to Competencies

Developing Skills

17. Describe how you would design a model to represent the process of binary fission. Your model can take any form you wish. For example, you could design it digitally or with materials found in the kitchen.

18. How are haploid cells different from diploid cells? What processes produce haploid and diploid cells?

19. You are working as a counsellor in a summer camp. Some of the buildings are old and the roofs leak. You notice dark, fuzzy-looking material that you think is mould growing in one of the buildings. Develop an explanation for where the dark fuzzy growth might have come from, how it is growing, and why it may cause health problems. Make sure your explanation could be understood by people without a science background.

Unit 1 Review *(continued)*

20. Bacteria have both positive and negative influences in the food industry.
    a) What are some of these negative and positive influences?
    b) Develop a hypothesis about the effect of temperature on the reproduction of bacteria.
    c) Describe how you could carry out an investigation to test your hypothesis.
    d) How could the results of your investigation be applied to a real-world example of the use or control of bacterial reproduction?

Thinking Critically and Creatively

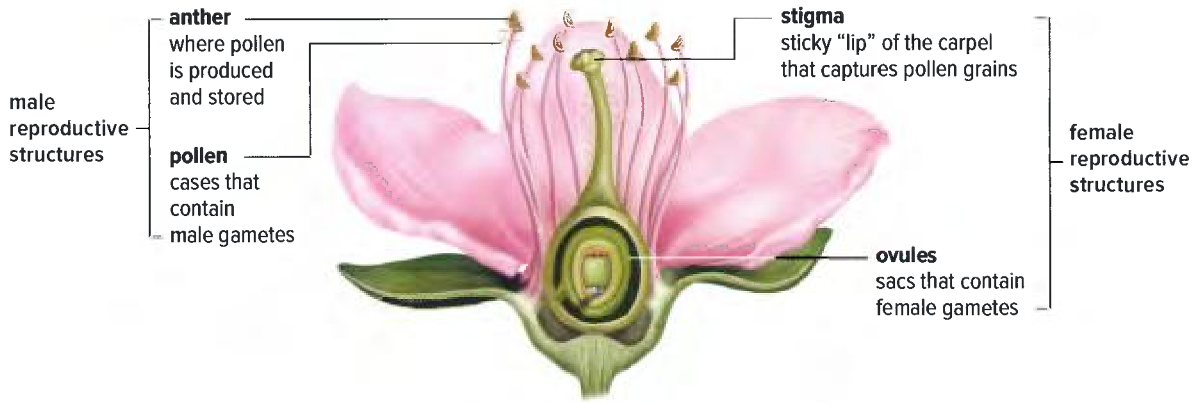
21. The offspring below has a male and a female parent. Do all living things have two biological parents? Explain.

22. Explain why sexual reproduction is an advantage for species that live in a changing environment.
23. Science has manipulated reproductive processes for different organisms. Do you think manipulating these reproductive processes has resulted in positive or negative outcomes? Use your understanding of science to support your opinions.

Understanding Big Ideas
Making New Connections

Applying Your Understanding

24. In eukaryotic cells, every time DNA is copied a section of DNA at the end of each chromosome is lost. These sections are called telomeres.
    a) At what point in the life cycle of a cell is the DNA copied?
    b) How would the size of telomeres in cells that go through many cell divisions compare with telomeres in cells that rarely divide? Discuss the cell cycle as part of your answer.
25. Flowering plants that grow from seeds can contain both male and female reproductive structures within the flower, as shown in the diagram on the next page.
    a) Where are the male and female gametes in a flower?
    b) How are gametes in humans and flowers similar?
    c) For fertilization, pollen must first land on the stigma of a plant of the same species. Some plants can pollinate themselves. For most plants, pollen from another plant is used. Why do you think pollen is often seen collecting on objects outside at certain times of the year?
    d) What type of reproduction is described in this question? Explain your answer.
    e) Compare this form of plant reproduction with what you know about human reproduction. How are they the same? How are they different?



Thinking Critically and Creatively

26. Many fruit crops rely on bees to pollinate the flowers on the trees. Bees are attracted to the flowers, which provide a nutrient called nectar. As they move from flower to flower searching for nectar, the bees carry pollen from one flower to another. Many people are now concerned about the decline in bee populations.

a) How do you think human actions could affect the bee populations?

b) Reflect on the following quote: "Every third bite of food you take, thank a bee or other pollinator."

Why do you think the decline in bee populations is a problem?

27. Different mammals, such as cattle, sheep, dogs, and cats, have been cloned. This means a new offspring was developed using one parent's body cell and its genetic information.

a) Based on your understanding of the term *clone*, why is this process called cloning?

b) What does this tell you about the offspring's genetic information?

c) Is cloning considered asexual or sexual reproduction? Explain your answer.

Connecting to Self and Society

28. The liver is capable of regenerating. Even if only 25% of the liver remains, it is capable of restoring itself back to full size.

a) Do you think mitosis or meiosis is involved in this process? Explain your choice.

b) Is this process considered reproduction? Why or why not?

c) Many scientists are working on ways to generate new organs and tissues in the laboratory. Do you consider this a valid research project? Support your opinion with scientifically informed reasons.

29. Refer to "First Peoples Perspectives in Science" on page xxii near the start of the textbook.

a) Review and reflect on the four themes of interconnectedness, transformation, renewal, and connections with place.

b) In a journal or in small groups, share ideas about how the concepts you have been learning about in this unit relate to these four themes.

Unit Assessment

How do we depend on reproductive cloning technologies?

Dutch artist Vincent van Gogh (1853–1890) is almost as famous for the mysterious loss of his ear as he is for his paintings. Fast-forward over 100 years to Diemut Strebe, an artist interested in the interplay of art and science. Strebe worked with scientists to recreate van Gogh's missing ear using cells donated by one of his modern relatives. The "living" ear is currently on display in a machine that mimics the conditions of the human body. This sensational story is just one application of cloning. Cloning is the process of making an identical copy of a biological entity—a strand of DNA, a cell, an organ such as van Gogh's ear, or even an entire organism.

Work as part of a group to do the following.

STEP 1 ► Reflect on the three options, their photos, and the question asked for each option.

STEP 2 ► Brainstorm three more options and questions of your own about a situation that involves cloning and reproduction.

STEP 3 ► Decide on one of the six option questions to investigate.

STEP 4 ► Plan and conduct a scientific inquiry to explore your question.

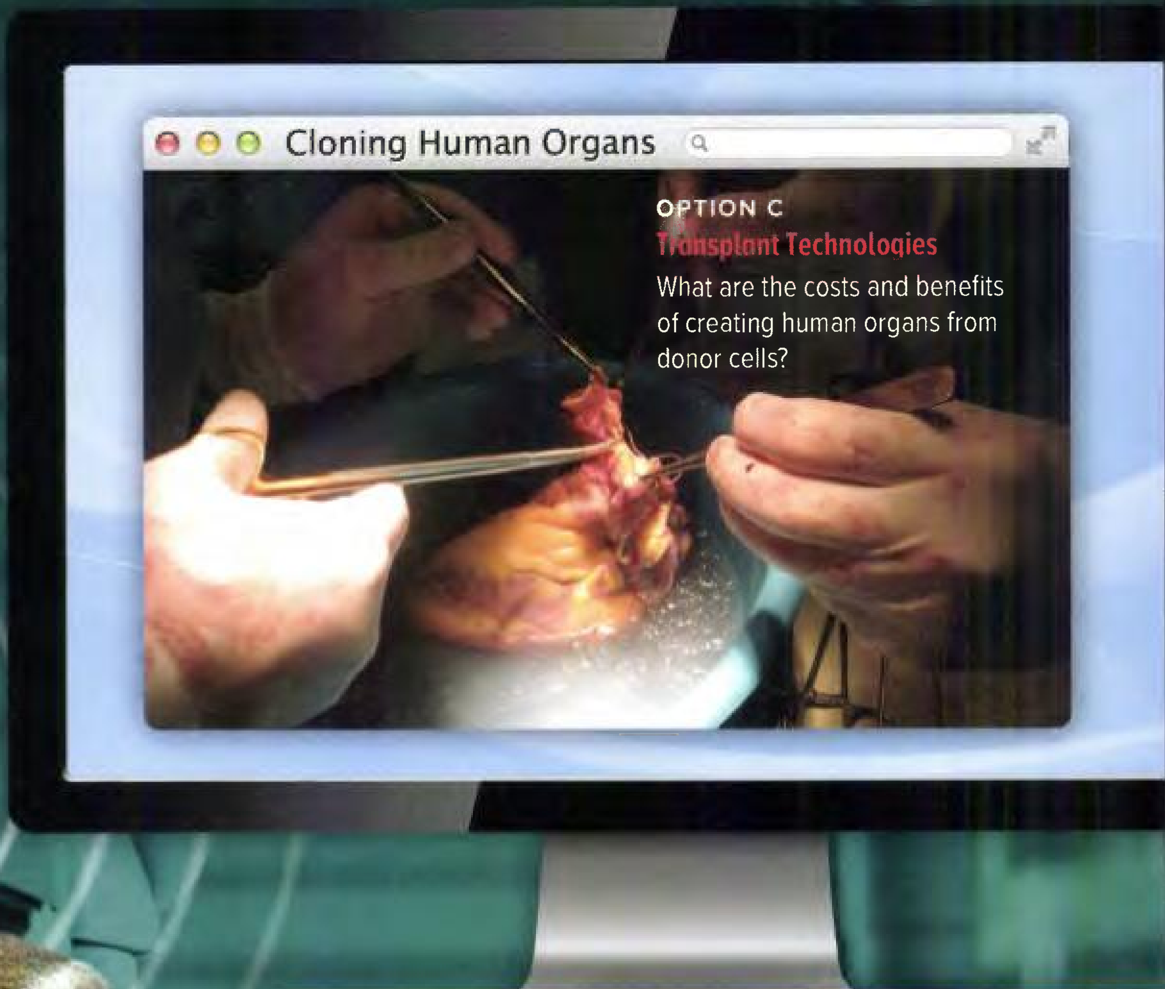
STEP 5 ► Organize and analyze the data and information that you find and collect.

STEP 6 ► Communicate the results of your inquiry in a suitable manner.

OPTION A

Food Production

Are you eating food that comes from cloned plants or animals?



OPTION C

Transplant Technologies

What are the costs and benefits of creating human organs from donor cells?

OPTION B

Saving Species

Should we use cloning to help endangered species or bring extinct ones back to life?

Vancouver Island marmot

Assessment Criteria

Did I and my group...

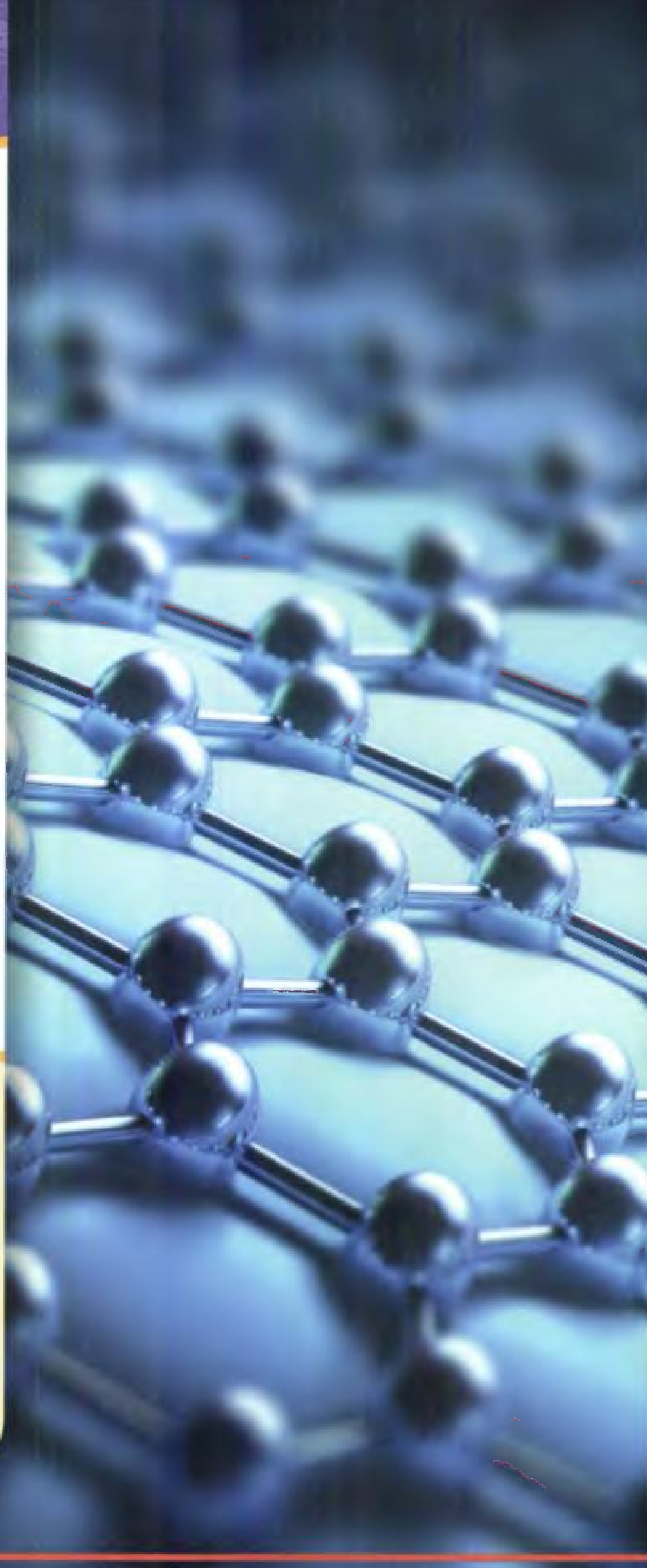
- Develop one or more questions that provided opportunities for rich investigation? QP
- Develop effective methods to collect and record reliable data and information? PC
- Apply different ways of knowing to analyze, reflect on, and draw meaningful conclusions that are consistent with evidence? PA
- Consider and demonstrate an awareness of assumptions, bias, and social, ethical, and environmental implications over the whole process of our inquiry? E
- Propose alternative courses of thought and/or action that contribute to care for self, others, community, and world? AI
- Construct evidence-based arguments using language, conventions, and representations appropriate for a specific purpose and audience? C

UNIT 2

The electron arrangement of atoms impacts their chemical nature

Graphene forms a flexible honeycomb structure that is just one atom thick, but it is stronger than steel and an excellent conductor of electric current. It is one of several forms of the element carbon, and carbon is just one of the hundred or so elements that make up the millions of compounds in the universe. Why does carbon have different forms? What are the properties of elements, and how can we organize and explain them? Why do elements combine to form compounds? The answers lie in the arrangement of electrons in atoms.

> **"I kept dreaming of the periodic table in the excited half-sleep of that night—I dreamed of it as a flashing, revolving pinwheel ... and then as a great nebula, going from the first element to the last, and whirling beyond uranium, out to infinity."**
>
> *Oliver Sacks, MD*
> *Neurologist, naturalist, author*



- Graphene is at the heart of developments in electronics and nanotechnology. Why might that be?
- Other forms of the element carbon are diamond, soot, and graphite. How can an element take different forms?
- What questions do you have about—this photo? the introduction? the quotation? the title for this unit? ...?

UNIT 2

At a Glance

You will demonstrate what you know, can do, and understand by being able to

- Perform investigations and use other investigative methods to explore properties and patterns involving a variety of elements
- Use scientific understandings to describe and evaluate the development of the periodic table
- Develop and use models and other methods to represent atoms, ions, and the ability of atoms to form compounds
- Seek patterns and connections to describe, name, and write formulas for a variety of chemical compounds

ESSENTIAL QUESTION

How do the electron arrangements of atoms determine the chemical and physical properties of elements and compounds?

TOPIC 2.1:

How and why do we study matter?

Some things you will do:

- choose and use equipment safely and accurately
- contribute to care for self, others, community, and world

Some things you will come to know:

- You can describe and explain much about matter based on its properties and interactions.
- You must handle matter and equipment used to investigate it safely.

TOPIC 2.2:

How does the periodic table organize the elements?

Some things you will do:

- seek and analyze patterns, trends, and connections in data
- analyze cause-and-effect relationships

Some things you will come to know:

- The periodic table is an extremely powerful tool for organizing our knowledge about the matter of the universe.

TOPIC 2.3:

How can atomic theory explain patterns in the periodic table?

Some things you will do:

- identify questions of interest based on curiosity and learning
- construct, analyze, and interpret graphs, models, and/or diagrams
- draw conclusions that are consistent with evidence

Some things you will come to know:

- You can use simple diagrams to represent the structure of atoms.
- You can use the periodic table to predict relationships between atoms of different elements.

TOPIC 2.4:

How do elements combine to form compounds?

Some things you will do:

- use scientific concepts to draw conclusions
- use physical or mental models to describe phenomena

Some things you will come to know:

- Forming compounds is all about the stability of a full valence shell.
- Some compounds are made up of ions, while others are made up of molecules.

TOPIC 2.5:

How do we name and write formulas for compounds?

Some things you will do:

- work together to develop a game about naming and writing formulas for compounds
- analyze patterns, trends, and connections in data to help you name and write formulas for compounds

Some things you will come to know:

- You can name and write formulas for compounds if you know their structures or compostions.
- The periodic table can help you name and write formulas.

TOPIC 2.1

How and why do we study matter?

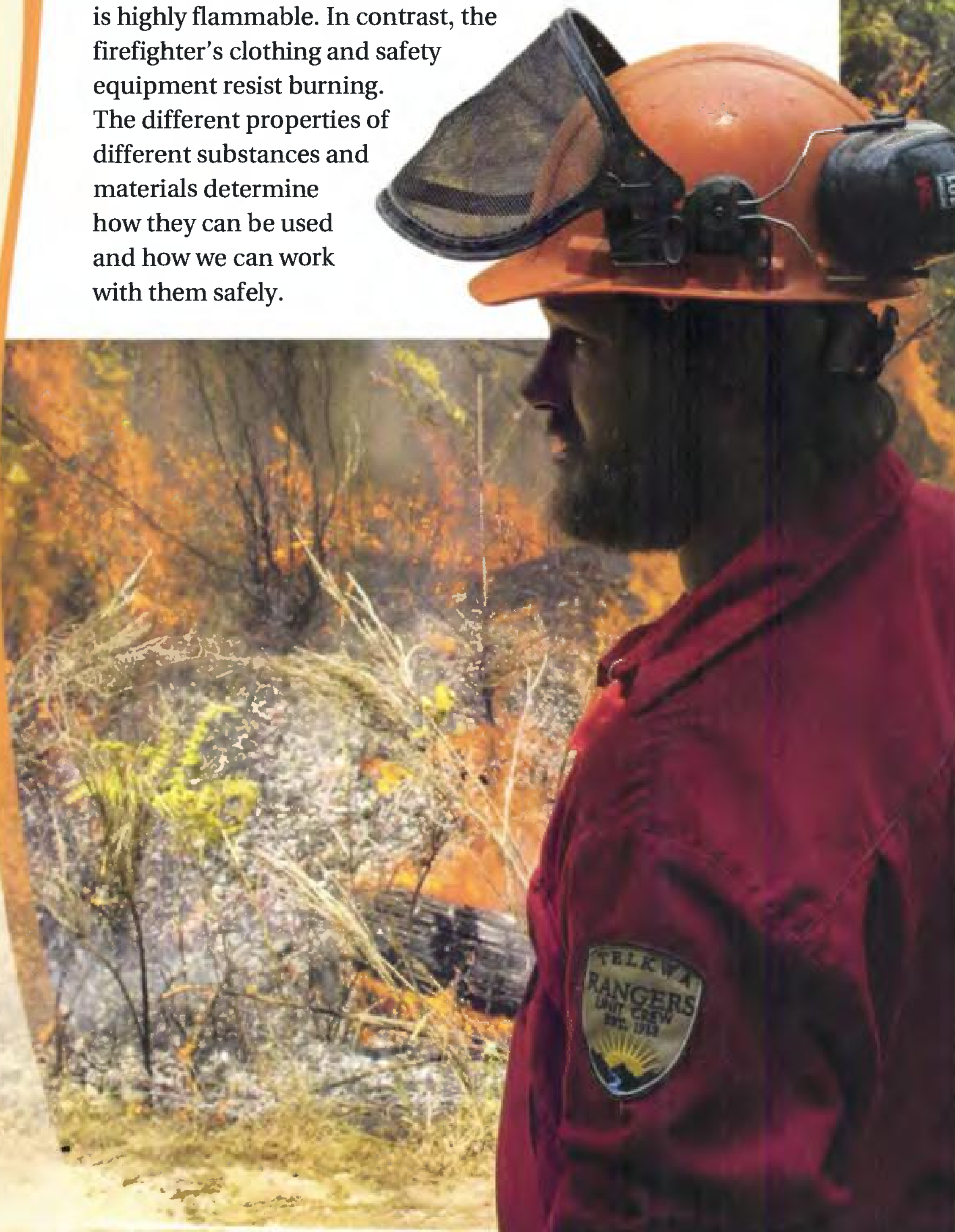
Key Concepts

- Matter and its interactions make up our world.
- Safety is key when working with matter.

Curricular Competencies

- Demonstrate a sustained intellectual curiosity about a scientific topic or problem of personal interest.
- Ensure that safety and ethical guidelines are followed in your investigations.
- Critically analyze the validity of information in secondary sources and evaluate the approaches used to solve problems.

According to the B.C. government, about 2000 wildfires occur in the province each year. One strategy to prevent wildfires or to fight existing ones is to carry out planned, or prescribed, burns. The firefighter shown here is working at a prescribed burn, which was started on purpose and is carefully kept within planned boundaries. The fuel used to start the fires is highly flammable. In contrast, the firefighter's clothing and safety equipment resist burning. The different properties of different substances and materials determine how they can be used and how we can work with them safely.



Starting Points

Choose one, some, or all of the following to start your exploration of this Topic.

1. **Identifying Preconceptions** What is matter? In your own words, define the term. Use your definition to explain whether each of these terms related to the introduction is an example of matter: wood, smoke, oxygen, fuel, plan, firefighter, fire, heat, gloves, crackling sound.
2. **Questioning and Predicting** Wildfires can occur naturally, but today most are started by human activities. It is not just the burning that causes harm but the smoke. What compounds are released into the air when wood burns? What are the chemical and physical properties of these compounds? How are they dangerous to human and animal life?
3. **Communicating** First Peoples in B.C. have used controlled burning techniques as part of their traditional practices. Invite an Elder or traditional knowledge keeper to share how and why controlled burns may be used and how they are done safely.

Key Terms

There are six key terms that are highlighted in bold type in this Topic:

- matter
- mixture
- compound
- pure substance
- element
- chemical reaction

Flip through the pages of this Topic to find these terms. Add them to your class Word Wall along with their meaning. Add other terms that you think are important and want to remember.

CONCEPT 1

Matter and its interactions make up our world.

Activity

Describe It, Separate It

Your teacher will provide your group with a mixture. You will have access to equipment such as magnets, filters, and sieves. Before starting, examine Figure 2.1 below.

1. Is your mixture heterogeneous or homogeneous (a solution)? How do you know?
2. Can you separate your mixture into parts? Try to do so.
3. Are the parts of your sample mixtures or pure substances? Explain.
4. What further tests would you like to conduct to gather more information about the components of your sample?

matter anything that has mass and takes up space

pure substance matter that has a definite composition and cannot be separated by physical means

mixture a blend of two or more pure substances in which each substance retains its individual properties; can be separated by physical means

You are surrounded by **matter**, and chemistry is the science of matter and its interactions. By studying chemistry, we can better understand the properties and behaviour of matter on Earth and beyond. Matter can be classified as either a **pure substance** or a **mixture**. Pure substances are made up of one type of particle. Mixtures are made up of two or more pure substances, and therefore two or more types of particles. Figure 2.1 summarizes the classification of matter.

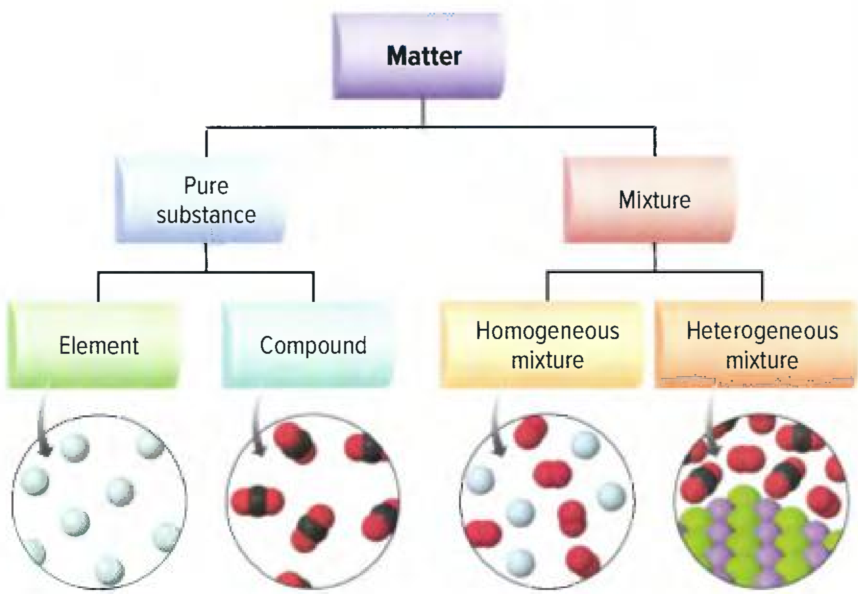


Figure 2.1 Matter is either a mixture or a pure substance. A mixture can be homogeneous or heterogeneous. A pure substance can be an element or a compound. **Give one example of each of these: a mixture, an element, and a compound.**

This train runs on diesel fuel. Diesel is a mixture of chemical compounds made of the elements hydrogen and carbon.

The metal used to make the bridge is steel. Steel is a very strong solid mixture—an alloy—composed of iron and small amounts of other elements, such as carbon.

The rock of the hillside is a mixture that includes quartz, which is a compound made of the elements silicon and oxygen.

This river water is a mixture made up of the compound water, a variety of compounds and elements dissolved in the water, and suspended bits of rock.

Figure 2.2 This pair of railway bridges, called the Cisco bridges, is found at Siska, B.C. **Make a table to list the mixtures, compounds, and elements mentioned. Add one example not mentioned.**

Mixtures, Compounds, and Elements

Most of the materials we interact with each day are mixtures. Figure 2.2 shows and describes some examples of solid, liquid, and gas mixtures. Some—such as air and steel—are homogeneous mixtures, or *solutions*. They are mixed uniformly throughout, and you cannot see their components, even with a microscope. Others, such as rock, have different parts that you can see. These are *heterogeneous mixtures*. But all are made up of two or more different pure substances.

Pure substances can be elements or compounds. **Elements** are made up of just one type of atom and cannot be broken down into simpler substances by chemical means. **Compounds** are made up of atoms of two or more elements.

element a pure substance that cannot be broken down into simpler substances by physical or chemical means

compound a pure substance made up of two or more elements; can be broken down into elements by chemical means

Properties of Matter

The steel of the railway tracks in Figure 2.2 is a strong, hard, shiny solid. Rock is also a hard solid, but it is brittle. Air is a clear, colourless gas. These descriptions all use *physical properties*. These are characteristics of matter that can be observed or measured without changing its chemical identity. In contrast, *chemical properties* describe the ability of matter to react with another substance to form one or more different substances. Table 2.1 gives further examples.

Table 2.1 Physical and Chemical Properties

Physical Properties		Chemical Properties
• colour	• state of matter	• combustibility
• malleability	• melting point	• reactivity with acids
• texture	• boiling point	• reactivity with oxygen
• viscosity	• hardness	• lack of reactivity
• ability to conduct heat and electricity	• solubility	

Chemical Reactions

chemical reaction a process in which the atoms of one or more pure substances are rearranged to form a different substance or substances.

An important part of studying matter is carrying out and observing chemical reactions. In a **chemical reaction**, one or more pure substances interact to form a different substance or substances. For example, elements can react to form compounds, compounds and elements can react to form different compounds, and compounds can break apart to form elements and simpler compounds.

A fire is a common example of a chemical reaction. In a forest fire, compounds in plants react with oxygen in the air to form many compounds, including carbon dioxide, carbon monoxide, and water, as well as the element carbon. You cannot see or smell carbon dioxide or carbon monoxide, but water is a visible part of smoke as it cools and forms droplets in the air. You can see the carbon as the black charcoal left behind by the fire. Energy is also released in the form of light and heat. Figure 2.3 shows other examples of chemical reactions.

Figure 2.3 A Explosive chemical reactions are used in mining to break apart rock and soil. B In a sparkler, metals react with air and release energy in the form of light and sound. C Exposing food to heat results in chemical reactions that change its taste and appearance. D The chemical reaction between substances in this tablet and water produces gas, which you can see as bubbles in the water.

Before you leave this page . . .

1. What is the difference between a pure substance and a mixture? Use diagrams in your answer.
2. List three physical properties of water at room temperature.
3. Give one example of an element and one example of a compound. Explain how they are different.
4. What happens in a chemical reaction?

CONCEPT 2

Safety is key when working with matter.

Activity

Be Prepared; Be Safe

Figure 2.4 shows two students carrying out Investigation 2A. How have they ensured that they are doing their investigation safely? First do the following:

- Read Safety in Your Science Classroom on page xiv–xvii.
- Review the safety guidelines in Figure 2.5 on the next page.
- Read Investigation 2A on pages 96–97.

Then answer these questions.

1. What is the meaning of each safety symbol in Investigation 2A?
2. Why should the test tube be angled away from you and your partner?
3. What would you do if some hydrochloric acid spilled on the lab bench?
4. Where are the fire extinguishers in your classroom and how are they used?

Making sure that you know how to handle materials safely in the laboratory is an essential part of studying chemistry. Figure 2.4 shows some of the blue safety icons that you will see attached to investigations in this unit. You will also see Workplace Hazardous Materials Information System (WHMIS 2015) symbols, which alert you to potential hazards when working with specific substances in the lab. As part of the WHMIS 2015 system, Safety Data Sheets (SDS) are available for each chemical you will handle.

Connect to Investigation 2A on pages 96–97

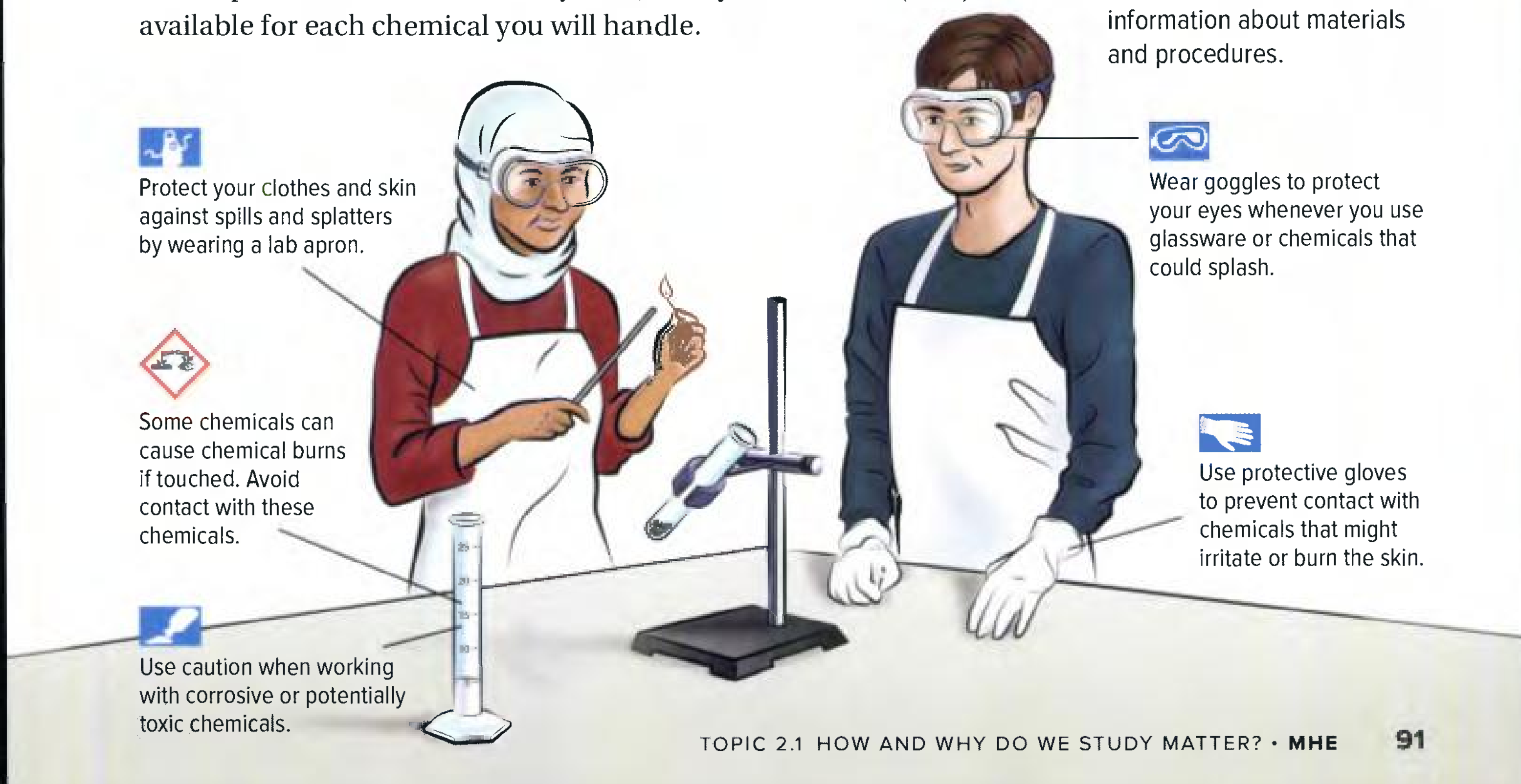


Figure 2.4 Safety icons (blue and white) and WHMIS symbols (black and red) communicate important information about materials and procedures.

Staying Safe in Your School Laboratory

1. Before you begin

- Inform your teacher if you have any allergies or medical conditions, or if there are other factors that could affect your work in the chemistry lab.
- Know the location of the nearest fire alarm, fire extinguisher, fire blanket, first-aid kit, safety shower (if there is one), and eye wash station. Know how to use them.
- Study your activity, investigation, or other lab assignment carefully before you start. Ask for help if you have questions.
- Be sure you understand the safety icons.

2. Dressing the part

- Wear protective clothing as appropriate and as directed, such as a lab apron, gloves, and safety glasses.
- Tie back long hair, and secure or remove scarves, caps, ties, or long necklaces.
- Wear footwear that covers your entire foot, including toes.

3. Acting responsibly

- Never chew gum, eat, or drink in the lab.
- Work carefully with your partner or group and make sure you keep your work area clear.
- Stay focused on what you are doing. Acting irresponsibly is dangerous in the lab.

Staying Safe; Being Aware

Before you start any activity or investigation in the lab, read the procedure carefully. Be sure you understand what is involved in each step, including safety precautions. Be aware of what you are doing and what others are doing at all times. Know where safety equipment such as fire extinguishers and eyewash stations are, and how to use them. By following safety guidelines such as the ones listed in Figure 2.5, and by staying alert, you and your classmates create an environment in which you can confidently explore the properties and interactions of matter.

4. Using equipment

- When carrying equipment for an activity or investigation, hold it carefully. Carry only one object at a time.
- When working with electrical equipment, make sure your hands are dry, especially when touching electrical cords, plugs, or sockets. Pull the plug, not the cord.
- Report damaged equipment to your teacher immediately.
- Place electrical cords where people will not trip over them.

5. Working with heat

- If you use a laboratory burner, be sure you understand how to light and use it safely.
- Point the open end of a container being heated away from yourself and others.
- Do not allow a container to boil dry.
- Handle hot objects carefully. Remember that glassware and equipment looks the same hot as it does cold.
- Inform your teacher if you receive a burn. Apply cold water to the burned area immediately.

6. Working with chemicals

- Read and understand all safety labels, including WHMIS symbols.
- Never taste any substances you use in the lab.
- If any part of your body contacts a substance in the lab, inform your teacher. Immediately wash the area thoroughly with cold water. If you get anything in your eyes, wash them immediately and continuously for 15 minutes.
- Handle substances carefully. If you are asked to smell a substance, never smell it directly. Hold the container slightly in front of and beneath your nose, and waft the fumes toward your nostrils.

7. Cleaning up

- Clean up any spills according to your teacher's instruction.
- Clean equipment and glassware before you put it away.
- Dispose of all materials as directed by your teacher. Never discard materials in the sink or garbage unless your teacher directs you to.
- Wash your hands thoroughly after doing an activity or investigation.

Figure 2.5 These are just some of the safety rules to follow in your school laboratory.

Connect to Investigation 2B on pages 98–99

Before you leave this page . . .

1. What is an SDS?
2. List three things you should do before beginning any investigation in the lab.
3. What are the locations of the eyewash stations and fire extinguisher in your classroom?

AT ISSUE Should we use flame-retardant substances?

What's the Issue?

In Canada, many, many household products—from upholstered furniture, electronics, and children's toys to kettles, chairs, and carpet backing—and even our cars contain polybrominated diphenyl ethers (PBDEs). The purpose of these chemicals is to slow or stop fires, and so protect the consumer.

But are we really protected by these chemicals, or do they pose a health risk to us? The David Suzuki Foundation warns that exposure to these chemicals can damage our immune systems, reproductive systems, neurological systems, and more. It's a bit ironic: the very chemicals that are included in products in order to keep us safe from the effects of fire actually expose us to harm when they burn. And scientists are concerned that we're exposed to them at other times too. For example, they are released into the air while they are being manufactured. And when products containing them disintegrate, the toxic chemicals accumulate in household dust. Recently, the Canadian government agreed that PBDEs do pose a risk to people and the environment. It has put in place regulations to prevent their manufacture in Canada and to restrict their use.

Dig Deeper

Collaborate with your classmates to explore one or more of these questions—or generate your own questions to explore.

1. Canada has recently restricted the use of PBDEs in new Canadian-made products, but there are still many existing products in Canadian households, including carpets and toys, which contain these PBDEs. Do you think these might pose an ongoing health risk to the public? If so, which part of the population might be most at risk? Explain your answer. Research to find suggestions about what families can do to minimize their exposure.
2. The flammability of children's sleepware has been regulated in Canada since 1971. How have the regulations changed since then? Are the regulations successful in protecting children?
3. What materials might First Peoples have used that have flame-retarding properties? A local Elder or Knowledge Keeper could assist with answers to this question.

Check Your Understanding of **Topic 2.1**

QP Questioning and Predicting PC Planning and Conducting PA Processing and Analyzing E Evaluating
AI Applying and Innovating C Communicating

Understanding Key Ideas

1. State whether each of the following is an example of matter. Explain your answer in each case. PA C

a) a brick
b) sunlight
c) the sound of a train
d) air
e) the colour red
f) a text message

2. Classify each of the following as an element, a compound, or a mixture. PA C

a) ocean water
b) gold
c) carbon dioxide
d) a pencil

3. List at least two physical properties of each of the following pure substances. PA C

a) oxygen
b) copper
c) carbon (diamond)
d) carbon (coal)

4. When you cook food, its appearance and taste changes. Why does this indicate a chemical reaction is occurring? PA E C

5. What is each of these safety icons telling you? PA C

a)  Eye Safety

b)  Fire Safety

c)  Chemical Safety

d)  Disposal Alert

Connecting Ideas

6. Which WHMIS 2015 symbols would you expect to see on a cylinder of oxygen like the one shown here? Explain your answer. (Refer to Safety in Your Science Classroom on pages xiv–xvii.) AI

7. You are about to carry out an investigation involving a laboratory burner. AI

a) Which safety icons would you expect to see in the instructions?
b) What precautions would you take?

Making New Connections

8. Physical and chemical properties define both the uses and hazards associated with materials. PA E AI

a) What does the chemical property of combustibility refer to?
b) List three combustible materials.
c) List three materials that are not combustible.
c) List one application in which a combustible material is needed.
d) List one application in which a material that is not combustible is needed.

9. Early chemists would taste the substances they were working with as a way to identify and describe them. PA E AI C

a) Would you characterize taste as a physical or chemical property? Explain.
b) Why is it essential not to eat or drink anything, even chewing gum, when working in the laboratory?

INVESTIGATION

2-A

STRUCTURED INQUIRY

Safely Observing a Chemical Reaction

An important part of investigating matter involves observing what happens when different substances interact. In order to perform lab activities safely, including those that involve potential hazards such as splint tests and acids, it is essential to read and understand the procedure and safety precautions before you start.

One technique for identifying substances is to observe the effect on the substance of a flame or glowing ember. For example, when a flame is brought close to a source of hydrogen, the flame will ignite the hydrogen and produce a loud "pop" sound.

Question

How can a burning splint test be carried out safely to help you identify the element produced when zinc and hydrochloric acid are mixed?

Procedure

1. Work in pairs. Place 2.5 g of mossy zinc in a large test tube.
2. Place the test tube in a clamp and attach the clamp to a ring stand so that the mouth of the test tube is angled up and away from you. Attach the clamp about halfway down the tube.
3. Measure 5 mL of 1 mol/L hydrochloric acid in a graduated cylinder. CAUTION: 1 mol/L hydrochloric acid could cause burns and produce hazardous fumes.
4. Light a wooden splint with a match. Dispose of the match as directed by your teacher. CAUTION: If you are using gloves, do not wear them for this step.
5. Place the burning splint at the mouth of the test tube, then move the burning splint to the mouth of the graduated cylinder. Record your observations.

Skills and Strategies

- Processing and Analyzing
- Evaluating
- Communicating

Safety

- 1 mol/L hydrochloric acid can cause burns. Inform your teacher immediately of any spills. If any hydrochloric acid contacts your skin, flush the area with cold water for 15 minutes.

What You Need

- 2 5 g mossy zinc
- large test tube
- 50 mL beaker
- test tube clamp
- 5 mL 1 mol/L hydrochloric acid
- graduated cylinder
- 2 wooden splints
- matches
- ring stand

6. Extinguish the flame and dispose of the splint as directed by your teacher.
7. Carefully pour the hydrochloric acid into the test tube.
8. Wait 2 minutes. Then invert the small beaker over the top of the test tube.
9. Wait 90 seconds. Then repeat step 4.
10. Remove the beaker from the test tube. Then place the burning splint at the mouth of the test tube. Record your observations.

Evaluate and Communicate

1. Describe any changes you observed during the test.
2. What caused the bubbles to form when you added the hydrochloric acid to the zinc metal?
3. Why did you test the zinc metal and hydrochloric acid with the burning splint before mixing them?
4. What happened to the burning splint in step 10? Compare this to what happened in step 5. How do you explain the differences in what you observed?

INVESTIGATION
2-B

STRUCTURED INQUIRY

Skills and Strategies

- Processing and Analyzing
- Evaluating
- Communicating

What You Need

- Safety in Your Science Classroom on pages xiv–xvii
- Internet access
- several copies of an SDS

Explore Safety Data Sheets

Under the WHMIS 2015 system, each chemical has a Safety Data Sheet (SDS). The SDS lists information about the properties of the chemical, as well as instructions about how to handle and store it safely. For example, your teacher may use a concentrated hydrochloric acid, such as 37% hydrochloric acid, to make the solutions you use in class. Because it is reactive and corrosive, this acid has many safety precautions associated with its use. A portion of an SDS for concentrated hydrochloric acid is shown below.

A1 Chemical Company

A1 Chemical Company
Safety Data Sheet (SDS)
Version 5.4
Revision Date 05/17/2016
Print Date 07/20/2016

1. PRODUCT AND COMPANY IDENTIFICATION

Product name:	Hydrochloric acid 37%
Brand:	A1
Product use:	For research purposes
Supplier:	A1 Chemical Company
Manufacturer:	Acme Chemical Manufacturer
Telephone:	(555) 555-5555

2. HAZARDS IDENTIFICATION

Emergency Overview

WHMIS Classification
E   Corrosive Material   Corrosive

GHS Classification
Corrosive to metals (Category 1)
Skin corrosion (Category 1B)
Serious eye damage (Category 1)
Specific target organ toxicity – single exposure (Category 3), Respiratory system

GHS Label elements, including precautionary statements

Pictogram: 

Signal word: Danger

Question

What is an SDS and how is it meant to be interpreted and used?

Procedure

1. Work in small groups. Each group will be given several copies of the SDS of a particular hazardous material. (If possible, your teacher will also provide a sample of the material for your reference.)
2. Read the procedure and divide up tasks among group members.
3. Research and answer the following questions about SDSs in general.
    - What are the purposes of an SDS?
    - What types of materials are required to have an SDS?
    - How is the information on an SDS categorized?
4. Research and answer the following questions about your SDS.
    - What is the name of your material?
    - Where and how is the material used?
    - What are the chemical and physical properties of your material?
    - What first-aid measures are recommended if one of the following occurs:
        - inhalation
        - skin contact
        - eye contact
        - ingestion
    - What precautions are listed for safe handling and storage?
5. Each member of the group must come up with at least one additional question about your assigned material or about SDSs in general that arose from the research. Do additional research to answer your questions.

Process and Analyze

1. Within your group, share the results of your research. How do the chemical and physical properties of your material affect the safety measures listed on the SDS?
2. Which sections on the SDS are most relevant to you as a student in a high school science classroom?

Communicate

3. Give each member of your group a number. For a group of five, for example, give each person a unique number from one to five. Have all the like numbers in the classroom gather in groups. Be sure there is one person from each of the original groups in each new group.
4. In the new groups, take turns sharing what you learned about your assigned material and its SDS.
5. From a First Peoples perspective, safe interactions with the natural world may be seen as part of our reciprocal relationships with the universe. How does understanding and following safety procedures show respect for the interconnectedness of life?

TOPIC 2.2

How does the periodic table organize the elements?

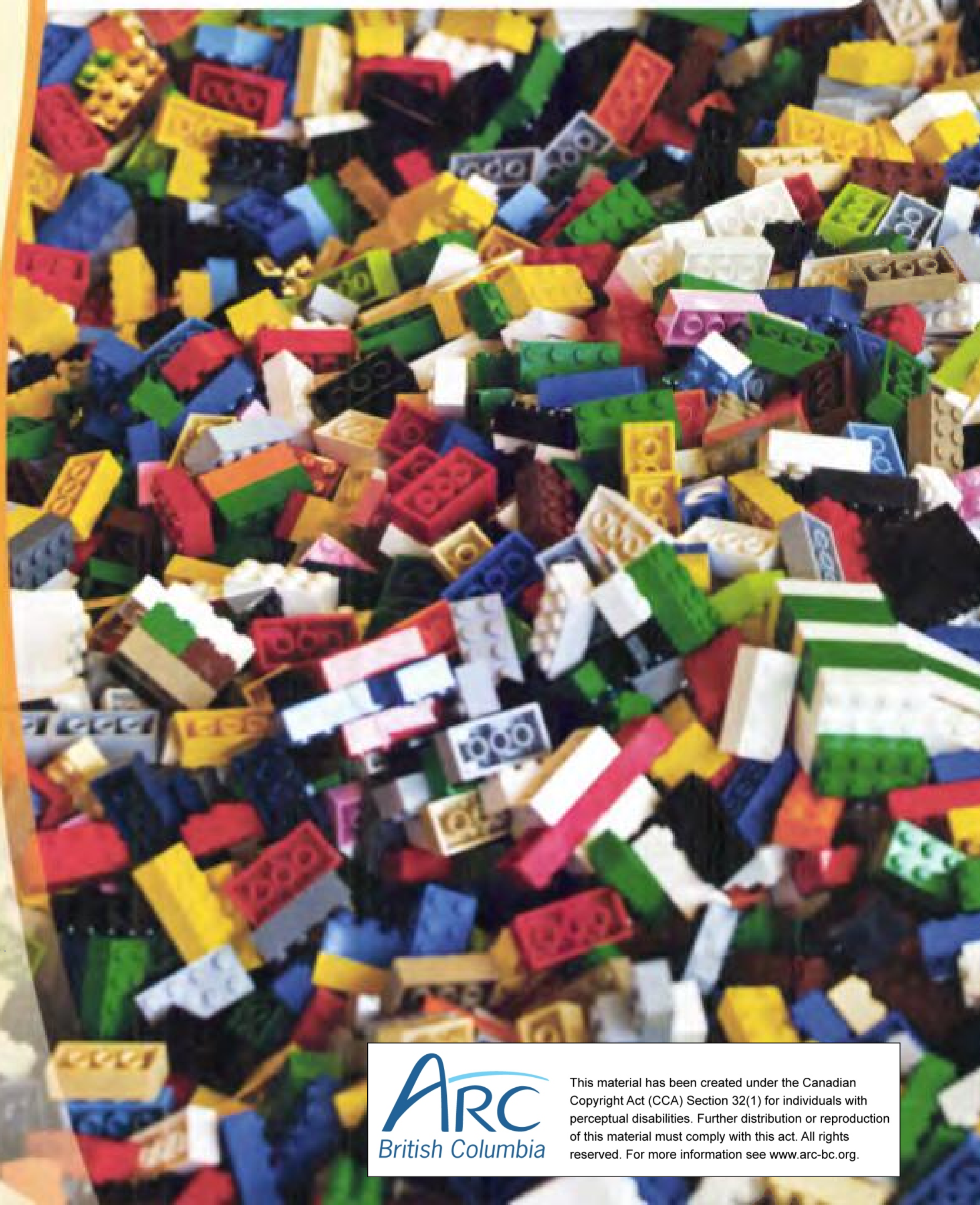
Key Concepts

- Elements are the building blocks of matter.
- Elements can be organized by their properties.
- The modern periodic table organizes elements in groups and periods.
- Elements are classified as metals, non-metals, or semi-metals.

Curricular Competencies

- Make observations aimed at identifying your own questions, including increasingly complex ones, about the natural world.
- Collaboratively and individually plan, select, and use appropriate investigation methods to collect reliable data.
- Consider the role of scientists in innovation.

Suppose you were given the task of organizing this pile of Lego bricks into various containers. How would you go about it? Would you organize by colour? Shape? Size? How would you arrange your containers once you were finished sorting? Scientists in the mid-1800s faced an organizing challenge as they tried to come up with a principle for arranging the elements based on their known properties.



Starting Points

Choose one, some, or all of the following to start your exploration of this Topic.

1. **Identifying Preconceptions** How many elements can you name? List as many as you can think of. Then list as many physical and chemical properties associated with each element as you can. As a class, share your lists. In what ways could your list be organized?
2. **Evaluating** How many different types of Lego bricks can you see in the photo on this page? What different characteristics define them? When scientists first started trying to come up with a system for organizing the elements, they knew of about 60 elements and their properties. How is organizing a set of Lego by their characteristics similar to organizing elements by their properties? How is it different?
3. **Applying First Peoples Perspectives** The world view of many First Peoples recognizes four elements in nature: earth, air, fire, and water. How do these differ from the elements of Western science? How might Western scientists view the world differently using these elements? How might First Peoples scientists view the world differently using the elements of Western science?

Key Terms

There are five key terms that are highlighted in bold type in this Topic:

- group
- period
- metal
- non-metal
- semi-metal

Flip through the pages of this Topic to find these terms. Add them to your class Word Wall along with their meaning. Add other terms that you think are important and want to remember.

CONCEPT 1

Elements are the building blocks of matter.

Activity

Elements on Brick World

What if you lived in an alternate reality in which the building blocks of matter are Lego bricks, not atoms? Work in groups. Your teacher will give you a set of bricks. Use your set to do the following:

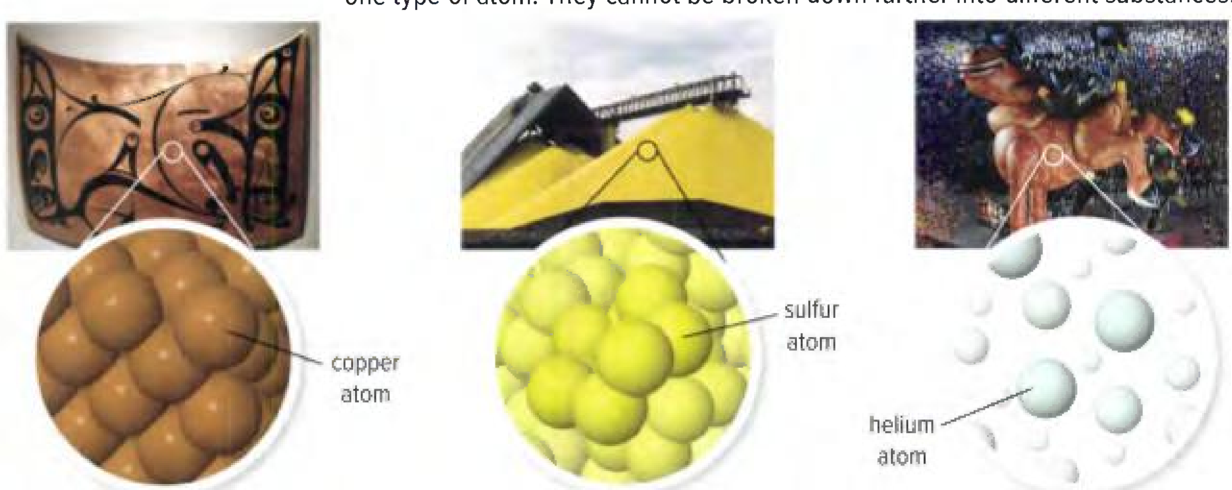
- Make sketches of each "element" and give them names.
- Make models of two different "compounds" using your brick elements.
- Make a model of a mixture that contains two or more brick compounds.

When you are finished, do a gallery walk to see the work of your classmates. What do you notice about the variety of brick elements, compounds, and mixtures?

Connect to Investigation 2C on page 118

Matter can take many different forms, but all forms of matter can be broken down into a fairly small number of basic building blocks—the elements. On Earth, about 90 elements occur naturally. Carbon, silver, and oxygen are examples of naturally occurring elements. There are also a number of elements that do not exist naturally but have been synthesized in laboratories. Three examples of elements with very different properties are shown in Figure 2.6.

Figure 2.6 Like all elements, copper, sulfur, and helium are each made up of one type of atom. They cannot be broken down further into different substances.



Copper (Cu) is shiny and malleable. This means it can be hammered into thin sheets such as the copper leaf used on this car hood by B.C. artist Michael Nicoll Yahgulanaas. This piece is part of a series called *Coppers from the Hood*.

Sulfur (S) is a powdery, bright yellow solid. The piles shown here in Vancouver harbour are awaiting export overseas. Sulfur is used mainly to make sulfuric acid. Sulfuric acid is used to make many industrial products such as fertilizers, detergents, batteries, and medicines.

This giant floating moose was used in the closing ceremonies of the Vancouver 2010 Winter Olympics. To make it float, it was filled with helium (He), which is a colourless, odourless gas that is less dense than air.

Element Names and Symbols

Each element has a unique chemical name and symbol. The chemical symbol is one or two letters. (Synthetic elements that have not yet been named are given placeholder names and three-letter symbols.) The first letter is always capitalized, and the remaining letter or letters, if any, are always lowercase. The names and symbols of the elements are accepted and used by all scientists worldwide in order to standardize the communication of chemical information. Many element names come from an ancient language called Latin. Others are named for countries or continents (polonium, americium) or to honour scientists of note (bohrium, rutherfordium). The symbols and names of some elements are shown in Table 2.2.

Table 2.2 Symbols and Names of Selected Elements

Name of Element	Element Symbol	Origin of Symbol or Name
carbon	C	*Carbo* = Latin for coal and charcoal. Carbon in the form of soot and charcoal has been known to humans for many thousands of years. 
copper	Cu	*Cuprum* = Latin for cyprium, meaning metal of Cyprus, an island country near Greece. The ancient Romans obtained much of their copper from mines on Cyprus. 
francium	Fr	*France* = Marguerite Perey discovered this element in France in 1939. 
lead	Pb	*Plumbum* = Latin for lead. This element's name has the same root as "plumbing" because the ancient Romans used lead in their plumbing systems. Unfortunately, lead is toxic and their pipes poisoned their water. 
sulfur	S	*Sulphuium* = Latin for sulfur. In Canada, the United States, and Great Britain, there has been some switching back and forth of the name of this element from sulfur to sulphur. The spelling "sulfur" is now considered standard. 

Before you leave this page . . .

1. How many elements occur naturally on Earth?

2. What distinguishes one element from another?

CONCEPT 2

Elements can be organized by their properties.

Activity

Element Cards

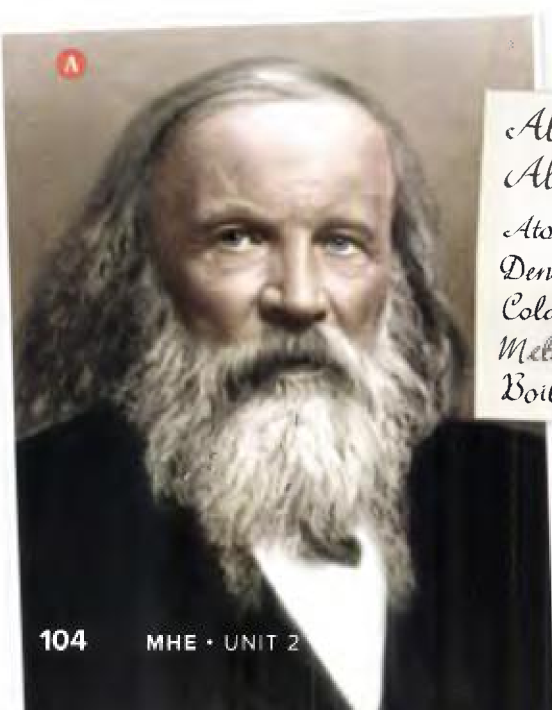
Work in groups. Your teacher will give your group a set of cards. On each card is an element and information about its properties. Your challenge is to arrange the cards in rows and columns in a way that makes sense to you and your team members. When you are finished, explain your reasoning to the rest of the class.

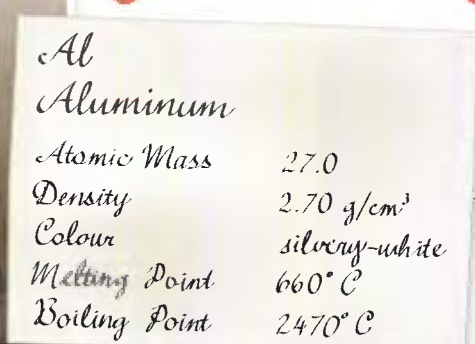
In the mid-1800s, scientists had identified nearly 60 elements, and nobody knew how many more there might be. Scientists needed a classification system that would organize their observations. They were already grouping elements into "families" based on similar properties, but many family relationships were not obvious. What else could a classification system be based on?

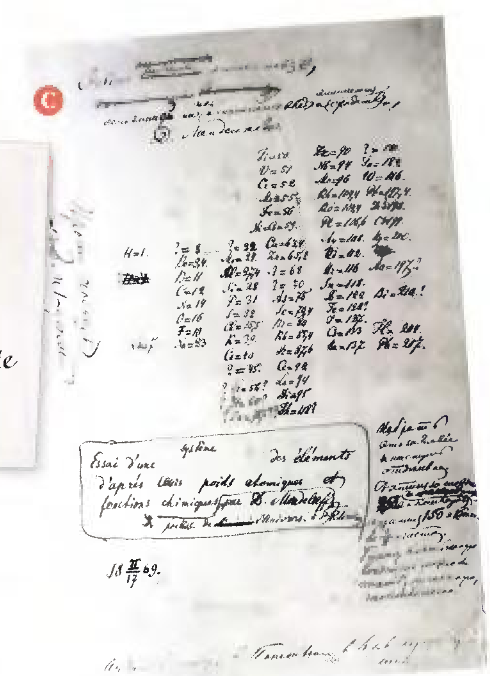
By the 1860s, some scientists were trying to sort the known elements according to atomic mass. *Atomic mass* is the average mass of an atom of an element. Among them was a Russian chemist named Dmitri Mendeleev (1834–1907).

To help him experiment with different ways to organize the elements, Mendeleev made a card for each one. On each of these cards, he put data similar to the data you see in Figure 2.7. He shuffled and reordered the cards, playing a game of "chemical solitaire" to try to make sense of the repeating patterns of properties.

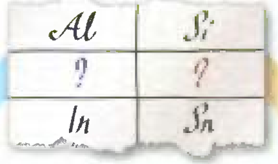
Figure 2.7 A Dmitri Mendeleev was a Russian teacher and chemist. He was the youngest of 17 children. B Mendeleev wrote the properties of elements on cards like this one so he could rearrange them and compare properties. C These are some of his original notes.

A


B


C


Mendeleev's Table



Properties of Gallium

Property	Mendeleev's Prediction	Actual Data
Atomic mass	68	69.72
Density (g/cm^3)	6.0	5.904
Melting point (°C)	low	29.78

Properties of Germanium

Property	Mendeleev's Prediction	Actual Data
Atomic mass	72	72.61
Density (g/cm^3)	5.5	5.32
Melting point (°C)	high	947

Figure 2.8 The gaps in Mendeleev's table predicted the existence of yet-to-be-discovered elements. Mendeleev used the properties of other elements in the same families to predict the properties of these elements.

The Predictive Power of Mendeleev's Table

After several months of "chemical solitaire," Mendeleev arrived at an arrangement that organized the elements according to their properties. Like other scientists before him, Mendeleev knew that the properties of elements tended to repeat over regular intervals. Like other scientists, he was ordering the elements by increasing atomic mass. However, Mendeleev realized that he needed to leave gaps in his arrangement—blank spaces predicting the existence of elements not yet found or even suspected by other chemists.

Using these gaps, he was able to accurately predict properties of elements that were not yet known but would be discovered later, including scandium, gallium, and germanium. How did Mendeleev's table make it possible for him to predict the properties of undiscovered elements? Mendeleev noted which families had spaces. He inferred that the missing elements would have properties similar to those of other members of their family. Gallium and germanium, shown in Figure 2.8, are famous for having been discovered after Mendeleev predicted their existence and physical properties.

Extending the Connections

Other Contributors to the Periodic Table

Research to find out how other scientists contributed to the development of the periodic table. Choose one of the following scientists: John Dalton, Alexandre Béguyer de Chancourtois, John Newlands, Julius Lothar Meyer, or Henry Moseley.

Before you leave this page . . .

1. Why did Mendeleev leave gaps in his periodic table?
2. How was Mendeleev able to predict the properties of gallium and germanium?

Figure 2.9 The modern periodic table enables the presentation of a wealth of information about each element on a single page.

Periodic Table of the Elements

Key: Atomic Number, Symbol, Name, Atomic Mass — e.g. 22 Ti Titanium 47.9, Ion charge(s) 4+ 3+

metal | semi-metal | non-metal

O natural | Db synthetic

Period	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	1 H Hydrogen 1.0 (1+)																	2 He Helium 4.0 (0)
2	3 Li Lithium 6.9 (1+)	4 Be Beryllium 9.0 (2+)											5 B Boron 10.8	6 C Carbon 12.0	7 N Nitrogen 14.0 (3–)	8 O Oxygen 16.0 (2–)	9 F Fluorine 19.0 (1–)	10 Ne Neon 20.2 (0)
3	11 Na Sodium 23.0 (1+)	12 Mg Magnesium 24.3 (2+)											13 Al Aluminum 27.0 (3+)	14 Si Silicon 28.1	15 P Phosphorus 31.0 (3–)	16 S Sulfur 32.1 (2–)	17 Cl Chlorine 35.5 (1–)	18 Ar Argon 39.9 (0)
4	19 K Potassium 39.1 (1+)	20 Ca Calcium 40.1 (2+)	21 Sc Scandium 45.0 (3+)	22 Ti Titanium 47.9 (4+, 3+)	23 V Vanadium 50.9 (5+, 4+)	24 Cr Chromium 52.0 (3+, 2+)	25 Mn Manganese 54.9 (2+, 3+, 4+)	26 Fe Iron 55.8 (3+, 2+)	27 Co Cobalt 58.9 (2+, 3+)	28 Ni Nickel 58.7 (2+, 3+)	29 Cu Copper 63.5 (2+, 1+)	30 Zn Zinc 65.4 (2+)	31 Ga Gallium 69.7 (3+)	32 Ge Germanium 72.6 (4+)	33 As Arsenic 74.9 (3–)	34 Se Selenium 79.0 (2–)	35 Br Bromine 79.9 (1–)	36 Kr Krypton 83.8 (0)
5	37 Rb Rubidium 85.5 (1+)	38 Sr Strontium 87.6 (2+)	39 Y Yttrium 88.9 (3+)	40 Zr Zirconium 91.2 (4+)	41 Nb Niobium 92.9 (3+, 5+)	42 Mo Molybdenum 95.9 (2+, 3+)	43 Tc Technetium (98) (7+)	44 Ru Ruthenium 101.1 (3+, 4+)	45 Rh Rhodium 102.9 (3+, 4+)	46 Pd Palladium 106.4 (2+, 4+)	47 Ag Silver 107.9 (1+)	48 Cd Cadmium 112.4 (2+)	49 In Indium 114.8 (3+)	50 Sn Tin 118.7 (4+, 2+)	51 Sb Antimony 121.8 (3+, 5+)	52 Te Tellurium 127.6 (2–)	53 I Iodine 126.9 (1–)	54 Xe Xenon 131.3 (0)
6	55 Cs Cesium 132.9 (1+)	56 Ba Barium 137.3 (2+)	57 La Lanthanum 138.9 (3+)	72 Hf Hafnium 178.5 (4+)	73 Ta Tantalum 180.9 (5+)	74 W Tungsten 183.8 (6+)	75 Re Rhenium 186.2 (4+, 7+)	76 Os Osmium 190.2 (3+, 4+)	77 Ir Iridium 192.2 (3+, 4+)	78 Pt Platinum 195.1 (4+, 2+)	79 Au Gold 197.0 (3+, 1+)	80 Hg Mercury 200.6 (2+, 1+)	81 Tl Thallium 204.4 (1+, 3+)	82 Pb Lead 207.2 (2+, 4+)	83 Bi Bismuth 209.0 (3+, 5+)	84 Po Polonium (209) (2+, 4+)	85 At Astatine (210) (1–)	86 Rn Radon (222) (0)
7	87 Fr Francium (223) (1+)	88 Ra Radium (226) (2+)	89 Ac Actinium (227) (3+)	104 Rf Rutherfordium (265)	105 Db Dubnium (268)	106 Sg Seaborgium (269)	107 Bh Bohrium (270)	108 Hs Hassium (269)	109 Mt Meitnerium (278)	110 Ds Darmstadtium (281)	111 Rg Roentgenium (280)	112 Cn Copernicium (285)	113 Nh Nihonium (286)	114 Fl Flerovium (289)	115 Mc Moscovium (289)	116 Lv Livermorium (293)	117 Ts Tennessine (294)	118 Og Oganesson (294)

58 Ce Cerium 140.1 (3+, 4+)	59 Pr Praseodymium 140.9 (3+, 4+)	60 Nd Neodymium 144.2 (3+)	61 Pm Promethium (145) (3+)	62 Sm Samarium 150.4 (3+, 4+)	63 Eu Europium 152.0 (3+, 2+)	64 Gd Gadolinium 157.3 (3+)	65 Tb Terbium 158.9 (3+, 4+)	66 Dy Dysprosium 162.5 (3+)	67 Ho Holmium 164.9 (3+)	68 Er Erbium 167.3 (3+)	69 Tm Thulium 168.9 (3+, 2+)	70 Yb Ytterbium 173.0 (3+, 2+)	71 Lu Lutetium 175.0 (3+)
90 Th Thorium 232.0 (4+)	91 Pa Protactinium 231.0 (5+, 4+)	92 U Uranium 238.0 (6+, 4+, 5+)	93 Np Neptunium (237) (5+, 3+, 4+, 6+)	94 Pu Plutonium (244) (4+, 6+, 3+, 5+)	95 Am Americium (243) (3+, 4+, 5+, 6+)	96 Cm Curium (247) (3+)	97 Bk Berkelium (247) (3+, 4+)	98 Cf Californium (251) (3+)	99 Es Einsteinium (252) (3+)	100 Fm Fermium (257) (3+)	101 Md Mendelevium (258) (2+, 3+)	102 No Nobelium (259) (2+, 3+)	103 Lr Lawrencium (262) (3+)

Based on mass of C-12 at 12.00.

Any value in parentheses is the mass of the most stable or best known isotope for elements that do not occur naturally.

CONCEPT 3

The modern periodic table organizes elements in groups and periods.

Activity

Observing the Elements

Turn the page and take a look at the pictorial periodic table shown in Figure 2.11. What patterns do you see among elements of the same group (vertical column) and in the same period (horizontal row)?

Today's periodic table, shown in Figure 2.9 on the left, is strikingly similar to Mendeleev's. The principle behind the order of the elements, though, is different. For the most part, Mendeleev ordered the elements in his table based on increasing atomic mass. But this principle did not work perfectly: he had to place a few elements out of order so that they would appear in the group they seemed to belong to, based on their properties. Later, a scientist called Henry Moseley developed a way to determine the number of positive charges in an atom, which told him the number of protons in the atom. This number is now known as an element's *atomic number*. When arranged according to increasing atomic number, the elements all fit perfectly in the table, with no reordering needed.

Connect to Investigation 2D on page 120

Meet the Modern Periodic Table

The modern periodic table consists of boxes arranged in vertical columns and horizontal rows by increasing atomic number. The box for oxygen is shown in Figure 2.10. Mendeleev called the vertical columns of the periodic table families. Today they are often called **groups** and are numbered 1 through 18. The horizontal rows of the table are called **periods**. Beginning with hydrogen in the first period, there are a total of 7 periods.

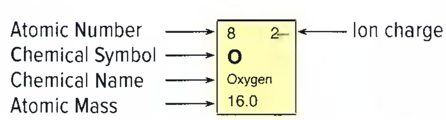


Figure 2.10 A typical box from the periodic table tells you the element's name, symbol, atomic number, and atomic mass. The symbol's font tells you the element's state.

group a vertical column of elements in the periodic table; also called a *family*

period a horizontal row of elements in the periodic table

Before you leave this page . . .

1. What was Moseley's contribution to the periodic table and what problem did it resolve?

2. Give the symbol and atomic number of each of the following elements:
   a) manganese
   b) magnesium
   c) arsenic
   d) astatine

Figure 2.11 This version of the periodic table includes photos of many of the elements
What property do most of the elements have in common?


He 2 Helium
B 5 Boron
C 6 Carbon
N 7 Nitrogen
O 8 Oxygen
F 9 Fluorine
Ne 10 Neon
Al 13 Aluminium
Si 14 Silicon
P 15 Phosphorus
S 16 Sulfur
Cl 17 Chlorine
Ar 18 Argon
Ni 28 Nickel
Cu 29 Copper
Zn 30 Zinc
Ga 31 Gallium
Ge 32 Germanium
As 33 Arsenic
Se 34 Selenium
Br 35 Bromine
Kr 36 Krypton
Pd 46 Palladium
Ag 47 Silver
Cd 48 Cadmium
In 49 Indium
Sn 50 Tin
Sb 51 Antimony
Te 52 Tellurium
I 53 Iodine
Xe 54 Xenon
Pt 78 Platinum
Au 79 Gold
Hg 80 Mercury
Tl 81 Thallium
Pb 82 Lead
Bi 83 Bismuth
Po 84 Polonium
At 85 Astatine
Rn 86 Radon
Ds 110 Darmstadtium
Rg 111 Roentgenium
Cp 112 Copernicium
Nh 113 Nihonium
Fl 114 Flerovium
Mc 115 Muscovium
Lv 116 Livermorium
Ts 117 Tennessine
Og 118 Oganesson
Eu 63 Europium
Gd 64 Gadolinium
Tb 65 Terbium
Dy 66 Dysprosium
Ho 67 Holmium
Er 68 Erbium
Tm 69 Thulium
Yb 70 Ytterbium
Lu 71 Lutetium
Am 95 Americium
Cm 96 Curium
Bk 97 Berkelium
Cf 98 Californium
Es 99 Einsteinium
Fm 100 Fermium
Md 101 Mendelevium
No 102 Nobelium
Lr 103 Lawrencium

CONCEPT 4

Elements are classified as metals, non-metals, or semi-metals.

Activity

Comparing Conductivity

One property that is used to describe and classify matter is electrical conductivity. Materials that are electrical conductors allow electric current to move through them. Your teacher will give you an electrical conductivity meter and items to test. Make a table like the one below, and predict whether each item will conduct electric current. Then test your prediction. What do you notice about the materials that conduct electric current?

Item	Prediction	Is it a conductor?

The boxes on the periodic table in Figure 2.9 are shaded to show the three broad categories of elements: metals (blue), non-metals (yellow), and semi-metals (green). These classifications are based on similarities in physical and chemical properties within each category. The elements of Groups 1, 2, and 13 to 18 are called *main-group elements* or *representative elements*. The elements in Groups 3 to 12 are called *transition elements*.

Metals

metal typically, an element that is hard, shiny, malleable, ductile, and that conducts electricity and heat; found to the left of the zigzag line on the periodic table

Most of the elements are metals. The **metals** are found on the left side of the zigzag line on the periodic table and are shaded in blue. Except for mercury, metals are solid at room temperature. They are shiny when smooth and clean, and most are silver or grey in colour. They are good conductors of thermal energy and electric current. They are also malleable and ductile, which means they can be beaten into sheets or drawn out into wires.

The two rows of metals shown at the bottom of the periodic table are called the *inner transition metals*. They are normally shown below the table to keep it compact. Figure 2.12 shows two important groups of metals: the *alkali metals*, found in Group 1, and *alkaline-earth metals*, found in Group 2. Notice that although hydrogen is shown as part of Group 1, it is not an alkali metal. Figure 2.13 explains why.

Activity

Predict Properties

Francium is a rare, unstable alkali metal. It was discovered in 1939, but its existence was predicted by Mendeleev in the 1870s. Use data about the properties of other alkali metals to predict some of francium's properties.

Alkali Metals Data

Element	Melting Point (°C)	Boiling Point (°C)	Atomic radius (pm)
lithium	180.5	1342	152
sodium	97.8	883	186
potassium	63.4	759	227
rubidium	39.3	688	248
cesium	28.4	671	265
francium	?	?	?

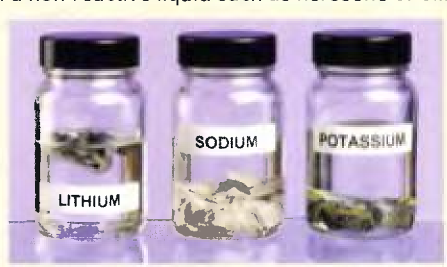
1. Come up with a way to clearly display the trends for each of the properties given in the table that will help you to predict a value for francium.
2. Predict whether francium is a solid, a liquid, or a gas at room temperature. How can you support your prediction?
3. Which of the following atomic radii is most likely to belong to francium: 252 pm, 270 pm, or 283 pm? Explain your prediction.

Figure 2.12 This periodic table has been cropped to show only the main-group elements. **What are some differences and similarities between the alkali metals and the alkaline-earth metals?**

1	2						
1 H							2 He
3 Li	4 Be	5 B	6 C	7 N	8 O	9 F	10 Ne
11 Na	12 Mg	13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
19 K	20 Ca	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr
37 Rb	38 Sr	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe
55 Cs	56 Ba	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn
87 Fr	88 Ra						
alkali metals	alkaline-earth metals						

Alkali Metals

The elements of Group 1, except for hydrogen, are known as the alkali metals. They are shiny and soft—soft enough to be cut easily with a butter knife. Alkali metals are highly reactive with many substances, including water and oxygen. This reactivity is why pure alkali metals are stored in a non-reactive liquid such as kerosene or oil.



Alkaline-earth Metals

All of the elements of Group 2 are alkaline-earth metals. They are shiny and soft, but not as soft as the alkali metals. Alkaline-earth metals are also highly reactive, but not as reactive as the alkali metals. For example, magnesium does not need to be stored in a non-reactive liquid, but it burns easily in air when ignited, as shown here.

Non-metals

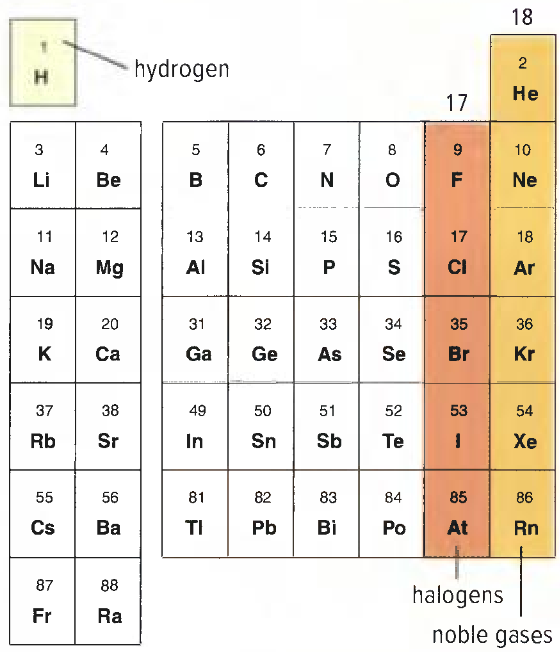
non-metal typically, an element that is not shiny, malleable, or ductile, and is a poor conductor of electric current and heat; found to the right of the zigzag line on the periodic table

The **non-metals** are found on the upper right side of the periodic table. Hydrogen, which is found in the upper left, is also a non-metal. In the periodic table in Figure 2.9, the nonmetals are shaded in yellow. Non-metals are elements that are generally gases or brittle, dull-looking solids. They are poor conductors of heat and electric current. Figure 2.13 shows hydrogen as well as two important groups of non-metals: the *halogens* and the *noble gases*.

Figure 2.13 Halogens, the Group 17 elements, are highly reactive. The defining characteristic of noble gases, the Group 18 elements, is that they are unreactive.

Hydrogen: A Special Case

Hydrogen is usually placed on the left side of the periodic table. However, hydrogen is a non-metal, not a metal. The lightest element, hydrogen is a colourless, odourless, tasteless, and highly flammable gas. Hydrogen makes up over 90 percent of the atoms in the universe. On Earth, most hydrogen is found combined with oxygen as part of the compound water.



Halogens

The halogens are the elements of Group 17 These non-metals are highly reactive, which means they are usually found in nature as part of compounds. Bromine, shown here, is the only non-metal element that is a liquid at room temperature.

Noble Gases

The noble gases are the elements of Group 18. They are all odourless, colourless gases. They are the least reactive of all of the elements. Helium and neon never form compounds, and the other noble gases form compounds only with great difficulty. Incandescent light bulbs are filled with argon because the argon does not react with the tungsten filament in the bulb.

Semi-metals

The elements in the green boxes in a staircase shape are called the **semi-metals** or *metalloids*. Semi-metals are the in-between elements—they have physical and chemical properties of both metals and non-metals. For example, like metals, they are shiny solids at room temperature. But semi-metals are brittle and not ductile like non-metals. They also tend to be poor conductors of heat and electric current. Figure 2.14 shows some important applications of semi-metals.

semi-metal an element that shares some properties with metals and some properties with non-metals

Extending the Connections

What makes silicon special?

Silicon is so important to the electronics industry that an area near San Francisco that has become a hub of this industry is nicknamed "silicon valley." What properties make silicon so important in the manufacture of electronics? Can other semi-metals be used in similar ways? Research to find out.

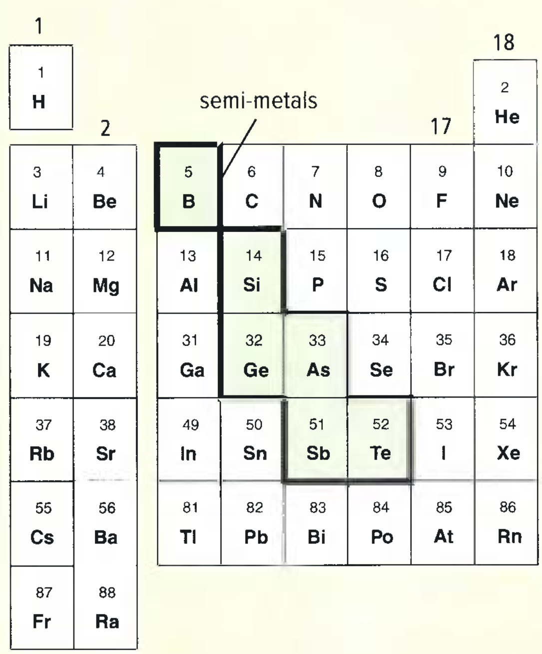


Figure 2.14 Semi-metals have some metallic properties and some non-metallic properties. Some of their properties are in-between. For example, semi-metals do not conduct electric current as well as metals, but they are better conductors than non-metals.

Semi-metals

The semi-metals are boron, silicon, germanium, arsenic, antimony, and tellurium. Silicon is the second-most abundant element in Earth's crust (after oxygen). It has many applications in electronic devices including computers, tablets, and smartphones. Silicon is also used to make silicone, which is part of a huge variety of applications, including car grease, cookware, satellite parts, contact lenses, and film props and prosthetics.

Before you leave this page . . .

1. Make a table to summarize the characteristic properties of metals, non-metals, and semi-metals.
2. What makes hydrogen an unusual element?
3. What characteristics define semi-metals?

AT ISSUE How do trace elements affect our health?

What's the Issue?

There are at least 20 different elements that our bodies need in order to function properly. We can divide them into two groups. There are seven elements known as the major minerals, which are sodium, chloride (ionized chlorine), potassium, calcium, phosphorus, magnesium, and sulfur. There are at least thirteen other elements, known as trace elements, which include iron, zinc, iodine, selenium, copper, manganese, fluoride (ionized fluorine), chromium, and molybdenum. Our body mass includes about 1 kilogram of calcium and about half a kilogram of each of the other major minerals. All the trace elements in our body at any one time have a mass on the order of tens of grams.

We need to ingest major minerals in large amounts of about 100 milligrams per day or more. We need trace elements in very small amounts, between 20 and 0.02 milligrams per day. Of all the trace elements, we need the largest amount of iron and the tiniest amounts of nickel, silicon, vanadium, and cobalt. But just because our bodies do not need trace elements in large amounts doesn't mean they aren't important. They are just as important as the major minerals. Trace elements make up key parts of our bodies' enzymes, hormones and cells. Each one serves a vital function.

We can get the trace element molybdenum by eating legumes.

Dig Deeper

Collaborate with your classmates to explore one or more of these questions—or generate your own questions to explore.

1. Many Canadians are careful to get the right amount of vitamins and minerals in their diets. Others take supplements to try to achieve this.
   a) Find out what foods different trace minerals are in.
   b) Is taking a trace element as a supplement different than getting it from foods? Explain why or why not.
   c) Can it be harmful to take too much of any one trace mineral, and if so, what are the potential health risks?
2. What are the 13 trace elements? Choose two and research the role each one has in keeping us healthy.
3. Look at labels on packages and cans of food. Read several Nutrition Facts labels. What do you think Percent Daily Value (% DV) means? Which vitamins and minerals must have their % DV listed in the nutrition facts table? Which of these are trace minerals? Why do you think certain nutrients are required to be listed on the table but others are not?

Check Your Understanding of Topic 2.2

QP Questioning and Predicting PC Planning and Conducting PA Processing and Analyzing E Evaluating
AI Applying and Innovating C Communicating

Understanding Key Ideas

1. How is the atomic number of an element related to the structure of an atom of that element? PA C
2. List five pieces of information that are recorded on a typical periodic table. PA
3. Compare and contrast the alkali metals and alkaline-earth metals. PA
4. Classify each of the following elements as a metal, a non-metal, or a semi-metal.
   - a) silicon, Si
   - b) antimony, Sb
   - c) krypton, Kr
   - d) mercury, Hg
   - e) nitrogen, N
   - f) cesium, Cs
   - g) lead, Pb
5. Make a Venn diagram to compare physical properties of metals and non-metals. PA C
6. Which group on the periodic table has elements in all three states of matter? Give examples. PA C
7. Describe where on the periodic table you find the following: PA C
   - a) metals
   - b) non-metals
   - c) semi-metals

Connecting Ideas

8. Anishnabae Elder Betty McKenna has said that "we contain all those little bits and pieces that's out there. We have calcium, we have salt, we have iron, we have copper, zinc and potassium.... [We] go from the universe right down to Mother Earth and that's us." How does this quote relate to what you have learned about the elements? E C

Making New Connections

9. In the past, gold rushes in British Columbia and elsewhere saw large numbers of everyday people travelling long distances, hoping to find veins of pure gold. Gold is somewhat unusual among metals—most have to be extracted from compounds and are not found in their elemental form, as gold is. What does this tell you about the reactivity of gold? E C
10. On May 6, 1937, a passenger airship called the *Hindenburg* caught fire and crashed, killing nearly half of its passengers as well as one person on the ground. The airship was filled with hydrogen gas. Although people disagree about the sequence of events that led to the disaster, the combustibility of the hydrogen likely contributed. PA E AI

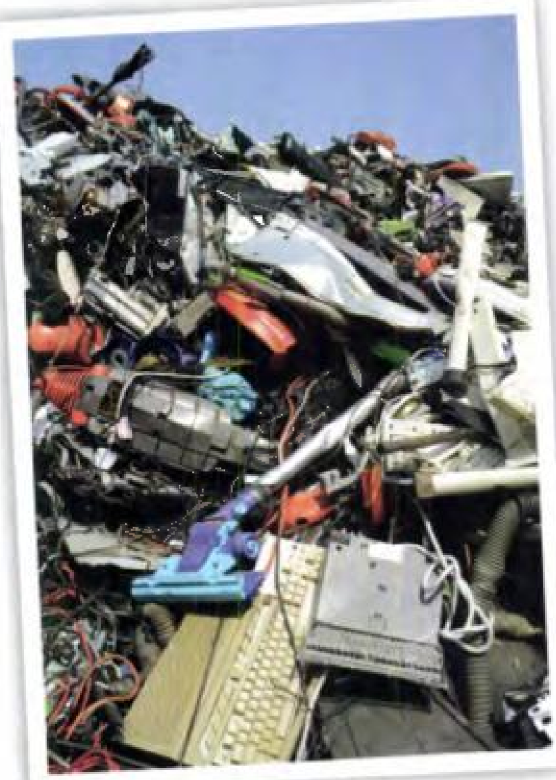
   - a) What property of hydrogen would have led to its use in airships?
   - b) Helium is the gas used today for airships. What property of helium makes it more suitable for use in airships than hydrogen?

TAKE Action

Make a Difference

Campaign to Reduce E-waste

Electronics are all around us: our computers, cellphones, electronic readers, tablets … It's difficult to imagine a world without them. Every year more and more electronic equipment and batteries are produced for our use. What this also means, of course, is that every year large amounts of electronics are being discarded as waste. Worldwide, this electronic waste (or e-waste) is skyrocketing. In Canada alone, in 2002, we produced over 11 million tonnes of electronic waste. Ten years later, this number had climbed to 14.3 million tonnes produced in a year.



Is e-waste garbage?

E-waste includes batteries and electrical and electronic equipment such as cameras, microwaves, printers, radios, speakers, and telephones. But just because we call it "waste," it doesn't mean it should be treated as garbage to be lugged away to the landfill site.

Electronic devices contain metals and other elements such as lead, cadmium, barium, chromium, mercury, and arsenic that can be harmful. For example, when chromium exists in compounds as the ion chromium(VI), it can easily be absorbed into our bodies, where it can cause permanent eye injury and even DNA damage over time.

How do these substances come to be absorbed into human bodies? Worldwide, large amounts of e-waste are still dumped into regular landfill sites where it breaks down and the hazardous substances are permitted to leach into the soil or water. In some places, people burn the e-waste to extract metals for resale. Toxins can become airborne, or may be left behind in the ash. The land, water, and air become polluted, and plants, fish, and other animals, including humans, can be harmed or killed by taking them in.

Diverting e-waste from landfills

What's the alternative? Instead of being thrown away, many intact electronics can be repaired or re-used. In addition, many parts of electronic equipment can be recycled to make new parts. Or, the materials making up the equipment—

including glass, steel, plastic, aluminum, and copper—can be recycled. People can dispose of them at special recycling centres so they can be directed to this purpose. Recycling helps to conserve natural resources. It also saves the energy that would have been required to produce new equipment.

There are several regulated programs for e-waste in Canada that allow us to dispose of our e-waste safely. Many jurisdictions offer e-waste pick-up days from specific locations or provide collection sites. Specialized recyclers take them away for safe processing.

Planning for Your Campaign

Your task is to run a campaign to educate your fellow students and their families about the importance of reducing e-waste—and motivate them to take part. Research successful campaigns. Think about how to target and influence your specific local audience. Questions to consider when developing your campaign can include the following:

- Will you work on your campaign alone or would it be more effective to get one or more partners? How will you do that? How will you agree on your roles?
- How can you ensure that your target audience connects with your campaign? Should you focus on one or two specific types of electronics that they use primarily? If so, how can you find out what these are?
- How can you convince your target audience that this issue is important? What information do you need to investigate and learn about?
- Many successful campaigns use posters, slogans, videos, or websites. How will you communicate your message?
- What catchy title and graphics can you use?
- How can you evaluate the success of your campaign?

Write out your plan and, with your teacher's approval, carry it out.

Analyze and Evaluate

1. How successful was your plan? How well did your evaluation plans help you to determine its success?
2. What did you learn that could help you to improve your campaign?

Apply and Innovate

3. Suppose other schools in your province learn of your successful campaign and want to do something similar. They have asked you for advice. Write a short bullet-point list of tips and strategies. Don't be afraid to inform them of areas where you were less successful; you can use what you learned to help guide them toward success.

INVESTIGATION

2-C

GUIDED INQUIRY

Skills and Strategies

- Planning and Conducting
- Processing and Analyzing
- Evaluating
- Communicating

What You Need

- Internet access
- print sources of information on your element
- other materials to be determined by your plan, such as posterboard, markers, other art supplies, a smartphone for recording video

Present an Element at ElementCon

As a world-renowned expert on a particular element, you have been invited to present information about that element at ElementCon—an annual convention for fans of the periodic table.

Question

What can you learn about the history, properties, and applications of an element?

Procedure

1. Your teacher will assign you an element. Use print and online resources to find out all about your element. Be sure to answer the following questions as you research:
   - **a)** What is the name, symbol, and number of the element? What are the origins of its name and symbol?
   - **b)** When and how was the element first discovered?
   - **c)** What are the physical and chemical properties of the element, including the following, if applicable:
     - melting and boiling point
     - density
     - state at room temperature
     - colour
     - texture
     - hardness or softness
     - odour
   - **d)** Where on the periodic table is your element found? Is it a metal, a non-metal, or a semi-metal?
   - **e)** What features define an atom of your element?
   - **f)** Where is the element found?
     - Where in the world and in the universe is it found?
     - Can it be found pure or is it always in compounds?
     - What types of compounds does it form?
     - How can the element be isolated from its compounds?
   - **g)** How is the element used today and how was it used in the past? What is the economic importance of the element in Canada or elsewhere in the world?

2. Take notes to record the information you find. Record the sources of information you used.

Process and Analyze

1. Did you find conflicting information as you researched? Give one example. How did you decide which source to use?
2. Evaluate the sources you used. Were they
   - trustworthy? Explain how you know.
   - current? Explain how you know.

Apply and Communicate

3. Make a plan to decide how you will present your findings at your "booth" at the ElementCon. You may use one or more of the following ideas to present the information you found.
   - Put up an informative poster with tables and images.
   - Use storytelling to creatively reveal properties and other information about your element.
   - Make a display showing a model of an atom of your element.
   - Create a comic book in which your element is the superhero, with powers and weaknesses related to its chemical and physical properties.
   - Write a clickbait-style "Which element are you?" quiz for classmates to try that has questions relating to the properties of your element that distinguish it from others.
   - Collect and display items that contain your element or that relate to your element in some other way.
   - Make a video in which you explain why your element is interesting, unique, and important.
   - Make a video re-creating the discovery of your element.
   - Create a slide show with photos, text, and music relating to your element.
4. Have your teacher approve your plan before you design your booth. On ElementCon day, your teacher will divide the class in half. Half the class will visit booths, while the other half will present. Then the groups will switch.

INVESTIGATION

2-D

STRUCTURED INQUIRY

Meet the Elements

Skills and Strategies

- Planning and Conducting
- Evaluating
- Applying and Innovating
- Communicating

Safety

- Never eat or drink anything in the laboratory.

What You Need

- a selection of elements and information cards—these elements will include a variety of solid, liquid, and gaseous elements from different families of the periodic table

Most of the matter we interact with every day is in the form of compounds and mixtures. In this investigation, you will observe a number of elements in uncombined form.

Question

How can we distinguish among elements by observing some of their physical and chemical properties?

Procedure

1. Your teacher will give a list of the elements you will be observing. Use this list to prepare a table like the one opposite. (Alternatively, your teacher may provide a table for you to fill out.) Be sure to leave plenty of room for observations.
2. Observe the elements as directed by your teacher. Record properties provided on the information cards. Your teacher may demonstrate additional properties.

Process and Analyze

1. Where within any period do you find the following:
   a) the most dense metals
   b) the most reactive metals
2. Where within any group do you find the following:
   a) the most dense elements
   b) the most reactive elements
3. Many of the elements you examined were metals.
   a) List four properties that most metal elements have in common.
   b) List the elements that are exceptions to the properties you listed above, and explain why.
   c) List the elements that are magnetic.
4. List the elements that conducted electric current. Were they all metals?

Symbol	Element Name	State	Colour	Additional Properties (lustre, malleability, density, conductivity, magnetism)	Group
H					
Li					
Na					

Communicate and Question

5. Summarize your findings about metals and non-metals.
6. What questions do you have about the elements or a specific element as a result of this investigation? Come up with at least three questions. Choose one and do Internet research to find the answer.

TOPIC 2.3

How can atomic theory explain patterns in the periodic table?

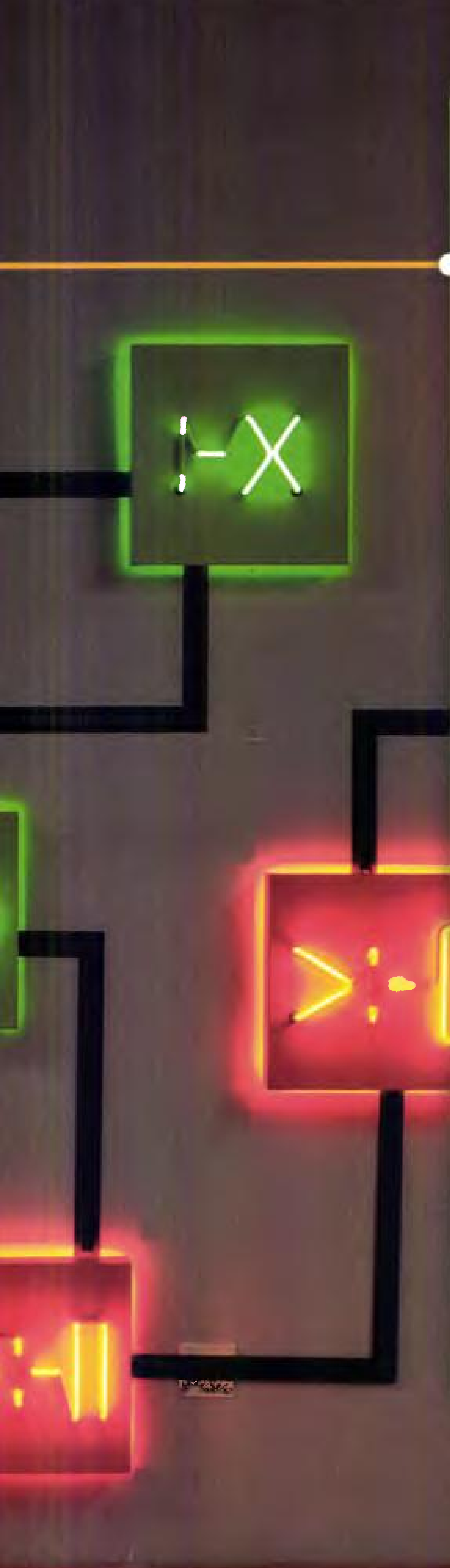
Key Concepts

- The structure of atoms can be represented using simple diagrams.
- Elements in chemical groups have similar electron arrangements.
- The periodic table shows how properties of elements change in predictable ways.

Curricular Competencies

- Seek and analyze patterns, trends, and connections in data, including describing relationships between variables (dependent and independent) and identifying inconsistencies.
- Construct, analyze, and interpret graphs, models, and/or diagrams.
- Formulate physical or mental theoretical models to describe a phenomenon.

This playful sculpture by artist Lisa Schulte is called *A Conversation*. Schulte used neon and argon lights to create a trail of emojis that tell a story. In contrast to the increasingly strong emotional "reactions" portrayed here, noble gases such as neon and argon are inert—they do not undergo chemical reactions. The inertness of noble gases is one example of a pattern revealed by the periodic table. But what causes these patterns?



Starting Points

Choose one, some, or all of the following to start your exploration of this Topic.

1. **Identifying Preconceptions** Atoms are made up of subatomic particles. Electrons are negatively charged, protons are positively charged, and neutrons have no charge. How do these particles affect one another in the atom? How do forces between charged particles affect chemical properties?
2. **Questioning** What causes the different colours in lights like the ones shown in the photo? Why are noble gases used in lights of this type? How are neon lights made and what causes them to glow?
3. **Communicating** The light sculpture shown uses emojis to create an artistic effect. Can emojis be used to model the periodic table? Select at least 10 emojis and make a meaningful arrangement of them in columns and rows. Write a brief blog post to explain your arrangement.
4. **Applying First Peoples Perspectives** Investigate the work of First Nations artist Kevin McKenzie, who combines neon lighting, chrome, and other modern materials with traditional materials. What are some effects of using materials and techniques of two cultures?

Key Terms

There are four key terms that are highlighted in bold type in this Topic:

- valence shell
- ion
- valence electrons
- periodic trend

Flip through the pages of this Topic to find these terms. Add them to your class Word Wall along with their meaning. Add other terms that you think are important and want to remember.

CONCEPT 1

The structure of atoms can be represented using simple diagrams.

Activity

What do you know about atoms?

In your notebook, and without referring to your textbook, draw a diagram of a helium atom. What information did you provide about the atom in your diagram?

Mendeleev arranged elements in his periodic table based on the physical and chemical properties of different elements. Metals appear on the left side of the zigzag line, and non-metals appear on the right. Elements in the same families share similar properties. But why is this the case? What characteristic of elements causes their properties to repeat in this predictable way? To find the answer, we need to consider the structure of the atom.

Key Features of Atomic Structure

Recall that the atom is the smallest unit of an element that has the properties of that element. For example, an atom of carbon is represented in Figure 2.15. Each atom has a tiny, dense nucleus containing neutrons and protons. (A hydrogen nucleus has a single proton only.) The nucleus is surrounded by electrons, which exist in specific electron energy shells. Most of the mass of an atom is in the nucleus. Table 2.3 summarizes key characteristics of protons, neutrons, and electrons.

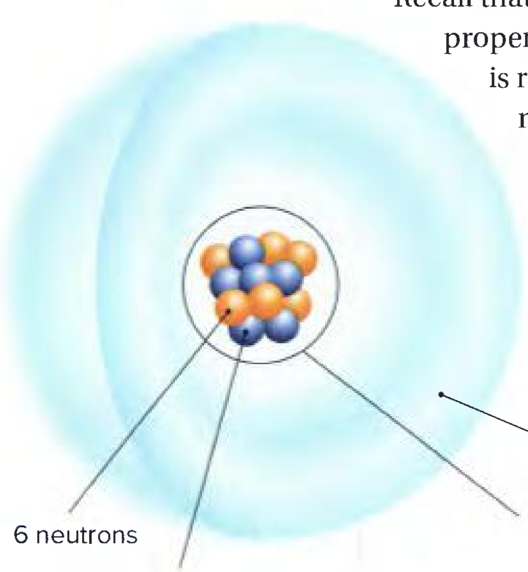


Figure 2.15 Every carbon atom has six positively charged protons in its nucleus and six negatively charged electrons surrounding the nucleus. (Most carbon atoms have six neutrons, but some have seven or eight.)

Table 2.3 Subatomic Particles

Name	Relative Mass	Electric Charge	Symbol	Location in Atom
proton	1836	+	p^+	nucleus
neutron	1837	0	n^0	nucleus
electron	1	−	e^-	electron energy shells surrounding the nucleus

Bohr Diagrams Are a Useful Way to Model Atoms

It is useful to be able to represent atoms in a simplified, two-dimensional way that provides information about their structure. Bohr diagrams represent the electron arrangements of atoms using the "energy shell" concept of Bohr's model of the atom. As shown in Figure 2.16, a Bohr diagram shows how many electrons occupy each specific energy level or shell. The number of electrons that can occupy each energy shell changes as you move outward from the nucleus. The first energy shell can have a maximum of two electrons. The second and third energy shells can have a maximum of eight electrons. (This is true for the first 20 elements, after which things become more complex.) The outermost occupied shell of an atom is called a **valence shell**. Electrons in the valence shell are called **valence electrons**.

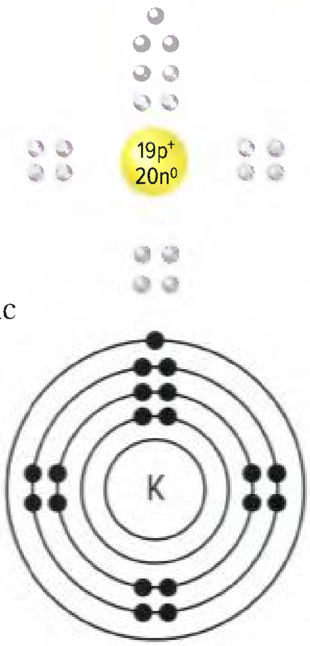


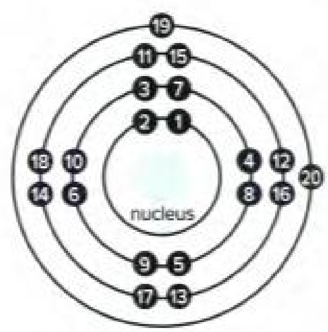
Figure 2.16 Both of these Bohr diagrams represent an atom of potassium. **What is one drawback and one advantage of each diagram?**

valence shell the outermost occupied energy shell of an atom

valence electrons the electrons in the outermost occupied energy shell of an atom

Activity

Model Bohr Atoms



Your teacher will assign you a number from one to 20. Using a pie plate, a marker, construction paper, pom-poms, and glue, create a Bohr diagram for the element that corresponds to your number. For example, if you are number 6, your element is carbon.

1. Glue a construction paper circle "nucleus" in the centre of your pie plate. Write the symbol for your element on the circle.
2. Examine the diagram on the right to see in what order you will place the pom-pom "electrons" and how many shells will be occupied. (For a neutral atom, number of electrons = atomic number.)
3. Draw circles on the pie plate to represent the occupied energy shells for your atom. Then glue on pom-poms to represent your electrons.
4. Display your model. In your notebook, use the models to help you draw Bohr diagrams for each of the first 20 elements.

Before you leave this page . . .

1. Draw a diagram of an atom, labelling protons, electrons, and neutrons.
2. List how many electrons can be found in the first and second energy shells.

CONCEPT 2

Elements in chemical groups have similar electron arrangements.

Activity

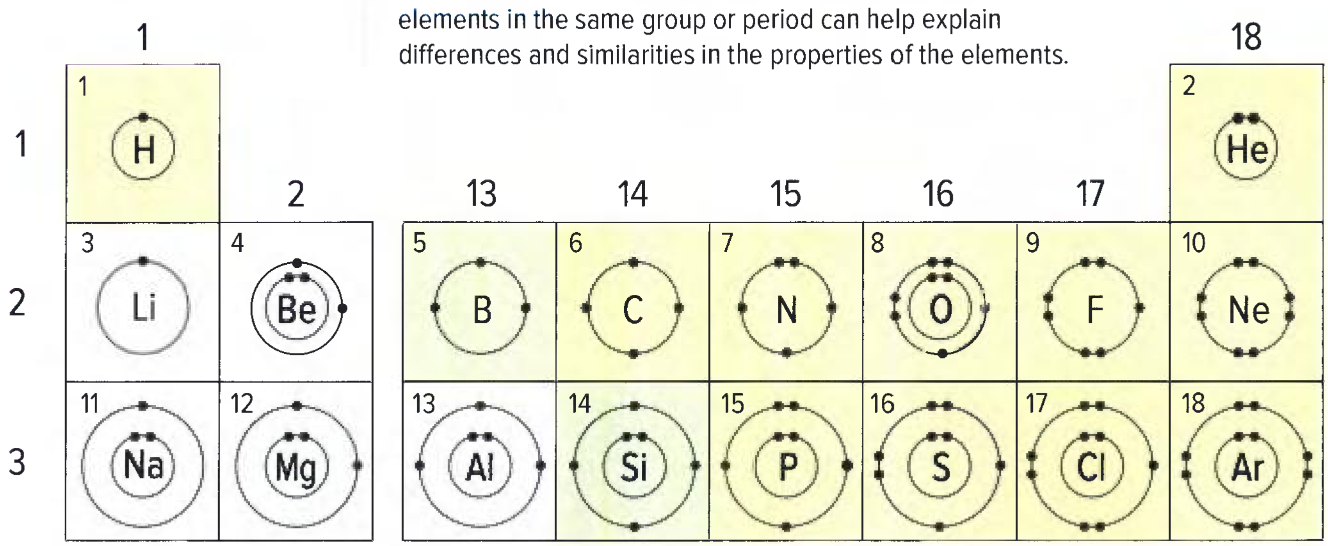
Valence Electrons and Group Numbers

Examine Figure 2.17. How do the valence electrons in each group relate to the group number?

Figure 2.17 shows Bohr diagrams for elements in the first three periods of the periodic table. If you look carefully at the electron arrangements, you will see that two key patterns emerge:

1. *Atoms in the same group have the same number of valence electrons.* Each element in Group 1 has one valence electron, and each element in Group 2 has two valence electrons. The elements in Groups 13 to 18 have 3, 4, 5, 6, 7, and 8 valence electrons, respectively. An exception is helium. Helium has only two valence electrons, but the other noble gases have eight.
2. *Atoms in the same period have the same number of occupied energy shells.* The two elements in the first period, hydrogen and helium, have only one occupied energy shell. The eight elements in the second period have two occupied energy shells. The eight elements in the third period have three.

Figure 2.17 Analyzing the electron arrangements of elements in the same group or period can help explain differences and similarities in the properties of the elements.



Noble Gas Stability: A Full Valence Shell

During a chemical reaction, atoms gain, lose, or share valence electrons with other atoms. Noble gases are special among the elements, because they all have full valence shells. This feature makes them unusually stable. Their atoms do not tend to gain, lose, or share electrons with other elements— for the most part, they are unreactive. As you can see in Figure 2.18, helium has two electrons, which is the maximum number of electrons for the first energy shell. The other noble gases have eight electrons in their valence shells.

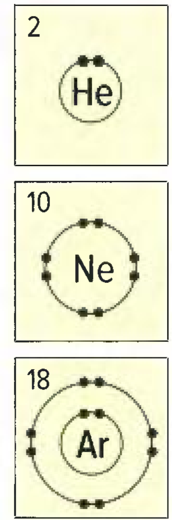


Figure 2.18 The noble gases have full valence shells.

How Other Elements Achieve Full Valence Shells

One way that atoms of elements other than the noble gases can achieve a full valence shell is by gaining or losing electrons during chemical reactions. When a neutral atom gains or loses an electron, it becomes charged—it becomes an **ion**. When an atom loses an electron, it becomes a positively charged ion. When an atom gains an electron, it becomes a negatively charged ion.

ion an atom with a positive or negative charge

The reactivity of an element is linked to how close it is to having a full valence shell. For this reason, the most reactive elements are those of Groups 1 and 17. The atoms of these elements are only one electron away from having a full set of valence electrons. As shown in Figure 2.19, Group 1 atoms can give up an electron, exposing the full energy shell underneath. Group 17 atoms can gain an electron, completing their valence shell.

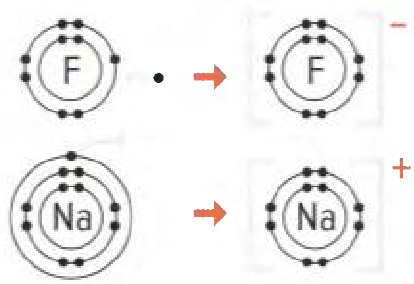


Figure 2.19 If a fluorine atom gains an electron, forming the ion F^-, it will have the same electron arrangement as neon, including a full valence shell. A sodium atom can have the same electron arrangement as neon by losing an electron and forming the ion Na^+.

Extending the Connections

A Noble Gas is Hard to Find

When Mendeleev developed his periodic table, he did not include a column for the noble gases, because they had not yet been discovered. Which noble gas was found first and how was it discovered? Who realized where the noble gases should be placed on the periodic table? Do research to find out.

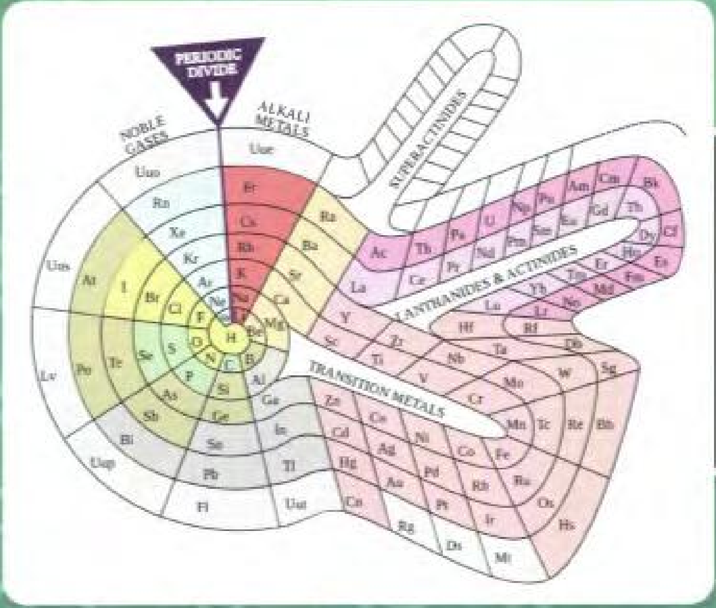
Before you leave this page . . .

1. Explain why metals tend to lose electrons and non-metals tend to gain them.
2. Use diagrams to compare the electron arrangements of a chloride ion, a potassium ion, and an argon atom.

AT ISSUE How can the periodic table be represented in a different form?

What's the Issue?

The modern periodic table that you have been learning about is organized in columns and rows according to the atomic numbers of the elements. When the elements are arranged in order of increasing atomic number, a periodic pattern in the properties of the elements emerges.

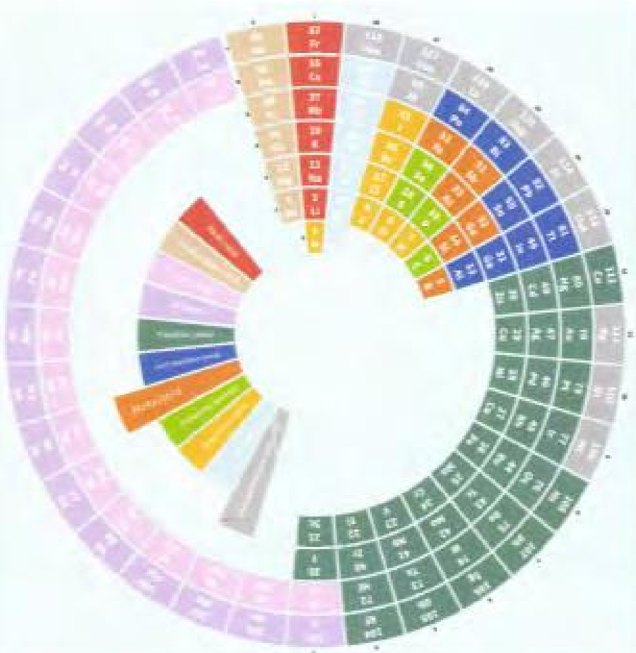


Dr. Theodor Benfey designed this spiral periodic table in 1964. One of his aims was to show the continuity of the elements and remove the apparent "jump" from one period to the next that occurs in the traditional periodic table.

In this three-dimensional digital periodic table, the heights of the columns represent the magnitude of the atomic numbers of the elements.

But is that the only way that all the elements could be organized? Many people have argued no—and have developed their own versions of the periodic table. In fact, since the early 1900s more than 300 versions of the periodic table have been developed. Some tables have been developed purely for creative reasons. Others have been developed to show different types of information or relationships between elements and their properties that the standard version of the periodic table does not show.

This three-dimensional periodic spiral was designed in 1977 by Dr. Hinsdale Bernard. The connected platforms represent the periods, and the elements are colour-coded to show what part of the table they belong to.



Like Dr. Benfey's spiral table, this circular periodic table emphasizes the continuity between periods. However, its shape is simpler and it uses only colour-coding to show the groups.

Dig Deeper

Collaborate with your classmates to explore one or more of these questions—or generate your own questions to explore.

1. What key pieces of information do you think should be in a periodic table?
2. Choose one of the periodic tables shown on these pages to learn more about, or choose another table to research, such as an online interactive table. Why did the designer of your chosen table choose to present it that way? What other questions do you have about the table? Perform research to find the answers to your questions.

CONCEPT 3

The periodic table shows how properties of elements change in predictable ways.

Activity

On Trend

What does the term *trend* mean to you? Write a brief definition. How have you seen the term used in the news media and on social media? How is your life influenced or affected by trends?

periodic trend a regular variation in the properties of elements based on their atomic structure

In chemistry, the term **periodic trend** refers to a regular variation in the properties of elements based on their atomic structure. The periodic table is a powerful tool for analyzing such trends because it can help you see and compare variations in groups and periods. One trend that can be analyzed in this way is atomic size.

Atomic Size Trends

Figure 2.20 compares the sizes of atoms of each main-group element. Observe the sizes of the atoms in each group and period.

1. *Atomic size increases moving down a group.* As you move down a group in the periodic table, elements have atoms with increasing numbers of energy shells. The greater the number of shells, the farther the valence electrons are from the nucleus, and therefore the larger the atom is.

2. *Atomic size decreases moving left to right across a period.* Elements have increasing numbers of electrons in their valence shells as you move left to right across a period. And yet the atomic size *decreases*. Why? As you move from left to right in a period, the number of occupied valence shells stays the same, but the number of protons in the nucleus increases. The attraction between each valence electron and the nucleus increases because a greater positive charge on the nucleus pulls more strongly on the negatively charged electrons. As a result, the valence electrons are pulled more tightly towards the nucleus.

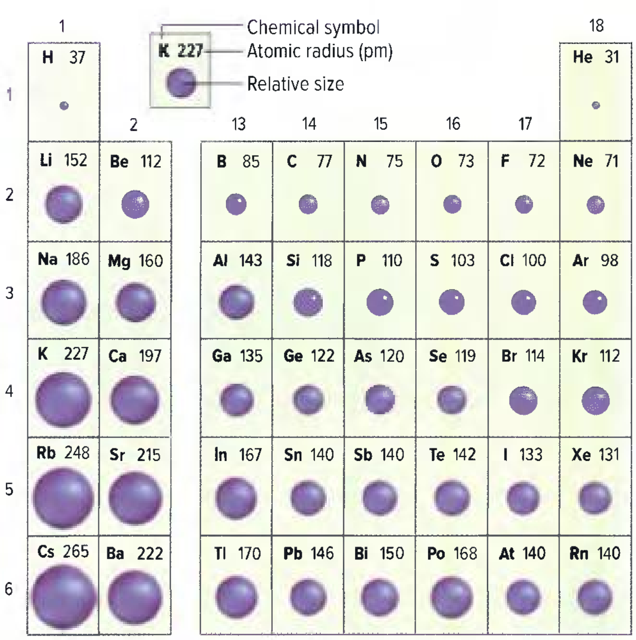


Figure 2.20 Atomic size is represented here by the sizes of the spheres. The number under each element is the radius of the atom in picometres (pm). One picometre is equal to 1/1 000 000 000 000 m.

Metal Reactivity and Atom Size

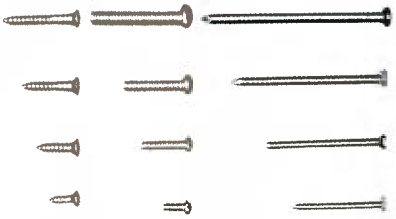

Figure 2.21 Potassium (A) is more reactive than sodium (B) because less energy is needed to remove the valence electron from potassium.

Figure 2.21 compares what happens when potassium and sodium are added to water. As you can see, the reaction is more vigorous and violent for the potassium. In other words, potassium is more reactive than sodium. Why is this the case? They are both in Group 1, and both have one valence electron. The difference is that a potassium atom is larger than a sodium atom. A potassium atom's valence electron is farther away from the nucleus than the sodium atom's valence electron. As a result, the pull of the nucleus is weaker, and the electron is easier to remove. That is what makes potassium more reactive.

Activity

Recognizing Trends

The periodic table makes it easy to see trends in atomic properties such as atomic size. Can you use a similar arrangement to reveal trends in the characteristics of everyday objects?



1. Obtain a sample of fasteners, including nails, bolts, and screws.
2. Measure the length of each nail with a ruler.
3. Use a balance to measure the mass of each nail.
4. Place the nails in a series from smallest to largest.
5. Continue to arrange a series of screws and a series of bolts that also correspond to the series of nails created in Step 4.
6. Make a table listing the length and mass of each fastener according to its position.
7. Describe the following:
   a) the trend in mass as you go from left to right across each row
   b) the trend in mass as you go down each column of the table
8. Analyze your organization of the fasteners, and explain any other trends that you find in the table.
9. Describe how you could make a similar "periodic table" of another type of familiar item.

Before you leave this page . . .

1. Explain why atoms get larger down a group on the periodic table.
2. Explain why atoms get smaller from left to right across a period on the periodic table.
3. Explain why an alkali metal is more reactive than an alkaline-earth metal in the same period.

AT ISSUE Who decides a new element's name?

What's the Issue?

When Mendeleev first published his periodic table, would he have been surprised to learn that scientists are still updating this ultimate source of chemical information 150 years later? Today, all of the elements that occur naturally have been discovered. Therefore, the discovery of new elements involves making them in laboratories and analyzing complex results to confirm their existence. Who decides when a new element has been made and what to call it?

The International Union of Pure and Applied Chemistry, or IUPAC for short, is the international scientific organization that is in charge of naming chemical elements, as well as other chemicals. They are also in charge of confirming that new elements have actually been synthesized. In 2016, IUPAC confirmed that the new elements numbered 113, 115, 117, and 118 actually existed, and assigned these elements temporary names that were added to the periodic table. The seventh row of the periodic table was completed when these four elements were assigned official names and symbols as shown below.

Newly Synthesized Elements

Element Number	Name	Symbol
113	nihonium	Nh
115	moscovium	Mc
117	tennessine	Ts
118	oganesson	Og

Dig Deeper

Collaborate with your classmates to explore one or more of these questions—or generate your own questions to explore.

1. According to IUPAC, what are the rules for naming new elements? What were the reasons behind the names for new elements 113, 115, 117, and 118? What were the temporary names given to these elements before their official names were decided?
2. IUPAC announced the four new names in June 2016. They then waited 5 months to allow for both scientific and non-scientific people to review the names. Why did IUPAC do this?
3. Choose a synthetic element and find out how it was made. How does IUPAC confirm the synthesis of a new element? Why are multiple results required to make this decision?
4. Does the naming of these last four elements mean that scientists are finished making new elements and that the periodic table is complete? Explain your answer.

Check Your Understanding of **Topic 2.3**

QP Questioning and Predicting PC Planning and Conducting PA Processing and Analyzing E Evaluating
AI Applying and Innovating C Communicating

Understanding Key Ideas

1. What is a periodic trend? PA C

2. Compare the number of protons and electrons in each of the following: PA C
- **a)** a positively charged ion
- **b)** a negatively charged ion
- **c)** a neutral atom

3. Why are the noble gases so stable? PA C

4. What is the relationship between reactivity among elements (other than the noble gases) and the number of valence electrons? PA

5. Describe and explain the periodic trends relating to atomic sizes. PA C

6. Which of the following pairs of metals would you expect to be more reactive? Briefly explain your answers. QP PA C
- **a)** potassium or calcium?
- **b)** rubidium or potassium?

7. How many valence electrons do atoms in the following groups have? (If there are exceptions to the rule, state them.) QP
- **a)** Group 1
- **b)** Group 2
- **c)** Group 17
- **d)** Group 18

Connecting Ideas

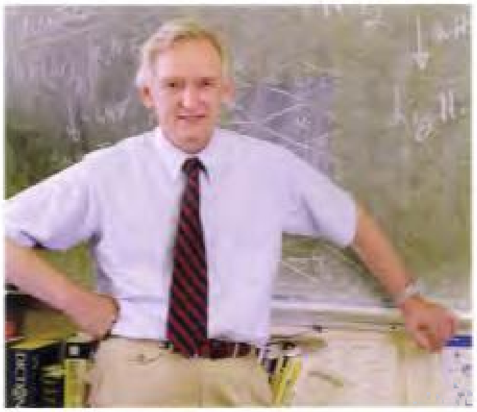
8. Do you expect a calcium ion, Ca^{2+}, to be larger or smaller than a calcium atom? Explain your answer. QP PA C

9. The noble gases were not identified until after Mendeleev first published his periodic table. Use your knowledge of noble gases to infer why it took so long to discover them. E C

Making New Connections

10. Fluorine is the most reactive of the halogens. It is more reactive than chlorine, which is just below it. Bromine is less reactive than chlorine. How would you summarize and explain this trend? PA AI C

11. Neil Bartlett, shown below, was a chemist and a teacher at the University of British Columbia who specialized in the chemistry of the element fluorine. Bartlett is celebrated as the first chemist to succeed in getting a noble gas to react and form a compound. PA E AI C



- **a)** Bartlett was working on getting the noble gas xenon to react with fluorine. He eventually succeeded in making a number of compounds of xenon and fluorine. Why do you think fluorine was a good choice of element to work with in trying to get noble gases to react? **Hint:** Refer to Question 10.
- **b)** What features of xenon made it a good choice of noble gas for Bartlett to use in his attempts to get a noble gas to react? Research to find out.
- **c)** What effect did Bartlett's discovery have? Research to find out.

INVESTIGATION
2-E

STRUCTURED INQUIRY

Skills and Strategies

- Planning and Conducting
- Processing and Analyzing
- Communicating

Safety

- Hydrochloric acid can burn skin.
- Clean up any spills and inform your teacher immediately.
- Do not handle calcium with your bare hands.

What You Need

- water
- 3 test tubes
- test-tube rack
- aluminum
- pea-sized piece of calcium
- 1 cm strip magnesium ribbon
- 1 mol/L hydrochloric acid

Reactivity Trends in the Periodic Table

Periodic trends include both physical and chemical properties of elements. In this investigation, find out if (and how) the reactivity of metals relates to their position on the periodic table.

Question

Is there a relationship between the reactivity of a metal and its position in the periodic table?

Procedure

1. Read the Procedure steps and design a table to record your observations.
2. Put 10 mL of water into each of the three test tubes. Add one metal to each test tube. Record your observations.
3. When the reactions stop, dispose of the liquid as directed by your teacher. You will use the magnesium and aluminum metals again for the next step.
4. Add 10 mL of HCl to the remaining magnesium and aluminum samples. Record your observations and indicate the relative reactivity of each metal. CAUTION: Be very careful when working with the hydrochloric acid. Acid can burn skin. If you spill any of the acid solution on your hands, rinse it off immediately with cold water and inform your teacher.
5. Clean up your work area and dispose of materials as directed by your teacher.

Analyze and Interpret

1. Compare the reactivities of magnesium and calcium. Use evidence to support your comparison.
2. Compare the reactivities of magnesium and aluminum. Use evidence to support your comparison.
3. Which of the three metals was the most reactive? Which metal was the least reactive?

Conclude and Communicate

4. Draw Bohr diagrams for magnesium, calcium, and aluminum. Does your understanding of atomic structure support yuor observations from this investigation? Justify your response.

Apply and Innovate

5. What other metals could you test in this way?
   a) Suggest two or three additional metals that you could test.
   b) Write a procedure for testing the reactivity of the metals. Include safety precautions.
   c) With your teacher's permission, carry out your procedure.
   d) Make a brief digital slide show to compare and analyze the findings of your own investigation together with your results from Investigation 2-E.
6. What other questions do you have about the different reactivities of elements as a result of carrying out this investigation?
   a) Choose one question to investigate.
   b) Conduct research to help you come up with a procedure for investigating your question in the laboratory.
   c) Write a procedure for investigating your question.
   d) With your teacher's permission, carry out your procedure.
   e) Write a brief report to describe your investigation and your results.

TOPIC 2.4

How do elements combine to form compounds?

Key Concepts

- Compounds account for the huge variety of matter on Earth.
- Ionic compounds are made of ions.
- Covalent compounds are made of molecules.
- Covalent bonding also occurs in elements and network solids.

Curricular Competencies

- Select and use appropriate equipment, including digital technologies, to systematically and accurately collect and record data.
- Apply First Peoples perspectives and knowledge, other ways of knowing, and local knowledge as sources of information.
- Evaluate their methods and experimental conditions, including identifying sources of error or uncertainty, confounding variables, and possible alternative explanations and conclusions.

This climber depends on chalk—a white, powdery compound—to absorb the sweat from her hands and improve her grip on the rock. The sweat itself is mainly the compound salt, also called sodium chloride, dissolved in another compound, water. The climber breathes deeply to stay focussed, and the mixture that is her exhaled breath includes gaseous water, along with carbon dioxide, another compound. A variety of compounds make up her hard, durable helmet, her strong, flexible rope, and the grippy soles of her shoes. The staggering variety of matter in our world is due to the many, many ways in which the elements of the periodic table can combine to form different compounds.

Starting Points

Choose one, some, or all of the following to start your exploration of this Topic.

1. **Identifying Preconceptions** Sweat is a mixture made up of several compounds, including salt and water. How is a mixture different from a compound? How are compounds different from elements?
2. **Questioning** Chalk is a compound called calcium carbonate. What elements do you think are found in calcium carbonate? Make a prediction. Then come up with three additional questions. Conduct research to answer your questions and test your prediction.
3. **Applying** What properties make chalk suitable for the use shown here? What properties make chalk unsuitable for making flexible, grippy shoe soles?
4. **Applying First Peoples Perspectives** According to the law of conservation of mass, matter is conserved when matter changes. There is an equal quantity of matter before and after the change because atoms are rearranged, not created or destroyed. Matter is constantly being recycled. How might looking at the formation of compounds in terms of transformation and renewal help in thinking about chemical change?

Key Terms

There are five key terms that are highlighted in bold type in this Topic:

- ionic compound
- covalent compound
- covalent bond
- ionic bond
- molecule

Flip through the pages of this Topic to find these terms. Add them to your class Word Wall along with their meaning. Add other terms that you think are important and want to remember.

CONCEPT 1

Compounds account for the huge variety of matter on Earth.

Activity

What is it made of?

For each of the following familiar compounds, list as many properties as you can. Then list properties of the elements that make up the compounds.

- table salt, or sodium chloride (made of sodium and chlorine)
- water (made of hydrogen and oxygen)
- carbon dioxide (made of carbon and oxygen)
- sugar, or sucrose (made of carbon, hydrogen, and oxygen)

Can you get clues about the properties of compounds from the properties of the elements that make them up? Explain your answer.

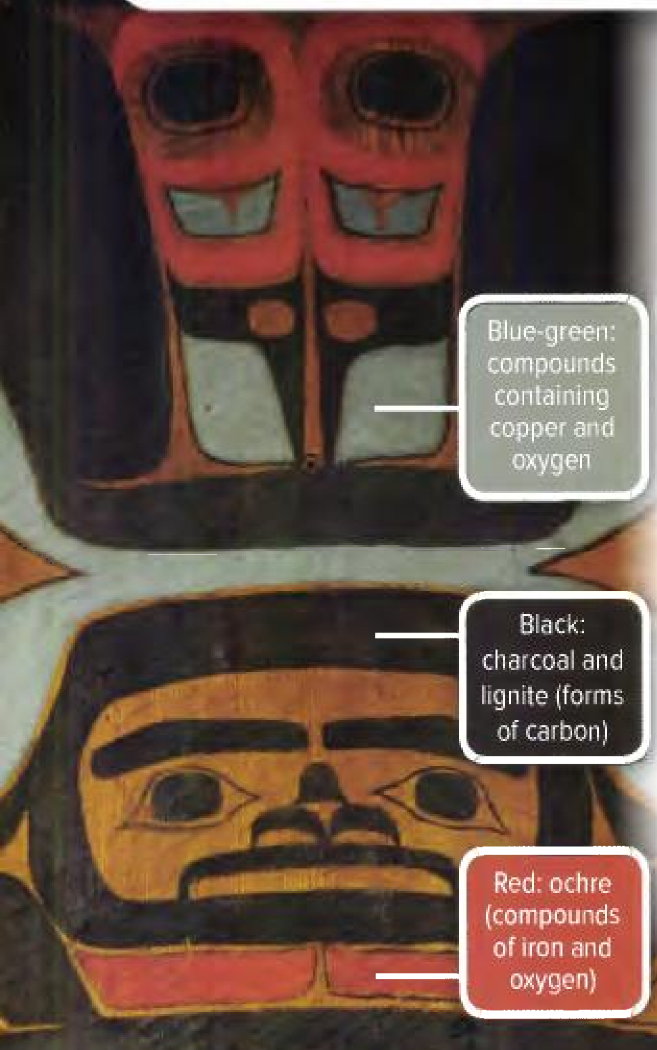
All of the compounds that exist on Earth are built from the elements of the periodic table. The periodic table lists 118 elements, and only 80 of these commonly form compounds. Yet there are 10 million known compounds—and scientists estimate that there could be billions of possible compounds. Figure 2.22 shows just a few examples. The variety of ways in which elements chemically combine to form compounds accounts for the astonishing variety of matter.

Figure 2.22 Hydrogen and carbon alone can be combined in millions of ways to make compounds with very different properties. The plastic bag, candle wax, gasoline, and acetylene gas used in the torch are all made up of compounds containing hydrogen and carbon.

Before you leave this page . . .

1. Distinguish between elements and compounds.
2. Compare the number of elements with the number of compounds on Earth.

AT ISSUE How can pigments influence art styles?



What's the Issue?

First Peoples of British Columbia's northwest coast, including the Tlingit, Haida, Tsimshian, Nisga'a, Gitksan, Haisla, and Heiltsuk peoples, developed an artistic style that has come to be known as formline painting. Recognized and appreciated worldwide for its bold and beautiful designs based on stylized animals and abstract shapes, the formline style has been used to adorn a variety of objects including house fronts, chests, and screens.

Traditionally, this style of painting was based on three colours: black, red, and blue-green. The paints were made from pigments—the substances that give colour to the paint—sourced from materials from the earth. Contemporary Aboriginal artists are no longer restricted to using paints they can make themselves, and new pieces in the formline style often now make use of a wider palette of colours.

Dig Deeper

Collaborate with your classmates to explore one or more of these questions—or generate your own questions of interest to explore.

1. Find some examples of contemporary and traditional formline art. How has the availability of a wider variety of paints influenced the art style?
2. In 2015, a pair of UBC students, Jun Lee and Vinicius Lube, replicated the traditional method of making paints. Find out more about what they discovered. What was the role of salmon eggs and how were they prepared?
3. Find out more about traditional paints and pigments around the world. How have paints changed over time in terms of safety, durability, and colour?
4. Many modern pigments contain compounds that are synthetic. This means that they were made rather than found. Choose one synthetic pigment. How is it made? What elements does it contain?

CONCEPT 2

Ionic compounds are made of ions.

Activity

Salt or Sugar?

Your teacher has a sample of salt and a sample of sugar. Without tasting them, how can you tell which is which? As a class, based on prior knowledge of these two compounds, come up with a test or tests you could conduct to distinguish between the two. With the help of volunteers, your teacher will conduct the tests and record the results. Which properties of salt and sugar are you testing for? What do you think accounts for the differences between salt and sugar?

ionic compound a compound made of oppositely charged ions

ionic bond a strong attraction that forms between oppositely charged ions

Compounds made of ions are called **ionic compounds**. Ionic compounds consist of regular arrangements of negatively charged ions and positively charged ions. The ions are held together with **ionic bonds**, which is the name for the attraction between oppositely charged ions. Ionic bonds are very strong.

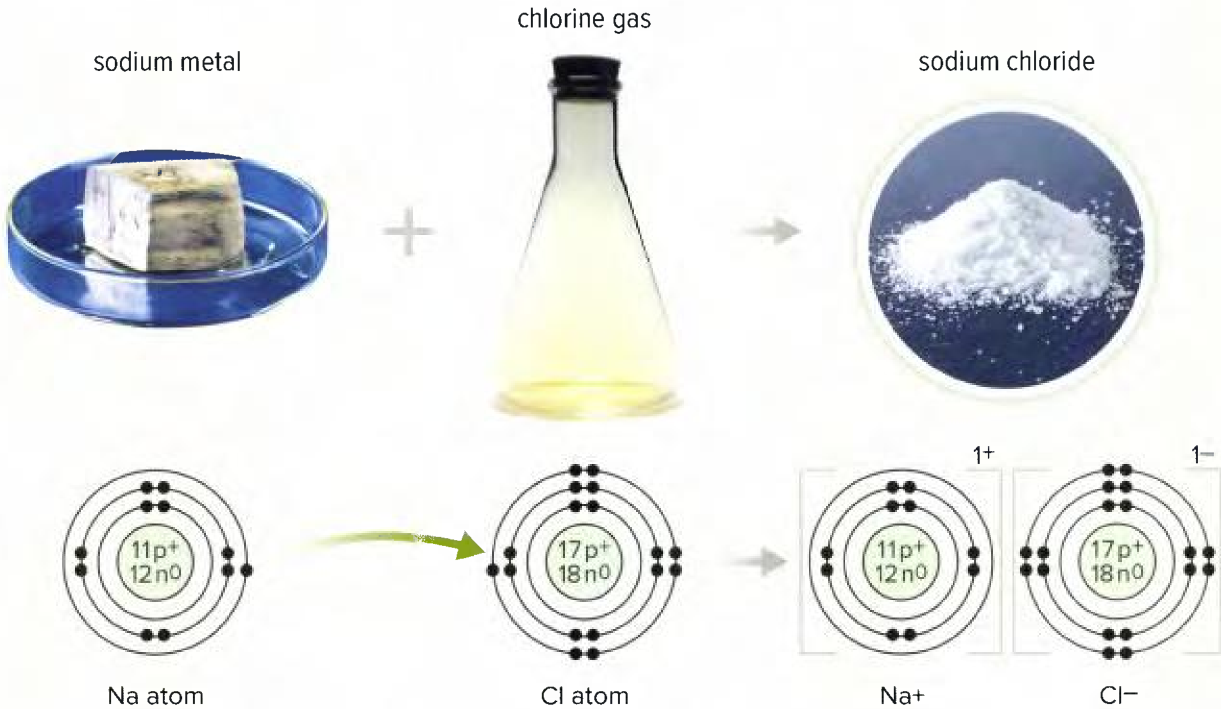
Formation of Ionic Compounds

The simplest types of ionic compounds are made up of two elements: a metal and a non-metal. Ionic compounds containing just two elements are called *binary ionic compounds*. These types of ionic compounds form when atoms of the metal element each lose one or more electrons to atoms of the non-metal element. For example, table salt—sodium chloride—forms when sodium atoms each transfer one electron to chlorine atoms. Each sodium atom becomes positively charged, a positive ion: Na^+. Each chlorine atom becomes negatively charged, a negative ion: Cl^-. This is what happens when sodium metal reacts with chlorine gas to form sodium chloride, as shown in Figure 2.23.

Why do ionic compounds form? In binary ionic compounds, neutral atoms of metals transfer the electrons in their valence shells to neutral atoms of non-metals. This transfer results in full valence shells for the oppositely charged ions that are formed. The stability of a full valence shell is what drives the formation of compounds.

To analyze what happens when ionic compounds form, recall what you have learned about the electron arrangements of elements in the different groups of the periodic table. How can atoms of alkali metals or halogens achieve full valence shells? Explore these questions in the Activity on the next page.

Figure 2.23 A sodium atom loses one electron to a chlorine atom, forming a sodium ion, Na^+, and a chloride ion, Cl^-. These ions are strongly attracted to each other. **What do you notice about the valence shells of the sodium ion and the chloride ion?**



Activity

Patterns in Ion Formation

Examine the periodic table to learn how elements in various groups form ions.

11	1+
Na	
sodium	
23.0	

1. Take a look at the periodic table. Notice that many of the element cells have one or more charges listed in the upper right-hand corner. What are these charges?
2. Look at the groups (vertical columns) of the periodic table. What patterns in ion charges do you notice?
3. What ions are formed by the atoms of elements from Groups 1, 2, 16, 17, and 18? Make generalizations for each group.
4. Think about what you know about the electron arrangement for atoms of each element. How would you explain the patterns in ion formation that you have noticed?
5. Many elements of the periodic table have ion charges listed. What do these charges mean? Do these elements always exist as ions? Explain your answer.

The Structure of Ionic Compounds

Ionic compounds consist of positive and negative ions arranged in regular repeating patterns called *lattices*. The cube-shaped, or *cubic*, structure of sodium chloride is an example of a lattice. Notice the cubic shape of the sodium chloride crystals in the magnified image in Figure 2.24. This shape reflects the underlying lattice structure of the ionic compound.

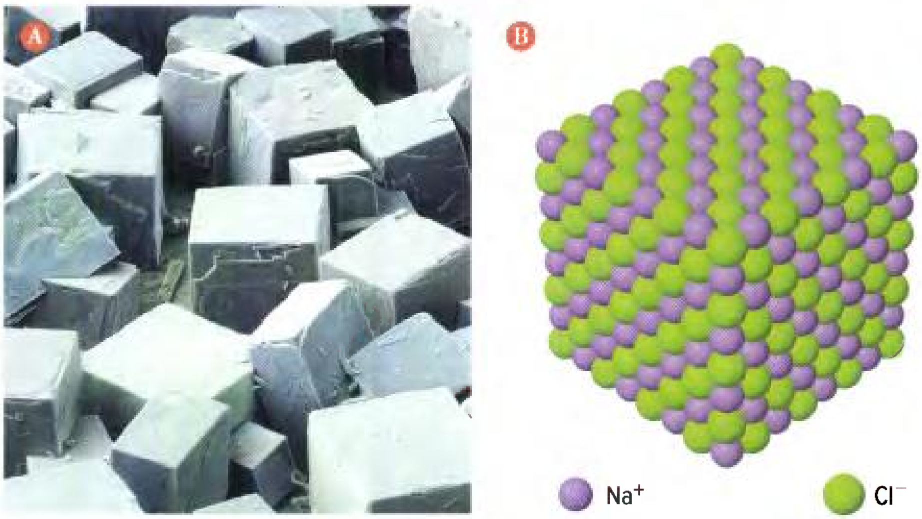


Figure 2.24 A This image shows the cubic structure of sodium chloride crystals. Each crystal contains millions and millions of sodium ions and chloride ions. B Sodium chloride crystals consist of sodium and chloride ions arranged in a repeating pattern. **Sodium chloride is made of charged particles, but the compound overall has no charge. Why?**

Properties of Ionic Compounds

Although ionic compounds have a wide variety of properties, they all have high melting points. They tend to be hard and brittle, breaking along sharp lines. In addition, they are good conductors of electric current when melted or dissolved. These characteristics can all be explained by the structure of ionic compounds.

What are some typical properties of ionic compounds? Ionic compounds ...

- *Have high melting points:* To melt an ionic compound requires overcoming the strong electrostatic forces holding the ions together in the lattice structure of the solid—the ionic bonds. Because these bonds are so strong, a great deal of energy is required to break them. As a result, ionic compounds tend to melt only at very, very high temperatures. For example, the melting point of sodium chloride is 801°C.

- *Are hard and brittle:* Because of the strength of ionic bonds, ionic solids are very hard. But when enough force is applied, the ions will shift out of alignment. This causes ions with the same charge to be close together. The resulting repulsive force pushes the solid apart, as shown in Figure 2.25.
- *Conduct electric current when liquid or dissolved:* Ionic compounds are not electrical conductors in the solid state, as shown in Figure 2.26. Even though they are made of ions, those ions are held rigidly in place, and charged particles that can move are required to conduct an electric current. Ionic compounds dissolved in water or melted ionic compounds do, however, conduct electric current. In those forms, the ions in an ionic compound are free to move and can therefore conduct electric current.

Figure 2.25 When a force strong enough to overcome the strong forces of attraction between oppositely charged ions is applied, ions with like charges come close together. They repel one another and the solid cracks.

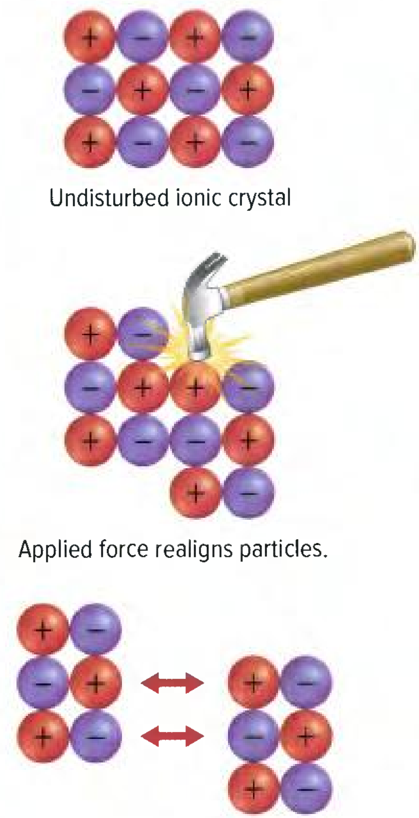
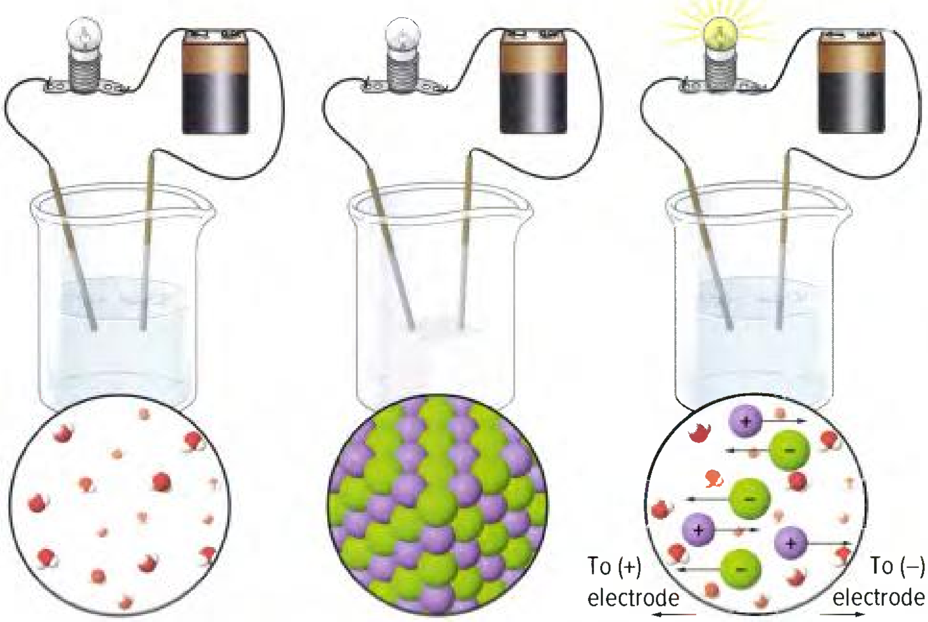


Figure 2.26 Electric current is the flow of charged particles. In solid form, ionic compounds do not conduct electric current because the ions are held tightly in place. But when dissolved in water, ionic compounds are good conductors because the ions are free to move around.

A Distilled water does not conduct a current.

B Positive and negative ions fixed in a solid do not conduct a current.

C In solution, positive and negative ions move and conduct a current.



Before you leave this page . . .

1. What is an ionic bond?
2. Describe the formation of sodium chloride from sodium and chlorine.
3. Binary ionic compounds form when which two types of elements react?
4. When do ionic compounds conduct electric current? Explain.

CONCEPT 3

Covalent compounds are made of molecules.

Activity

Model a Compound

Your teacher will assign you an ionic or covalent compound. Research the structure of the compound. Is it made of molecules? ions? How are they arranged? Then plan how you will make your model. You may choose to use a modelling kit, craft supplies, computer software, beadwork, or collage, for example. Your model should communicate something meaningful about the structure of your compound. Display your model along with a brief description of your compound.

molecule a particle made up of two or more atoms bonded by covalent bonds

covalent bond a strong attraction between atoms that forms when atoms share valence electrons

covalent compound a compound that results when atoms of two or more elements bond covalently

Water, sugar, and carbon dioxide may seem like very different substances. Water is a clear, colourless liquid at room temperature, while sugar is a white solid and carbon dioxide is a colourless gas. But they are all composed of neutral atoms of non-metal elements joined together as molecules. A **molecule** is a particle made up of two or more neutral atoms bonded together by covalent bonds. Unlike ionic bonds, which form when atoms transfer electrons and become ions, **covalent bonds** form when atoms *share* electrons. Covalent bonds and ionic bonds are similar, however, in that they are both very strong. Compounds that form when atoms of two or more elements form covalent bonds are called **covalent compounds**. A molecule of water, a covalent compound, consists of two hydrogen atoms and one oxygen atom bonded together as shown in Figure 2.27.

As shown in Figure 2.28, a covalent bond is similar in some ways to a never-ending tug of war. Each team (atom) tries to pull the rope (shared electrons) toward itself. Neither side wins, and the bond is the rope that connects them. Figure 2.29 on the next page shows some examples of covalent compounds and the molecules that make them up.

Figure 2.27 Water molecules consist of two hydrogen atoms bonded to one oxygen atom.

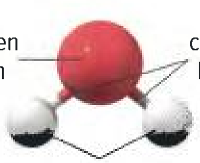
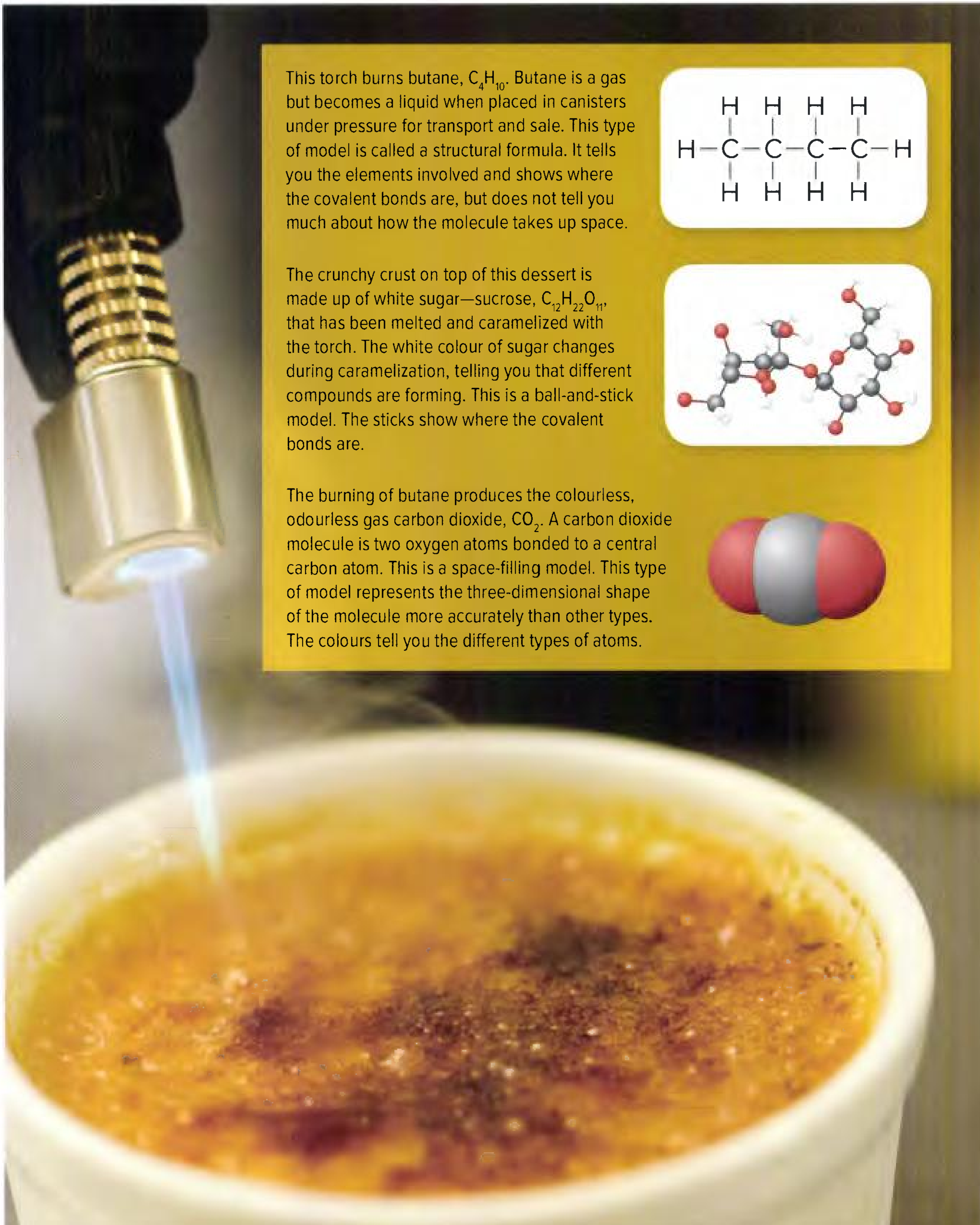


Figure 2.28 A covalent bond is like a tug-of-war in which both atoms attract the shared electrons.

Figure 2.29 Several examples of covalent compounds and the molecules that make them up are shown here using three different types of models. **Which type of model do you find most helpful for understanding the structure of molecules? Explain.**



Achieving Stability by Sharing Electrons

The formation of a covalent compound is based on the same principle as the formation of an ionic compound: namely, the stability that is associated with a full valence shell. Instead of transferring electrons, however, non-metals in covalent compounds achieve a full valence shell by sharing electrons. Figure 2.30 shows how electrons are shared in a molecule of water. Notice that the hydrogen atoms achieve a full valence shell of two electrons, while the oxygen atom achieves a full valence shell of eight electrons. A covalent bond is the result of a single pair of shared electrons. Table 2.4 compares how different types of elements achieve stability in compounds.

Figure 2.30 Each hydrogen atom contributes a single electron to the shared pair of electrons in its covalent bond with oxygen.

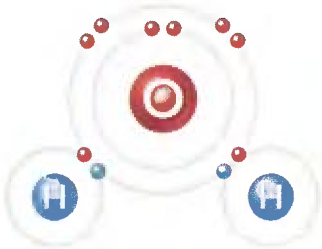
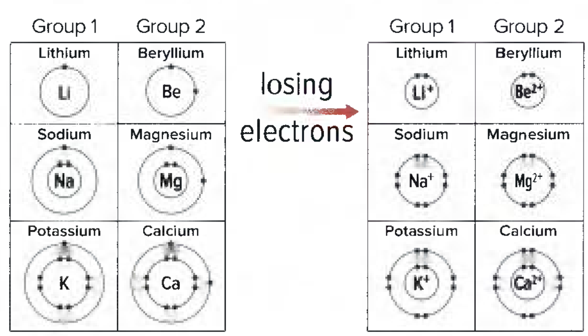
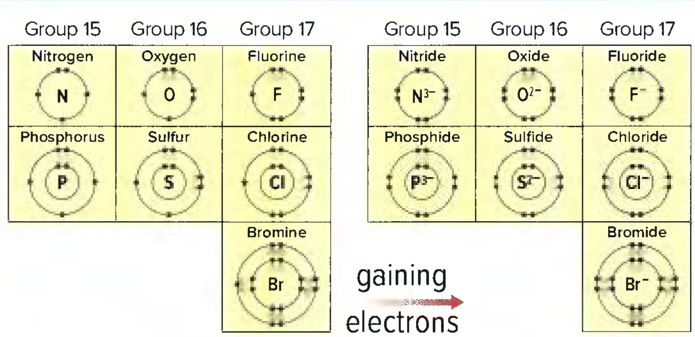
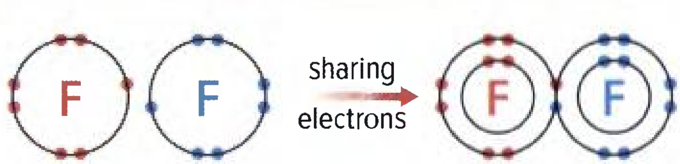


Table 2.4 Three Ways That Atoms Become Stable

1. Metals may lose electrons to form positive ions. The charge on the Group 1 metal ions is 1+ because they have lost one electron. The Group 2 metal ions have a charge of 2+, and the Group 3 metal ions have a charge of 3+.		Metals atoms can lose electrons to achieve a full valence shell. They form positive ions because they lose electrons but retain the same number of protons in the nucleus.
2. Non-metals may gain electrons to form negative ions. The charge on the Group 17 non-metal ions is 1– because they have gained one electron. The Group 16 non-metal ions have a charge of 2–, and the Group 15 nonmetal ions have a charge of 3–.		Non-metal atoms can gain electrons to achieve a full valence shell. They form negative ions because they gain electrons. Non-metal ion names end in "-ide."
3. Non-metals may share electrons.		Non-metal atoms can share electrons with other non-metal atoms to achieve a full valence shell.

Properties of Covalent Compounds

Covalent compounds have widely varying properties. The plastic casing of a ballpoint pen, the components of gasoline, the strongly scented compounds in a banana, and the carbon dioxide that we exhale with every breath are all covalent compounds. But there are some properties that many covalent compounds share, due to their structure at the molecular level. Covalent compounds ...

Connect to Investigation 2-F on pages 152–153

- *Have low melting points:* Although the forces that hold atoms together in molecules are very strong, the bonds that attract one molecule to another in a covalent compound are relatively weak, as modelled in Figure 2.31. When you melt or vaporize a covalent compound, you need to supply enough energy to overcome the attraction between the molecules. Because this attraction is weak, most covalent compounds boil and melt at relatively low temperatures.
- *Are relatively soft:* The weakness of the forces between molecules also explains the relative softness of covalent compounds. Compared with ions in ionic compounds, it is easier for molecules to shift and move relative to one another.
- *Are poor conductors:* Unlike ionic compounds, covalent compounds do not have free electrons or ions, and they are relatively poor conductors of electric current and heat. Figure 2.32 shows an application of this property.

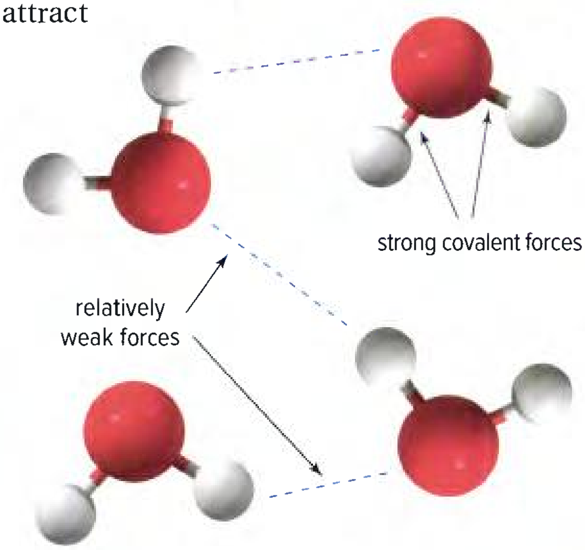


Figure 2.31 The forces that hold atoms together in molecules—covalent bonds—are very strong. Compared with these strong covalent bonds, the forces that hold one molecule to another in a liquid or solid are weak.

Figure 2.32 Covalent compounds are poor conductors of electric current. This makes them useful as insulating covers for computer cables. **Why is it important that covers for electrical wires not conduct electric current?**

Before you leave this page . . .

1. What type of bond is formed when two non-metal atoms share electrons?
2. What is a molecule?
3. Why do covalent compounds tend to have low melting points?

CONCEPT 4

Covalent bonding also occurs in elements and network solids.

Activity

Dare to Pair

What common items can you think of that come in pairs? Write or sketch as many as you can in one minute. Keep these in mind as you learn about paired atoms in molecules on this page. Which images will help you remember what you learn?

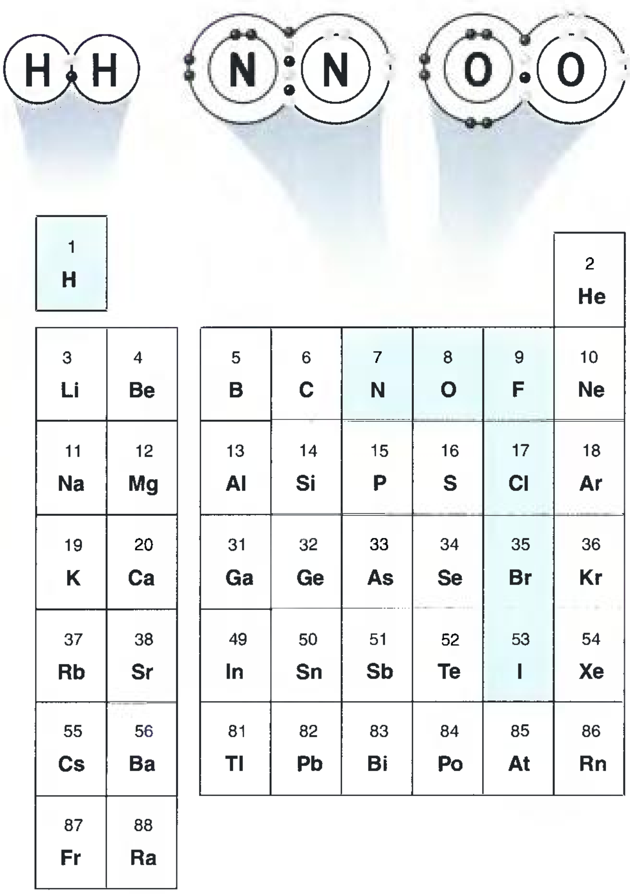


Figure 2.33 Seven of the elements exist as diatomic molecules under normal conditions: H_2, N_2, O_2, F_2, Cl_2, Br_2, and I_2. Bohr diagrams of hydrogen, nitrogen, and oxygen are shown as examples.

Compounds are not the only place where covalent bonds exist. Some elements in their natural form are made up of molecules held together with covalent bonds. Hydrogen, H_2, and all of the common halogens are diatomic molecules when they are isolated as pure elements under normal conditions (F_2, Cl_2, Br_2, I_2). Atoms of these elements share one electron in a covalent bond. Oxygen and nitrogen also exist as diatomic molecules. As shown in Figure 2.33, two oxygen atoms share two pairs of electrons to form two covalent bonds: a *double bond*. Two nitrogen atoms share three pairs of electrons to form three covalent bonds: a *triple bond*.

Atoms of the element sulfur also form molecules. In solid form the molecules have eight sulfur atoms each, S_8. In gaseous form sulfur exists as diatomic molecules, S_2.

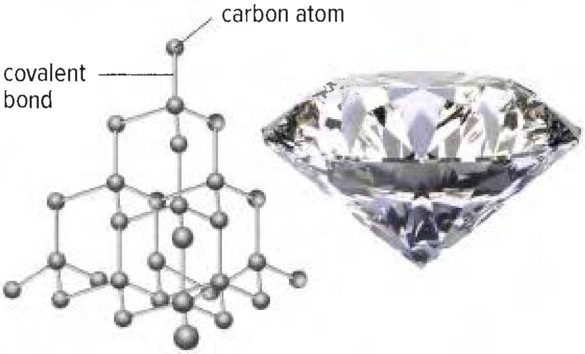
Network Solids

Some compounds and non-metal elements contain covalent bonds that connect their atoms in one large network. Essentially, these substances consist of one giant molecule. Compounds or elements that are bonded in this way are called *network solids*. Silicon dioxide, SiO_2, is an example of a compound network solid. You can see the structure of silicon dioxide in Figure 2.34.

Figure 2.34 A Silicon dioxide, quartz, is a network solid. Its atoms are bonded into a regular, repeating structure by covalent bonds. This model shows a small part of the structure. In real quartz crystals like the ones shown in B, billions of atoms are bonded together in this same repeating structure, forming one giant molecule.

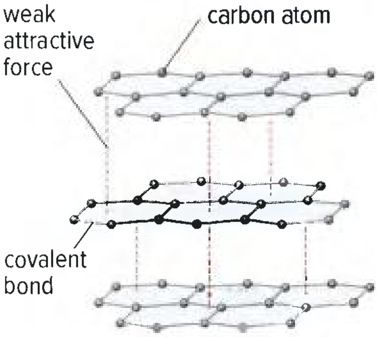
Carbon in the form of diamond is an example of an element that is a network solid. Carbon comes in a number of different forms, including diamond, graphite, and coal. As you can see in Figure 2.35, each carbon atom in a diamond crystal is bonded to four other carbon atoms by covalent bonds, forming an extremely strong three-dimensional structure. In graphite, each carbon atom forms covalent bonds with three other carbon atoms, forming sheets. These sheets are only weakly attracted to one another and can slide past one another. This is why graphite is a good material to use for pencils: as you write on paper, layers of graphite slide off the pencil tip and onto the page.

Figure 2.35 Diamond and graphite both contain covalent bonds but have very different properties due to their structure. **Think about the properties of coal, another form of carbon. How do you think it is structured? Make a prediction, then research to find out.**



Diamond

In a diamond, carbon atoms bond to one another in a three-dimensional network. Because of the strength of the bonds in three dimensions, diamond is an extremely hard material.



Graphite

Graphite is made up of carbon atoms that are each bonded to three other carbon atoms, forming flat sheets. The sheets can slide past one another relatively easily.

Before you leave this page . . .

1. Describe a molecule of hydrogen.
2. Why does neon gas consist of individual, unbonded neon atoms while chlorine exists as diatomic chlorine molecules?
3. What is a network solid?

AT ISSUE Is a synthetic diamond a real diamond?

What's the Issue?

The sparkle of diamonds has long made them prized gemstones. Formed at high pressures and temperatures deep underground, natural diamonds are obtained by mining. Diamond mining is big business, but mining practices can cause environmental and social damage. What if we could just make diamonds in a lab instead?

For well over a hundred years people have been trying to do just that. Several different methods have been tried, including attempts to reproduce conditions underground (the *high-pressure, high temperature* method), and *chemical vapour deposition* in which carbon atoms in a gas are induced to settle layer by layer, forming the network solid structure of a diamond, shown below in comparison with graphite. As technologies improve, synthetic diamonds are hitting the market more and more. Many of these are for practical uses, such as for specialized saw blades or dental tools such as the ones shown here, but synthetic diamonds are also being used for jewellery.

The structure of a synthetic diamond is identical to that of a natural diamond. Is there any way to tell the difference? Should they be worth the same?

Dig Deeper

Collaborate with your classmates to explore one or more of these questions—or generate your own questions of interest to explore.

1. Is there any difference between natural and synthetic diamonds? Can jewellers tell the difference? Why would people want to know which kind of diamond they are getting? Research to explore and discuss natural and synthetic diamonds from a seller, and consumer's points of view.
2. What are some of the social and environmental problems that traditional diamond mines cause? How do different diamond mines compare in terms of their social and environmental impact?
3. What is the difference between a synthetic diamond and a simulated diamond? Give examples of simulated diamonds and explain the difference in their structure. Why are simulated diamonds less costly to buy than real diamonds?
4. Graphite and diamond are two forms of carbon, but they are not the only ones. Carbon can also exist in the form of graphene, fullerene, and nanotubes. Choose one of these and research its structure, how it is made, and its applications.

Check Your Understanding of Topic 2.4

QP Questioning and Predicting · PC Planning and Conducting · PA Processing and Analyzing · E Evaluating · AI Applying and Innovating · C Communicating

Understanding Key Ideas

1. In ionic compounds, Group 1 metals exist as ions with charges of 1+, while Group 2 metals exist as ions with charges of 2+. Why is this? PA C

2. Briefly describe the structure of a crystal of sodium chloride, NaCl. PA C

3. Iodine, I_2, reacts with potassium, K, to form potassium iodide, KI. PA C
   - a) What type of compound is formed? How do you know?
   - b) Describe what is happening to the atoms of potassium and iodine and their electrons during bonding.

4. Someone on the news is talking about the compound magnesium chloride, $MgCl_2$, and refers to "molecules of magnesium chloride." What is wrong with this phrase? E C

5. At room temperature, many covalent compounds exist as liquids or gases, while ionic compounds are all solids. Why is this? PA C

6. Seven elements exist as diatomic molecules. PA C
   - a) List the seven elements.
   - b) Why do the halogens exist as diatomic molecules while the noble gases do not?

7. Classify each of the following compounds as ionic or covalent. Briefly explain your answers. PA C
   - a) lithium fluoride, LiF
   - b) nitrogen triiodide, NI_3
   - c) bromine dioxide, BrO_2
   - d) barium iodide, BaI_2

Connecting Ideas

8. Copy and complete the following table to show the differences between ionic and covalent compounds. Give your table a title. E C

Characteristic	Ionic Compounds	Covalent Compounds
Melting point		
Hardness		
Conductivity		
Types of elements		
Description of bonding		
Three examples		

Making New Connections

9. The conductivity of samples of deionized water, tap water, and ocean water were tested. The results are given below. The higher the value, the higher the conductivity. (Deionized water is water from which ions have been removed.) AI C

Conductivity of Water Samples

Sample	Conductivity
Deionized water	0.000 006
Tap water	0.005–0.05
Ocean water	5

   - a) Which sample conducts electric current the best? The worst?
   - b) Use your knowledge of covalent and ionic compounds to explain these results.

INVESTIGATION

2-F

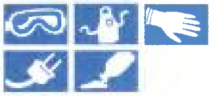
STRUCTURED INQUIRY

Properties of Ionic and Covalent Compounds

Skills and Strategies

- Planning and conducting
- Processing and Analyzing
- Evaluating
- Communicating

Safety



- Review safety rules for working with a hot plate before you begin.

What You Need

- 6 test tubes with stoppers
- 6 samples of compounds
- glass plate or watch glass
- scoop
- plastic water bottle
- hot plate or laboratory burner
- distilled water
- conductivity tester
- tongs

Physical properties such as hardness and melting point can help you classify compounds as ionic or covalent. In this investigation, test six different compounds to determine whether they are ionic or covalent.

Question

How can you use properties to classify compounds as ionic or covalent?

Procedure

1. Label six test tubes A to F. Place samples of six different compounds in the test tubes. Use enough of each compound to fill the rounded bottom of the test tube.
2. Prepare a table like the one shown. It should take up one full page so you have enough space for all your observations. Give your table a title.

Substance	A	B	C	D	E	F
Crush / Hardness						
Melting						
Solubility						
Conductivity						
Total Score						

3. Perform the following tests on each compound. At each test step, analyze all the compounds before moving on to the next test. If a substance responds like a covalent compound, record a score of one (1). If a substance responds like an ionic compound, record a score of zero (0). Also record short, descriptive observations for each test in your table.
4. When you are finished, clean up and dispose of materials as directed by your teacher.

Crush/Hardness Test

Place one or two grains of the compound on a glass plate or watch glass. Press on the compound with a scoop or another metal tool. Ionic compounds withstand considerable force and then crush suddenly into a gritty powder (score 0). Solid molecular compounds are often more flexible and crush like wax or plastic (score 1).

Solubility Test

Each test tube should still contain most of the original substance. Add 10 mL of distilled water to each of the test tubes. Stopper each test tube. Keeping your fingers on the stopper and test tube, gently shake or swirl the water and substance together. Many ionic compounds will dissolve in water, although there are exceptions (score 0). Many molecular solids are insoluble in water (score 1), although again there are exceptions.

Melting Test

Your teacher will use a hot plate or laboratory burner to test whether the compounds will melt. Observe carefully. Among the compounds that do melt, compare the time it took. Do any compounds vaporize? Ionic compounds do not melt except at very high temperatures (score 0). Many covalent compounds melt at relatively low temperatures (score 1).

Conductivity Test

Use a conductivity tester to test the conductivity of the solution in each test tube. When ionic compounds dissolve, the resulting solution will conduct electric current (score 0). When molecular compounds dissolve, the resulting solution will usually not conduct electric current (score 1). Make sure that you clean the probes of the conductivity tester between readings.

Process and Analyze

1. Add up the scores for each compound. A low score, near 0, indicates that a compound is ionic. A high score, near 5, indicates that the compound is covalent. What patterns do you see?
2. If a compound has a score of 2 or 3, use your descriptive observations to help you decide whether it is ionic or covalent.

Evaluate and Communicate

3. Summarize your classification of each substance, including a rationale for each decision.
4. What was the purpose of assigning a number to each test? Did the numbers have any scientific meaning?
5. If you could perform only two tests to identify ionic and covalent compounds, which two tests would you choose? Explain your thinking. If these tests are more important than the others for classifying, how could you reflect that in the scoring system if you were to perform the investigation again?
6. Your teacher will tell you the names and formulas of the compounds. What do the names and formulas tell you, if anything, about the compounds?
7. Examine the element symbols in the chemical formulas. What do you notice about the elements that are in the formulas for the ionic compounds compared to the elements that are in the formulas for the covalent compounds?

TOPIC 2.5

How do we name and write formulas for compounds?

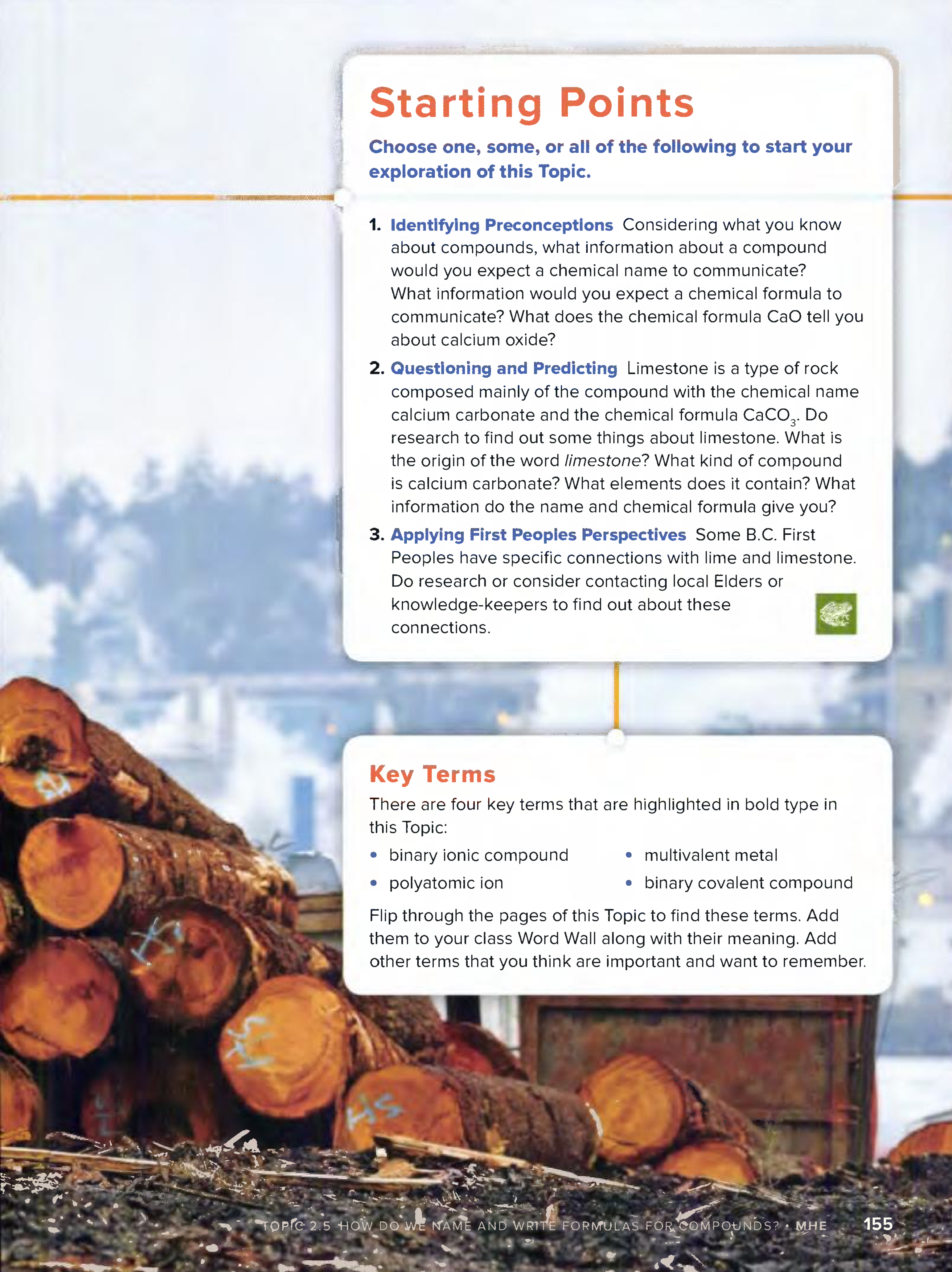
Key Concepts

- The chemical name of an ionic compound communicates its composition.
- You can determine the formula of an ionic compound from its name.
- Multivalent metals form more than one ion.
- Polyatomic ions are made up of more than one atom.
- Names and formulas of covalent compounds reflect their molecular structure.

Curricular Competencies

- Transfer and apply learning to new situations
- Generate and introduce new or refined ideas when problem solving
- Contribute to finding solutions to problems at a local and/or global level through inquiry

What comes to mind when you hear the word *lime*? You may have pictured a small green citrus fruit. But lime is also the common name for a hugely important chemical with a broad variety of applications in farming, the food industry, and pulp and paper manufacturing, to name just a few. Chemists working with the compound lime know that it is an ionic compound composed of calcium and oxygen, but the name *lime*, its common name, does not communicate that. In fact, the fruit lime and the compound lime are not related. The chemical name calcium oxide and the chemical formula CaO, however, clearly describe the composition of the compound.



Starting Points

Choose one, some, or all of the following to start your exploration of this Topic.

1. **Identifying Preconceptions** Considering what you know about compounds, what information about a compound would you expect a chemical name to communicate? What information would you expect a chemical formula to communicate? What does the chemical formula CaO tell you about calcium oxide?
2. **Questioning and Predicting** Limestone is a type of rock composed mainly of the compound with the chemical name calcium carbonate and the chemical formula $CaCO_3$. Do research to find out some things about limestone. What is the origin of the word *limestone*? What kind of compound is calcium carbonate? What elements does it contain? What information do the name and chemical formula give you?
3. **Applying First Peoples Perspectives** Some B.C. First Peoples have specific connections with lime and limestone. Do research or consider contacting local Elders or knowledge-keepers to find out about these connections.

Key Terms

There are four key terms that are highlighted in bold type in this Topic:

- binary ionic compound
- polyatomic ion
- multivalent metal
- binary covalent compound

Flip through the pages of this Topic to find these terms. Add them to your class Word Wall along with their meaning. Add other terms that you think are important and want to remember.

CONCEPT 1

The chemical name of an ionic compound communicates its composition.

Activity

Names in Everyday Life

Names are important in every part of our lives. Write a few sentences to explain the importance of names in each of the following aspects of your life. Why are clear, unique names important in each case?

- Getting around: streets, cities, towns, landmarks
- Communicating: conversation, social media, messaging
- Consuming: product and brand names; names of medications; names of books, songs, and movies

The large bulging mass around the person's neck in Figure 2.36 is called a goitre. These growths are caused by iodine deficiency. Goitres are uncommon today in developed countries because compounds containing the iodide ion, such as potassium iodide, KI, are added to our table salt. Before iodized table salt, goitres were common in Europe, but they were never common among coastal Aboriginal peoples of British Columbia. Why not? Traditional foods of coastal peoples include seaweed, a rich source of iodine. Potassium iodide is an example of a binary ionic compound. In chemistry, *binary* means "composed of two elements." **Binary ionic compounds** are composed of ions of one metal element and ions of one non-metal element joined by ionic bonds.

binary ionic compound
a compound made up of ions of one metal element and ions of one non-metal element

Figure 2.36 When a person does not take in enough iodine, their thyroid gland swells in an attempt to absorb as much iodine as possible, resulting in a goitre. To prevent iodine deficiency, iodine is added to table salt in the form of compounds containing the iodide ion, such as potassium iodide. Seaweed contains other compounds that include the iodide ion.

Names of Binary Ionic Compounds

The name of a binary ionic compound comes from the names of its elements, as described below.

- The first part of *potassium iodide* names the positive ion, potassium, K^+. The positive ion is always a metal in a binary ionic compound. The positively charged metal ion is always named first. Its name is the same as the name of its element.
- The second part of *potassium iodide* names the negative ion, iodide, I^- The negative ion in a binary ionic compound is always a non-metal. The name of the negative ion in a binary ionic compound always ends with the suffix *-ide*. The negative ion of iodine is iodide.

Common negative ions of non-metals are shown in **Table 2.5**. The periodic table also lists ion charges.

Table 2.5 **Ions of Non-Metals**

Element	Ion	Symbol	Group
fluorine	fluoride	F^-	17
chlorine	chloride	Cl^-	17
bromine	bromide	Br^-	17
iodine	iodide	I^-	17
oxygen	oxide	O^{2-}	16
sulfur	sulfide	S^{2-}	16
selenium	selenide	Se^{2-}	16
nitrogen	nitride	N^{3-}	15
phosphorus	phosphide	P^{3-}	15

Extending the Connections

Where do the naming rules come from?

The international system for naming chemicals is maintained by the International Union of Pure and Applied Chemistry (IUPAC). Research to find out more about IUPAC, its history, its systems, and its members.

Before you leave this page . . .

1. Each of the following pairs of elements react to form a binary ionic compound. What is the name of the compound in each case?
   a) lithium and oxygen
   b) calcium and fluorine
   c) magnesium and sulfur
   d) rubidium and bromine
2. What is the difference between the name of a non-metal element and the name of the negative ion it forms?

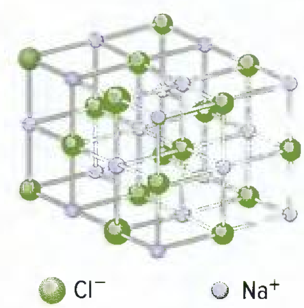
CONCEPT 2

You can determine the formula of an ionic compound from its name.

Activity

Ion Ratios

This diagram represents a crystal of sodium chloride. How does the structure of sodium chloride relate to its chemical formula? Follow these steps to find out:



1. Count the total number of ions of each element.
2. Compare the total number of positive ions with the total number of negative ions.
3. What is the ratio of positive ions to negative ions for each compound?
4. The chemical formula of sodium chloride is NaCl. The chemical formula of calcium chloride, another ionic compound, is $CaCl_2$. What ratio of ions would you expect to see in calcium chloride?

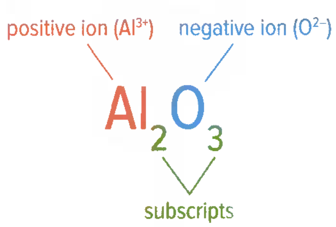


Figure 2.37 Formulas for ionic compounds are always written with the positive ion first and the negative ion second. In binary ionic compounds, the positive ion is a metal ion and the negative ion is a non-metal ion.

The chemical formula of a binary ionic compound contains element symbols to identify each ion. The positively charged metal ion comes first and the negatively charged non-metal ion comes second, as shown in Figure 2.37. Some formulas have small numbers, called subscripts, written to the right of one or both symbols. The subscripts indicate the ratio of each type of ion in the compound. If no subscript is shown, you assume the number to be 1. For example, the formula Ag_2O means Ag_2O_1. The chemical formula for an ionic compound represents the smallest repeating part of the crystal lattice. This unit is called the *formula unit* for that compound. Examine Figure 2.38 to see some examples of chemical formulas of binary ionic compounds, and their meanings.

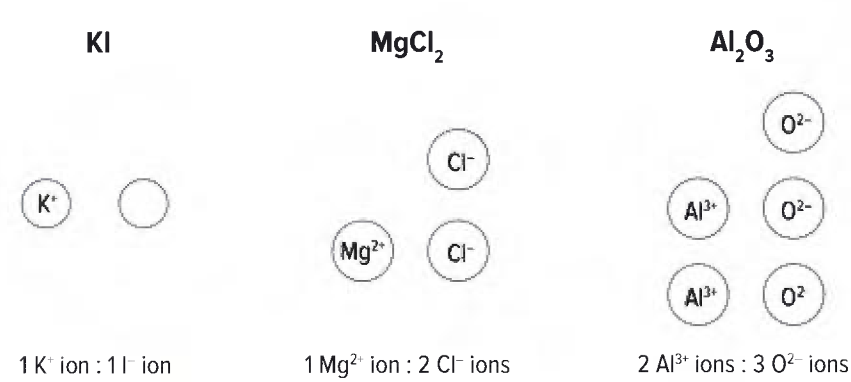


Figure 2.38 The subscripts in chemical formulas of ionic compounds tell you the ratio of the ions in the compound.

Writing Formulas of Ionic Compounds

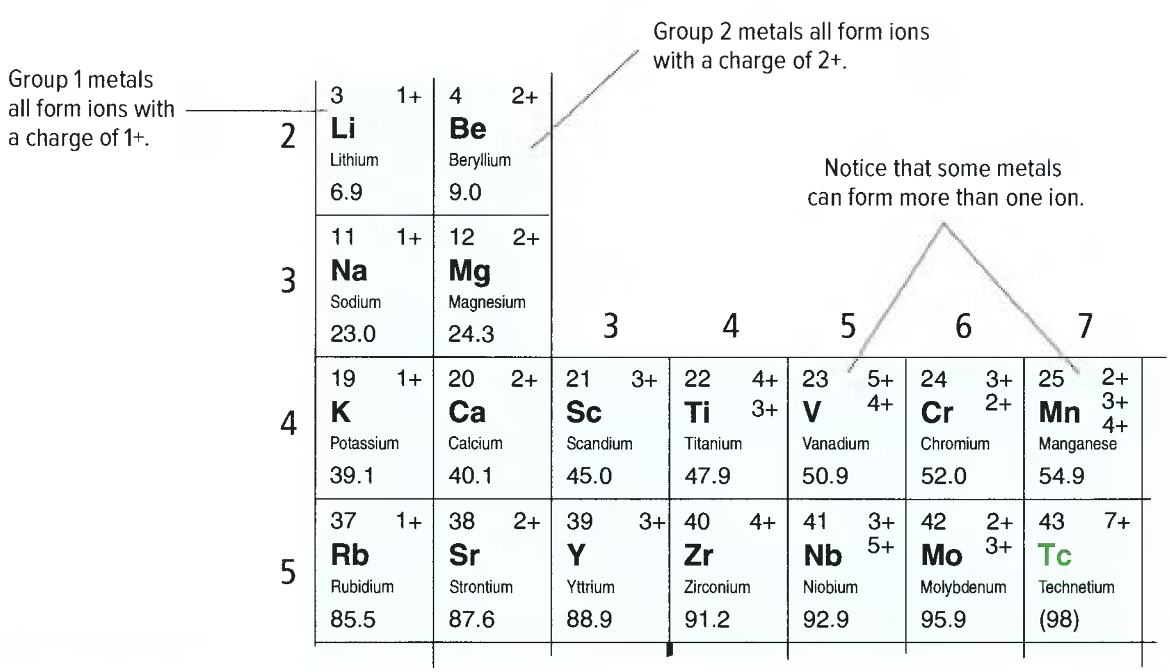
Although an ionic compound is made up of ions, overall the compound is electrically neutral—it has no charge. So the positive charges on the metal ions must balance the negative charges on the non-metal ions. For example, in aluminum oxide, there are two aluminum ions, Al^{3+}, and three oxide ions, O^{2-}. What is the total charge?

Charge from Al^{3+} ions	Charge from Cl^{-} ions
There are 2 aluminum ions in the formula, each with a charge of 3+. $2 \times (3+) = 6+$	There are 3 oxide ions in the formula, each with a charge of 2−. $3 \times (2-) = 6-$

Total charge: $(6+) + (6-) = 0$

When writing the formula of a binary ionic compound, you first need to determine the charges on the ions. Table 2.5 lists the ions of non-metals. For metals that form only one type of ion, all you need to do to figure out the ion charge is to look at the periodic table, as shown in Figure 2.39. (You can find the charges for non-metal ions on the periodic table, too.) Once you know the charges, you can figure out the formula.

Figure 2.39 The periodic table lists the charges of ions commonly formed by the various elements.



Sample Problem

Writing the Formulas of Ionic Compounds

What are the chemical formulas of each of these compounds?

a) calcium chloride

b) aluminum sulfide

Solutions

a) calcium chloride

1. Identify each ion and its charge.

Calcium is a Group 2 metal, so its ion charge is 2+: Ca^{2+}

Chlorine is a Group 17 non-metal, so its ion charge is 1−: Cl^{-}

2. Determine the number of ions needed to balance positive charges with negative charges. In this case, two chloride ions are needed to balance the positive charge on a calcium ion.

Charge from Ca^{2+}	Charge from Cl^{-}
A calcium ion has a charge of 2+. $1 \times (2+) = 2+$	A chloride ion has a charge of 1−. Therefore, two chloride ions are needed to balance the charge of one calcium ion. $2 \times (1-) = 2-$

3. Use subscripts to write the formula. Remember to write the metal ion first. Do not include a subscript if the subscript would be "1."

The formula for calcium chloride is $CaCl_2$.

b) aluminum sulfide

1. Identify each ion and its charge.

From the periodic table, the aluminum ion is Al^{3+}.

Sulfur is a Group 16 non-metal, so its ion charge is 2−: S^{2-}

2. Determine the number of ions needed to balance positive charges with negative charges. In this case, two aluminum ions are needed to balance the charges on three sulfide ions.

Charge from Al^{3+}	Charge from S^{2-}
An aluminum ion has a charge of 3+. The lowest common multiple of 3 and 2 is 6. To get 6+, multiply 3+ by 2. $2 \times (3+) = 6+$	A sulfide ion has a charge of 2−. To get 6−, multiply 2− by 3. $3 \times (2-) = 6-$

3. Use subscripts to write the formula. Remember to write the metal ion first.

The formula of aluminum sulfide is Al_2S_3.

Practice Problems

1. Write the formulas of the ionic compounds containing the following ions.
   a) Na^+ and Br^-
   b) K^+ and S^{2-}
   c) Zn^{2+} and I^-
   d) Mg^{2+} and N^{3-}

2. Write the formulas of the following ionic compounds.
   a) sodium iodide
   b) zinc oxide
   c) magnesium chloride
   d) potassium selenide
   e) silver sulfide
   f) aluminum iodide
   g) aluminum phosphide
   h) barium phosphide
   i) calcium sulfide
   j) rubidium bromide

3. Silver iodide has a crystal structure similar to ice and can cause water to freeze. It has been used in rainmaking experiments, in which it is released into clouds to try to induce precipitation. A silver iodide generator is shown in Figure 2.40. What is the chemical formula of silver iodide?

Figure 2.40 Silver iodide generators are designed for cloud seeding.

Extending the Connections

A Grain of Salt

Sodium chloride, ordinary table salt, is probably the most familiar of ionic compounds. Although salt is inexpensive and plentiful today, this was not always the case. Why was salt so expensive in the past? Where did people get salt in the past? How do we get salt today? What is the role of sodium chloride in the human body? What happens when you get too much? Choose one or more of these questions to investigate.

Connect to Investigation 2-G on page 174

Before you leave this page . . .

1. What is a formula unit and how does it relate to the formula for an ionic compound?
2. Even though ionic compounds are made up of charged particles, they are electrically neutral. Why is this?

CONCEPT 3

Multivalent metals form more than one ion.

multivalent metal a metal element that can form two or more types of ions with different charges

As you can see when you examine the periodic table, some metals form more than one type of ion. Such metals are called **multivalent metals**. For example, copper can form ions with a 1+ or 2+ charge, as shown in Figure 2.41. To distinguish between the ions, a Roman numeral is written after the name of the metal. For example, Cu^{+} is written as copper(I), pronounced "copper one." Cu^{2+} is written as copper(II), pronounced "copper two." On the periodic table, the ion charges for a given element are listed with the most common charge at the top and the least common charge at the bottom.

Figure 2.41 Although both of these compounds contain copper and oxygen, copper(II) oxide, CuO, is black and copper(I) oxide, Cu_2O, is red.

Naming and Writing Formulas for Ionic Compounds Containing Multivalent Metals

To write the chemical formula of a multivalent metal, follow the same process as for the binary ionic compounds you have been naming so far. The only difference is that you cannot tell the charge on the metal ion by looking at the periodic table because there is more than one choice. Instead, look at the Roman numeral in the name, which will tell you the charge.

The Roman numerals for charges 1+ through 7+ are given in Table 2.6. For example, the name chromium(III) chloride tells you that the chromium ion in the compound is Cr^{3+}. The chloride ion is Cl^{-}. For a neutral compound, there must be three chlorine ions for every one chromium ion, so the formula is $CrCl_3$. When naming a compound that contains a multivalent ion, you must include a Roman numeral to show which charge the ion has. Sample Problem on the next page shows how.

Table 2.6 Roman Numerals

Metal Ion Charge	Roman Numeral
1+	I
2+	II
3+	III
4+	IV
5+	V
6+	VI
7+	VII

Sample Problem

Naming an Ionic Compound with a Multivalent Metal

The compound Fe_2O_3 is the main source of iron in the making of steel, which in turn is used for a huge number of applications, from cutlery to freighters like the one shown in Figure 2.42. Pure Fe_2O_3 is reddish in colour and is used as a pigment in paints. What is the name of Fe_2O_3?

Solution

1. Identify the ions.
   - The ion of iron may be either Fe^{2+} or Fe^{3+}.
   - The ion of oxygen is O^{2-}.
2. Determine the ratio of ions in the compound.
   - According to the formula, the compound has 2 iron ions for every 3 oxide ions.
3. The negative charges and the positive charges must be equal in magnitude for the compound to be electrically neutral. Determine which of the two possible iron ions achieves this balance.
   - Since there are 3 oxide ions, there is an overall negative charge of 6−.
   - Since there are 2 iron ions, they must each have a charge of 3+ to give an overall positive charge of 6+.
4. Write the name of the compound using a Roman numeral to indicate the charge of the metal ion.
   - The name of Fe_2O_3 is iron(III) oxide.

Figure 2.42 The iron compound Fe_2O_3, also called hematite, is the source of most iron used to make steel today. The rust that forms on iron and steel is a form of Fe_2O_3 combined with water.

Practice Problems

1. Write the names of the compounds with the following ions.
   a) Co^{3+} and O^{2-}
   b) Cu^{+} and Br^{-}
   c) Cu^{2+} and Cl^{-}
   d) Mn^{4+} and S^{2-}
2. Write the names of the following compounds. Each contains an ion of a multivalent metal.
   a) FeO
   b) Cu_3N
   c) SnS_2
   d) Sn_3N_2
   e) Ni_2S_3
   f) $MoCl_3$
   g) PbF_4
   h) TiS_2

Before you leave this page . . .

1. Explain why copper is able to form two different compounds with oxygen.
2. Why are Roman numerals included in the names of multivalent metal ions?

CONCEPT 4

Polyatomic ions are made up of more than one atom.

Activity

Research a Polyatomic Ion

Work in groups. Your teacher will assign you one of the polyatomic ions in Table 2.7. For your ion, conduct research to answer the following questions:

1. What is the shape of your ion? Use a kit or craft supplies to make a model.
2. What are two compounds in which your ion is found?
3. Choose one compound from question 2 and find out more about it. What are its properties? Is it found in nature? Does it have any applications?

Figure 2.43 Shellfish use calcium carbonate to make their shells. The carbonate ion is shown here.

polyatomic ion an ion made up of two or more covalently bonded atoms

Limestone is an important industrial mineral that is obtained from quarries in several locations around British Columbia. Limestone is made of an ionic compound called calcium carbonate, $CaCO_3$, which is also the compound that shells such as those shown in Figure 2.43 are made of. The carbonate ion, CO_3^{2-}, is composed of carbon and oxygen atoms. An ion that, like carbonate, is composed of two or more atoms is a **polyatomic ion**—essentially, a charged molecule. Compounds containing polyatomic ions are not binary compounds because they always contain at least three elements. But like binary compounds, compounds containing polyatomic ions are named by writing the name of the positive ion followed by the name of the negative ion.

There are a limited number of polyatomic ions that regularly occur in compounds. You can look up their names, formulas, and charges in a table such as Table 2.7. Notice that the only positively charged polyatomic ion listed is the ammonium ion, NH_4^+.

Table 2.7 **Names, formulas, and charges of some common polyatomic ions**

1+ Charge	1− Charge	2− Charge	3− Charge
ammonium, NH_4^+	acetate, CH_3COO^-	carbonate, CO_3^{2-}	phosphate, PO_4^{3-}
	chlorate, ClO_3^-	chromate, CrO_4^{2-}	phosphite, PO_3^{3-}
	chlorite, ClO_2^-	dichromate, $Cr_2O_7^{2-}$	
	hydrogen carbonate, HCO_3^-	peroxide, O_2^{2-}	
	hydroxide, OH^-	sulfate, SO_4^{2-}	
	nitrate, NO_3^-	sulfite, SO_3^{2-}	
	nitrite, NO_2^-		
	permanganate, MnO_4^-		

Sample Problem

Writing Chemical Formulas of a Compound with a Polyatomic Ion

Calcium nitrate is a key component of nitrogen-containing fertilizers. Nitrogen-containing fertilizers are important in increasing the yield of farms, but can also cause problems when an excess of nitrogen enters waterways. What is the formula of calcium nitrate?

Solution

1. Identify each ion and its charge. Use Table 2.7 (or another table of polyatomic ions) to find the formula of the polyatomic ion.

   calcium: Ca^{2+} nitrate: NO_3^-

2. Determine the number of ions needed to balance positive charges with negative charges. In this case, two nitrate ions are needed to balance the charge on calcium.

Charge from Ca^{2+}	Charge from NO_3^-
A calcium ion has a charge of 2+. $1 \times (2+) = 2+$	A nitrate ion has a charge of 1−. Therefore, 2 nitrate ions are needed to balance the charge of one calcium ion. $2 \times (1-) = 2-$

3. Use subscripts to write the formula. *If the polyatomic ion is going to take a subscript, use parentheses to enclose the polyatomic ion before adding the subscript, as shown.* This shows that the nitrate ion is a unit, and that there are two of them for each calcium ion. The formula of calcium nitrate is $Ca(NO_3)_2$.

Practice Problems

1. Write the formula of each of the following compounds.
   - **a)** barium nitrate
   - **b)** potassium carbonate
   - **c)** nickel(II) sulfate
   - **d)** magnesium phosphate
   - **e)** sodium dichromate
   - **f)** iron(II) chromate
   - **g)** lead(IV) acetate
   - **h)** ammonium sulfate

2. There is an error in each of the formulas of the following ionic compounds. Explain the error and correct each formula.
   - **a)** sodium phosphate, Na_3P
   - **b)** magnesium nitrate, $MgNO_3^{2-}$
   - **c)** potassium sulfite, KSO_3^-
   - **d)** sodium hydroxide, $Na(OH)$
   - **e)** ammonium chloride, NH_3Cl
   - **f)** sodium acetate, $Na(CH_3COO)_2$
   - **g)** potassium dichromate, $(K)_2Cr_2O_7$

Before you leave this page . . .

1. What is a polyatomic ion?
2. How are parentheses used in writing formulas containing polyatomic ions?
3. Give the names and chemical formulas of two different polyatomic ions that contain nitrogen and oxygen.

AT ISSUE What happened at B.C.'s molybdenum ghost town?

What's the Issue?

About 180 km northwest of Terrace sits Kitsault, a modern-day ghost town that has been abandoned for over 30 years. In 1979, Kitsault was built as an instant town to provide a home for workers at the nearby molybdenum mine. The town was meant to be a community that workers and their families would call home year round. It offered apartments and family housing, shops, recreation centres, a theatre, a library, and even a hospital. Yet just three years later, the 1200 people living in Kitsault abandoned the town nearly overnight. Since then, caretakers have looked after the buildings and properties, many of which look eerily as if residents had just stepped out for a breath of fresh air.

Dig Deeper

Collaborate with your classmates to explore one or more of these questions—or generate your own questions to explore.

1. Find out more about what happened to Kitsault in the past, and what is happening there now.
   a) Why was Kitsault abandoned? What did molybdenum have to do with it?
   b) What is the status of the mine and town today?
2. Molybdenum is a multivalent transition metal. In nature it is found in the form of various compounds (minerals) in rocks. All of Canada's molybdenum is mined in British Columbia. In what forms is molybdenum found in nature? What are some uses of molybdenum? Where is it currently mined in British Columbia and how? What effects does the mining have on local people and the environment?
3. The town of Kitsault lies within the traditional territory of the Nisga'a Nation. What sort of concerns do you think that First Peoples living near the molybdenum mine might have and why? Find out how any concerns have been addressed by the Nisga'a Nation.

Chemistry Connections

hazardous waste technician

chemistry teacher

occupational safety officer

What kinds of jobs are there for people interested in elements and compounds?

toxicologist

pharmacologist

Materials Engineer

Put your natural scientific curiosity and innovative mind to the test as a materials engineer. These experts spend their days researching and manipulating the properties of metals and other materials.

Chemistry Teacher

Organized, energetic, and passionate about chemistry: if this describes you, then you might have what it takes to be an inspiring chemistry teacher.

Forensic Scientist

It may not be the thrill-a-minute job you see on television, but if you are patient and detail-oriented, you may enjoy forensic science, a field that uses chemistry to help settle legal cases.

Questions

1. What other jobs and careers do you know or can you think of that involve working with chemicals or studying chemical reactions?
2. Research a job or career related to Unit 2 that interests you. Explain what attracted you to it. What kinds of things do you have to know, do, and understand for this job or career?

CONCEPT 5

Names and formulas of covalent compounds reflect their molecular structure.

Activity

Chemical Formulas of Covalent Compounds

Your teacher will provide models of each of the following compounds:

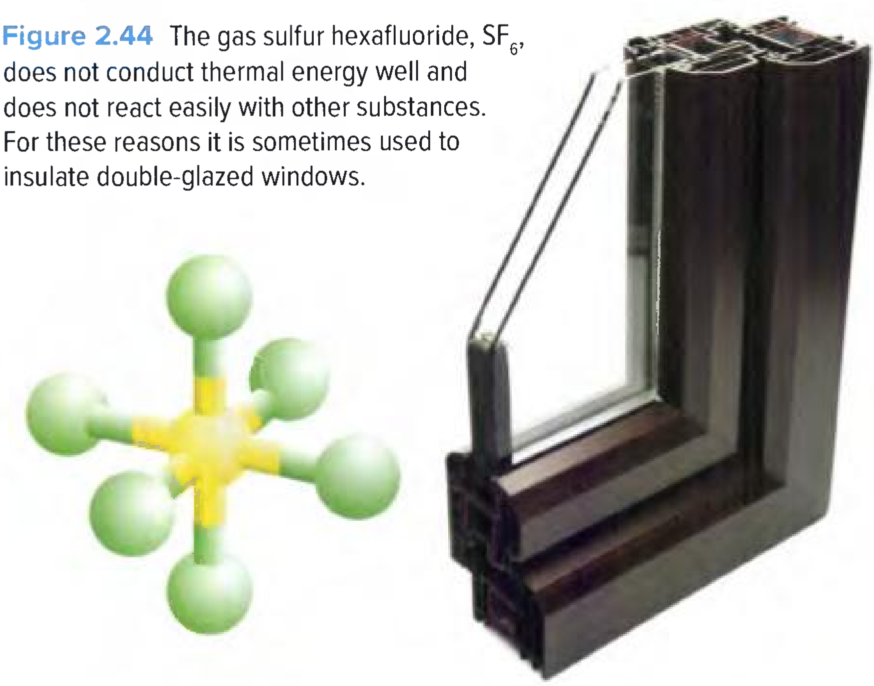
water, H_2O	carbon monoxide, CO
hydrogen peroxide, H_2O_2	propane, C_3H_8
carbon dioxide, CO_2	glucose, $C_6H_{12}O_6$

Sketch the models in your notebook. For each compound, compare the molecular model with the formula. What do chemical formulas of covalent compounds represent? How do they differ from ionic compounds? Why is the chemical formula of hydrogen peroxide not simplified to HO?

binary covalent compound a compound made up of the atoms of two elements joined by covalent bonds

Like binary ionic compounds, **binary covalent compounds** are made up of two elements only. Chemical formulas of binary covalent compounds indicate how many atoms of each element are present in a single molecule of the compound, as shown for sulfur hexafluoride, SF_6, in Figure 2.44. Like names for ionic compounds, names for binary covalent compounds have two parts—one part for each element in the compound. The following three rules will help you write names and formulas of binary covalent compounds.

Figure 2.44 The gas sulfur hexafluoride, SF_6, does not conduct thermal energy well and does not react easily with other substances. For these reasons it is sometimes used to insulate double-glazed windows.



Writing Names and Formulas of Binary Covalent Compounds

Follow these steps to write the name of a binary covalent compound.

1. The first element in the name and formula of a binary covalent compound is usually the one that is farther to the left on the periodic table.

   Example: In carbon monoxide, CO, carbon comes first because carbon is to the left of oxygen on the periodic table.

2. When naming, the suffix *-ide* is attached to the name of the second element.

   Example: Oxygen is changed to oxide in the name carbon monoxide.

3. When naming, prefixes are used to indicate how many atoms of each type are present in one molecule of the compound. **Table 2.8** lists the first 10 prefixes. The prefix *mono-* is used only for the second element in the name. When there is no prefix, *mono-* is implied, as in carbon monoxide. Also, when *mono-* comes before *-oxide*, an "o" is dropped. Thus, you write *monoxide*, not *monooxide*.

   Example: Using prefixes correctly, the name of CO is carbon monoxide.

   Note that when the addition of a prefix results in two vowels appearing together, the vowel at the end of the prefix is usually dropped. The "i" at the end of the prefixes *di-* and *tri-* are never dropped, however.

   Example: the correct name for PI_3 is phosphorus triiodide.

To write the formula for a binary covalent compound, write the element symbols in the order they appear in the name. Add subscripts based on the prefixes used in the name. Examples are provided in the Sample Problem on the next page.

Table 2.8 Prefixes Used to Name Binary Covalent compounds

Prefix	Number	Prefix	Number
mono-	1	hexa-	6
di-	2	hepta-	7
tri-	3	octa-	8
tetra-	4	nona-	9
penta-	5	deca-	10

Sample Problem

Names and Formulas of Binary Covalent Compounds

Nitrogen and oxygen form a wide variety of different covalent compounds with different properties. Two examples are described below. A third is shown in Figure 2.45.

a) Dinitrogen tetroxide is used in rocket fuels. What is its formula?

b) The toxic brown gas NO_2 is found in smog in urban areas. What is its name?

Figure 2.45 The compound NO acts to widen blood vessels, which can lessen chest pain in heart patients. The patient takes nitroglycerin pills, which react in the body to form NO. **What is the name of the compound NO?**

Solution

a) Nitrogen comes first in the formula, as in the name, because it is to the left of oxygen in the periodic table. The prefix *di* tells you that there are 2 nitrogen atoms and the prefix *tetr-* tells you that there are 4 oxygen atoms. (The *a* in *tetra* was dropped.)

The formula of dinitrogen tetroxide is N_2O_4.

b) Follow these steps to name a binary covalent compound.

1. Name the leftmost element in the formula first.	The first element is N (nitrogen).
2. Name the second element, making sure the name ends with the suffix *-ide*.	The second element is O (oxygen), which becomes *oxide*.
3. Add a prefix to each element's name to indicate the number of atoms of each element in a molecule of the compound. If the first element would get the prefix *mono*, do not include that prefix.	The compound's name is nitrogen dioxide.

The name of NO_2 is nitrogen dioxide.

Practice Problems

1. Write formulas for each of the following covalent compounds.

a) sulfur tetrafluoride

b) disulfur difluoride

c) dinitrogen trioxide

d) oxygen difluoride

e) nitrogen tribromide

f) diiodine hexachloride

2. Write the names of the following covalent compounds.

a) PI_3

b) SO_2

c) SO_3

d) S_2F_{10}

e) CCl_4

f) N_2O_5

g) N_2O

h) NI_3

i) P_2O_5

j) PBr_5

k) As_2S_3

l) ICl_3

Exceptions to the Rules

One important group of compounds breaks the naming rules given in this section. These are the compounds that contain hydrogen. You might think that HCl, for example, would be ionic. It contains hydrogen, found in the same group as the alkali metals, and a halogen. In fact, hydrogen is a non-metal, and HCl is known to be molecular. In its pure form, it is a gas at room temperature.

Although it is a covalent compound, HCl is not named in the same way as other covalent compounds you have encountered so far. Like other binary hydrogen-containing compounds, it is named as though it is an ionic compound. The correct name for HCl is thus hydrogen chloride, not hydrogen monochloride. Similarly, the name of H_2S is hydrogen sulfide, not dihydrogen monosulfide. When these types of compounds are added to water they form acidic solutions. You are probably already familiar with the name "hydrochloric acid," which is what HCl is called when it is dissolved in water.

Compounds containing hydrogen and carbon, such as ethane, C_2H_6, or ethanol, C_2H_5OH, are called *organic compounds*, and these have yet another set of naming rules, which you will encounter if you continue your studies in chemistry.

Figure 2.46 The characteristic smells of strawberries, pineapples, and bananas are due to organic compounds: methyl hexanoate, ethyl butanoate, and isoamyl acetate respectively. These compounds are named according to detailed rules based on their composition and structure.

Extending the Connections

Organic Compounds

Why are organic compounds so called? Are all organic compounds found in living things, like the ones in **Figure 2.46**? Find out the origin of the term *organic* in this context, and give some examples to demonstrate the diversity of organic compounds.

Before you leave this page . . .

1. What does the formula for a covalent compound tell you about the compound?
2. Identify two problems with the name mononitrogen monooxide for the compound NO and correct them.
3. Sketch a model of a molecule of carbon dioxide, CO_2, and carbon monoxide, CO. How do the names and formulas communicate the difference between these compounds?

TAKE a Stand

Make a Difference

What can we do about overconsumption of salt and sugar?

Salt and sugar: these two compounds, one ionic and one covalent, each have profound implications for human health. The media bombards us with different messages about consuming too much of these compounds, but how much is too much? On average, Canadians consume about 1.2 kg of salt and 40 kg of sugar annually. In other words, we consume the mass of a human brain in salt and the mass of four car tires in sugar each year. Are we consuming too much as a society? It would be hard to find an expert who did not think so. Many major health concerns in North America have been linked to overconsumption of these two compounds.

Too much sugar can lead to

- obesity
- heart disease
- diabetes
- tooth decay
- high blood pressure
- cancer
- ageing of the body and brain

Too much salt can lead to

- high blood pressure
- asthma
- osteoporosis
- obesity
- cancer

Changing how much of these compounds we eat and drink isn't always easy. Some foods that seem healthy are hidden sources of salt and sugar. For instance, ketchup actually contains more sugar than the same mass of ice cream. A piece of store-bought bread has a surprisingly large amount of salt in it. Reading nutrition labels can help, but are they clear enough and do they provide enough information?

Evaluate

1. Choose three packaged foods from your home and determine the sugar and salt content. Was this easy to do? How could the information have been clearer? What names were used for salt and sugar?

Analyze and Communicate

2. Choose one health problem related to consuming too much sugar that interests you, and one related to consuming too much salt. Find out more about each one. Do the results of your research leave you concerned about your own personal intake of salt or sugar, or that of family members? Explain your answer.
3. Decide which is more of a hazard, overconsumption of salt or overconsumption of sugar. Explain your position. Then design a plan to increase awareness about the hazards of overconsumption of salt or sugar at your school or at your home. Include strategies for reducing consumption.

Check Your Understanding of Topic 2.5

QP Questioning and Predicting PC Planning and Conducting PA Processing and Analyzing E Evaluating
AI Applying and Innovating C Communicating

Understanding Key Ideas

1. What ending do all binary compounds share, whether they are ionic or covalent compounds? PA C

2. Examine the following list of compounds. Which of these are binary compounds? $AlCl_3$, H_2O, CNO, $C_6H_{12}O_6$, MgS, PbF_2, $NaHCO_3$, NaOH PA E

3. Write the names of the ionic compounds that form when the following elements react. PA C
   a) silver and chlorine
   b) oxygen and zinc
   c) beryllium and iodine
   d) fluorine and magnesium

4. Write formulas for each of the following compounds. PA C
   a) iron(II) nitride
   b) lead(II) oxide
   c) copper(I) sulfide
   d) tin(IV) fluoride

5. Write formulas for each of the following compounds. PA C
   a) nitrogen dioxide
   b) sulfur trioxide
   c) dinitrogen tetroxide
   d) phosphorus pentachloride

6. Name each of the following compounds. PA C
   a) $AlPO_4$
   b) Na_2CO_3
   c) $KHCO_3$
   d) $Mg(OH)_2$
   e) NH_4Cl
   f) $Na_2Cr_2O_7$

7. Identify the charge on the metallic ion in the following ionic compounds. Then name the compound. PA C
   a) PbO_2
   b) CuS
   c) CrF_3
   d) FeN

Connecting Ideas

8. Chromium is a transition metal used in chrome plating. PA E C
   a) What ions does chromium form?
   b) List the formulas and names of the possible binary ionic compounds chromium could form with oxygen and with fluorine.

Making New Connections

9. Seawater contains large quantities of dissolved ions, including sodium, calcium, magnesium, chloride, and bromide ions.

   a) List all of the binary ionic compounds that could form from these ions. Give the chemical name and formula for each.
   b) Which ions would you predict to be present in the greatest quantity in a sample of seawater? Explain your prediction and do research to check.
   c) Come up with an additional question about the ions in seawater and research to answer your question. QP PA C

INVESTIGATION

2-G

GUIDED INQUIRY

How can you make a game out of names and formulas of ionic compounds?

Apply your creativity and knowledge to design a game to let you and your classmates practise naming and writing formulas for ionic compounds.

Skills and Strategies

- Planning and Conducting
- Processing and Analyzing
- Evaluating
- Communicating

What You Need

(suggested)

- craft materials
- computer access

Question

How can you design a game based on names and formulas of ionic compounds?

Procedure

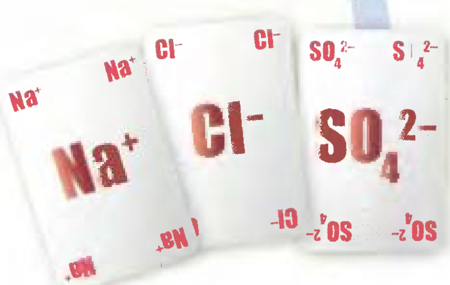
1. Work in groups to come up with a game that involves the names and formulas for ionic compounds. Ask the following questions as you design your game:
   - What type of game will it be? a card game? a board game? a puzzle game? a computer game? a dice game?
   - What ions will you include in your game?
   - How will you include opportunities for naming and making formulas?
   - What will the rules for your game be?
   - What pieces will you need to make, if any?
2. Make a plan and produce your game.

Process and Analyze

3. Test your game several times within your group. Make adjustments to the game rules and pieces as necessary.
4. Set up a games café within the class. Teach other groups how to play your game and try out the games of other groups. Offer feedback on game play, accuracy of science content, and quality of game components.

Conclude and Communicate

5. Which was your favourite game, and why?
6. What worked well about the game you designed? If you were to try to market your game to science classrooms, what changes would you make, and why?



INVESTIGATION

2-H

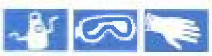
STRUCTURED INQUIRY

Colours of Ionic Compounds

Skills and Strategies

- Planning and Conducting
- Processing and Analyzing
- Evaluating
- Communicating

Safety



- Some of these compounds are toxic. Do not remove them from their vials.

What You Need

- 8 vials of ionic compounds labelled with formulas
- 8 vials of ionic compounds labelled with names

Although the majority of common ionic compounds are white (as powders) or clear and colourless (as crystals), some compounds are coloured. The colour in these compounds is due to either the negative or positive ion (or very rarely, to both). By analyzing observations of a variety of compounds with different combinations of ions, we can infer which ion is coloured in a compound. For example, copper(II) nitrate is blue whereas sodium nitrate is white. We can conclude that the nitrate ion is not coloured and that therefore the copper(II) ion is coloured.

Question

How can we use our observations of different ionic compounds to identify coloured ions?

Procedure

1. Make a chart with columns for Formula, Name, and Appearance and eight blank rows. Examine the eight vials of ionic compounds that have the formulas marked on them. Record the formulas. Write the name for each compound after the formula. Also, describe the appearance of each compound, including its colour.
2. Make a chart with columns for Name, Formula, and Appearance and eight blank rows. Examine the eight vials of ionic compounds that have the names marked on them. Write the formula for each compound after the given name. Also, describe the appearance of each compound, including its colour.

Process and Analyze

1. Write the formulas of all the coloured compounds.
2. Inspect the formulas of the coloured compounds. What ions do the colourless or white compounds have in common?

Conclude and Communicate

3. Which positive and negative ions were coloured? Explain your conclusion. What further data could help you feel more confident about your conclusion?

UNIT 2

Summary

ESSENTIAL QUESTION

How do the electron arrangements of atoms determine the chemical and physical properties of elements and compounds?

TOPIC 2.1:
How and why do we study matter?

- Matter and its interactions make up our world.
- Safety is key when working with matter.

Key Terms

matter	pure substance
mixture	element
compound	chemical reaction

TOPIC 2.2:
How does the periodic table organize the elements?

- Elements are the building blocks of matter.
- Elements can be organized by their properties.
- The modern periodic table organizes elements in groups and periods.
- Elements are classified as metals, non-metals, or semi-metals.

Key Terms

group	period	metal
non-metal	semi-metal	

TOPIC 2.3:
How can atomic theory explain patterns in the periodic table?

- The structure of atoms can be represented using simple diagrams.
- Elements in chemical groups have similar electron arrangements.
- The periodic table shows how properties of elements change in predictable ways.

Key Terms

valence shell   valence electrons   ion   periodic trend

TOPIC 2.4:
How do elements combine to form compounds?

- Compounds account for the huge variety of matter on Earth.
- Ionic compounds are made of ions.
- Covalent compounds are made of molecules.
- Covalent bonding also occurs in elements and network solids.

Key Terms

ionic compound   ionic bond   covalent compound
molecule   covalent bond

TOPIC 2.5:
How do we name and write formulas for compounds?

- The chemical name of an ionic compound communicates its composition.
- You can determine the formula of an ionic compound from its name.
- Multivalent metals form more than one ion.
- Polyatomic ions are made up of more than one atom.
- Names and formulas of covalent compounds reflect their molecular structure.

Key Terms

binary ionic compound   polyatomic ion
multivalent metal   binary covalent compound

UNIT 2

Review

What Do You Know?

Connecting to Concepts

Visualizing Ideas

1. As you prepare for an investigation, you read the procedure before starting and see the symbols below. In bulleted list, describe what precautions you would take based on each symbol.

a) 

b) 

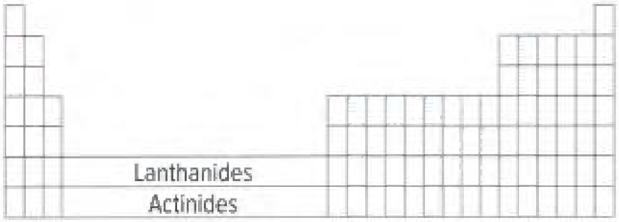
c) 

d) 

e) 

f) 

2. The silhouetted periodic table below shows how it would look with the inner transition metals, the lanthanides and actinides, in their place in the 6th and 7th period. What are the pros and cons of the periodic table being shown in this form, compared with the way you are used to seeing it?



Using Key Terms

3. Draw a concept map that shows the relationship between the following terms.
   - compound
   - element
   - matter
   - mixture
   - pure substance

4. Sketch an outline of the periodic table, and identify the following on your outline.
   - alkali metal
   - alkaline-earth metal
   - group
   - halogen
   - metal
   - noble gas
   - non-metal
   - period
   - semi-metal

Communicating Concepts

5. Draw a Bohr diagram that represents an atom of each of the following elements.
   a) oxygen
   b) neon
   c) lithium

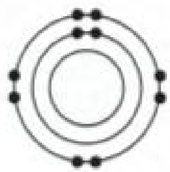
6. Describe the relationship between the reactivity of an element and the number of electrons in the valence shell of each atom of the element.

7. Use this incomplete box from the periodic table to answer the following questions.

12 2+
Mg
24.3

   a) What is the atomic number of the element?
   b) What is the full chemical name of the element?
   c) Draw the Bohr diagram of an atom of this element.
   d) Draw the Bohr diagram of an ion of this element. Explain why the element forms this ion.

8. Use this Bohr diagram to answer the questions below.



a) If this model represents an atom, what element is it? How do you know?

b) If this model represents an ion with a charge of 2+, what element is it? Explain your answer.

c) If this model represents an ion with a charge of 1−, what element is it? Explain your answer.

9. Copy and complete the table below in your notebook.

Properties of Neutral Atoms

Symbol	Atomic Number	Number of Electrons	Number of Protons
Ne			
	3		
Ca			
		18	

10. Use atomic theory to explain why noble gases are inert. Use a Bohr diagram as part of your explanation.

11. Describe two trends in the periodic table. Use examples of elements to support your answer.

12. Write the chemical formulas of each of the following ionic compounds.

a) lithium chloride

b) zinc sulfide

c) copper(II) chloride

d) ammonium acetate

e) manganese(III) nitrate

f) cobalt(II) phosphate

13. The giant crystals shown below are the largest so far discovered on Earth. They formed naturally in extreme conditions (50°C and 100% humidity) in a cave in Mexico called Cueva de los Cristales.

a) The crystals are made up of a compound consisting of calcium ions and sulfate ions. What is the name of the compound?

b) Write the chemical formula for the compound.

c) List at least three properties you would expect these crystals to exhibit.

14. Write the chemical formulas of each of the following covalent compounds.

a) sulfur dioxide

b) silicon tetrabromide

c) phosphorus pentachloride

d) dinitrogen trioxide

15. The vividly-coloured compound below is chromium(III) chloride. Chromium is a multivalent element.

a) What does multivalent mean?

b) What ions can chromium form?

c) Predict all of the different compounds that chromium could form with chlorine. Give their names and formulas.

Unit 2 Review *(continued)*

16. Write the chemical names for the following compounds. Identify each as an ionic or covalent compound.

a) SCl_2 **c)** $NiSO_4$

b) $AlBr_3$ **d)** P_2O_5

17. Compare how an ionic bond forms with how a covalent bond forms. How are they the same? How are they different?

What Do You Know?

Connecting to Competencies

Developing Skills

18. The properties of some common substances are listed below.

Properties of Common Substances

Material	Melting Point (°C)	Soluble in Water	Conducts Electric Current in Solution
Baking soda	decomposes	yes	yes
Cooking oil	–5	no	no
Table salt	801	yes	yes
Lip balm	40	no	no
Candle wax	50	no	no
sugar	170	yes	no
Dishwasher soap powder	851	yes	yes

a) Use the data to classify the substances as ionic or covalent.

b) Are there any substances that cannot be clearly classified as ionic or covalent? If so, explain why.

19. Design a flowchart that you could use to help you write a chemical formula when given the name of a compound. Make sure that your method includes how to write formulas for both ionic and covalent compounds.

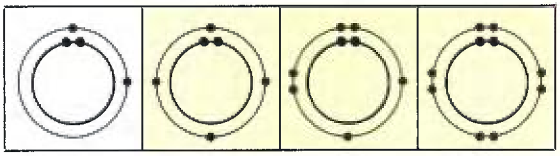
20. List the steps you would take to deal with each of the following situations safely.

a) While you are using a hot plate to heat a liquid, the fire alarm sounds.

b) You are heating a test tube that has liquid in it in using a laboratory burner. You notice that your test tube has a chip near the top.

Thinking Critically and Creatively

21. Diagrams showing the electron arrangements of atoms of five elements are shown below. Use these to answer the following questions.



a) Write the element symbol for each. Explain how you determined what element each diagram represents.

b) Do these elements belong to the same period or the same group? Which common period or group do they belong to? How do you know?

c) Describe a periodic trend of these elements.

22. Compare and contrast the bonding in a diamond crystal and a sodium chloride crystal.

23. The air we breathe is 78 percent nitrogen by mass. Write the chemical formula for nitrogen to show how it exists in air. Is a molecule of nitrogen considered a compound? Explain your answer.

24. Suppose you have been given two different white solids. One is a covalent compound and one is ionic.
   a) Describe three safe tests you could perform to decide which is which.
   b) If you could only perform one test, which one would it be? Explain your answer.

What Do You Know?
Making New Connections

Applying Your Understanding

25. Sucrose (white sugar) dissolves well in water. Would you expect a sugar-water solution to conduct electric current? Explain your answer.

26. Why would wearing gloves made from a covalent compound, such as rubber, help to prevent an electrician from being electrocuted?

Thinking Critically and Creatively

27. Sodium fluoride is added to many toothpastes to help reduce cavities.
   a) What is the chemical formula for sodium fluoride?
   b) Is sodium fluoride an ionic or a covalent compound? How do you know?
   c) Predict at least three properties you would expect sodium fluoride to have.
   d) Describe what happens when sodium and fluorine react to form sodium fluoride.

28. Covalent compounds are also called molecular compounds. Why is this name appropriate?

29. Use a graphic organizer to compare a crystal of diamond and a crystal of sodium chloride in terms of their properties, structure, and composition.

Connecting to Self and Society

30. Make a list of three ionic compounds and three covalent compounds that you use or rely on each day.
   a) Describe the properties of these substances.
   b) How are their properties associated with what they are used for?

31. Electrolytes are substances that exist as ions in solution. Common electrolytes are calcium, magnesium, and sodium. Electrolytes are required for your body to function properly. People lose electrolytes when they sweat.
   a) People who run ultramarathons must take in water to rehydrate and foods with sugar for energy. What else would they need to take in? What kinds of foods could they eat?
   b) In what other situations might a person need to replenish electrolytes quickly? Explain your answer.

32. Refer to "First Peoples Perspectives in Science" on page xxii near the start of the textbook.
   a) Review and reflect on the four themes of interconnectedness, transformation, renewal, and connections with place.
   b) In a journal or in small groups, share ideas about how the concepts you have been learning about in this unit relate to these four themes.

Unit Assessment

What are the effects of mining for metals and industrial minerals in B.C.?

Metals or industrial minerals are part of the electrical wiring that lets you turn on a light or charge a device; the cement used to make a concrete sidewalk or a skyscraper; the glass in a window; paints, textiles, cosmetics, pharmaceuticals, electronics—the list goes on and on.

B.C.'s landscapes are rich in minerals. As a result, mining is an important industry in this province. Metals such as copper, gold, silver, lead, zinc, and molybdenum are all mined here, as well as industrial minerals such as limestone, clay, sand, and gypsum. The properties of these materials determine how we use them. Their properties also determine how they are extracted. Some types of mines and methods have greater effects on the environment and society than others.

Work as part of a group to do the following.

STEP 1 ► Reflect on the three options, their photos, and the question asked for each option.

STEP 2 ► Brainstorm at least three more options and questions of your own about metals or industrial minerals in British Columbia.

STEP 3 ► Decide on one of the six option questions to investigate.

STEP 4 ► Plan and conduct a scientific inquiry to explore your question.

STEP 5 ► Organize and analyze the data and information that you find and collect.

STEP 6 ► Communicate the results of your inquiry in a suitable manner.

Cariboo Gold Rush

OPTION A

Gold-Rush-Era Mining

What were the main events and mining techniques of the Cariboo gold rush, and how do the properties of gold relate?

OPTION B

Impacts of Metal Mining

In what forms are copper, lead, and zinc found, and how does their mining affect the land and people, nearby and beyond?

OPTION C

Industrial Minerals

What are the chemical formulas, properties, extraction methods, and applications of industrial minerals such as limestone and magnesite?

Assessment Criteria

Did I and my group...

- Develop one or more questions that provided opportunities for rich investigation? QP
- Develop effective methods to collect and record reliable data and information? PC
- Apply different ways of knowing to analyze, reflect, and draw meaningful conclusions that are consistent with evidence? PA
- Consider and demonstrate an awareness of assumptions, bias, and social, ethical, and environmental implications over the whole process of our inquiry? E
- Propose alternative courses of thought and/or action that contribute to care for self, others, community, and world? AI
- Construct evidence-based arguments using language, conventions, and representations appropriate for a specific purpose and audience? C

UNIT 3

Electric current is the flow of electric charge

The first generator to provide a constant source of electrical energy was developed in 1844. This development made it possible to use the first practical light bulb, patented in 1879. Less than 150 years later, North America is lit up by so many electrical lights that it can be seen from a satellite at night. Despite the convenience they provide, these lights also have a dark side: light pollution.

> **"Light pollution seems to have a widespread, negative impact on many different species. The evidence for the impact of light pollution in migratory birds, hatchling sea turtles, and insects is striking."**
>
> *Biologist Sharon Wise*

- What electrical devices do you rely on today that did not exist 100 years ago? 200 years ago?
- Modern society uses a huge amount of electrical energy. What are its sources? How does generating and using it affect the environment?
- What questions do you have about this—photo? the quotation? the title for this unit? ...?

UNIT 3

At a Glance

You will demonstrate what you know, can do, and understand by being able to

- Perform investigations to explore how charges behave in specific circumstances
- Develop and use models and other methods to show connections between chemical energy, electrical potential energy, and electrical potential difference
- Seek patterns and connections to describe, explain, and evaluate the relationship between voltage, current, and resistance in a circuit
- Use scientific understandings to describe, explain, and evaluate the development of a sustainable energy system

ESSENTIAL QUESTION

How do we apply our understanding of charges to generate and use electrical energy?

TOPIC 3.1: How is electrical energy part of your world?

Some things you will do:

- co-operatively design projects
- make predictions about inquiry findings
- ensure safety guidelines are followed in investigations

Some things you will come to know:

- Some types of energy can be transformed into electrical energy.
- Electrical energy is generated from different sources.

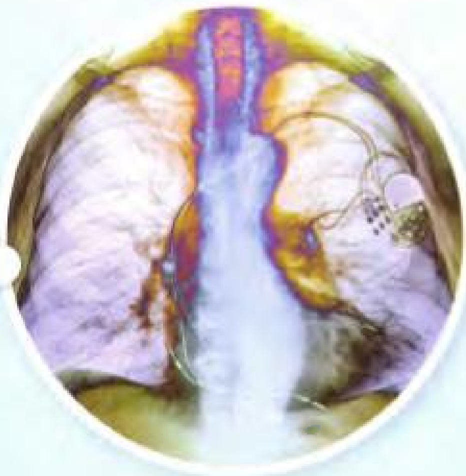
TOPIC 3.2: How do electrical charges behave?

Some things you will do:

- identify questions you have about the natural world
- use scientific understandings to identify relationships and draw conclusions
- reflect on your investigation methods

Some things you will come to know:

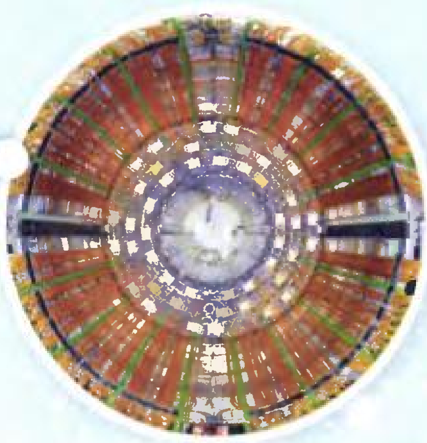
- Charges can transfer from one object to another.
- The law of electric charge describes how charges interact.



TOPIC 3.3:
How do charges flow through the components of a circuit?

Some things you will do:
- observe, measure, and record data
- measure and control variables through fair tests
- connect scientific explorations to careers in science

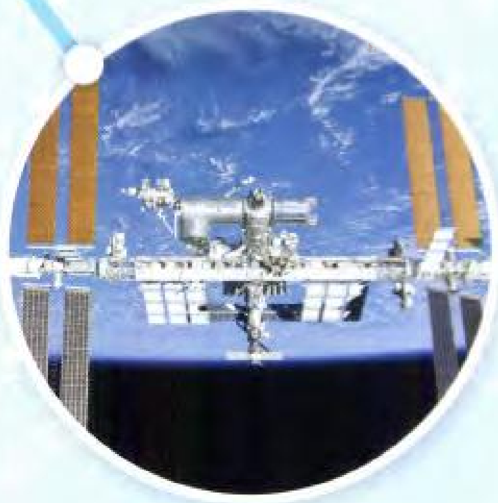
Some things you will come to know:
- Batteries and cells work by separating charges.
- Charges can move more easily through some materials than others.
- Each component in a circuit plays a specific role.



TOPIC 3.4:
How are circuits used in practical applications?

Some things you will do:
- use mathematical formulas to demonstrate relationships between variables
- seek patterns and connections in data
- construct and use a range of methods to represent patterns or relationships in data
- identify a question to answer or a problem to solve through scientific inquiry

Some things you will come to know:
- Ohm's law describes the relationship among voltage, current, and resistance in a circuit.
- Loads can be connected in different ways in a circuit.



TOPIC 3.5:
How can electrical energy be generated and used sustainably?

Some things you will do:
- contribute to care for self, others, community, and the world
- consider Aboriginal perspectives and knowledge
- communicate ideas, information, and a suggested course of action for a specific audience

Some things you will come to know:
- Electrical energy can be generated and used sustainably.
- Some resources for generating electrical energy are renewable and others are not.

TOPIC
3.1

How is electrical energy part of your world?

Key Concepts

- Electrical energy has many applications.
- Many different types of energy can be transformed into electrical energy.
- Electrical energy is generated in different ways from different sources.

Curricular Competencies

- Contribute to care for self, others, community, and world through personal or collaborative approaches.
- Formulate multiple hypotheses and predict multiple outcomes.
- Describe specific ways to improve investigation methods and quality of data.
- Transfer and apply learning to new situations.

Underwater, the shock from an electric eel is strong enough to knock out a full-grown horse. Could this source of energy be harnessed to power electrical devices like a portable media player? Jiwan Toor, a student from Fleetwood Park Secondary School in Surrey, B.C., asked the same question. Working with researchers at UBC, the 16-year-old determined an answer. But it might surprise you. It would take 14 000 eels two hours to recharge a media player. Electrical energy doesn't always act the way you think it might. And since electrical energy is such an essential part of your world, it is definitely important to understand it better.

Starting Points

Choose one, some, or all of the following to start your exploration of this Topic.

1. **Identifying Preconceptions** What do you know about electricity and electrical energy? What questions do you have about them? Discuss your questions as a class.
2. **Communicating** Electric eels are not found off the B.C. coast, but Pacific electric rays are. These fish can knock out a scuba diver. What kind of safety precautions might you take when diving where Pacific electric rays are found? What other safety precautions do you take around electrical energy in the world around you?
3. **Applying First Peoples Perspectives** Since everything is connected, we must have a close relationship with electrical energy. What ways can you think of that show this connection? How are people and electrical energy interdependent? How are people dependent on electrical energy?

Key Terms

There are two key terms that are highlighted in bold type in this Topic:

- electrical energy
- generator system

Flip through the pages of this Topic to find these terms. Add them to your class Word Wall along with their meanings. Add other terms that you think are important and want to remember.

CONCEPT 1

Electrical energy has many applications.

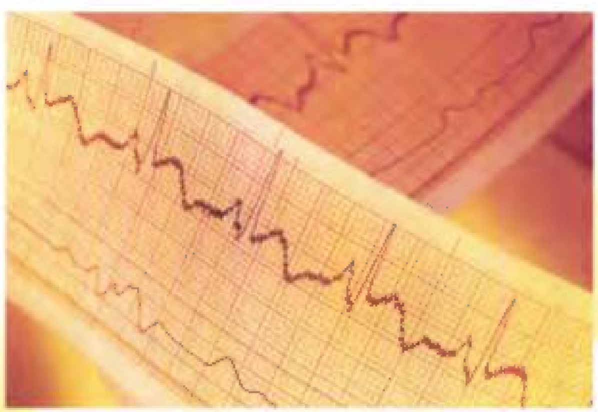
Activity

Power Failure!

What would a day in your life look like without electrical energy? What problems would you encounter, and how would you deal with them? (Yes, boredom is a problem.) Brainstorm with your group. Use your ideas to create a video or skit of what a typical day would be like if the power failed in your community for 48 hours or more.

From the first ring of your morning alarm clock to when you turn the light off to go to bed, your day is filled with different applications of **electrical energy**. Many of these are familiar, like your clock and a light bulb. Others may surprise you. For instance, Figure 3.1 shows how several functions of the human body use electrical energy. It also explores how this energy is harnessed by different types of technology, from robots to levitating trains to neon signs.

Figure 3.1 Some applications of electricity.



You could not read this book without the help of electrical energy, even in the daytime. Moving your eyes to read the page relies on electrical signals in your muscle and nerve cells. Breathing and maintaining a heart beat do, too.

Most touch-sensitive screens are resistive screens. These work a lot like transparent keyboards. The pressure from a touch command completes an electrical pathway. A computer chip inside the tablet then determines the command to be carried out. Other screens, called capacitive screens, actually make your finger part of the electrical pathway. When your finger touches the screen, a tiny electrical charge passes through it. This completes a pathway, and the command is carried out.

Neon signs are familiar sights in most urban centres. In this photo, the orange-red colour is unique to neon gas. When electrical energy causes electrons to pass through neon gas, the electrons collide with neon atoms, transferring energy to them. The atoms then give off some of this energy as visible light of a specific colour: orange-red. Other gases, such as helium, argon, and xenon, are also used in neon signs. The atoms of each gas give off a different colour of light.

Robots are becoming more like humans every day thanks to technology that reacts to electrical signals like your muscles do. Using a flexible plastic that expands and contracts slightly in response to electrical energy, scientists are able to create robots with hand and facial movements that are eerily human.

Train travel at 500 km/h, without an engine, is a reality in many countries, including Japan and Germany. Maglev trains levitate (hover) above electrified coils that run along tracks. The coils create magnetic fields that repel large magnets under the train, causing it to levitate. With no friction between the train and the tracks, the train can travel at very high speeds.

Before you leave this page . . .

1. Describe three ways that you have depended on electrical energy since you woke up this morning.

CONCEPT 2

Many different types of energy can be transformed into electrical energy.

Activity

Electrical Energy Detective

Where does the electrical energy used in your community come from? Discuss your ideas as a class. If you are not sure, how can you find out?

Energy is neither created nor destroyed. Instead, it is transformed from one kind of energy into another kind of energy. The electrical energy that runs your phone, hair dryer, and other electrical devices was transformed from another type of energy. Several types of energy are reviewed in Figure 3.2. Each can be transformed into electrical energy.

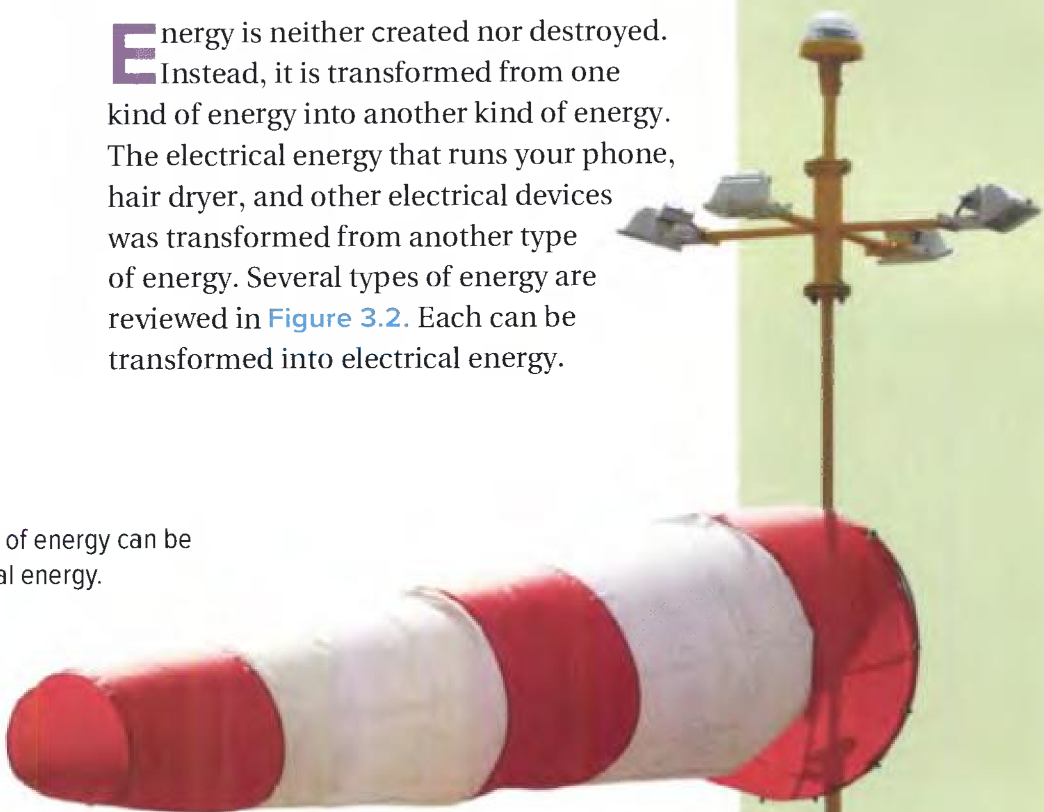
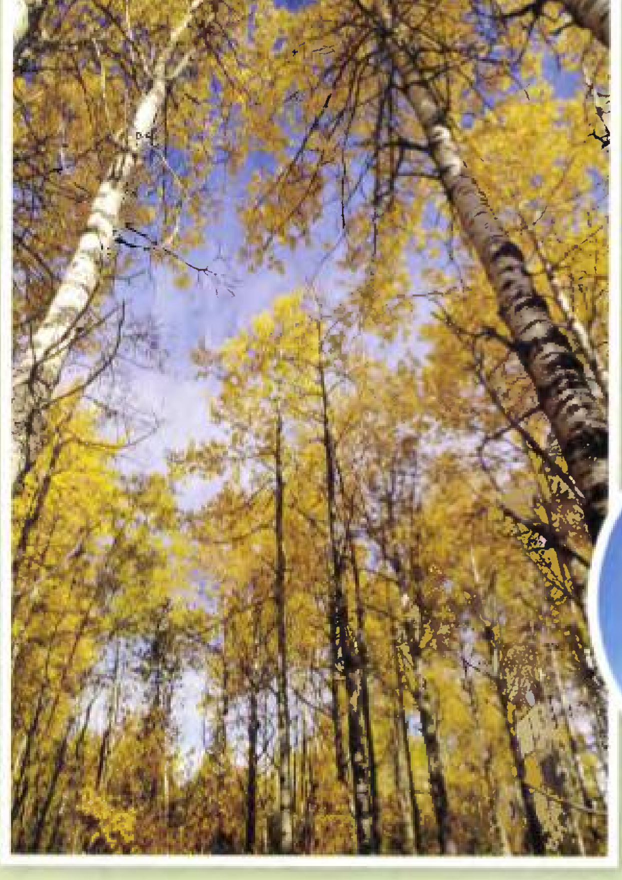


Figure 3.2 Many types of energy can be transformed into electrical energy.

Mechanical Energy *Mechanical energy* is the sum of kinetic energy and potential energy. *Kinetic energy* is the energy of motion. Any moving object has kinetic energy, even air. *Potential energy* is stored energy that a system has due to its position or condition. For example, the water at the top of a waterfall, just before it falls, has *potential energy* because of its position, and kinetic energy because it is moving. The potential energy is converted into more kinetic energy as the water falls due to gravity.



Chemical Energy

Chemical energy is stored in chemical bonds. It is released when a chemical reaction occurs. Batteries store chemical energy. Chemical energy stored in animals and in plants, such as these trees near Bowron Lake Provincial Park, is called biomass. Fossil fuels (coal, oil, natural gas) also store chemical energy.

Solar Energy

Solar energy is energy carried by electromagnetic radiation given off by the Sun. Fossil fuels and biomass are the result of energy from the Sun being captured by plants and plant-like organisms.

Nuclear Energy

Nuclear energy is generated by forming new atoms. In *nuclear fusion*, new atoms are made as smaller atoms collide and fuse. Fusion reactions occur in the Sun and other stars. In *nuclear fission*, new atoms are made by splitting larger atoms. Fission reactions are carried out in reactors on Earth.

Thermal Energy

Thermal energy is the energy due to the rapid motion of particles that make up an object. We detect it as heat. It can come from many sources, such as nuclear reactions or from Earth's interior (geothermal energy), where steam and hot water form naturally. These are seen in geysers, volcanoes, and hot springs, like those at Liard River Hot Springs Provincial Park shown here.

Before you leave this page . . .

1. Explain the difference between kinetic energy and potential energy.
2. Describe the relationship among solar energy, biomass, and fossil fuels.

CONCEPT 3

Electrical energy is generated in different ways from different sources.

Activity

Charge It

You are at school working on a group science project late one afternoon. An unexpected snowstorm hits your region. It knocks out all the electrical energy, and none of the school phones work. It looks like you may be here a while. Luckily the cafeteria is stocked with food, and you have warm clothing. You do have one cellphone, but it needs to be charged. As a group, brainstorm how you could charge the phone to tell your families that you are safe. You can only use materials and objects found in your school. When you are done, share your ideas as a class.

Many different types of energy can be transformed into electrical energy, but how? Several different methods are explored in this Concept.

Kinetic Energy to Electrical Energy

Most of the electrical energy in Canada is generated by transforming kinetic energy into electrical energy. The source of kinetic energy may be moving water or wind. It may also be moving steam produced by thermal energy generated in nuclear reactions, or by burning fossil fuels. In each case electrical energy is generated using a **generator system**. Figure 3.3 shows a model of a simple generator system. The system has three parts: a *turbine*, a *shaft*, and a *generator*.

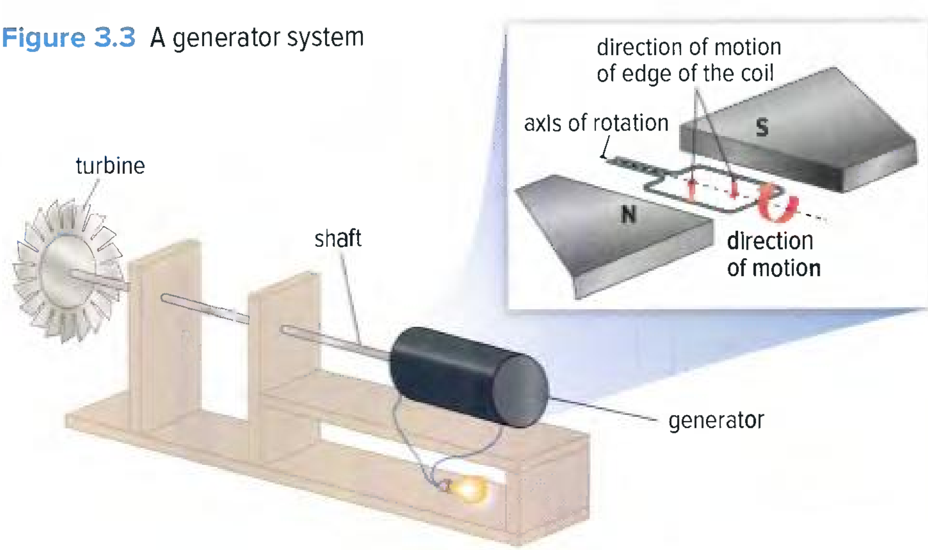
generator system a system that transforms kinetic energy to electrical energy

Turbine: Steam, water, or wind cause the turbine to spin.

Shaft: The shaft connects the turbine to the generator. As the turbine spins, it makes the shaft spin.

Generator: The kinetic energy of the spinning shaft is transformed into electrical energy inside the generator. This happens when energy from the shaft turns a wire loop or coil. A magnet surrounds the rotating wire, as shown in the inset. As the wire turns, electrons flow in the wire. This flow of electrons powers electrical devices.

Figure 3.3 A generator system



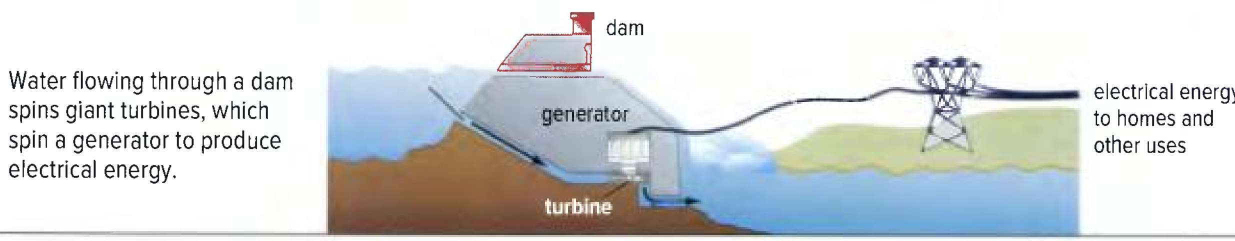
Generating Electrical Energy in Canada

Most of the electrical energy used in Canada comes from river flow, fossil fuels, and nuclear reactions. In B.C., river flow is the main source. B.C. also uses fossil fuels to generate electrical energy, but it has no nuclear reactors. **Figure 3.4** outlines how river flow, fossil fuels, and nuclear reactions generate electrical energy.

Figure 3.4 Comparing how river flow, fossil fuels, and nuclear reactions generate electrical energy

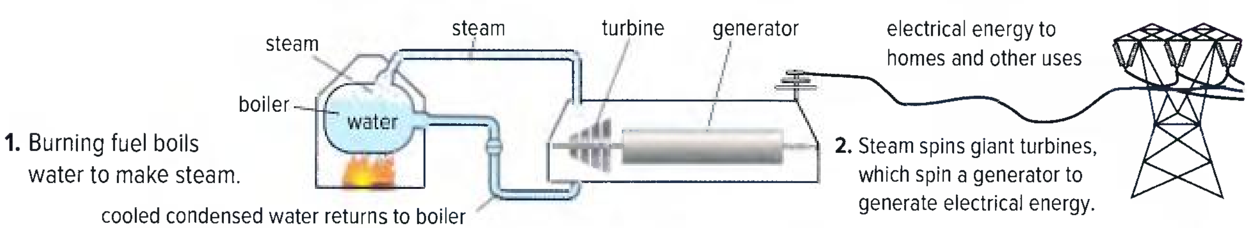
Hydroelectric Energy from River Flow

Electrical energy from river flow is called *hydroelectric energy*. Two systems generate hydroelectric energy. At the dam station below, water stored behind the dam has potential energy. As it flows downhill, it gains kinetic energy, which turns a turbine connected to a generator. At a run-of-river station, water flowing freely in a river turns a turbine.



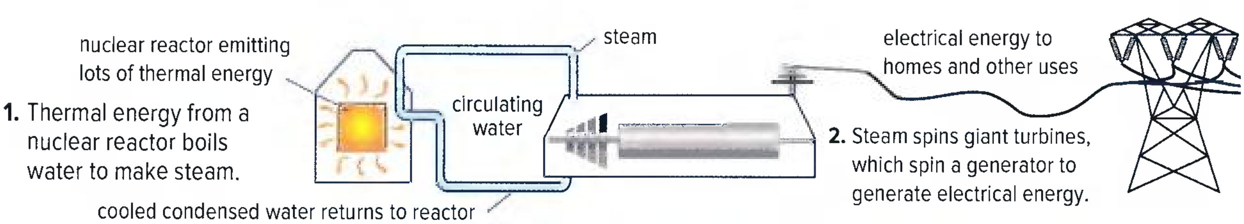
Electrical Energy from Fossil Fuels

In the generating station shown here, thermal energy from burning coal is used to boil water into steam. Pressure associated with the moving steam turns the blades of turbines connected to generators.



Electrical Energy from Nuclear Reactions

Inside a nuclear reactor, uranium or plutonium atoms undergo fission reactions. Splitting one atom sets off a chain reaction that causes more atoms to split. The nuclear reactor contains and controls these reactions and the energy they release. Most of this energy is thermal energy, which is used to boil water into steam. Pressure associated with the moving steam turns turbines connected to generators.



Generating Electrical Energy from Other Energy Sources

Connect to Investigation 3-A on page 200

Transformation of kinetic energy from wind and solar energy to electrical energy is on the rise in B.C. and Canada as a whole. These processes are described in Figures 3.5 and 3 6. Geothermal sources, waves, and tides are small players now, but they hold promise for the future. These sources are described in Figure 3.7 and Figure 3.8.

Figure 3.5 A wind turbine and generator transform kinetic energy to electrical energy.

Electrical Energy from Wind

The kinetic energy of wind is transformed into electrical energy as the moving air turns the turbine of a generator system. The most common type of wind turbine in Canada is mounted on a high tower to take advantage of greater wind speeds higher above the ground. This height also reduces turbulence from wind blowing around buildings.

A wind turbine starts to produce electrical energy when wind speed is about 13 km/h. Gears on the shafts increase the speed of the generator. This process increases until wind speed reaches about 55 km/h. For safety, a controller shuts the turbine down when the wind speed reaches 90 km/h. An anemometer is used to measure wind speed.

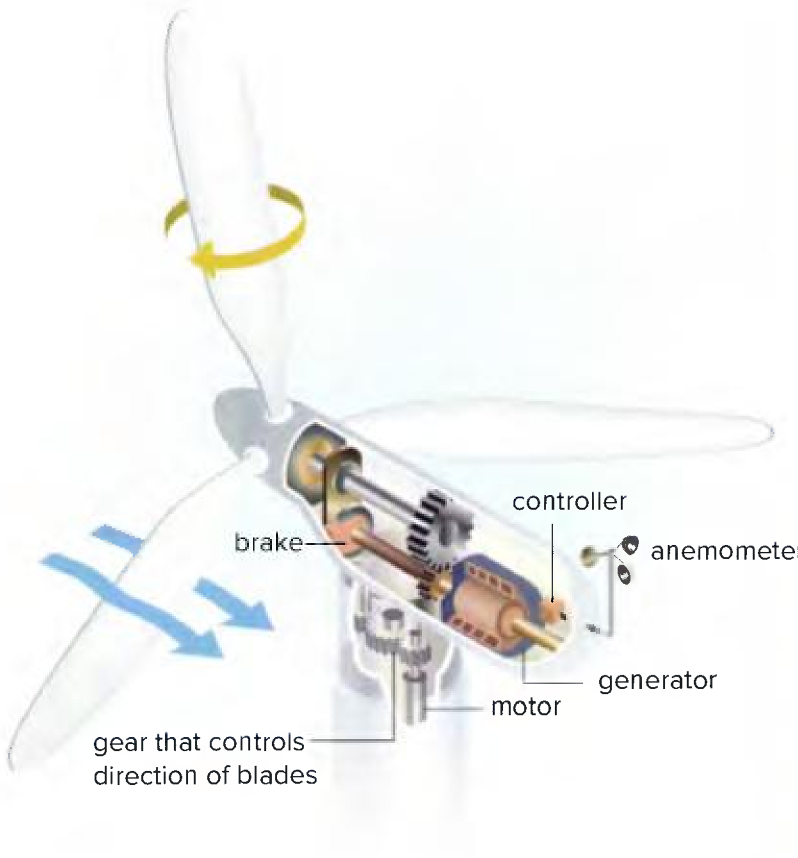


Figure 3.6 A photovoltaic cell transforms solar energy to electrical energy.

Electrical Energy from Sunlight

Some materials produce electrical energy when they are exposed to light. This is called the *photovoltaic effect*. Photovoltaic cells generate electrical energy when visible light strikes their surfaces. The cells are made of thin layers of silicon crystals. When visible light strikes electrons trapped in the cells, the electrons absorb just enough energy to flow freely and generate electrical energy. The Sun emits enormous amounts of solar energy, but converting this energy to electrical energy is a challenge. Currently, photovoltaic cells only transform the energy of visible light to electrical energy. However, scientists are working to create cells that transform other types of electromagnetic radiation into electrical energy.

Figure 3.7 A geothermal generating station transforms thermal energy to kinetic energy to electrical energy.

Electrical Energy from Geothermal Sources

Where Earth's crust is thin and molten rock comes close to the surface, hot steam can be used to turn turbines to generate electrical energy. Some parts of the world have greater access to geothermal sources than others. For instance, the volcanic island nation of Iceland generates 25% of its electrical energy from these sources.

Figure 3.8 A tidal generating station transforms kinetic energy from tides to electrical energy.

Electrical Energy from Waves and Tides

The vertical rise and fall of the waves can compress an air column, which turns a turbine. The B.C. coast is considered one of the best places to generate electrical energy from waves. Tides can spin turbines to produce electrical energy. However, they are only effective where they vary by 5 m or more. At high tide the gates of the tidal generating station shown here close and trap water in a basin. When the tide goes out, the water is directed through pipes to turn a turbine. Such stations only generate electrical energy for about 10 hours a day, as the tide moves in or out.

Activity

What Are the Properties of an Ideal Energy Source?

1. In small groups, make a list of properties of an energy resource that you think makes it the best for all or most possible uses. Note: You are not being asked to name which source you think is best. Your task is to create a list of the most desirable properties that an energy resource should have.
2. Share your group's list with other groups in the class. See if your class can agree on a list of properties that make the ideal energy source.
3. Assess each energy source in this Concept with your final list. In your mind, which source is closest to being an ideal energy source? Explain.

Before you leave this page . . .

1. List the three key parts of a generator system. Briefly describe their functions.
2. Use a flowchart to explain how moving water can generate electrical energy.

TAKE Action

Make a Difference

People Power

British Columbia: Max Donelan of Simon Fraser University has designed a device that transforms human-generated energy into electrical energy. The PowerWalk® Kinetic Energy Harvester is secured around the knee. Each time we take a step, our leg muscles speed the movement of the leg and then slow it down at the end of the step. The Harvester could harvest the energy of leg motion at all times, but walking would become tiring. Instead, it extracts energy only when the muscles are slowing leg motion, making walking easier. How much electrical energy can be generated this way? An hour of walking can charge up to four smartphones.

Japan: Something unique happens when special materials, called *piezoelectric materials*, are compressed or pulled. The mechanical energy associated with the force or stress is transformed into electrical energy. Piezoelectric materials include quartz crystals, some ceramics, amber, and even cane sugar (although the crystals break too easily to be used in applications). It is possible to use these materials and human energy to generate electrical energy on a large scale. For instance, the floors in several Japanese subway stations are made out of piezoelectric materials. As people walk on the floor, they compress the materials, which generates electrical energy.

Apply and Innovate

1. Come up with some possible applications for the two examples discussed in this feature. What factors would you need to consider?
2. Ann Makosinski, a 15-year-old student in B.C., designed a flashlight that transforms human body heat (thermal energy) into electrical energy.
   a) Why would this and other human-powered electrical devices be especially useful to people and communities in developing countries?
   b) Find out more about initiatives that are bringing human-powered electrical energy to people in developing nations. Choose a specific project. How could you get involved? Come up with an action plan.

Check Your Understanding of **Topic 3.1**

QP Questioning and Predicting PC Planning and Conducting PA Processing and Analyzing E Evaluating
AI Applying and Innovating C Communicating

Understanding Key Ideas

1. Describe the role electrical energy plays in robotics. PA AI C

2. Identify the type of energy associated with each source below. PC
   a) the Sun
   b) river flow
   c) a battery
   d) wind
   e) uranium
   f) hot springs
   g) garbage

3. Use a table to compare the similarities and differences among the use of river flow, the burning of fossil fuels, and nuclear reactions to generate electrical energy. PA E C

4. Some photovoltaic cells, like the ones shown below, are mounted on towers that let them follow the Sun's path. What is the advantage of such designs? PA E AI

5. Consider a coastal community QP E AI
   a) Describe two cases in which a tidal generating system would be a good choice for the community.
   b) Describe two different cases in which a wind turbine would be a good choice.

Connecting Ideas

6. Imagine that a wind turbine has a faulty controller. Predict a problem that could arise as a result of this manufacturing defect. QP PA E AI

7. You are waiting outside school for a friend. It is a cold day in January, and you reach into your bag for your gloves and phone. You are early and decide to send a text while you wait. However, the screen is not responding to your touch commands. You take off your gloves and find that your screen now works. What type of touch screen do you most likely have and why did it not work when you wore gloves? PA E AI

8. Photovoltaic cells are commonly used to provide electrical energy for satellites. Suggest an advantage that photovoltaic cells might have in space, compared with similar cells on Earth. PA E AI

Making New Connections

9. Imagine there was a large-scale power failure that left your region without electricity for two weeks during the summer months. E AI C
   a) What would be the most serious consequences for you and for your community?
   b) How might the problems be different if the event took place in January?
   c) What alternative energy sources, if any, could be used?

INVESTIGATION

3-A

GUIDED AND OPEN INQUIRY

Skills and Strategies

- Questioning and Predicting
- Planning and Conducting
- Processing and Analyzing
- Evaluating
- Communicating

Safety

- Handle the meter with care.
- Use construction tools carefully.

What You Need

- 5 m of insulated copper wire (about 26 gauge)
- 2 alligator clips
- cardboard tube
- powerful bar magnets
- galvanometer
- other materials as determined by your design
- access to information resources (for example: online, in-print, interviews)

Investigating Generators and Turbines

PART A: BUILD AND TEST A SIMPLE GENERATOR—GUIDED INQUIRY

A generator uses a magnet and a coil of wire to transform kinetic energy into electrical energy.

Question

How can you investigate which factors affect the amount of electrical energy produced by a simple generator?

Procedure

1. Leaving about 15 cm for a lead at both ends of the wire, make a coil of about 25 turns by wrapping the wire around a cardboard tube. Remove the tube from the coil.
2. Strip the insulation off each end of the wire. Then connect the ends to the galvanometer with alligators clips. The galvanometer measures electrical activity.

3. While closely monitoring the meter, insert one end of the magnet into the coil and then pull it out. Record any movement you observe on the meter.
4. With your partner, brainstorm how you could increase the reading on the meter. Record your ideas. For each variable you decide to test, write a hypothesis to predict which possible outcome you think will occur.
5. Test your ideas and record your results.

Process and Analyze

1. Which condition or combination of conditions that you tested recorded the most electrical activity? Why do you think this was the case?

Evaluate

2. Were you surprised by your results? Explain.

PART B: DESIGN AND BUILD A TURBINE OR GENERATOR—OPEN INQUIRY

In Part B, your team will create a working turbine or generator based on your own design. If you build a generator, you can use the simple generator you built in Part A as a springboard, but your design must be your own. Think wind, water, human-generated energy, or any other source available to you.

Question

Read the Procedure. Determine the question that you will investigate.

Procedure

1. What questions do you have about how you could design, build, and test a turbine or generator? Brainstorm and record your ideas.
2. Use information resources to investigate answers to your questions.
3. Based on your research, develop a materials list, safety guidelines, and procedure for a specific turbine or generator that you will build. Your teacher must approve your plan before you build your device.
4. Once approved, build your device.
5. Test your device. Troubleshoot any problems that arise.

Evaluate

1. Did your device work as you expected? Why or why not?
2. If you were to repeat this investigation, what would you do differently? Explain why.

TOPIC 3.2

How do electrical charges behave?

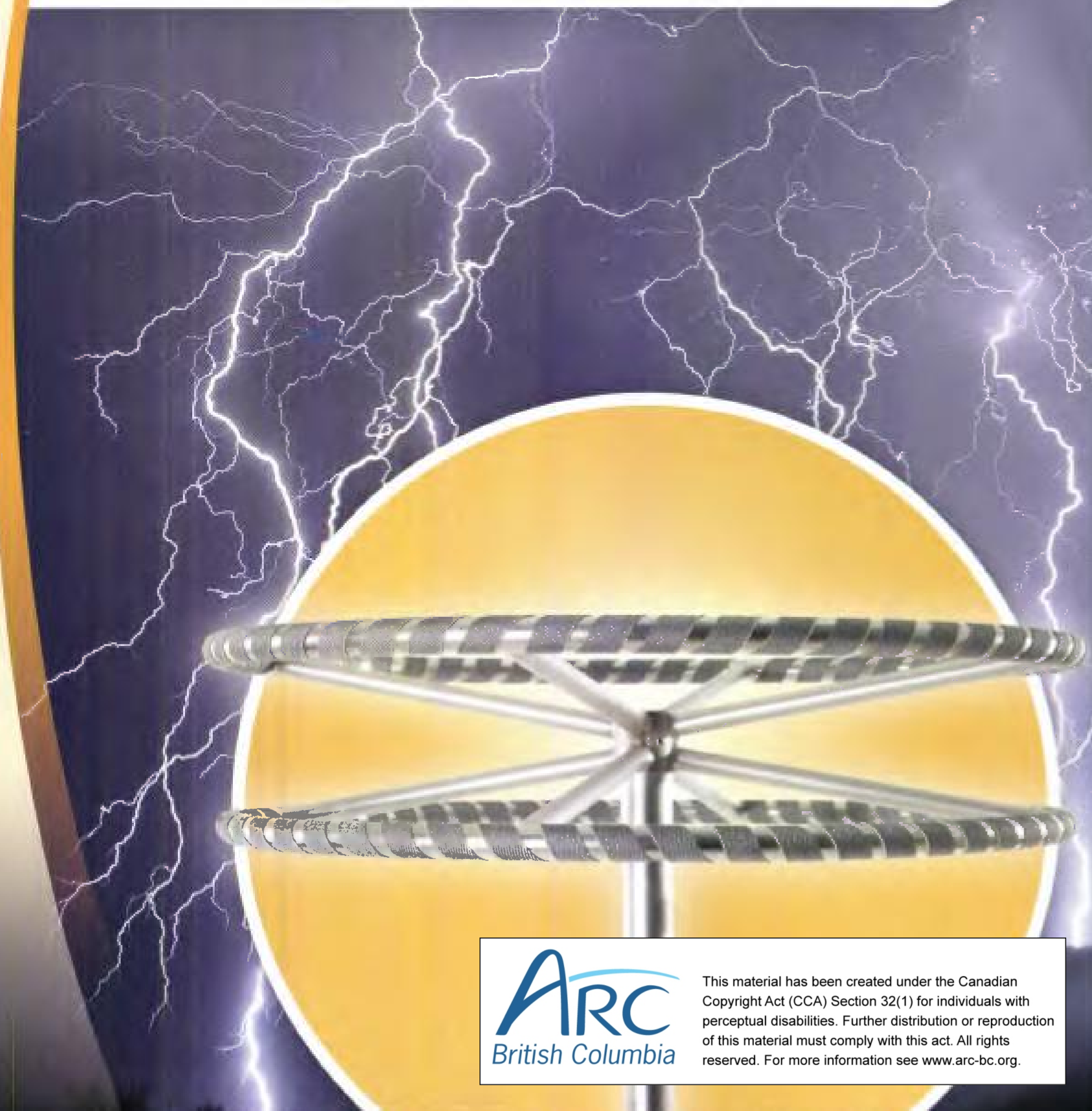
Key Concepts

- Electrons carry a negative charge, and protons carry a positive charge.
- Opposite charges attract each other, and like charges repel each other.

Curricular Competencies

- Use knowledge of scientific concepts to draw conclusions consistent with evidence.
- Consider changes in knowledge over time as tools and technologies have developed.
- Generate and introduce new or refined ideas when problem solving.
- Seek and analyze patterns, trends, and connections in data, including describing relationships between variables and identifying inconsistencies.

Lightning carries a large amount of electrical energy. It is beautiful to observe, but it is also extremely dangerous. For over 100 years, people have used lightning rods to reduce this danger. Lightning rods are designed to direct lightning strikes away from buildings and prevent damage and fires. However, they do not always succeed. To improve their success rate, scientists have studied the way that electrical charges build up around objects on the ground and interact with electrical charges in the clouds. This has led them to design new lightning rods like the one shown in the inset. These rods, designed by Canadian scientist Farouk Rizk, generate regions of electrical charges that cause lightning to strike in places where it will do no harm.



Starting Points

Choose one, some, or all of the following to start your exploration of this Topic.

1. **Identifying Preconceptions** The word "charge" can have many meanings. Discuss your understanding of this word. What does "charge" mean when it is used in connection with electrical energy?
2. **Applying** You have probably received a small shock from touching a door knob, another person, or a pet. What were the conditions like when this happened? What were you wearing? What was the weather like? What determined whether you got a shock?
3. **Applying First Peoples Perspectives** Investigate the role of lightning in First Peoples cultures. Are there traditional stories connected with its power? What do the stories teach? If possible, learn the word for lightning in the language of the local First Peoples in or near the place where you live.

Key Terms

There are three key terms that are highlighted in bold type in this Topic:

- negative charges
- positive charges
- law of electric charge

Flip through the pages of this Topic to find these terms. Add them to your class Word Wall along with their meanings. Add other terms that you think are important and want to remember.

CONCEPT 1

Electrons carry a negative charge, and protons carry a positive charge.

Activity

Recalling Atoms and Charge

Sketch an atom. Add labels to show protons and electrons. Write a caption to describe their properties.

negative charges the charges of electrons

positive charges the charges of protons

Rub two different materials together. Depending on the materials you use, something may come off one and transfer to the other, and the two materials will attract each other. About 250 years ago, American scientist Benjamin Franklin used the term **negative charges** to describe the "somethings" rubbed off a material. He said that an excess of **positive charges** were left behind.

Today we know the negative charges are the charges of electrons, and the positive charges are the charges of protons. Protons are part of the nucleus of atoms and are held firmly in place, so they cannot be rubbed off materials. Electrons can be rubbed off, because they surround the nucleus and some are not tightly bound to it.

When electrons are rubbed off a material, it becomes positively charged. The material that gains electrons becomes negatively charged. Charging a material by rubbing is called *charging by friction*. Figure 3.9 shows an example. Whether a material gains or loses electrons depends on the combination of materials.

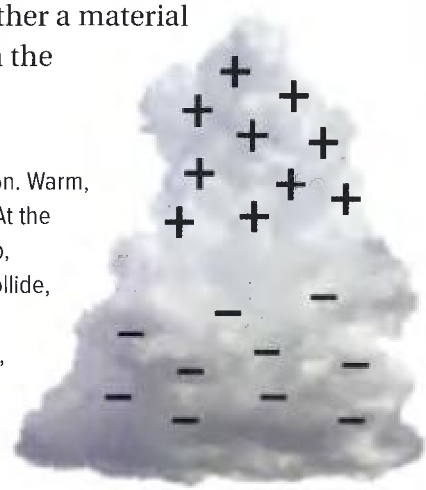


Figure 3.9 Clouds may be charged by friction in a thunderstorm. **How do you think lightning forms?**

Clouds in storms can become charged by friction. Warm, moist air causes strong updrafts in the clouds. At the same time, hail and ice crystals fall from the top, causing downdrafts. As droplets and crystals collide, electrons are stripped from upward-moving particles and are carried downward. As a result, clouds are negatively charged at the bottom and positively charged at the top.

Extending the Connections

Lightning Rock of the Sumas First Nation

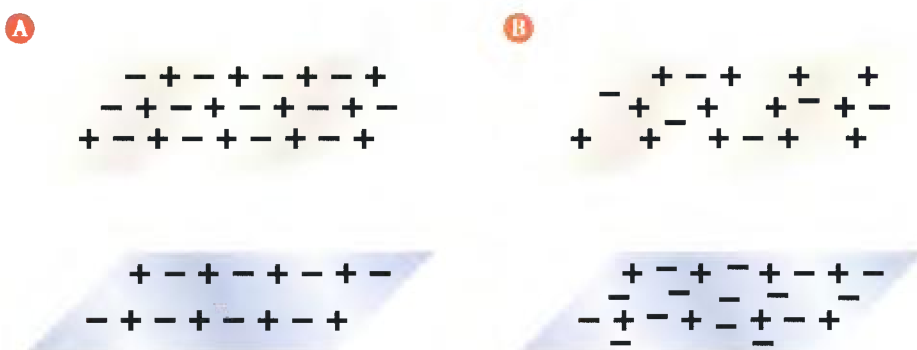
Find out the story of the "transformer rock" that challenged Thunderbird and how a culturally important site stopped a developer's plans.

Electrically Neutral and Electrically Charged Materials

The following is true of uncharged and charged materials or objects:

- **Uncharged Materials:** Before two materials are rubbed together, they have equal numbers of positively charged protons and negatively charged electrons. Because the equal numbers of positive and negative charges cancel each other out, the materials are *electrically neutral.*
- **Charged Materials:** If electrons are rubbed off one material, the protons stay behind and the material becomes *electrically charged*. So does the material that gains the electrons. A material or object that is electrically charged has an unequal number of positive and negative charges.

Figure 3.10 shows two materials before and after they were rubbed together. Observe the number of charges in each material.



A: This diagram shows a paper towel (top) and an acetate strip (bottom) before they are rubbed together. Therefore, each one has an equal number of positive and negative charges. These cancel each other out so each material is electrically neutral.

B: This diagram shows the two materials after they are rubbed together. Electrons are rubbed off the paper towel and transferred to the acetate strip. The paper towel now has fewer negative charges, and the acetate strip has more negative charges. The paper towel is positively charged, and the acetate strip is negatively charged.

Figure 3.10 Two materials before and after being rubbed together

Before you leave this page . . .

1. Explain the relationship among negative charges, positive charges, electrons, and protons.
2. Describe what sometimes happens in terms of charges when you rub two different types of materials together.

CONCEPT 2

Opposite charges attract each other, and like charges repel each other.

Activity

Charge the Tape

1. Cut cellophane tape into two 10 cm pieces. Fold over about 5 mm at the end of each piece to make handles.
2. Stick the two pieces of tape on your desk.
3. Hold the pieces of tape by their handles and quickly pull the tape off the desk.
4. Slowly bring the pieces of tape near to each other.
5. Describe what happens as the pieces of tape approach each other. Suggest a possible explanation.

Long before scientists knew what positive charges and negative charges were, they knew how charges interacted with each other. Two important properties of charges are summarized in the **law of electric charge**, which is stated in the box below.

law of electric charge the law stating that opposite charges attract each other, and like charges repel each other

The Law of Electric Charge

1. Opposite charges attract each other.
2. Like charges repel each other.

Connect to Investigation 3-B on page 210

The law of electric charge applies to all individual charges. This means that a negative charge does not just attract another positive charge. Instead, every negative charge attracts every positive charge. In the same way, every negative charge repels every other negative charge, and every positive charge repels every other positive charge. When you bring together objects that have an excess of either positive charges or negative charges, you see the overall result of all these different attractions and repulsions.

Extending the Connections

Applying Properties of Electrical Charges

People who work in jobs where they are exposed to nuclear energy carry a small device that measures exposure to radiation. This device makes use of electrical charges. What other types of technologies depend on the properties of electrical charges?

Attraction Between Charged Objects and Neutral Objects

The law of electric charge explains why charged objects attract neutral objects (Figure 3.11) All neutral objects have an equal number of protons and electrons. Therefore, they have an equal number of positive and negative charges. When you bring a charged object near a neutral object, the electrons in the neutral object do not come off. Instead, the positive and negative charges in the molecules of the object stretch apart from each other. Figure 3.12 shows what happens to a neutral wall when a charged balloon comes close to it.

Figure 3.11 In this photo, the comb is charged, and the water is neutral.

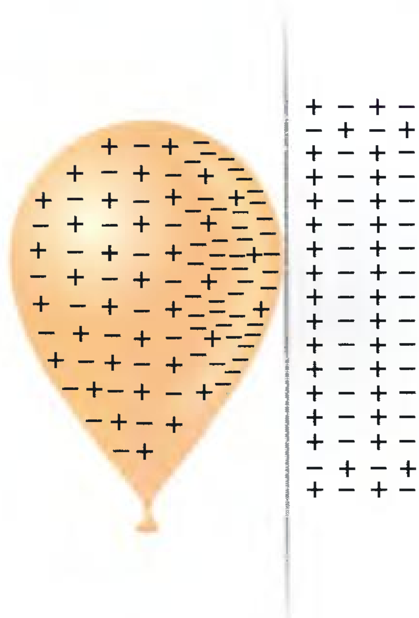


Figure 3.12 This diagram shows why a charged balloon sticks to an electrically neutral wall.

The negative charges in the wall are pushed away from the surface by the negative charges on the balloon. Then the positive ends of the molecules in the wall are attracted to the negative charges on the balloon. These forces of attraction are strong enough to hold the balloon to the wall.

Activity

Repulsion Between Two Charged Objects

Draw a diagram like the one in Figure 3.12 to explain what happens when two negatively charged objects come close to each other.

Before you leave this page . . .

1. State the law of electric charge.
2. Refer to Figures 3.11 and 3 12. Make a labelled sketch, including charges, to explain why a stream of neutral water bends toward a positively charged comb.

AT ISSUE Lightning Fatalities on the Rise in India

What's the Issue?

June 2016

Monsoons brought more than heavy rain to several states in India this summer. Lightning strikes associated with the storms killed nearly 100 people over just a two-day period. Lightning strikes are typical in monsoon season, but this level of lightning activity is unusual. Worst hit was the eastern state of Bihar, with 59 fatalities. Most of the victims were farmers and workers working in the fields. As one injured person told news agencies, "When it was raining we immediately took shelter. It [the lightning bolt] hit us there, and then we fell unconscious. We could not understand what had happened. Then in the middle, when I regained consciousness, I realised that I had been hit by something."

Thousands of lightning-related fatalities occur each year in India, and this number is on the rise. Nearly 25 000 people were killed by lightning in India over the last 10 years. This number is up nearly 50% from the previous 10 years. The Indian government has called on scientists to try to explain why there has been such an increase in lightning strikes and lightning-related fatalities.

Dig Deeper

Collaborate with your classmates to explore one or more of these questions—or generate your own questions to explore.

1. As a scientist, what questions might you have about the increased number of lightning fatalities in India? How could you find the answers to your questions?
2. A lightning bolt transfers a large amount of electrical energy to an object it strikes. Do you think this energy could be harnessed for human use? Discuss your ideas.
3. Find out what scientists are saying about the cause of the increase in lightning strikes in India.

Check Your Understanding of Topic 3.2

QP Questioning and Predicting   PC Planning and Conducting   PA Processing and Analyzing   E Evaluating
AI Applying and Innovating   C Communicating

Understanding Key Ideas

1. You have three objects. One is positively charged. One is neutral. And one is negatively charged. Use sentences and sketches to compare the numbers of positive and negative charges in each of these objects. PA C

2. Two items of clothing are made of different materials. They are tumbled together in a clothes dryer. The items stick together when they are removed from the dryer, as shown below.

   a) Name the process that has just taken place.
   b) Explain how this process could cause the clothing items to stick together. PA AI

3. Use the terms electrically charged and electrically neutral to explain how the comb in Figure 3.11 can attract the water stream without touching it. PA

4. You have four different materials labelled A, B, X, and Y. After you rub A and B together, they attract each other. After you rub X and Y together, they attract each other. Now you bring A near to X and observe that they attract each other. What would happen if you brought B near to Y? Explain your reasoning. PA

Connecting Ideas

5. You have been rubbing two materials together for several minutes, but neither seems to be charged. What questions do you have about this situation? What is one way you could begin to investigate a possible explanation? QP E

6. You are asked to explain the concepts of like charges repelling and unlike charges attracting each other to a grade 6 class. What could you use as an analogy to explain the concepts? Write presentation notes that use your example to explain the interaction between charges. AI C

Making New Connections

7. Consider the following set of facts.

   The first-known person to write about the charged behaviour of objects was a Greek thinker named Thales (THAY-leez), about 2500 years ago. He noticed that when he rubbed a material called amber against fur or wool fabric, he heard crackling sounds and saw small flashes of light. (Amber is a clear, yellow-orange solid that formed from the hardened sap of trees that lived millions of years ago.) Thales also noticed that rubbed amber picked up feathers, leaves, and other small, light objects. When the atom's negatively charged particle was discovered in 1897, it was given the name electron. This word comes directly from an ancient Greek word, *elektron*, which means amber.

   Write a brief paragraph of two or three sentences that describes how past and present are connected by this set of facts. AI C

INVESTIGATION

3-B

STRUCTURED INQUIRY

Skills and Strategies

- Planning and Conducting
- Applying and Innovating
- Communicating

Safety

- Use care when handling glass objects to avoid breaking them or being cut.
- Use care when handling any sharp objects.

What You Need

- materials that can charge an object by friction
- objects that can be charged by friction and that will roll, float, or slide easily
- masking tape or other similar tape
- non-latex gloves

The Great Race

Your team will be moving an object along a race track using only attraction and repulsion. The team that gets its object over the finish line first wins.

Question

How can you move an object using only attraction or repulsion?

Procedure

1. As a class, choose an area for a race track. Use tape to mark the starting line and the finishing line.
2. As a team, choose the object that you will be racing. You must be able to make the object roll, float, or slide without touching it or blowing on it, using only attraction and/or repulsion.
3. Select another object that you will use to attract or repel your object to make it move along the track.
4. Rub your objects with different materials to generate charges. Wearing gloves may improve your results. Observe how the charged objects behave when brought close together. Based on these tests, decide how you will charge your objects. Revise your choices as required.
5. When all of the teams have made their choices, carry out your race.

Process, Analyze, and Communicate

1. Make a sketch of the object that your team raced down the track, and the object that attracted or repelled the moving object. Add plus and minus signs to your sketch to show a possible explanation for why your racing object moved.
2. Write a paragraph that explains why you think that the winning team's object won the race. Use the concepts of the law of electric charge in your explanation.
3. What would you do differently if you were planning another race?

Apply and Innovate

4. As a team, design another type of "trick" based on the law of electric charge that you could perform. For example:
   - Could you make an object spin on a platform?
   - Could you design an obstacle course for a rolling, floating, or sliding object?
   - Could you set up a "Charged Circus" with different kinds of acts and feats?

   Choose your trick and design a procedure that will obtain your desired result. If there is time, practise and perform your trick.
5. Suggest one application that moving an object by attraction or repulsion might have in industry, in manufacturing, or in a consumer product.

TOPIC 3.3

How do charges flow through the components of a circuit?

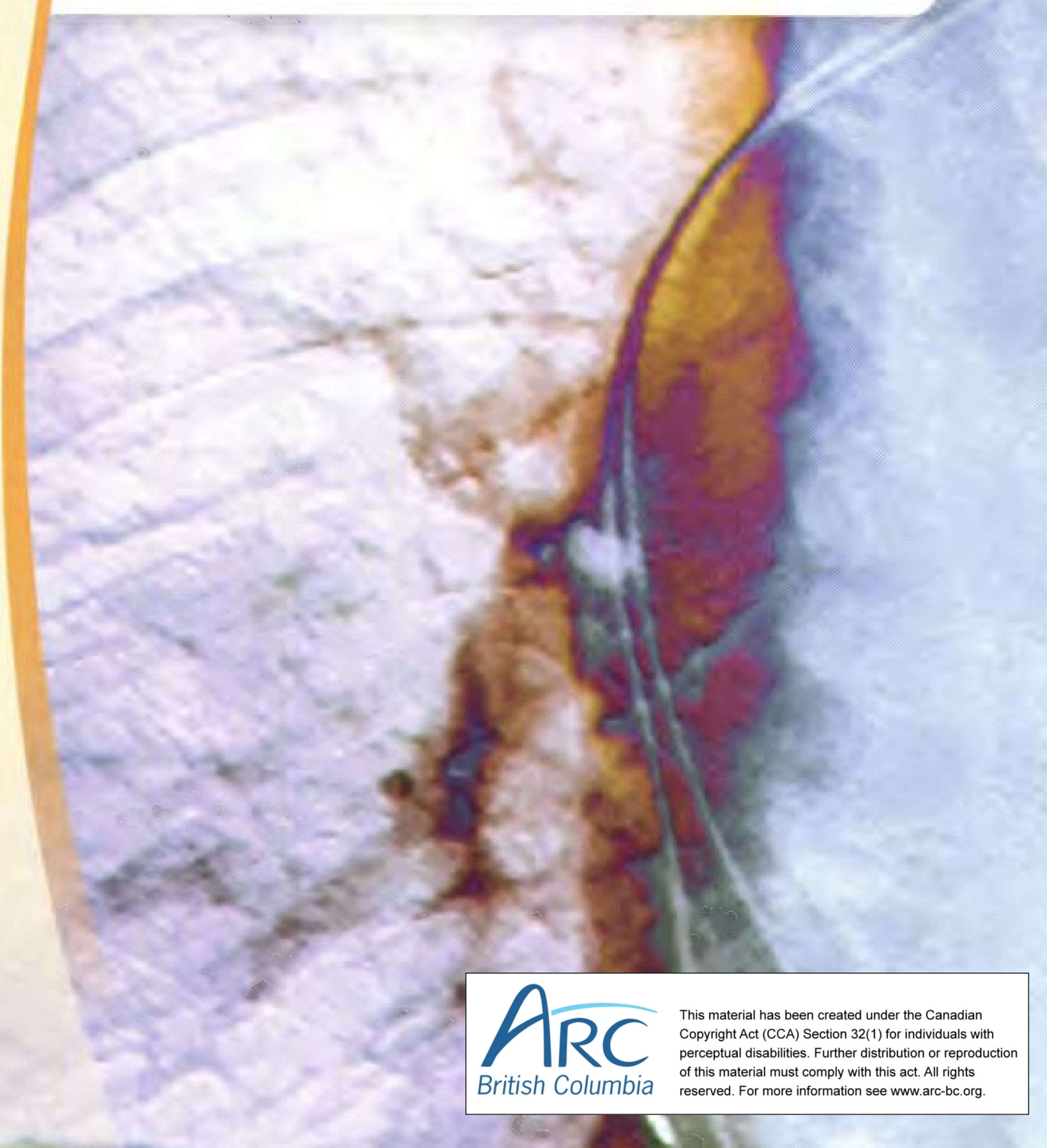
Key Concepts

- Chemical energy separates electrical charges in cells.
- Charges can flow through conductors, but not insulators.
- Moving electrical charges form an electric current.
- A load resists the flow of current.
- Conductors must form a closed loop to allow current to flow.

Curricular Competencies

- Collaboratively and personally plan, select, and use appropriate investigation methods to collect reliable data.
- Select and use appropriate equipment to systematically and accurately collect and record data.
- Demonstrate a sustained intellectual curiosity about a scientific topic or problem of personal interest.

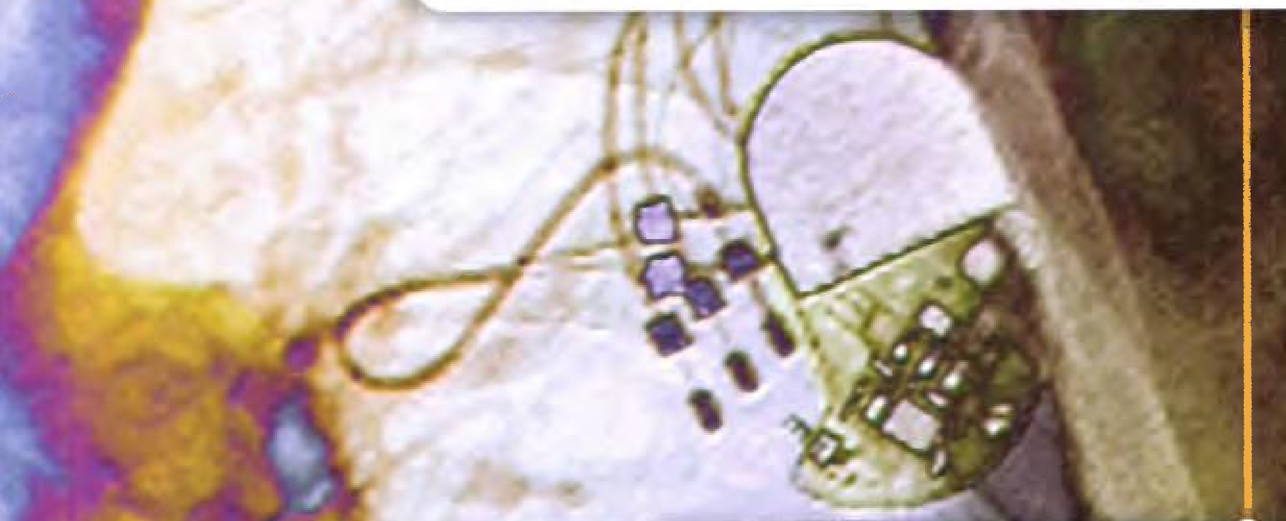
In 1950, Canadian Drs. Wilfred Bigelow and John Callaghan first used an external electrical device, developed by Dr. John Hopps, to pace the beating of a dog's heart. The device was the first pacemaker. Modern technology has brought the pacemaker a long way since those days. Pacemakers are used to help people with irregular heartbeats. As well, they are small enough to be surgically inserted under the skin on the chest. The electrical energy to run a pacemaker comes from a battery that lasts 10 years or longer. Electrical charges flow through the tiny electrical device, completing an electrical pathway called a circuit within the human body.



Starting Points

Choose one, some, or all of the following to start your exploration of this Topic.

1. **Identifying Preconceptions** Race car circuit. Circuit training. What does the term circuit mean when it is applied to electrical charges?
2. **Communicating** Electrical terms and concepts are often used in everyday communication. For instance, someone might say that lightning struck when coming up with a new idea. An idea may be drawn as a light bulb as well. What other examples can you think of? How does this highlight the influence of electrical energy on society?
3. **Applying First Peoples Perspectives** The idea of interconnectedness suggests that nature's energy flows through us. How is the human body similar to an electrical circuit? What could a comparison like this tell us about interconnectedness?



Key Terms

There are 10 key terms that are highlighted in bold type in this Topic:

- source
- conductor
- current
- resistance
- electrical potential difference
- conductivity
- electrical circuit
- short circuit
- insulator
- load

Flip through the pages of this Topic to find these terms. Add them to your class Word Wall along with their meanings. Add other terms that you think are important and want to remember.

CONCEPT 1

Chemical energy separates electrical charges in cells.

Activity

Battle of the Batteries

Although most people buy batteries at the store, it is actually possible to make your own. Find out how online. Check your design with your teacher before building the battery. Then enter a class "battle of the batteries" to see who can get their battery to run a device your teacher specifies.

Connect to Investigation 3-C on page 228

An AA "battery" is an *electrochemical cell*. In a cell, chemical reactions of two different metals or metal compounds occur on the surface of *electrodes*. The electrodes are in a solution called an *electrolyte*. The reactions cause one electrode to become positively charged, and the other to become negatively charged. The electrodes are in contact with *terminals* in the cell. When terminals are connected to an electrical pathway, charges flow through it. Figure 3.13 shows two types of cells. A *dry cell* contains a moist paste as an electrolyte. In a *wet cell*, the electrodes sit in a liquid solution. Both transform chemical energy into electrical energy to run portable devices.

Figure 3.13 A dry cell A and a wet cell B.

A

B

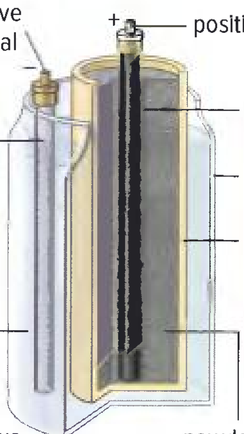


Figure 3.14 The battery shown here is made up of six individual cells.

source anything that supplies electrical energy

In comparison, a *battery* is a connection of two or more cells. You make a battery when you place AA cells together in an electrical device. Often, several cells are packaged together in a casing to make a battery (Figure 3.14) Cells and batteries are sources. A **source** is anything that supplies electrical energy. Electrical outlets are also sources.

Understanding How a Cell Works

Because opposite charges attract each other, it takes energy to separate positive and negative charges. The previous Topic explained how friction can provide this energy. In a cell, chemical reactions separate the positive and negative charges. In other words, chemical energy does the work of separating the charges. (Energy is the ability to do work. Work is done on an object when a force acts on it and makes it move through some distance.) Because work went into separating the charges, the electrons now have the energy to do other work, such as running a fan or a watch. The electrical energy now stored in the cell is a form of potential energy. It has the potential to do work because of the separation or position of the charges.

Figure 3.15 shows a model that explains how charges are separated and gain electrical potential energy as a cell becomes charged. A worker represents chemical energy released in chemical reactions.

Figure 3.15 The worker in this model represents chemical energy.

The worker carries electrons up a ladder and places them at the negative terminal. The worker leaves positively charged ions on the bottom at the positive terminal. The first electron is easy to carry up the ladder because only one pair of charges is being separated. The attraction is not very strong. Only a small amount of electrical energy is stored in the cell.

After a few charges have been separated, all of the positive charges of the positively charged ions at the positive terminal are attracting the negative charge of the electron that the worker is carrying. As well, the negative charges of the electrons at the negative terminal are repelling the negative charge of the electron that the worker is carrying. So it takes more energy to carry each additional electron up the ladder. The worker (chemical energy) has done a lot of work to separate the charges. This energy is now stored in the electrical potential energy of the separated charges.

Eventually, the repulsion of the electron by the negative charges and the attraction by the positive charges gets so strong that the worker cannot carry any more electrons up the ladder. No more chemical energy will be transformed into electrical energy.

Electrical Potential Difference

electrical potential difference a quantity that provides a measure of the electrical potential energy a unit of charge gains when passing through a source

A unit of charge, called a *coulomb*, gains electrical potential energy when it passes through a source, such as a battery. The quantity that provides a measure of the electrical potential energy that is gained by a unit of charge is called the **electrical potential difference**. It is called a difference because it measures the difference in electrical potential energy per unit of charge between the positive terminal and the negative terminal in a cell. Think of Figure 3.15. To charge a cell, a chemical reaction does work to separate electrons and positive ions. It takes more energy to carry each electron up the ladder. This is because the forces of attraction and repulsion acting on it get stronger and stronger. Separating the final charge requires the most energy of all. The electrical potential difference of the cell represents the amount of energy it took to carry the last unit of charge up the ladder.

The electrical potential difference of a cell is determined by the nature of the chemical reaction that takes place in the cell. Cells and batteries are rated according to their electrical potential difference between one terminal and the other. Other sources, like electrical outlets, are rated in a similar manner. The symbol and units for electrical potential difference are given below.

- The electrical potential difference is measured in volts (V).
- The symbol for electrical potential difference is *V*.

Because of its symbol and units, electrical potential difference is often called the voltage. For this reason the term *voltage* is frequently used on cells and batteries (Figure 3.16) In the 1.5 V cell shown in the figure, it took 1.5 units of energy to carry that last unit of charge up the ladder. Note that if two cells are linked together, as in a flashlight or radio, their voltages add up. For example, if two 1.5 V cells are placed in a radio, their voltage is 3 V. Similarly, if six cells are packaged together, they form a 9 V battery.

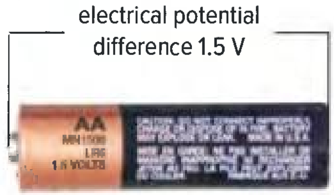


Figure 3.16 A typical AA or AAA cell provides an electrical potential difference of 1.5 V.

Before you leave this page . . .

1. Use an analogy other than a worker and a ladder to explain how chemical energy is transformed into electrical energy in a cell.
2. Why is the electrical potential difference of a source referred to as a difference?

CONCEPT 2

Charges can flow through conductors, but not insulators.

Activity

Charging Balloons

1. Wearing non-latex gloves, rub a rubber balloon with a wool cloth. Making sure the balloon does not touch anything, bring it near several tiny bits of paper.
2. Still wearing gloves, rub a metallic (mylar) balloon with a wool cloth. Bring the balloon near the bits of paper, being careful not to touch it to anything.
3. Repeat steps 1 and 2 without wearing the gloves.
4. Compare your observations. What differences do you observe among the four tests you completed? Suggest a reason for each difference you observed.

When two different solid materials are rubbed together, electrons can be transferred from one material to the other. The electrons will either stay on the surface of the new material or travel through it. Any material that electrical charges can move through is called a **conductor**. Electrons can move through almost all metals, but they move through some metals more easily than others. How easily the charges move through a material is referred to as its **conductivity**. A material through which charges cannot travel at all is an **insulator**.

Look at Figure 3.17. Most electrical wiring is made out of metals that conduct charges very well, such as copper. Most electrical cords and wires are covered with rubber or plastic. These materials are insulators. Most non-metals, such as glass and wood, are also insulators.

conductor a material charges can travel through

conductivity an indication of how easily charges travel through a material

insulator a material charges cannot travel through

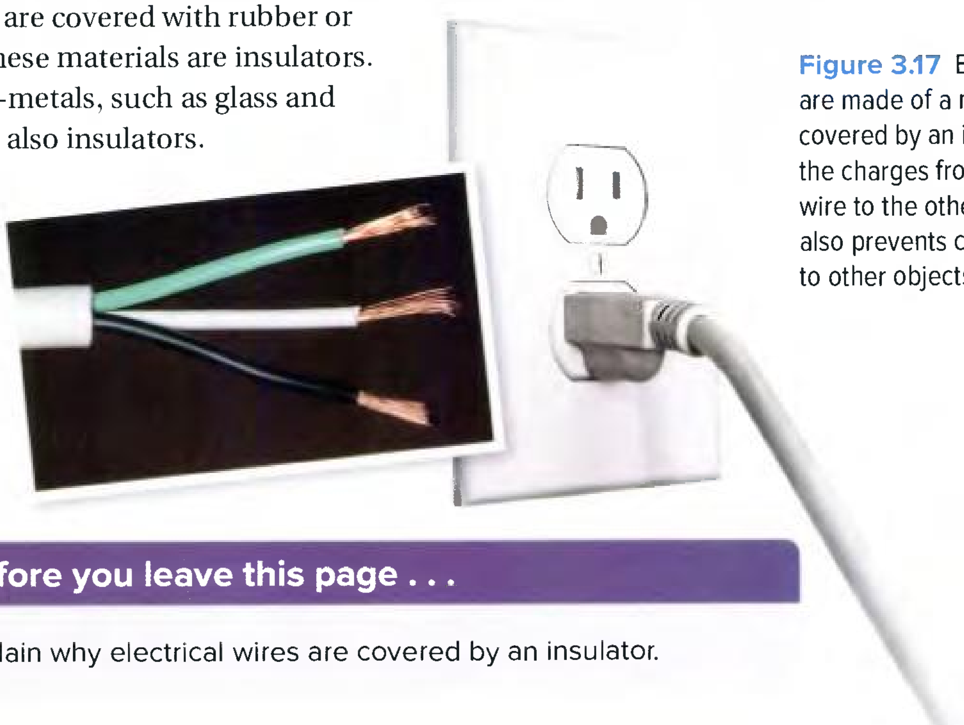


Figure 3.17 Electrical cords are made of a metal conductor covered by an insulator to prevent the charges from moving from one wire to the other. The insulator also prevents charges from moving to other objects, including you.

Before you leave this page . . .

1. Explain why electrical wires are covered by an insulator.

CONCEPT 3

Moving electrical charges form an electric current.

Activity

Electric Lemon

Safety: Advise your teacher if you are allergic to citrus fruits.

1. Stick a copper wire into one end of the lemon and a non-galvanized nail into the other.
2. Bend the top of the copper wire so it nearly touches the nail.
3. Put on the headphones. Hold the plug of the headphones on top of the nail and listen.
4. With your other hand, touch the copper wire to the plug as shown in the illustration. Make sure the plug is touching both the nail and the wire. Wait one or two minutes, listening carefully.
5. Try to account for the differences you observed.

Charges can flow from a source through conducting materials to an appliance or an electrical device, such as a cellphone. Chemical energy from the source causes charges to move through the conductor, usually wires, carrying energy to the device. The moving charges are called an electric **current**. You need to remember the symbol and units for current because you will be using them in calculations in the next Topic.

current moving charges

Connect to Investigation 3-D on page 230

- The symbol for current is I.
- Current is measured in units called amperes. The symbol for amperes is A.

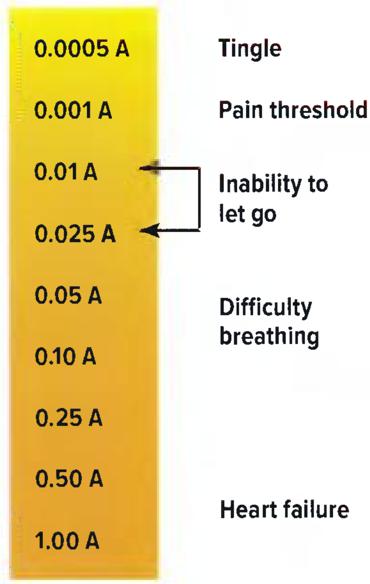
For example, the equation $I = 3$ A means that the current (I) is three amperes (3 A).

The smaller unit of electric current is the milliampere (1A = 1000 mA).

Activity

Effects of Voltage and Current on the Human Body

The scale on the right shows how the effects of current on the human body vary with the amount of current that flows through the body. The voltage is 120 V, the standard household voltage. Study the scale and then answer the questions that follow.



1. Find out what the electric current is in homes in B.C. What type of caution does the scale on the right suggest that you should take around household currents? Justify your response.
2. Electric current is used in some medical applications to treat health problems. Find out more about these applications and choose one that interests you. How does the treatment work? What kind of voltage and current is involved? What safety precautions, if any, are taken during the treatment?
3. Electrical hazard warning signs often say "Danger High Voltage." Considering the effects of current on the human body, do you think this warning should refer to current rather than voltage? Discuss your ideas as a class.

Before you leave this page . . .

Connect to Investigation 3-E on page 232

1. Describe the relationship between moving charges and electric current.

CONCEPT 4

A load resists the flow of current.

load device that converts electrical energy into another form of energy

resistance describes the amount that current is hindered by a load

A device that converts electrical energy into another type of energy is a **load**. A light bulb is a load that transforms electrical energy into light energy. A radio is a load that transforms electrical energy into sound energy. As electrons pass through a load, they lose energy as electrical energy is converted into another type of energy.

A load resists, or hinders, the flow of current. This happens because the electrons in the current collide with the atoms that make up the load, or even with each other, as shown in Figure 3.18. The collisions interfere with the flow of the current. The degree to which the flow of current is hindered is referred to as **resistance**. The symbol for resistance is *R*. The unit used to measure resistance is the ohm. The symbol for an ohm is the Greek letter omega, Ω. You need to remember these symbols and units to complete calculations in Topic 3.4. The filament in a light bulb is a good example of resistance to the flow of charges. Figure 3.18 shows how resistance makes a filament-type light bulb light up.

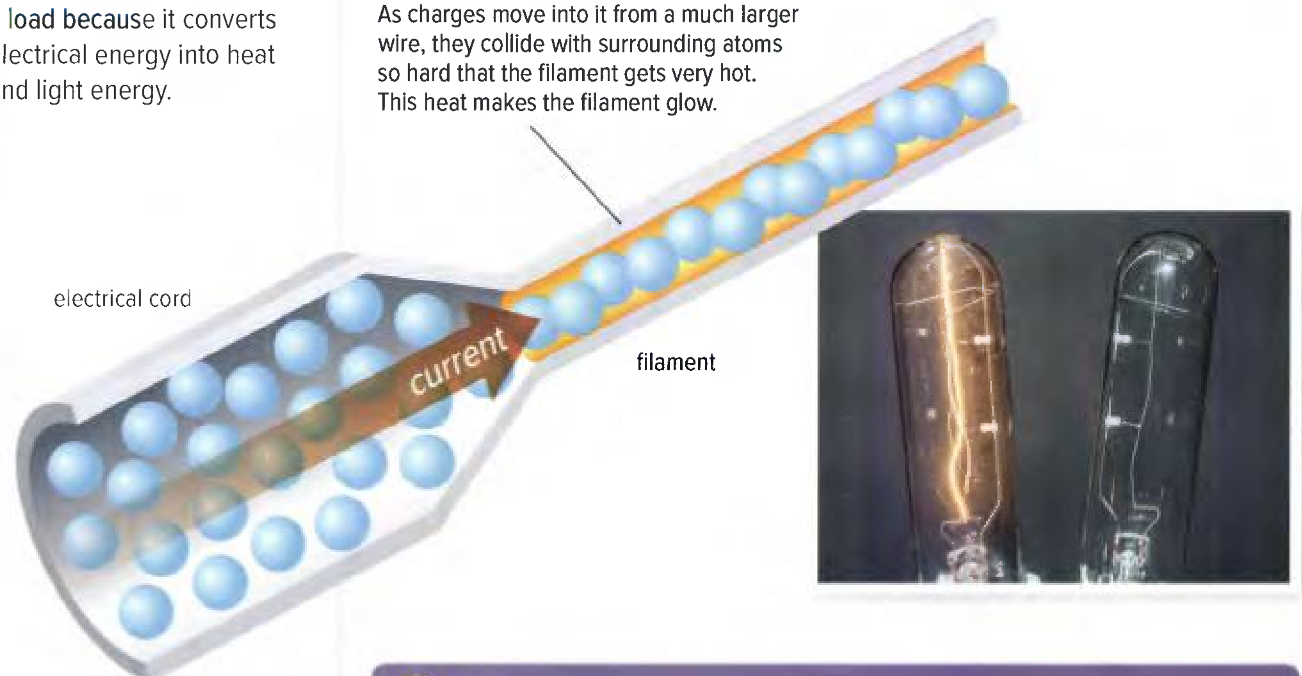


Figure 3.18 A light bulb is a load because it converts electrical energy into heat and light energy.

Before you leave this page . . .

1. Use the terms source, current, and load to describe how you think a flashlight works.

CONCEPT 5

Conductors must form a closed loop to allow current to flow.

Activity

Take Apart a Flashlight

1. Carefully take apart the flashlight provided. Draw a diagram of how the components fit together inside. Label the components.
2. Using a coloured pencil or marker, draw arrows to indicate the direction in which you think the charges flow through the components of the flashlight.
3. Compare your diagram to those drawn by others. Make any changes you think will improve your diagram.
4. Which components are essential to the function of the flashlight? What are the roles of the other components?
5. Use the materials provided by your teacher to light a flashlight bulb. Did the light go on? If not, explain why you think it did not. Try again until you are successful.

When a source, load, and conductor are connected in a way that allows current to flow, it is called an **electrical circuit**. In order for current to flow, a circuit must form a closed loop. Figure 3.19 shows the simplest possible circuit having only a source and a load.

electrical circuit at a minimum, a source, a load, and wires in a closed loop that allow current to flow

Without a load to resist the flow of current, the current would be so large that the conductor would quickly get very hot and start a fire. This would be called a **short circuit**. Short circuits are fire hazards if they occur within a building's wiring.

short circuit a circuit with a resistance that is too low, making the current so high that it is dangerous

Figure 3.19 A closed loop allows current to flow and light the bulb. **Short circuits can be dangerous if they occur in the wiring of a building. Suggest how a short circuit might form in a building.**

Modelling the Flow of Current

Figure 3.20 shows how current flows through a simple, closed circuit.

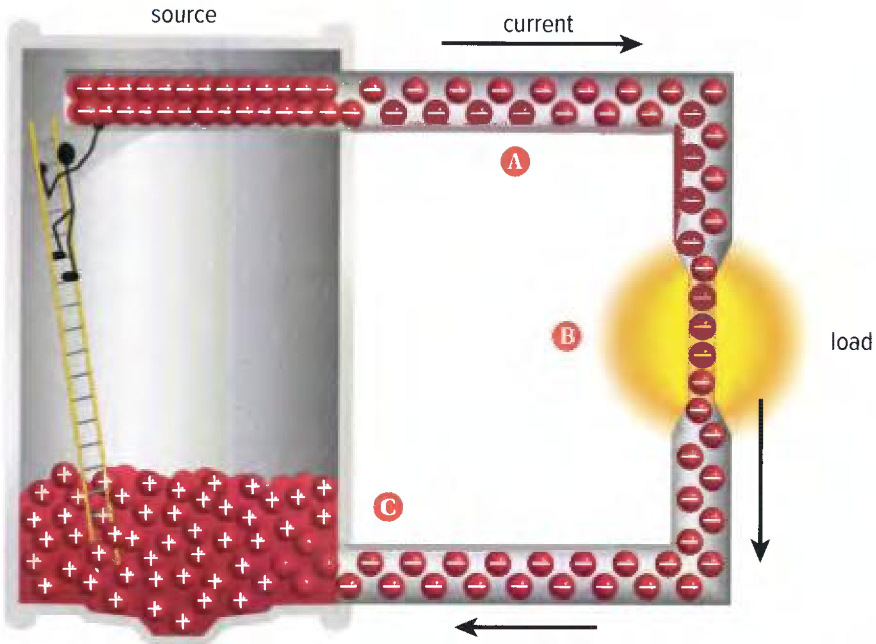


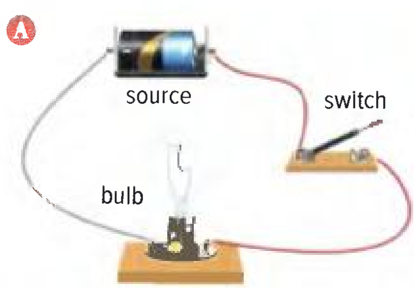
Figure 3.20 How current flows through a circuit

- A The conductors already have electrons in them. The negative terminal repels the negative charges in the conductor; the positive terminal attracts them. As a result, electrons move along the conducting wires, and electrons from the cell move into the conductor.
- B As the electrons pass through the load, they transfer some of their energy to the load. They then leave the load and return to the cell.
- C Electrons enter the cell and combine with positive ions to become neutral. Over time, there are fewer electrons at the negative terminal and fewer positive ions at the positive terminal. The worker can carry more electrons up the ladder, keeping the number of separated charges equal at all times.

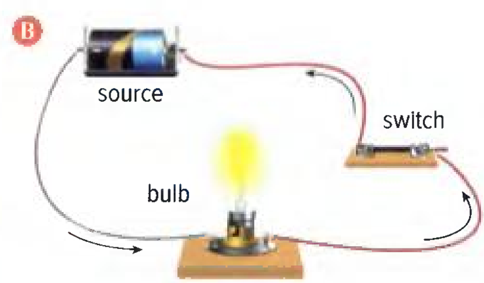
Controlling the Flow of Current

The light bulb in Figure 3.19 would always be on. In a typical circuit, a switch lets you turn the light on and off (Figure 3.21)

Figure 3.21 How a switch controls current in a circuit



The switch is open. There is no closed path so the current cannot flow. The circuit is open.



The switch is closed, allowing current to flow and the light to be on. The circuit is referred to as closed.

Using Circuit Diagrams

Simple symbols are used to make it easier to draw circuits. Table 3.1 lists the symbols for the basic parts of a circuit. The quantities used to describe the components and their units of measurement are also included. Figure 3.22 shows how the symbols are used to draw a circuit with a cell or a battery, conducting wires, a load, and a switch.

Table 3.1 Symbols for Circuit Diagrams

Component		Symbol	Quantity	Unit of Measurement
Source	Cell		Electrical Potential Difference (*V*)	Volt (V)
	Battery			
Conducting Wire			Current (*I*)	Ampere (A)
Load			Resistance (*R*)	Ohm (Ω)
Switch	Open			
	Closed			

Note: The long line in the symbols for cells or batteries represents the positive terminal and the short line represents the negative terminal.

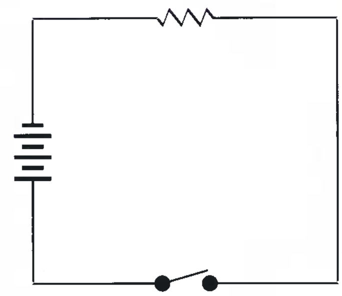


Figure 3.22 This circuit diagram describes the same circuit that is shown in Figure 3.21A. **Identify the source, the load, and the switch in the circuit diagram.**

Activity

Drawing Circuit Diagrams

Appendix A on page 394 provides more guidance on how to draw circuit diagrams. Use this appendix to draw circuit diagrams for the following circuits.

1. A circuit with a cell that runs a buzzer without a switch.
2. A circuit with a battery in which an open switch has turned off two light bulbs.
3. A circuit with a battery, a closed switch, two light bulbs, and a clock.

Putting It All Together

To gain a better understanding of how the components of an electrical circuit work together, compare the electrical circuit with the water circuit in Figure 3.23.

Water Circuit

In the water circuit, the pump lifts the water to a higher level against the pull of gravity. A valve at the top of the pipe controls whether the water flows down. When the water runs down, it turns a water wheel.

Electrical Circuit

In the electrical circuit, the cell or battery is similar to the pump. It raises charges to a higher level of electrical potential energy. The switch is like the valve. It determines whether the electrons are allowed to flow through the circuit. When the electrons are allowed to flow, the current runs through the load and lights the light bulb.

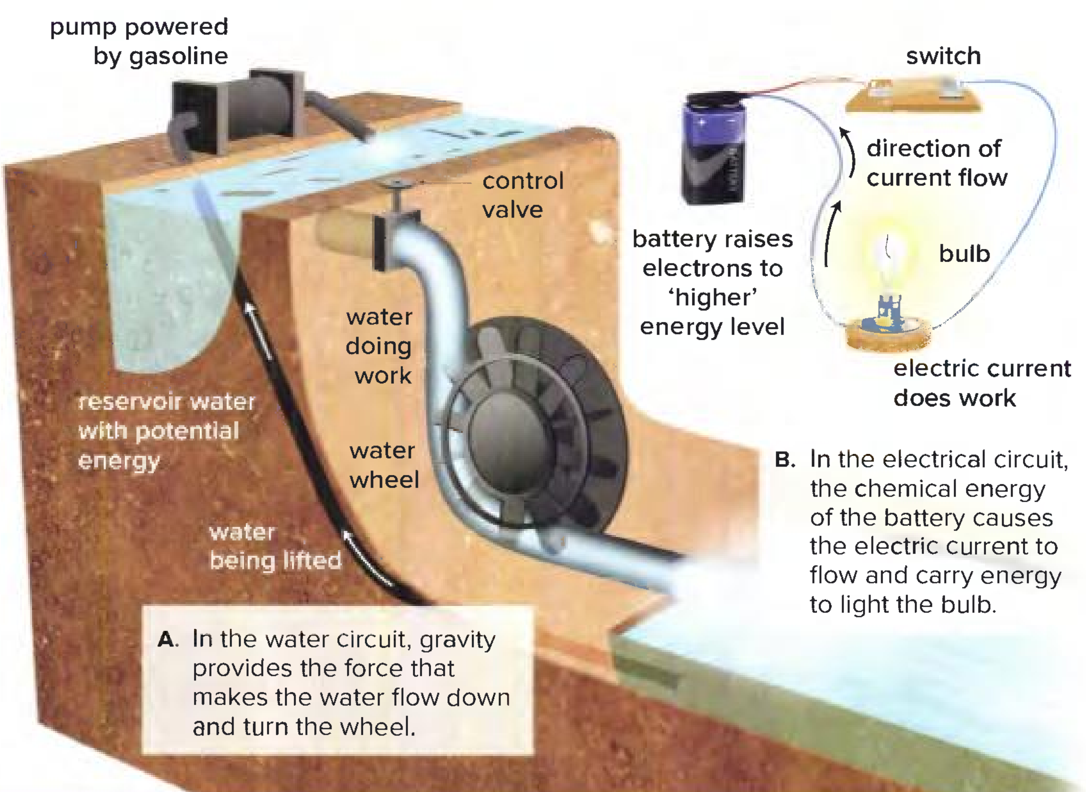


Figure 3.23 A comparison of a water circuit and an electrical circuit

Before you leave this page . . .

1. Explain what "short circuit" means.
2. Describe the role of a switch in an electrical circuit.
3. Draw a circuit diagram for the circuit shown in Figure 3.21B.

AT ISSUE Electric transportation and accessories hit the road

What's the Issue?

The world of electric vehicles is expanding at high speed. Electric cars, motorcycles, and scooters are already a common sight in many B.C. cities, but more unusual types of electric transportation are on the horizon. Electric airplanes, skateboards, and even paragliders are just a few ways to get around that rely on batteries. And the trend toward electric transportation doesn't just stop at vehicles. How about a motorcycle helmet with an electronic heads-up display that allows you to see your speed on your visor? Even a jacket wired to blink when you make a turn could be coming soon to a closet near you.

Dig Deeper

Collaborate with your classmates to explore one or more of these questions—or generate your own questions to explore.

1. Ben Gulak is the inventor of the motorcycle shown on this page. His invention began as a school science project. What questions do you have about electric vehicles in Canada? Choose the one that interests you most and explore it further.
2. The B.C. government has made it legal for electric vehicles to drive in HOV (high occupancy vehicle) lanes without meeting occupancy requirements. Discuss whether you agree or disagree with this legislation.
3. Electrical clothing isn't just for transportation fashions. Some are practical, like a hoodie wired for sound or a winter coat with a built in heater. Others are just fun and attractive, like a dress that lights up in full colour. What do you think of electric fashion? Is it a waste of electrical energy and one more way to add batteries to the landfill? Or is it a cool and practical trend you would follow?

Focus on Physics

What kinds of jobs involve electrical energy?

- Power Station Operator
- Construction Inspector
- Powerline Technician
- Electronic Service Technician
- Robotics Engineer

Electrical Engineer

Want to be involved in leading-edge research to build better generating systems, improve telecommunications technology, and enhance computer systems? If so, electrical engineering may be the career for you.

Electrician

Whether wiring residential homes or the tallest skyscrapers, it's an electrician's job to keep current flowing reliably and safely.

Meteorologist

Understanding electrical energy and how charges behave helps meteorologists predict where lightning will strike, and when.

Questions

1. What other jobs and careers do you know or can you think of that involve electrical energy?
2. Research a job or career related to Unit 3 that interests you. What attracts you to it? What kinds of things do you have to know, do, and understand for this job or career?

Check Your Understanding of Topic 3.3

QP Questioning and Predicting PC Planning and Conducting PA Processing and Analyzing E Evaluating
AI Applying and Innovating C Communicating

Understanding Key Ideas

1. a) How is energy stored in a cell or in a battery?
   b) What kind of energy was used to generate the electrical energy that is stored in a cell? PA
2. Compare the insulation in the building below to an insulator as it relates to the movement of electrons through a material. PA E AI

3. a) Define the term *load* as it applies to an electrical circuit.
   b) Give three examples of loads that you would find in an electrical circuit. PA
4. What is the relationship between a load and resistance in an electrical circuit? PA
5. Draw a circuit diagram for the following:
   a) an open circuit with one source, two loads, and one switch
   b) a closed circuit with one source, two loads, and one switch PA C
6. For each of the following pairs of terms, explain the relationship between the terms. PA
   a) conductor; conductivity
   b) closed circuit; short circuit
   c) source; electrical potential difference
7. a) Explain the difference between a cell and a battery.
   b) Identify a portable electrical device you use regularly. Do you think it uses a cell or a battery? Explain your reasoning. PA E C
8. Your lab partner tells you that the circuit that you are testing has an electrical potential difference of 2 A. What is wrong with the statement? Write the statement correctly. PA

Connecting Ideas

9. A classmate is working with a source that is labelled 18 V. The classmate refers to the source as a cell. Why might you think that the term cell is incorrect? How is the source most likely related to a cell? PA E AI

Making New Connections

10. You head out in a car for a picnic at a local park. Just as you finish your picnic, a thunderstorm rolls in. A moment later, lightning streaks across the sky. One friend urges you to take shelter under a nearby tree. Another suggests you return to the car, which is farther away. With which friend do you agree and why? Refer to insulators and conductors in your response. PA E AI

INVESTIGATION

3-C

STRUCTURED AND GUIDED INQUIRY

Skills and Strategies

- Processing and Analyzing
- Evaluating

What You Need

- access to information resources (for example: online, in-print, interviews)

Investigating Cells and Batteries

PART A: MAKE A CELL-ECTION—STRUCTURED INQUIRY

Question

What properties do you consider important in selecting a cell or battery for a specific application?

Procedure

1. Design a table with four headings: Application, Properties of Cells That Could Be Used, Recommended Cell, and Reasons for Recommendation. Give your table an appropriate title.
2. Research the meanings of these properties: storage, capacity, recharge life, primary cell, secondary cell.
3. Use the information in the Table of Cells and Batteries in Common Use on the next page, and other sources of your choice as information resources. For each application that follows, use your research to fill in a row in the table you created in step 1.
   - key holder with a light
   - travel alarm clock
   - child's singing teddy bear
   - pacemaker
   - scuba diver's light
   - cellphone
   - portable drill
   - wheel chair
   - snow blower
   - road-hazard warning light

   Consider the properties you listed in Procedure step 2, as well as cost and environmental impact.

Process and Analyze

1. Which cells that you recommended have the least impact on the environment? Explain your reasoning.
2. Did you recommend primary cells or secondary cells more often? Explain your choices.
3. Think about the portable devices you use and the cells or batteries that provide them with electrical energy. Would you change the type of cell or battery you use for any of these devices? Explain.

PART B: THE LIFE OF A CELL OR BATTERY—GUIDED INQUIRY

Question

What can you learn about the impacts of a cell or battery throughout its life?

Procedure

1. Choose a type of cell or battery from the Table of Cells and Batteries in Common Use.
2. What questions do you have about the impacts of the cell or battery from its production through to its disposal? Record your questions and then do research to find the answers.
3. Share your answers with the class using a medium of your choice.

Table of Cells and Batteries in Common Use

Name	Primary/ Secondary	Typical Uses	Pros	Cons
Zinc-carbon	Primary	Flashlights, small radios, music players	Is inexpensive	Gives poor performance at low temperature
Alkaline	Primary	Flashlights, small radios, music players	Lasts longer than zinc-carbon cells	Is more expensive than zinc-carbon cells
Silver-oxide	Primary	Calculators, watches, hearing aids, pagers	Is small and long lasting	Is relatively expensive
Zinc-air	Primary	Hearing aids, pagers	Has a long shelf life if sealed	Requires oxygen from the air
Nickel-cadmium	Secondary	Portable power tools, laptop computers, shavers, toothbrushes	Can be recharged 500 to 700 times	Is an environmental hazard because of the cadmium
Nickel-metal hydride	Secondary	Portable power tools, laptop computers, shavers, toothbrushes	Can be recharged 300 to 400 times; is good for high-demand applications, such as cameras and power tools	Is relatively expensive
Lithium-ion	Secondary	Cellphones, laptop computers	Can be recharged 300 to 400 times; has an excellent shelf life; is good at high and low temperatures	Is relatively expensive

INVESTIGATION

3-D

GUIDED INQUIRY

Skills and Strategies

- Questioning and Predicting
- Planning and Conducting
- Processing and Analyzing
- Evaluating
- Communicating

Safety

- Do not hold the photovoltaic cell by the wires.
- If you use any water, do not let wires get wet.
- Handle the electrical equipment carefully.

What You Need

- multimeter
- wires with alligator clips
- photovoltaic cell
- other materials depending on your design

Testing a Photovoltaic Cell

Question

How much current and electrical potential difference can a photovoltaic cell generate? What factors affect the ability of a photovoltaic cell to generate these quantities?

Procedure

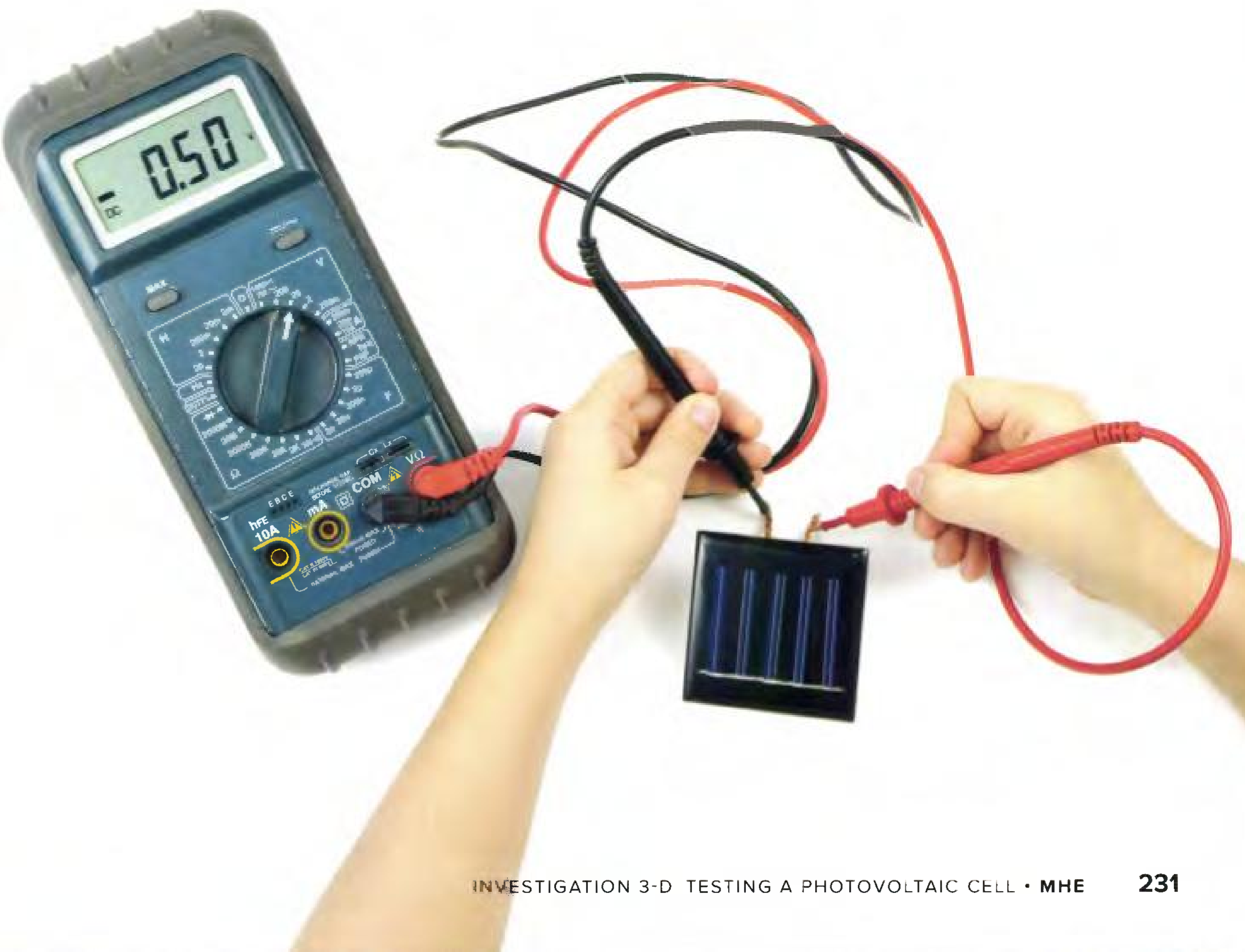
1. As a class, brainstorm some factors that might affect the current and electrical potential difference generated by a photovoltaic cell.
2. Review Appendix A on page 395 on how to use a multimeter to measure current and electrical potential difference. If you are still not sure how to connect the meter to your photovoltaic cell, do research to find out how to make these connections.
3. Draw and label a circuit diagram that shows how you will connect the multimeter to the photovoltaic cell.
4. Assemble your circuit. Measure and record the current generated by the photovoltaic cell and the electrical potential difference across the cell.
5. Within your group, choose one of the factors that might affect the ability of your photovoltaic cell to generate a current or electrical potential difference.
6. Decide how you will test the factor you chose in step 5 and measure any differences in current or electrical potential difference. Make a sketch of the arrangement of your apparatus. Be sure to keep all of the other factors constant while you change the factor that you are testing. Write a hypothesis and a procedure for your test. Check your experimental design with your teacher before you test it.
7. Carry out your procedure for testing the factor of your choice. Record your results.

Process and Analyze

1. Why is it important to keep all other factors the same while you are making changes in your chosen factor?
2. Describe any problems you had in assembling your apparatus and making measurements. Identify possible sources of error.
3. Share your results with the class. As a class, make a table of the amount of current and electrical potential difference that each group recorded for their photovoltaic cell in step 4. Then make a table of all of the factors that were tested by all of the groups in step 7 and include the results.
4. How similar were the currents and electrical potential differences that different groups recorded in their original measurements in step 4? Suggest some possible causes for any differences in these measurements.
5. As a class, discuss possible reasons that the factors tested in step 7 affected current or electrical potential difference.

Apply

6. Based on the findings of the class, make recommendations about designing an array of solar cells that will provide electrical energy for a home. Include as many different factors as you can.

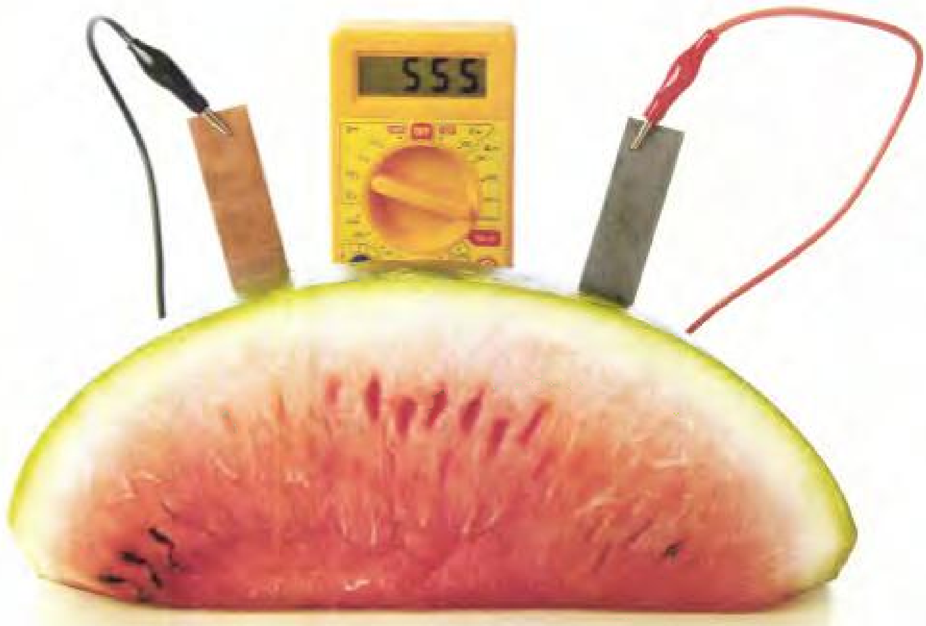


INVESTIGATION
3-E

GUIDED INQUIRY

The Fruit Cell Challenge

In this investigation, you will create a wet cell from a fruit. If you connect the cell to a multimeter as shown below, you will be able to see that a current is flowing.



Skills and Strategies

- Questioning and Predicting
- Planning and Conducting
- Processing and Analyzing
- Evaluating

Safety

- Be careful handling sharp pieces of metal.
- Handle the multimeter with care.
- Advise your teacher if you are allergic to any type of fruit.

What You Need

- several types of fruit
- multimeter
- various types of metal strips or nails such as copper, zinc, iron, aluminum
- small electrical devices such as bulbs or motors
- wires with alligator clips

Question

What properties of a piece of fruit make it act like an electrochemical cell?

Procedure

1. As a class, decide on some type of challenge that teams will participate in with the fruit cells. For example, can a fruit cell light a small light bulb, or run a toy motor in a car? How long can a fruit cell run a device?
2. As a team, brainstorm a list of possible characteristics of a fruit cell that might contribute to its function as an electrochemical cell.
3. As a team, select two or three types of fruit and metal strips/nails to test for their ability to act together as a cell.
4. As a team, write a procedure for how you will assemble and test your fruit cells. Create a table to record your results.
5. Carry out your procedure.

6. Compare your results. Then choose the best fruit cell to use in the challenge.
7. Write a procedure for carrying out the challenge that the class chose.
8. Carry out the challenge.

Process and Analyze

1. Describe the cell that won the challenge. Suggest reasons why it worked best.
2. What did you conclude about the properties of fruit that allow it to act as an electrochemical cell?
3. Why do you think that fruit cells are not commonly used to run electrical devices?

Evaluate and Innovate

4. What could you do to improve your design for this investigation? For example, could you use more than one piece of the fruit that you chose? What difference might more than one piece of fruit make? Would it have made a difference if you had softened the piece of fruit by rolling it with pressure? Write a paragraph explaining your ideas.

TOPIC 3.4

How are circuits used in practical applications?

Key Concepts

- Voltage, current, and resistance in a circuit are related by Ohm's law.
- Loads can be connected in series or in parallel in a circuit.
- Parallel loads are practical for circuits in the home.

Curricular Competencies

- Construct, analyze and interpret graphs, models, and/or diagrams.
- Evaluate the validity and limitations of a model in relation to the phenomenon modelled.
- Evaluate methods and experimental conditions, including identifying sources of error or uncertainty, confounding variables, and possible alternative explanations and conclusions.

In 2016, headlines around the world announced that the world's largest and most costly scientific instrument, the Large Hadron Collider (LHC), had been shut down for several days. The cause was a small and uninvited guest in the electrical building. A weasel had chewed on a single electrical cable. High tech, it seems, was no match for a lowly weasel. Even after fixing the damaged cable, scientists had to test many electrical circuits in the facility. Each connection and each wire in the thousands of kilometres of electrical wires in the LHC is designed to carry out a specific function. This photo shows just some of that wiring.

Starting Points

Choose one, some, or all of the following to start your exploration of this Topic.

1. **Identifying Preconceptions** When you walk into your room in the evening, you reach for the switch and turn on the light without even thinking about it. What exactly is happening when you flip the switch? Why does one light go on but no other lights in the room do?
2. **Communicating** Imagine that you are a time traveller from a time before electrical energy was available for everyday use. You suddenly drop into today's world and see all of the devices that everyone is using. Write a log entry describing what you have just seen in today's world.
3. **Applying First Peoples Perspectives** Electrical energy is transformed into different forms of energy in countless ways. How can electrical energy be seen or represented as a creative force?

Key Terms

There are three key terms that are highlighted in bold type in this Topic:

- Ohm's law
- series circuit
- parallel circuit

Flip through the pages of this Topic to find these terms. Add them to your class Word Wall along with their meanings. Add other terms that you think are important and want to remember.

CONCEPT 1

Voltage, current, and resistance in a circuit are related by Ohm's law.

Activity

Comparing Current and Resistance

The table shown here lists the resistance of some common home appliances. The last column shows the current that passes through each appliance when connected to a 120 V source (standard household voltage). Draw a graph of resistance versus current for these items. Put resistance on the *x*-axis and current on the *y*-axis Study your graph. How is current related to resistance? For example, when the resistance increases, what happens to the current?

Appliance	Resistance (Ω)	Current (A)
Lamp	150	0.8
Laptop computer	60	2.0
Toaster	20	6.0

Connect to Investigation 3-F on page 244

It is critical that too much current does not flow through the conductors in a circuit. If the current is too high, the wires can get extremely hot and start a fire. Fortunately, it is possible to predict what the current will be in a circuit.

Ohm's Law

German physicist Georg Ohm studied the relationship among electrical potential difference, current, and resistance in electrical circuits. He discovered that when he raised the electrical potential difference, the current increased for a given resistance in a conductor. He developed the relationship now known as **Ohm's law**, shown in the box below.

Ohm's Law law stating that the electrical potential difference between two points in a circuit is equal to the current times the resistance between those two points

Ohm's Law

The electrical potential difference between two points in a circuit is equal to the current times the resistance between those two points.

$$V = IR$$

V is the symbol for electrical potential difference, I is the symbol for current, and R is the symbol for resistance.

By rearranging the variables in Ohm's law, it is possible to calculate any of the variables if the value of the other two is known.

Activity

Using Ohm's Law

Study the following sample problem to learn how to use Ohm's law. Then solve the following problems. More sample problems are provided in Appendix A on page 397.

Sample Problem

Imagine that you are testing an electrical toy. You are going to plug it into your home outlet, which provides an electrical potential difference of 120 V. The wires are small and you do not want the current to go above 1.5 A. How high must the resistance of the electrical toy be?

Solution

Because you want to determine a resistance, you will need to rearrange the formula $V = IR$ into the formula $R = \frac{V}{I}$.

Substitute the values into the formula.

$$R = \frac{V}{I}$$

$$= \frac{120\ \text{V}}{1.5\ \text{A}}$$

$$= 80\ \Omega$$

The electrical toy must have a resistance of at least 80 Ω to ensure that the current does not go above 1.5 A.

1. A television that is plugged into a wall socket has an electrical potential difference of 120 V. If a current of 1.25 A is flowing through the television, what is its resistance?
2. The filament of a flashlight bulb has a resistance of 40 Ω. If a 6.0 V battery is used in the circuit, what is the current?
3. A circuit board has a resistance of 12 Ω and requires a current of 0.25 A. What electrical potential difference is required to operate the circuit board?

Before you leave this page . . .

1. List the three symbols used in Ohm's law. Explain what each symbol represents and give the units for each of the variables.

CONCEPT 2

Loads can be connected in series or in parallel in a circuit.

Activity

Circuit Challenge

1. You will be given a battery, two switches, two light bulbs, alligator clips, and several conducting wires. Your challenge is to build three different circuits.

   Circuit #1: One switch must control both light bulbs. When you close the switch, both light bulbs go on. If either bulb is removed (to simulate burning out), the other bulb goes off.

   Circuit #2: One switch must control both light bulbs. When you close the switch, both light bulbs go on. When either bulb is removed, the other bulb remains on.

   Circuit #3: Each light bulb is controlled by its own switch. When one switch is closed, one light bulb goes on. When the other switch is closed, the other light bulb goes on. Neither bulb is affected by the other one.

2. Discuss how these circuits might be applied in a home or classroom.

All of the circuits that you have studied so far have a single loop. In such a circuit, current flows along one pathway. Most circuits, however, are much more complex, and current may flow along more than one pathway.

One Pathway

When current can flow along just one path in a circuit, the circuit is called a **series circuit**. The circuit components are connected in series. Figure 3.24 shows three light bulbs connected in series. Trace the path of the current. Notice how there is only one path in which it can flow through the battery, switch, and loads.

series circuit a circuit in which current can only flow along one path

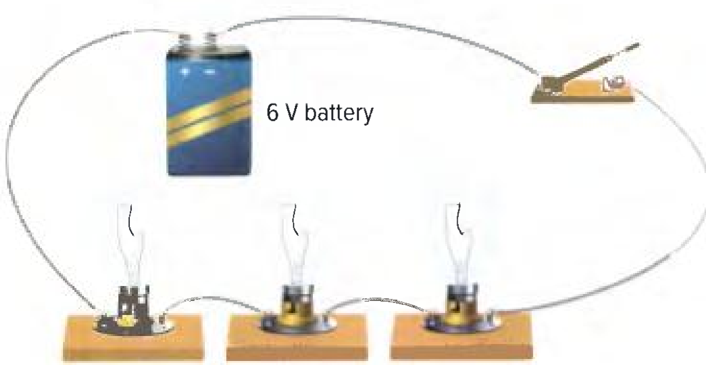


Figure 3.24 All of the components in this circuit are connected in series.

Multiple Pathways

When a circuit has at least one branch point where the current splits into two or more pathways, it is a **parallel circuit.** The components in these pathways are connected in parallel. Figure 3.25 shows a circuit that has all of the same components as the circuit in Figure 3.24. However, the bulbs are connected in parallel. Trace the path of the current. Notice where it branches and the current splits into two pathways.

Connect to Investigation 3-G on page 245

parallel circuit a circuit that has at least one branch point where the current splits into two or more pathways

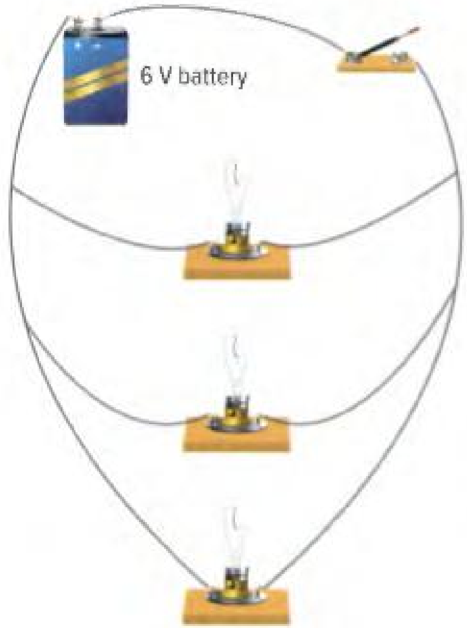


Figure 3.25 The three bulbs are connected in parallel. The battery and switch are in series.

At a branch point, the current splits so the sum of the currents in the branches is the same as the current in the single conductor before the branches. Figure 3.26 compares a series and a parallel circuit. In the parallel circuit, the current is reduced in each branch.

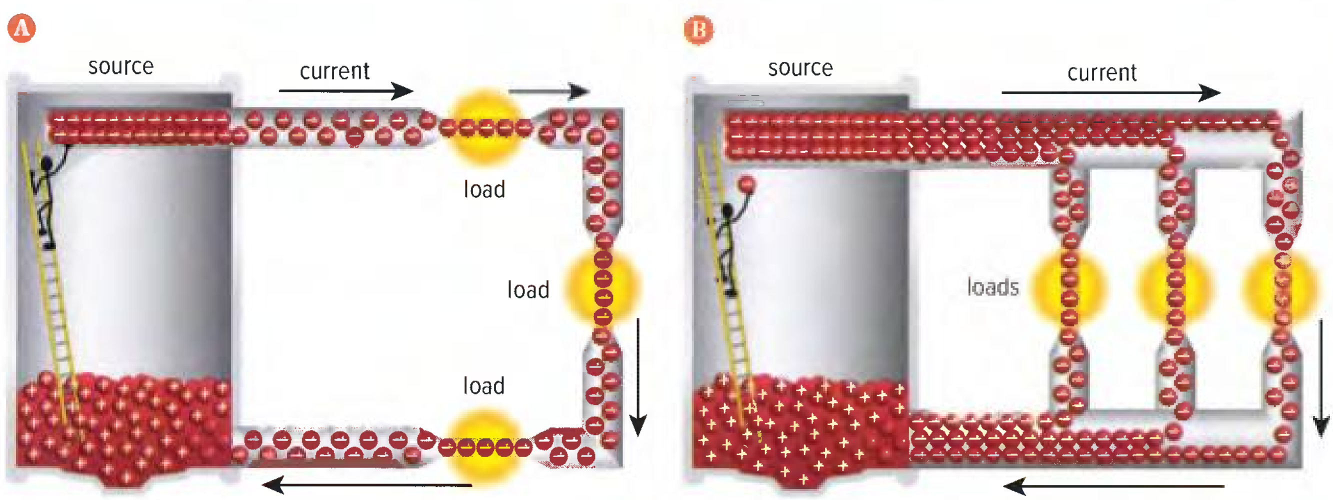


Figure 3.26 A In this series circuit, there is just one path through which the current can flow. The current is equal in all parts of the circuit. B In this parallel circuit, the current splits into three paths. In each path, the current is reduced.

Before you leave this page . . .

1. Use the analogy of two different roads or rivers to compare a series and parallel circuit.

CONCEPT 3

Parallel loads are practical for circuits in the home.

If one load in a series circuit burns out, the circuit will be open, charges will stop moving, and no loads in that circuit will work. This makes series circuits impractical in homes, where many loads are needed. Think of a kitchen. Each load must work independently of all others. Otherwise a burned out ceiling lamp would cause a toaster, microwave, and radio on the same circuit to stop working. Likewise, if you turned off the radio, all the other appliances would stop as well.

In Figure 3.27, all the devices are connected in parallel. Each can be controlled by its own switch without shutting off the others. The pathways in the diagram represent conductors, and the coloured lines represent current flowing to a specific device. The arrow in part A shows that, when all appliances are on, a large amount of current is passing through the conductor near the source. When large amounts of current flow through a wire, it can get very hot and it becomes a safety hazard.

Connect to Investigation 3-H on page 246

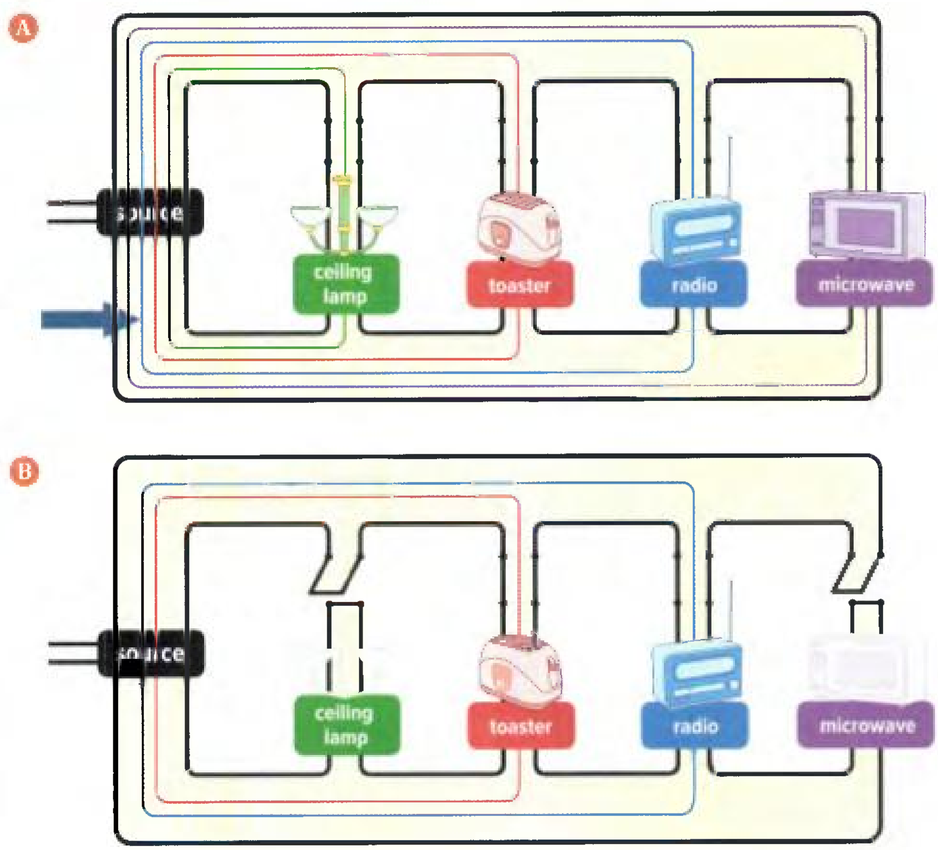


Figure 3.27 Parallel circuits are practical because each appliance is controlled by its own switch.

A All of the appliances are running.

B When the microwave and lamp are turned off, the toaster and radio still run.

Multiple Circuits Within a Building

While parallel circuits are convenient in one room, imagine if all the electrical devices in an entire home were connected to the same parallel circuit. The current flowing to each device also would be flowing through the wire conductors connected to the source. This large amount of current would make the wires extremely hot, possibly causing a fire.

Because of this safety concern, many separate parallel circuits are installed in buildings, as shown in Figure 3.28. Each colour represents a single parallel circuit. A very large electrical cable carries electrical energy from a power company to a building. This large cable branches out and is connected to each of the parallel circuits inside a circuit panel. The cables for all circuits leave this circuit panel and carry electrical energy throughout the building.

Connect to Investigation 3-I on page 249

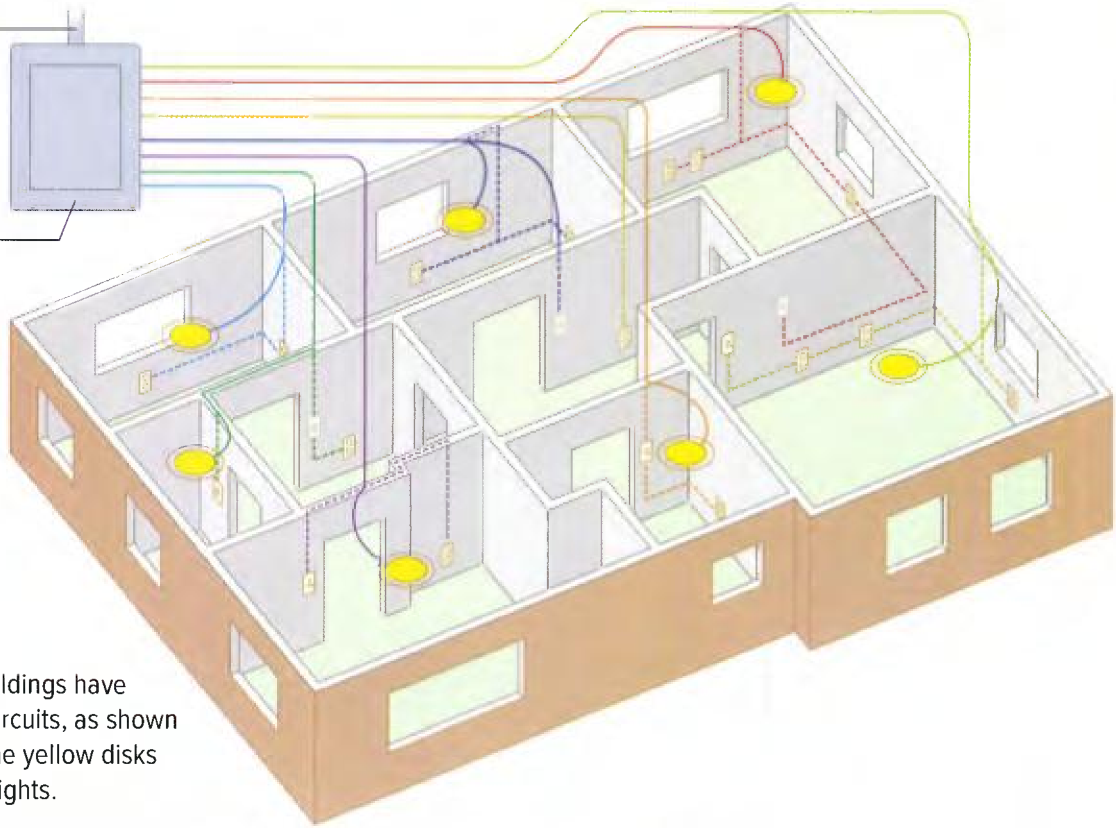


Figure 3.28 Buildings have multiple parallel circuits, as shown in this diagram. The yellow disks represent ceiling lights.

Before you leave this page . . .

1. Explain why it would be impractical to wire a home with a circuit in which all loads were connected in series.
2. Explain why a parallel circuit with too many electrical devices connected to it is not safe.

AT ISSUE

What was the AC/DC war about?

What's the Issue?

More than 100 years ago, an epic battle took place between two of history's greatest inventors. Nikola Tesla and Thomas Edison were involved in the dispute about whether to use direct current (DC) or alternating current (AC) to supply commercial electrical energy to customers. Tesla was in favour of using AC. Edison preferred DC. Let the battle begin!

Dig Deeper

Collaborate with your classmates to explore one or more of these questions—or generate your own questions to explore.

1. AC/DC: It's not just the name of a rock band. What questions do you have about these two different types of currents and how can you find the answers?
2. Imagine you lived at the time of Edison and Tesla. Find out why they had the opinions they did. Would you have been on Team Edison or Team Tesla? Explain your position.
3. Tesla's behaviour was very eccentric (considered to be unusual or odd), especially in his later years. How could the personality of a scientist affect the public's acceptance of his or her work?

Check Your Understanding of Topic 3.4

QP Questioning and Predicting PC Planning and Conducting PA Processing and Analyzing E Evaluating
AI Applying and Innovating C Communicating

Understanding Key Ideas

1. You have a circuit that has a battery, a switch, and a buzzer. You are asked to find the resistance of the buzzer. PA
   a) What two pieces of information would you need in order to calculate the resistance of the buzzer?
   b) Write the formula you would use to carry out the calculation.

2. The person in the figure below is pulling a heavy load. However, the load is resisting the forward motion.

   The figure can act as a model for what happens in electrical conductors, cells and batteries, and electrical devices in a circuit.
   a) Write a paragraph that explains what you think each circuit component would represent in the model, and why.
   b) How does the figure model resistance in a circuit? PA E AI C

3. Two identical light bulbs are connected in a closed circuit. The wiring of the circuit is not visible. Suggest a way that you can determine if the bulbs are wired in series or in parallel. PC PA

4. Draw a circuit diagram of a kitchen that has a toaster, blender, and bread machine that can each be turned off while the other appliances keep running. PA AI C

Connecting Ideas

5. A dimmer switch includes a variable resistor. When you adjust the dimmer, you increase or decrease the resistance in the circuit. The electrical potential difference supplied to the circuit remains the same.
   a) What happens to the current in the circuit when you change the resistance? Refer to Ohm's law in your response.
   b) Why do you think that this brightens and dims the light? PA AI

Making New Connections

6. Read the quote below and answer the questions that follow. PA E AI

> "Like many of our trees the cedar is in danger. There are very few old growth trees left and many young trees are cut down to use as hydro and telephone poles. When you drive down the highway these poles are standing along the road, holding hydro and telephone wires. So you all still receive help from the cedar tree."
>
> Chief Frank Malloway
> Yakweakwioose First Nation,
> Chilliwack

   In B.C., many cedar poles hold up wires that carry electrical energy to buildings.
   a) Describe the path that electrical energy takes from these poles into the different rooms in your home.
   b) The wires held up by the poles are much larger than the ones in your home. Why is this the case?
   c) The cedar is very important in First Peoples culture in parts of B.C. Suggest another way electrical energy could be transported.

INVESTIGATION

3-F

GUIDED INQUIRY

Resistance of Play-Doh®

Skills and Strategies

- Questioning and Predicting
- Planning and Conducting
- Evaluating
- Applying and Innovating
- Communicating

Safety

- Do not turn on the power supply without your teacher's approval.
- Use care in handling sharp pieces of metal.
- Do not cause short circuits.

What You Need

- Play-Doh® of several colours
- power supply
- wires with alligator clips
- ammeter and voltmeter or two multimeters
- ruler
- Play-Doh® extruder
- nails or pieces of metal

Question

What factors affect the resistance of a conductor such as Play-Doh®?

Procedure

1. Brainstorm factors that affect the resistance of a conductor. Choose at least three factors to investigate. For each factor you decide to investigate, write a hypothesis to predict which possible outcome you think will occur.
2. Decide on the dimensions and characteristics of the Play-Doh® you will test.
3. Use the extruder to prepare the pieces of Play-Doh® that you are going to test. Knead the Play-Doh® before extruding.
4. Draw a circuit diagram of your apparatus which shows how you will measure current and electrical potential difference.
5. Decide on how to connect the pieces of Play-Doh® to the parts of the circuit. For example, you might insert small nails or pieces of metal into ends of the Play-Doh® to connect to the wires with alligator clips.
6. Assemble your apparatus and have your teacher check it. Measure the current and electrical potential difference of each piece of Play-Doh® you made. Start at very low power and turn it up slowly. Record your measurements.

Process and Analyze

1. Use Ohm's law to calculate the resistance of each piece of Play-Doh®.
2. Use data for two tests that differ only by one variable. Compare the resistances of those two samples. Did that variable cause the resistances to differ? If so, how?
3. Write a paragraph that summarizes the factors that affect the resistance of Play-Doh®.

Evaluate

4. Describe possible sources of error in your measurements. Discuss how errors could be reduced if you repeat your investigation.

INVESTIGATION

3-G

GUIDED INQUIRY

Circuit City

Skills and Strategies

- Questioning and Predicting
- Planning and Conducting
- Evaluating
- Applying and Innovating
- Communicating

Safety

- Be careful not to make short circuits. Heat could cause the paper to burn.

What You Need

- conducting paint, ink, or tape
- sturdy paper, such as photo paper
- pencil
- LED light bulbs
- battery
- alligator clips
- masking tape
- small copper wires
- information resources

Question

How can you design a model of an electrical system for a city neighbourhood?

Procedure

1. What questions do you have about how to model the electrical system of a city neighbourhood? Write them down and find the answers.
2. Decide what tests you want to perform or questions you want to answer. For example, what will happen to the rest of the neighbourhood if a tree strikes a power line?
3. On a large piece of paper, sketch your streets and buildings. The buildings should be simple and large enough to put bulbs in them.
4. Before using conducting material, lightly sketch the paths of all electrical conductors and locations of the light bulbs.
5. Add your conducting material. Note that conducting paint or ink must dry before it will conduct an electric current.
6. Add the light bulbs to your circuit. Connect the battery with the small copper wires.
7. When your circuit city is working, perform the tests that you designed in step 2.

Evaluate

1. What problems did you have with your design? How were you able to fix them?
2. What type(s) of circuits did you include? Explain why you chose the type(s) you did.
3. What was the biggest challenge that you had to overcome?
4. Evaluate the limitations of using a model to demonstrate the electrical system of a city neighbourhood.

INVESTIGATION

3-H

STRUCTURED INQUIRY

Electrical Wiring in a Building

Skills and Strategies

- Questioning and Predicting
- Planning and Conducting
- Evaluating
- Applying and Innovating
- Communicating

Safety

- You must have an adult with you at all times when conducting your safety check.

What You Need

- pencil
- ruler
- paper
- graph paper

PART A: ELECTRICAL SAFETY CHECK

Just like you have regular health and dental checkups, the electrical system in your home or school should have regular checkups to keep it safe.

Question

Does your home or school pass an electrical safety check?

Procedure

1. Review the Table of Electrical Safety Equipment in Buildings on the next page so you understand the function of each device and how it works.
2. Review the electrical safety points below for ideas that can help with a safety check.
   a) Are switches and outlets:
      - warm to the touch
      - making a sound
      - discoloured
      - loose

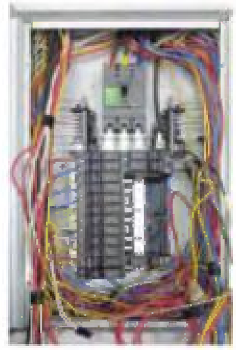
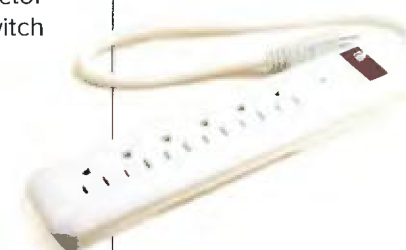
   b) Are appliance cords:
      - frayed
      - nailed in place
      - warm to the touch
      - pinched
      - under carpets
      - near hot surfaces

   c) In the circuit panel:
      - are the circuit breaker switches labelled?
      - do any of the breaker switches trip frequently?
      - if there are fuses, are they the right current rating?
3. Use the above information to write a checklist for giving your home or school an electrical safety check.
4. Carry out your safety check. You must have an adult with you at all times.

Analyze and Evaluate

1. Make a list of all observations that indicated to you that there might be a hazard.

Table Electrical Safety Equipment in Buildings

Device	Safety Purpose	How It Works	Example
Circuit breaker	Limits the amount of current to a set value; prevents overheating in wires and possible resulting fires	When a current is too large, a part of the circuit breaker is heated, and then bends and breaks contact with another part, opening the circuit; the circuit breaker must be manually reset	
Fuse	Limits the amount of current to a set value; prevents overheating in wires and possible resulting fires	Contains a metal conductor that melts at a temperature corresponding to a set amount of current, which creates an open circuit and stops the current; must be replaced	
Three-hole outlet and plug	Prevents shock resulting from faulty appliances	Outlet contains three slots, including a round one that is grounded; plug's round prong is electrically connected to appliance's metal frame; if a loose wire is connected to the frame, it sets up a large current that trips a circuit breaker connected to the outlet	
Ground fault circuit interrupter	Replaces wall outlet when it is within 1.5 m of water source, prevents shock	Contains a circuit breaker that trips extremely quickly if there is any difference in current between the right slot and the left slot; saves lives because it trips more rapidly that a regular circuit breaker in a building	
Power bar with surge protector	The power bar allows all appliances connected to it to be turned off with one switch. The surge protector prevents damage to circuits in electronic devices during power surges.	Each outlet on the surge protector is connected in parallel; the switch is in series with the wall outlet. Current above a pre-set maximum causes resistance of part of the surge protector to drop rapidly, diverting the current to ground.	

PART B: ELECTRICAL PLAN OF YOUR ROOM

To ensure the electrical safety of your own room, it would be helpful to know the electrical details of your room.

Question

How is your room electrically wired?

Procedure

1. Measure your bedroom and draw an accurate scale diagram of the floor plan that includes doors, windows, wall switches, electrical outlets, and permanent light fixtures.
2. Add any electrical components to your drawing using standard circuit diagram symbols for lights and switches, and a circle with an "X" inside for wall outlets.
3. Try to determine which electric components of your room are connected together. The light switch, for example, probably does not control the wall outlets. On your plan draw a possible wiring diagram for your room.
4. Label any current electrical safety features on your diagram. Would you add any others? Which would you add, and where would you use them? Explain. Label these safety features on your diagram as well.

Analyze and Evaluate

1. Describe at least two things an electrician must consider when wiring a bedroom.

Apply and Innovate

2. Imagine that you wanted to add an additional light to your room, controlled by the existing light switch. On your diagram, show the additional electric components and possible wiring in a different colour. Justify your choices.

INVESTIGATION
3-1

GUIDED INQUIRY

Skills and Strategies

- Planning and Conducting
- Evaluating
- Applying and Innovating
- Communicating

Safety

- Use caution when handling electrical supplies.

What You Need

- battery (6 V)
- connecting wires
- flashlight bulb in holder
- 2 three-connection switches

Build a Staircase Circuit

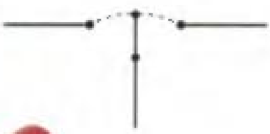
Many staircase lights can be turned on or off by operating either of two switches placed at the top and bottom of the staircase, like the one shown here.

Question

How do you design a circuit in which two switches control one light for a hallway or staircase?

Procedure

1. Design a circuit that will allow you to control one light with either of two switches. If the light is off, either switch must turn it on. If the light is on, either switch must turn it off. The switches that you will use are three-connection switches, as shown here.



2. Have your teacher approve your design. Then connect and test your circuit.
3. If your circuit does not operate properly, check the connections and your circuit diagram. If necessary, modify your circuit diagram and rebuild your circuit.

Evaluate

1. Did your first circuit work properly? If not, explain why not.
2. What precaution would you expect an electrician to take before wiring switches in a building?

TOPIC 3.5

How can electrical energy be generated and used sustainably?

Key Concepts

- Sustainable use of electrical energy begins with understanding how its use is measured.
- Making informed choices helps you use electrical energy sustainably.
- Renewable energy sources provide sustainable options for generating electrical energy.

Curricular Competencies

- Express and reflect on a variety of experiences, perspectives, and worldviews of place.
- Experience and interpret the local environment.
- Contribute to finding solutions to problems at a local and/or global level through inquiry.
- Co-operatively design projects with local and/or global connections and applications.

The International Space Station (ISS) orbits high above Earth. The ISS has limited resources available to it. To generate the electrical energy it requires, the Station uses a series of photovoltaic cells that transform solar energy into electrical energy.

Earth also has limited resources and has even been referred to as Spaceship Earth. As a planet, we still rely on finite supplies of fossil fuels such as coal and natural gas to generate electrical energy. As a result, much of the world is already turning to other energy sources that can be renewed quickly to ensure that we can continue to meet our demand for electrical energy.

Starting Points

Choose one, some, or all of the following to start your exploration of this Topic.

1. **Identifying Preconceptions** The solar energy used by the ISS is a form of renewable energy. In groups, come up with a definition of renewable energy and examples you agree on.
2. **Debating** To avoid depleting Earth's energy sources, should we focus most on how we generate this energy or how we use it? Debate this question in your group or as a class.
3. **Applying First Peoples Perspectives** How can Traditional Ecological Knowledge help us find ways to balance development with a sustainable future? Can we generate all the power we need and still live in harmony with nature and with one another? Share your thoughts and ideas.

Key Terms

There are eight key terms that are highlighted in bold type in this Topic:

- electrical power
- EnerGuide label
- phantom load
- nonrenewable energy source
- renewable energy source
- sustainable energy system
- smart meter
- ENERGY STAR® label

Flip through the pages of this Topic to find these terms. Add them to your class Word Wall along with their meanings. Add other terms that you think are important and want to remember.

CONCEPT 1

Sustainable use of electrical energy begins with understanding how its use is measured.

Activity

Toaster Versus Washing Machine

Several pairs of appliances are given below.

- a toaster and a washing machine
- a portable vacuum cleaner and a freezer
- a clothes dryer and a dishwasher
- a coffee maker and a computer

1. In a group, try to agree on which appliance in each pair uses electrical energy at a faster rate than the other. For example, if you run each appliance for one hour, which one uses more electrical energy?
2. Read the page of text below. Then use Table 3.2 to assess your choices.

electrical power the rate at which electrical energy is used by a load

Use of electrical energy is measured in two main ways. These ways are explained below.

Watts and Kilowatts

Electrical power is the rate at which electrical energy is used by a load. The load is typically an appliance, such as a washing machine or a television. Electrical power is measured in watts (W) or kilowatts (kW). 1 kW equals 1000 watts.

Most home appliances are labelled with their *power rating* (the rate they use energy) in watts. For example, a light bulb may be rated at 100 W. An iron may be rated at 1000 W or 1 kW. This tells you that if an iron and light bulb are on for the same length of time, the iron uses energy 10 times faster than the light bulb. The iron uses 10 times more energy. Table 3.2 lists the typical power ratings of several appliances.

Kilowatt-Hours

The electrical energy used by an appliance over time is measured in kilowatt-hours (kWh). Note that kWh combines the units for power and time. If you use an appliance rated at 1000 W or 1 kW for one hour, you will have used 1 kWh of electrical energy. You would need to use a 0.5 kW washing machine for 2 hours or a 2 kW dishwasher for half an hour to use the same amount of electrical energy.

Table 3.2 Typical Power Ratings of Appliances

Appliance	Typical Power Rating (kW)
Clock	0.0050
Clothes dryer	5.0
Washing machine	0.50
Coffee maker	1.0
Computer	0.20
Dishwasher	1.8
Freezer	0.34
Microwave oven	1.5
Toaster	1.1
Vacuum (portable)	1.6

Figure 3.29 Smart meters measure electrical energy use as it changes over the course of the day.

Measuring Electrical Energy Use in Homes and Businesses

In most homes and businesses in B.C., use of electrical energy is measured by smart meters (Figure 3.29) **Smart meters** measure how electrical energy use changes in a building over the course of the day. The data are sent to the utility company automatically by wireless signals like those used by phones and other wireless devices. The meters can encourage "smart" behaviour on the part of consumers by giving people a means to track how and when they use electrical energy each day.

smart meter an electrical energy meter that measures how energy use changes in a building over the course of the day

Activity

Personal Use of Electrical Energy

1. Predict how your use of electrical energy at home varies on an average day.
2. Then predict how your use of electrical energy in summer would be different compared with winter. Sketch bar graphs to show your predictions.
3. Compare your graphs with those of other students. How are they similar? How are they different?
4. Do you think these data could help change the way your family uses energy? Explain.

Before you leave this page . . .

1. What is electrical power and how is it measured?
2. Describe one benefit of smart meters.

CONCEPT 2

Making informed choices helps you use electrical energy sustainably.

In a typical home, some appliances use more electrical energy than others. For example, a stove and a clothes dryer use more energy than a TV and a radio. However, some appliances of the same type are more energy-efficient than others. How can you tell the difference? Just check the label.

EnerGuide label a label that gives details about the amount of energy that an appliance uses in one year of normal use

Understanding EnerGuide and ENERGY STAR® Labels

The Government of Canada requires companies to label new electrical appliances to show how much energy they use in a typical year. This **EnerGuide label** is shown in Figure 3.30. Using more energy-efficient appliances helps you use electrical energy more sustainably. It also helps you save on the cost of electrical energy.

Activity

Reading EnerGuide Labels

Your teacher will give you several EnerGuide labels for the same type of appliance.

1. **a)** Of the samples provided, how much electrical energy does the least efficient appliance use per year, on average?
   b) How does this compare with the least efficient appliance available, as indicated on the bar of the EnerGuide label?
2. **a)** Of the samples provided, how much electrical energy does the most efficient appliance use per year, on average?
   b) How does this compare with the most efficient appliance available, as indicated on the bar of the EnerGuide label?
3. What other information might a consumer want to know about each appliance before choosing to buy one?
4. **a)** On a scale of 1 to 10, how important would the electrical energy efficiency stated on an EnerGuide label be to you when making a decision to purchase this type of appliance? Explain your choice. In your explanation, describe any other factors you would consider when buying this type of appliance.
   b) How much do you think EnerGuide labels influence purchasing decisions made by the general public? Explain your reasoning.

Figure 3.30 How to interpret an EnerGuide label

The large number shows how much energy the appliance uses in one year of normal use.

The shaded bar below the large number shows how the appliance compares with similar ones on the market.

The numbers on the bar give a range of efficiency for yearly energy use. The left end is the lowest (most efficient). The right end is the highest (least efficient).

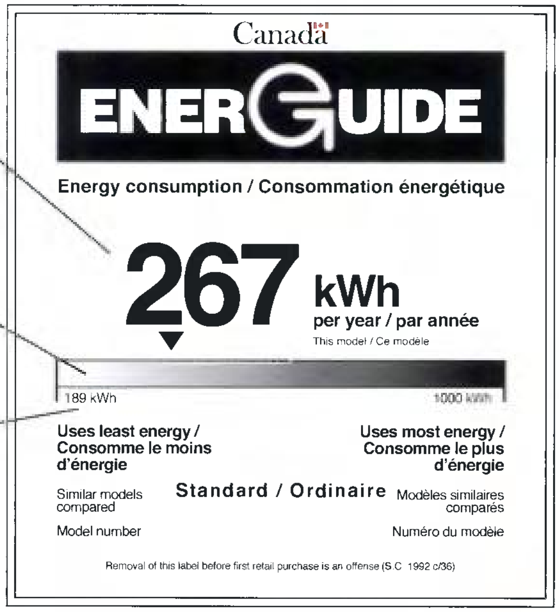


Figure 3.31 Appliances and equipment with the ENERGY STAR label use 10 to 50 percent less energy compared with a standard product in the same category.

Another tool that can help you use electrical energy more sustainably is the **ENERGY STAR® label** shown in Figure 3.31. Appliances and equipment with this label have met minimum efficiency standards set by the Canadian government.

ENERGY STAR® label identifies a product as meeting or exceeding certain standards for energy efficiency

Activity

Comparing Lighting Options

Some light bulbs claim to use less electrical energy than others but have the same light intensity. How could you test this claim?

Design an experimental procedure to compare the energy consumption of several types of light bulbs. For instance, you might compare halogen, compact fluorescent, and/or LED bulbs.

The following tip will help you get started:

- The intensity of light is measured in units called *lumens*. Make sure that each light bulb in your experimental procedure emits the same number of lumens.

Connect to Investigation 3-J on page 264

phantom load electrical energy a device uses when it is turned off

Phantom Loads

Are you aware that many electrical devices are on even when you think they are switched off? They are in stand-by mode. For instance, to turn on a television with a remote control, the television must be on to sense the signal. The electrical energy a device uses when it is turned off is called a **phantom load**. In addition to remote-controlled devices, many other appliances, such as computers, washing machines, and microwave ovens, also have phantom loads. Figure 3.32 shows some common appliances with phantom loads in a typical home. The term phantom load sounds ominous, and in a way it is. Studies have shown that phantom loads account for about 900 kWh of electrical energy use each year in the average home.

Figure 3.32 Devices with phantom loads are common in a typical home. **Identify the devices with phantom loads in this figure. For each device, explain why you think it has a phantom load.**

Activity

Fight the Phantom!

1. Create an inventory of possible phantom loads in your home or school. Use a table or other graphic organizer to organize your inventory. Your inventory should include the following information for each device.
   - type of device
   - location of device
   - number of devices in home or school
2. When you have completed your inventory, compare results with the class.
3. Do you think phantom loads are a significant waster of electrical energy in your home or school? Explain your reasoning.
4. How could you decrease the overall phantom load for the building you used for your inventory? Discuss your ideas with the class.

Before you leave this page . . .

1. Compare the information on an EnerGuide label with the information on an ENERGY STAR® label.
2. If a family goes away on vacation, why might electrical energy still be consumed in their home?

CONCEPT 3

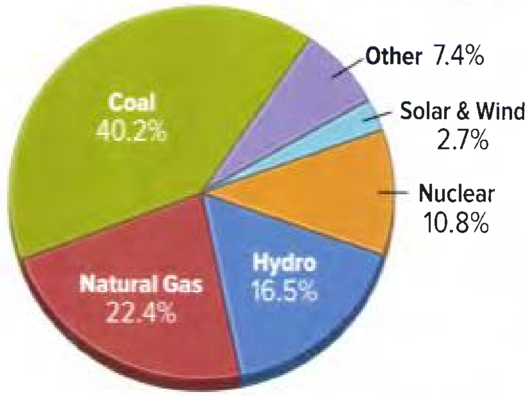
Renewable energy sources provide sustainable options for generating electrical energy.

Activity

Comparing Energy Sources

The graph on the right compares the percentage of different energy sources used worldwide. Use the graph to answer the questions that follow.

1. Identify the percentage of the world's electrical energy that is generated by the following energy sources.
   a) hydro **b)** nuclear **c)** fossil fuels
   d) wind and solar
2. What might the "other" sources on this graph refer to?
3. How do you think this graph would change if it showed energy sources used in **a)** Canada **b)** B.C. Provide your answers in the form of a graph.



Sources Used for World Electrical Energy Production

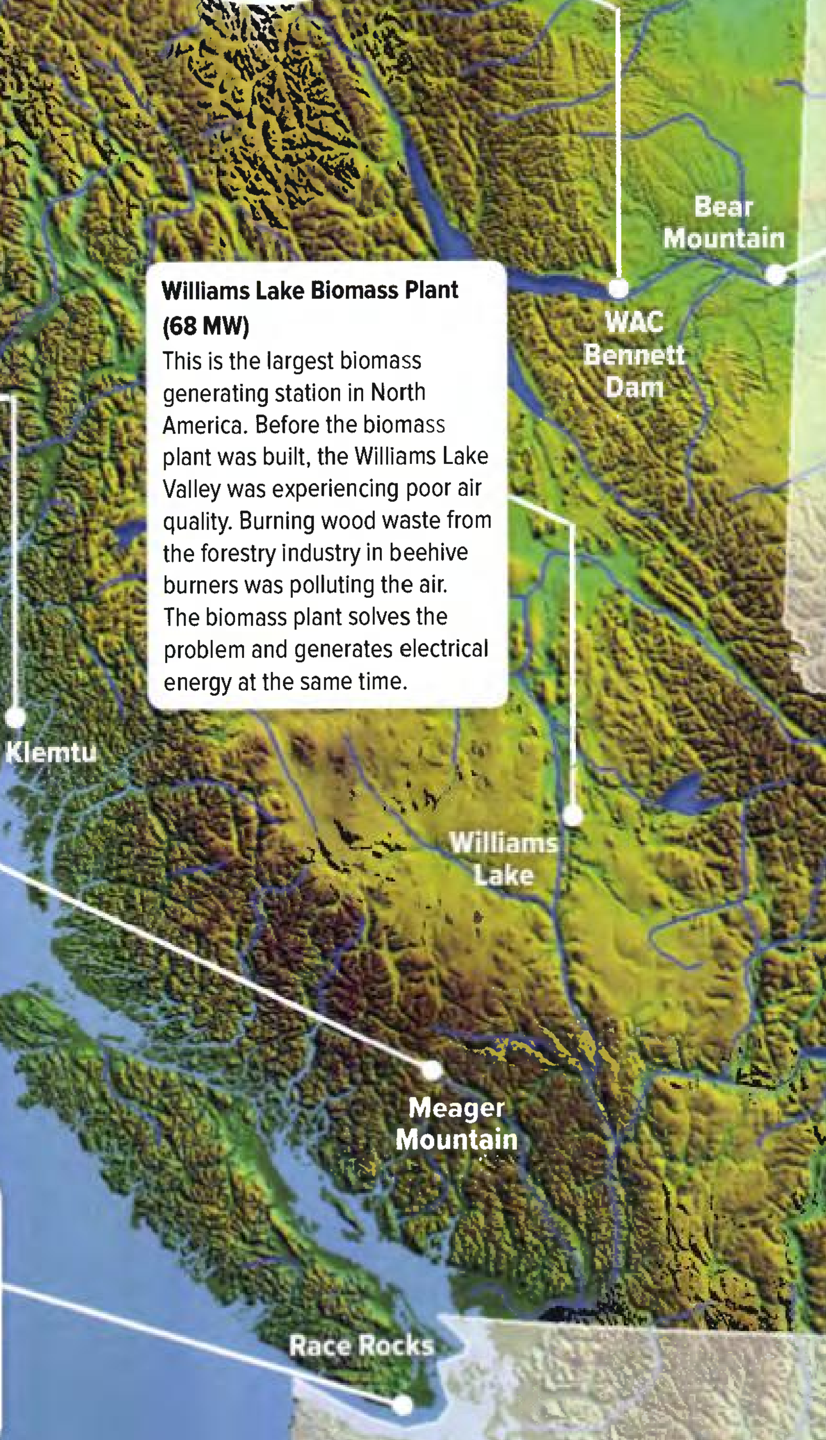
Electrical energy is always generated from another source of energy. The energy sources you learned about in Topic 3.1 are classified based on whether they are renewable or nonrenewable.

- **Nonrenewable energy sources** are not replaceable in a human lifetime. Fossil fuels are a nonrenewable energy source. Coal or natural gas is used to generate electrical energy in most provinces in Canada. The other nonrenewable energy resource is uranium (nuclear reactions), which is used to generate electricity in nuclear power plants. Since a human lifetime is so short in comparison, once these resources are used up, they are gone for good. As a result, nonrenewable energy sources are not a sustainable way to generate electrical energy.
- **Renewable energy sources** are produced on a continual basis or can be replenished fairly quickly. They are not at risk of being used up over the course of a human lifetime. Renewable energy sources include sunlight, wind, river flow, tides and waves, geothermal sources, and biomass. They provide sustainable options for generating electrical energy.

nonrenewable energy source an energy source that is non-replaceable in a human lifetime

renewable energy source an energy source that is available on a continuous basis

Connect to Investigation 3-K on page 266



WAC Bennett Dam (2730 MW)

Located on the Peace River, this massive 183 m high, large-scale hydroelectric dam provides most of B.C.'s electrical energy. However, several controversies surrounded the building of the dam. These included concern over negative environmental impacts when 350 000 acres of forested land was flooded, creating Williston Lake. The flooding also displaced residents of the area, including members of the Tsay Keh Dene First Nation.

The Klemtu Small-scale Hydro (1.7 MW) and Solar Project (0.023 MW)

A small-scale hydro generating station off Baron Lake and photovoltaic cells on the roof of the Kitasoo Community School in Klemtu help the entire Kitasoo/Xai'xais community. Electrical energy generated by these projects reduces the isolated community's reliance on diesel generators.

Williams Lake Biomass Plant (68 MW)

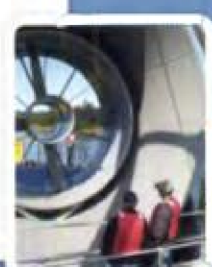
This is the largest biomass generating station in North America. Before the biomass plant was built, the Williams Lake Valley was experiencing poor air quality. Burning wood waste from the forestry industry in beehive burners was polluting the air. The biomass plant solves the problem and generates electrical energy at the same time.

Meager Mountain Geothermal Potential (200 MW)

Molten rock rises to just a few kilometres below B.C.'s Coast Mountain range. At average temperatures of 200-300°C, the molten rock holds great potential to heat water, producing steam to turn turbines to generate electrical energy. In fact, the Coast Mountains have the greatest geothermal potential in all of Canada. Meager Mountain in Upper Lillooet Provincial Park has the potential to generate electrical energy for over 90 000 homes annually.

Race Rocks Tidal Energy Project (0.65 MW)

The Race Rocks Tidal Energy Project is located southwest of Victoria in the Race Rocks Ecological Reserve. This small-scale demonstration project was installed in 2006. It is the first operating tidal current turbine in Canada. The turbine transforms the kinetic energy of tidal currents into electrical energy. The project also acts as a testing ground for further research into tidal technology.



Renewable and Nonrenewable Energy Sources in British Columbia

The map in Figure 3.33 shows a few ways that renewable and nonrenewable energy sources are used to generate electrical energy in B.C. on a large and small scale.

Fort Nelson Gas Plant (47 MW)
This natural gas generating station provides electrical energy to most homes and businesses in and around Fort Nelson.

Bear Mountain Wind Park (144 MW)
Sitting on a ridge looking over Dawson Creek, Bear Mountain Wind Park is the first wind park to provide electrical energy commercially in B.C. It consists of 34 wind turbines. Each turbine is 78 m high. The local initiative is a source of pride for the community. The wind park site is also used for recreational activities like hiking and cross-country skiing, as well as cattle grazing.

SunMine Solar Energy Project (1 MW)
SunMine is B.C.'s largest solar project. Located just outside of Kimberley, over 4000 photovoltaic cells are mounted on 96 solar trackers. These trackers follow the Sun's movement through the sky over the course of the day. The project received much of its funding from B.C.'s Innovative Clean Energy (ICE) Fund program. It can generate electrical energy for about 250 homes at peak production.

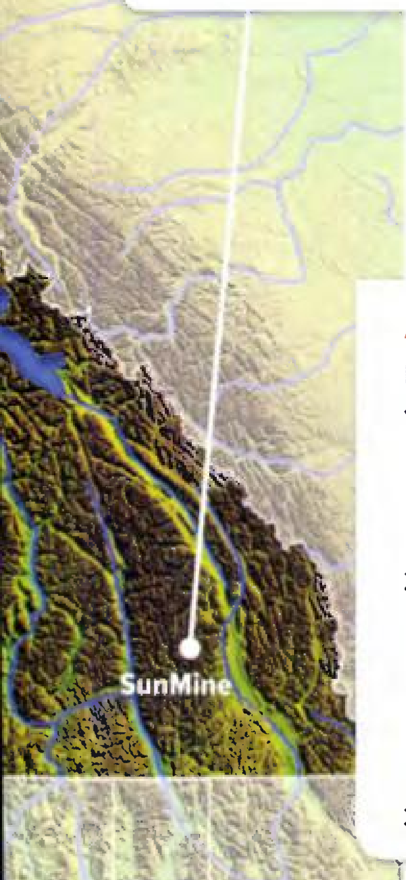


Figure 3.33 This map shows several renewable and nonrenewable energy projects in B.C. Note that 1 MW (megawatt) is equal to a million watts. **Which initiatives on this map make use of renewable energy sources? Which ones use nonrenewable energy sources?**

Activity

Map It!

1. Choose a renewable or nonrenewable energy source that interests you. Research the source to find out where it is currently being used to generate electrical energy in B.C. If it is not being used, choose another source.
2. Research the source further to answer the following questions.
   a) Is the source renewable or nonrenewable?
   b) What are the pros and cons of using it to generate electrical energy?
   c) Where and how is the source being used in B.C.?
   d) One other question you have about the source.
3. Record your answers and add them to a map of the province as directed.

Moving Toward a Sustainable Future

Connect to Investigation 3-L on page 268

Although we have tended to use electrical energy unsustainably in the past, our behaviour is beginning to change. A shift is occurring in how electrical energy is being generated, used, and even thought about. This is part of a larger movement that is pushing for sustainable use of all energy sources. People's growing concern about the environment has been driving this change. So has the realization that nonrenewable energy sources will one day run out. This awareness is not just occurring in British Columbia and Canada, but all over the world.

As a result of this greater awareness, individuals and governments have begun to see the need for a sustainable energy system. A **sustainable energy system** is a sustainable way of perceiving, producing, and using energy, including electrical energy. The system has the following characteristics:

sustainable energy system a sustainable way of perceiving, producing, and using energy

- the extraction, production, and use of energy have limited impact on environmental and human health
- there is less reliance on decreasing nonrenewable sources
- it ensures the availability of renewable and reliable energy sources for current and future generations
- it provides access to affordable energy for Earth's entire population

Activity

Voicing Your Concerns

Create a plan to raise awareness about the need for a sustainable energy system. For example, this could involve setting up an awareness group, creating a poster campaign, or raising awareness through social media. At a minimum, your plan should

- summarize how you will organize your campaign
- describe who your campaign will reach and how it will reach them
- discuss how your campaign will raise awareness about this issue
- explain how you will judge the success of your campaign once it is over

If there is time, present your plan using a medium of your choice.

First Peoples Ecosystem Based Management

Many of the characteristics of a sustainable energy system are in line with First Peoples Ecosystem Based Management (EBM). Some principles of EBM are given below.

Respect and Responsibility
Respect and responsibility go hand in hand. By making decisions that respect the natural world and the well being of all who call it home, First Peoples practise responsible use of resources. First Peoples consider themselves responsible for future generations, and respectful decision making helps them to be so.

Intergenerational Knowledge
Listening to Elders shares knowledge and decision making skills between generations. This way, decisions can be based on past experience. By sharing traditions and culture, the importance of place is also taught.

Balance and Interconnectedness
Balance keeps ecosystems healthy. It also makes sure that future generations are considered with each decision. Interconnectedness takes many relationships into consideration in decision making—not just between people, but also between other living things and their environment, and between ecosystems.

Giving and Receiving
Giving thanks for natural resources recognizes their value. It encourages shared responsibility for the natural world. Benefits of resources are shared between members of a community and with other communities.

Activity

Connecting with First Peoples Principles

T'sou-ke First Nation uses photovoltaic cells to generate electrical energy. It has started a project to use waves for this purpose as well. As a community, they are dedicated to using electrical energy sustainably. Their efforts have reduced their use of electrical energy by at least 75%.

1. Find out more about T'sou-ke First Nation's plan to use energy sustainably. In a group, discuss how First Peoples EBM applies to T'sou-ke First Nation. Research EBM principles further to gain a better understanding of how they reflect sustainability, environmental stewardship, resource management, and interconnectedness. If you are not sure what a term means, look it up.
2. How do you think the location of T'sou-ke First Nation influenced the type of renewable energy sources they chose to develop?
3. Consider where you live. How would your location and features of your region influence the choices you would make if you could choose the energy source used to generate electrical energy for your community? What other factors would it be important to consider?

Before you leave this page . . .

1. Explain why coal is a nonrenewable energy source and why moving water is a renewable energy source.
2. Identify the four main characteristics of **a)** a sustainable energy system and **b)** First Peoples Ecosystem Based Management.

TAKE a Stand

Make a Difference

Challenges of Changing to a Sustainable Energy System

To change to a sustainable energy system, everyone must learn to change how they act and how they think. The questions below highlight some of the challenges.

- Canada is a large and diverse country. Should a sustainable energy system be the same for all of Canada, or should it differ for different regions?
- What types of energy sources should be included? For instance, should only renewable resources be used?
- How can information about energy sources be obtained and presented in an unbiased way?
- How should we balance the needs of today with those of future generations?
- Developing renewable energy sources costs money. How much should we invest in these technologies? Who should pay?
- About 1.5 billion people on our planet have no access to electrical energy. How can individuals such as you help to reduce this number? How can a community help to reduce this number? How can society at large help?

Analyze and Evaluate

1. What is your opinion of the challenges listed in this feature? What other challenges are there? How easy do you think it will be to find and agree on solutions?

Communicate

2. Choose one issue that interests you in this feature. Research more information about it. Gather and evaluate sources that represent the many sides of the issue. Then take a stand on one side of the issue. Share your viewpoint with the public by writing a letter to the editor of a relevant newspaper or magazine, or commenting on a relevant web page.

Check Your Understanding of **Topic 3.5**

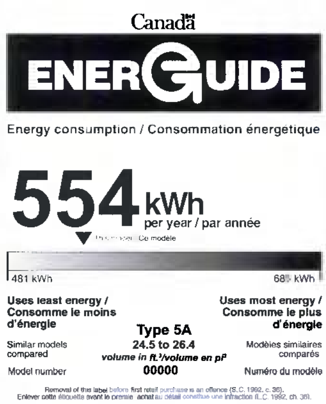
QP Questioning and Predicting PC Planning and Conducting PA Processing and Analyzing E Evaluating
AI Applying and Innovating C Communicating

Understanding Key Ideas

1. A light bulb is marked with 100 W. What does this mark tell a consumer about the light bulb? PA

2. Most B.C. homes and businesses have smart meters. PA
   a) How does a smart meter relay data to the utility company?
   b) What information does it relay?

3. Examine the label on the right. PA AI C



   a) Summarize, in your own words, the information provided on the label.
   b) Explain how you could use the information on the label when shopping for a new appliance.

4. You and your family have recently moved to a remote island on the B.C. coast. PA E AI
   a) Identify one nonrenewable energy source your family could use to generate electrical energy. Explain how it could be used to generate electrical energy.
   b) Identify one renewable energy source your family could use to generate electrical energy. Explain how it could be used to generate electrical energy.
   c) Explain which of the two sources you would recommend that your family uses. Justify your response.

5. Explain how electrical energy can be used by an electric toothbrush that is plugged in but is not running. PA AI

6. An environmental blog states that natural gas is renewable because it is generated from biomass. Do you agree? Explain. PA E

7. A letter to the editor of your local newspaper states that in a northern climate such as Canada's, sunlight can never be a reliable source of electrical energy. How would you explain, in a follow-up letter, that this is not the case? Refer to at least one example of how solar energy has been used to generate electrical energy in B.C. PA E AI C

Connecting Ideas

8. A source claims that phantom loads account for up to 5 percent of the electrical energy used in homes. Explain how you could collect and analyze data to test this claim. QP PA E AI

Making New Connections

9. During Earth Hour each year, for one hour, people all over the world are encouraged to use less electrical energy. E AI
   a) How might the organizers of future Earth Hours encourage more people to use less electrical energy for one hour on the day selected for Earth Hour?
   b) How might the organizers of future Earth Hours inspire people to make long-lasting lifestyle changes that will reduce their use of electrical energy?

INVESTIGATION

3-J

GUIDED INQUIRY

Skills and Strategies

- Questioning and Predicting
- Planning and Conducting
- Processing and Analyzing
- Evaluating
- Communicating

What You Need

- access to information resources (for example: online, in-print, interviews)

Create a Sustainable Energy Plan for Your School

Renewable energy sources, energy efficiency, and energy conservation each play an important role in a sustainable energy plan. In this investigation, you will apply these three components to create a plan to generate and use electrical energy more sustainably at your school.

Question

How can you create a sustainable energy plan for your school?

Procedure

1. Working in a group, you will prepare a presentation on the topic "A Sustainable Energy Plan for Our School." Your presentation format is up to you, but the presentation must meet the design criteria on the next page.
2. With your group, brainstorm how you will gather information. After you have collected your information, work together to organize it.
3. Design and create any images, models, or props that you will use.
4. Prepare your final presentation. Make your presentation as directed by your teacher.

Evaluate

1. Did you present enough data to convince your audience that your action plan was realistic? Explain.
2. What adjustments would you make to your plan for a new school being built in your community? Explain.

Design Criteria

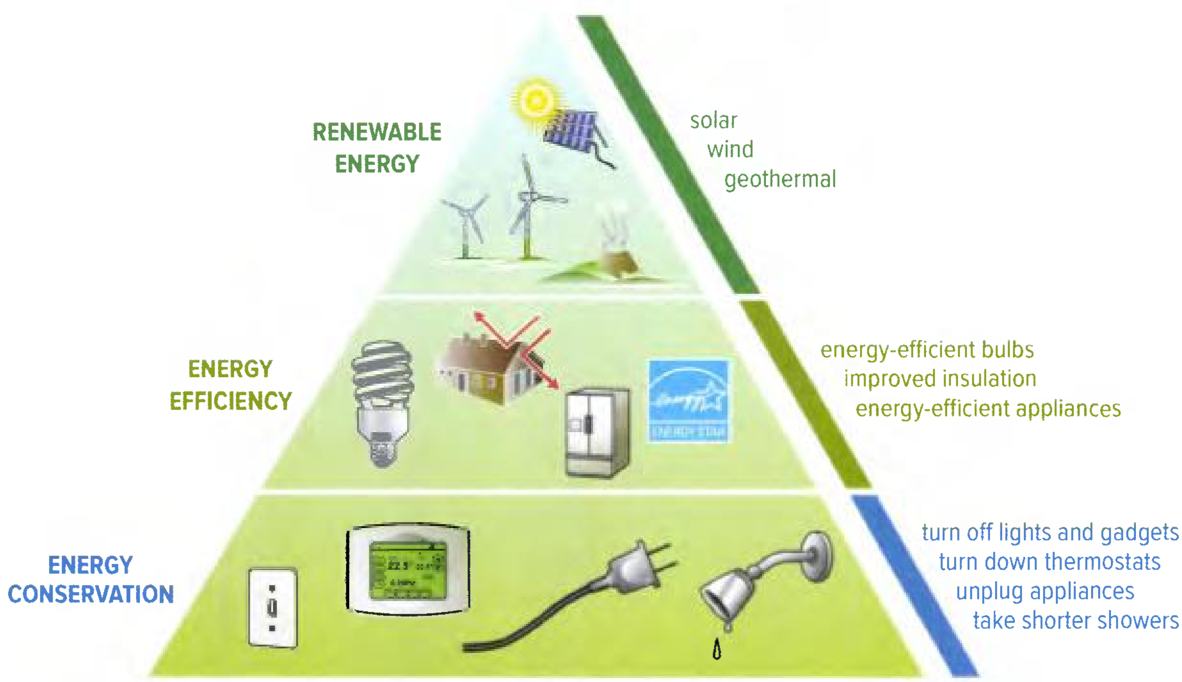
A. Your presentation should explain why it is important that your school generate and use electrical energy more sustainably.

B. Your presentation should answer the question "Can our school generate and use electrical energy more sustainably?" If your answer is "no," you must provide evidence and explain your reasoning. If your answer is "yes," include a step-by-step plan, focussing on how this change can be brought about.

C. Your presentation should include data on where and when electrical energy is currently used in the school, how much electrical energy is used, and what sources supply this energy.

D. Your presentation should assess the cost of implementing your plan. Consider the sustainable energy pyramid shown below.

- The top level consists of renewable energy sources. These resources tend to be expensive to produce. However, they are still important to a sustainable energy plan if affordable.
- The middle level addresses energy efficiency. This often involves buying newer, more efficient appliances and comes with a significant price tag.
- The base of the pyramid consists of energy conservation. It is the most cost-effective level and the one that the most people can participate in.



INVESTIGATION

3-K

STRUCTURED INQUIRY

Skills and Strategies

- Processing and Analyzing
- Evaluating
- Communicating

What You Need

- access to information resources (for example: online, in-print, interviews)

Energy Source Scenarios

Deciding on the best source of energy to generate electrical energy in a particular setting depends on many variables. Costs, environmental impacts, availability, reliability, and convenience are just a few of the many factors to consider.

Question

Which energy source is the best choice in a given situation?

Procedure

1. As a group, decide on a scenario in which you will compare two energy sources that can be used to generate electrical energy. Some scenarios you may choose from are below. You may also conduct research to create your own scenario.
    - **Scenario 1:** A ski hill on the south side of a mountain in southeastern B.C. is choosing between generating electrical energy with photovoltaic cells or buying electrical energy generated by a large commercial hydroelectric dam.
    - **Scenario 2:** A family wants to generate electrical energy for their isolated cabin in northwestern B.C. Their cabin is in a position to take advantage of a nearby geothermal energy source (hot springs) on a small scale. They are choosing between this option and a diesel-powered electric generator.
    - **Scenario 3:** A 20-home housing development is being constructed on the west coast of Vancouver Island. The owner would like the development to generate its own electrical energy. It is an area with strong steady winds, so building wind turbines on land is an option. The owner is also considering placing turbines in the ocean that will transform the kinetic energy of ocean waves into electrical energy.
    - **Scenario 4:** A mining operation in northeastern B.C. needs a source of electrical energy to run its processing facilities. The company could purchase electrical energy generated by a natural gas generating station or build a small run-of-river station on a river on its property.

2. Decide on factors you will consider and how you will rank and judge their importance. In a group, brainstorm answers to the following questions.
   - What key factors should be considered when choosing an energy source for a particular situation?
   - How can one factor be weighed against another?
3. Prepare a plan for comparing the two sources of energy in your group's scenario. Explain how you will assess the reliability of the sources you are using in your research. Have your teacher approve your plan before proceeding.
4. Make a list of the major advantages and disadvantages of each energy source.
5. Identify factors that might be particularly important in the scenario you chose.
6. Decide on which factors you think should be given the greatest weight, and rank them from most important to least important. Explain your reasoning.

Process and Analyze

1. Compare each energy source based on the factors you chose. Assign each energy source a score for each factor. For example, an energy source might receive a +2 for environmental impacts but a −1 for cost.
2. Some advantages and disadvantages are immediate (such as the initial cost of construction) while others are realized over a much longer period of time (such as gradual pollution of an ecosystem). Summarize how you weighed short-term versus long-term factors.

Evaluate and Communicate

3. Tally your results and reach a conclusion.
4. Prepare a recommendation that could be used to inform people involved in the situation you chose. Use a format of your choice, keeping your audience in mind.

INVESTIGATION

3-L

STRUCTURED INQUIRY

Skills and Strategies

- Questioning and Predicting
- Planning and Conducting
- Processing Information
- Evaluating
- Communicating

What You Need

- access to information resources (for example: online, in-print, interviews)

A Source of Electrical Energy for Riverside

The city of Riverside and its surrounding area (population: 10 000) is interested in establishing its own electrical energy generating station that utilizes a renewable energy source. The source must be able to supply 3 kW to every resident. Anything above this can be sold to neighbouring communities as surplus. Interested companies have been invited to present their proposals to the city council.

Question

What is the best renewable energy source to supply the city with reliable electrical energy year round?

This map shows the layout of the city, the shape of the valley, and two of the closest suburbs: Cedar Ridge and Cottonwood. The city is 20 km from an undeveloped coastline.

The Stonebank River winds through the valley and supplies water to the area. The city has a system of floodgates to cope with the spring floods that can affect the valley. The valley floor consists mainly of agricultural areas and neighbourhoods. The mountains around the valley are logged and used for recreation. A ski resort is located on a mountain just outside of the city. The mountain is a potential site of geothermal sources. The valley has an average wind speed of 14.3 km per hour. It has 288 sunny days per year on average.

Procedure

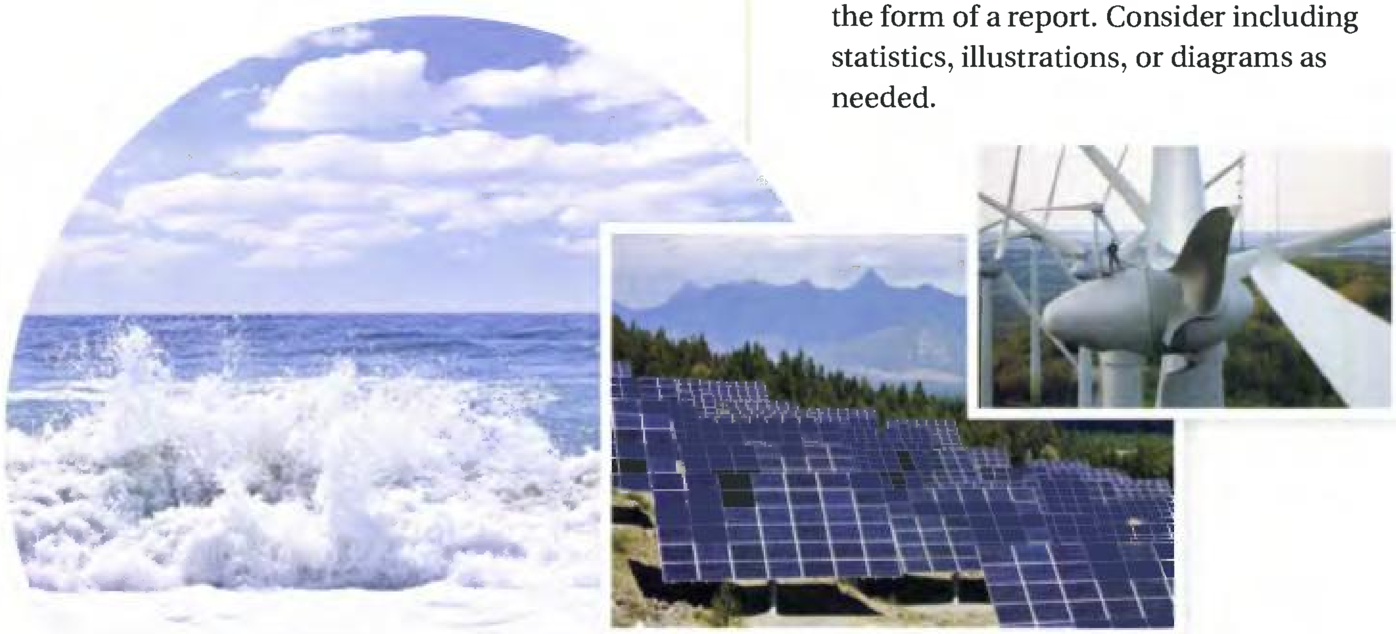
1. Your teacher will assign your group the role of one of the following stakeholders or energy companies that will be attending the council meeting.
   - Sunny Skies Solar Energy
   - Eagle Mountain Wind Energy
   - From the Ground Down Geothermal
   - River Run Hydroelectric
   - Tsunami Wave and Tidal Energy
   - Woodland Biomass
   - Riverside Nature and Wildlife Association
   - local residents association
   - Riverside Valley Agricultural Cooperative
   - city council
   - local First Peoples

   If your group is an energy company, you will be preparing a proposal for the new electrical energy generating station. If your group is representing a local stakeholder, you will be preparing a presentation of your concerns regarding the generating station.

2. Use the information on this page, including the map, as well as Internet and library resources to conduct research as needed to learn more about your group's proposal, stance, or role.
3. Organize the results of your research to prepare your presentation for a mock town council meeting.
4. Your teacher will briefly explain each group's proposal, stance, or role. As you listen to each group's presentation, take notes to help yourself prepare questions to ask.
5. Make your presentation before the council. If you represent the city council, you will present your concerns to the other presenters last.

Evaluate and Communicate

1. What was the final decision of the council? What was their reasoning?
2. Do you agree with the decision? Why or why not?
3. Summarize the presentation you made in the form of a report. Consider including statistics, illustrations, or diagrams as needed.



UNIT 3

Summary

ESSENTIAL QUESTION

How do we apply our understanding of charges to generate and use electrical energy?

TOPIC 3.1:

How is electrical energy part of your world?

- Electrical energy has many applications.
- Many different types of energy can be transformed into electrical energy.
- Electrical energy is generated in different ways from different sources.

Key Terms

electrical energy
generator system

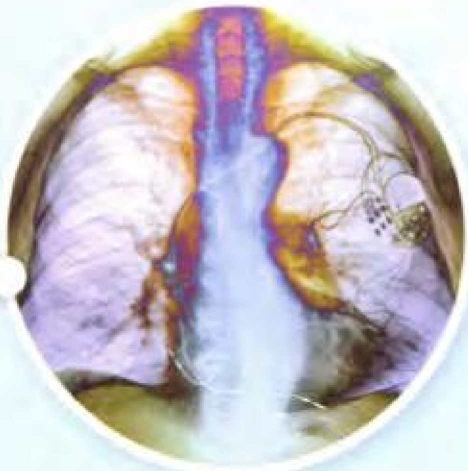
TOPIC 3.2:

How do electrical charges behave?

- Electrons carry a negative charge, and protons carry a positive charge.
- Opposite charges attract each other, and like charges repel each other.

Key Terms

negative charges
positive charges
law of electric charge



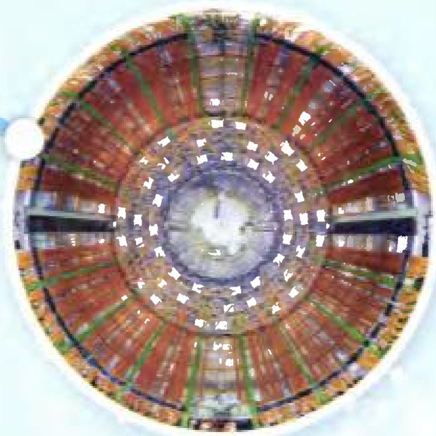
TOPIC 3.3:

How do charges flow through the components of a circuit?

- Chemical energy separates electrical charges in cells.
- Charges can flow through conductors, but not insulators.
- Moving electrical charges form an electric current.
- A load resists the flow of current.
- Conductors must form a closed loop to allow current to flow.

Key Terms

source	electrical potential difference		
conductor	conductivity	insulator	current
electrical circuit	load	resistance	short circuit



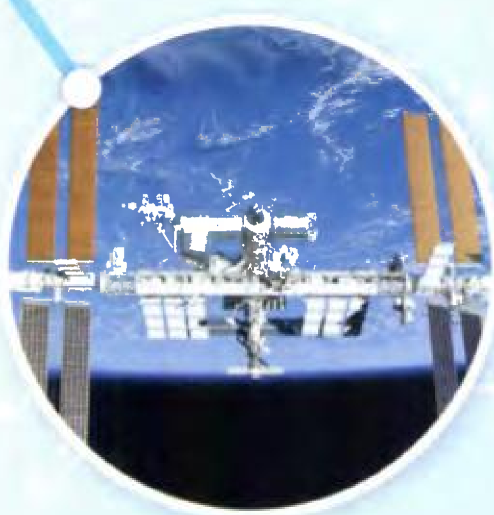
TOPIC 3.4:

How are circuits used in practical applications?

- Voltage, current, and resistance in a circuit are related by Ohm's law.
- Loads can be connected in series or in parallel in a circuit.
- Parallel loads are practical for circuits in the home.

Key Terms

Ohm's law	series circuit	parallel circuit



TOPIC 3.5:

How can electrical energy be generated and used sustainably?

- Sustainable use of electrical energy begins with understanding how its use is measured.
- Making informed choices helps you use electrical energy sustainably.
- Renewable energy sources provide sustainable options for generating electrical energy.

Key Terms

electrical power	smart meter
EnerGuide label	ENERGY STAR® label
phantom load	nonrenewable energy source
renewable energy source	sustainable energy system

UNIT 3

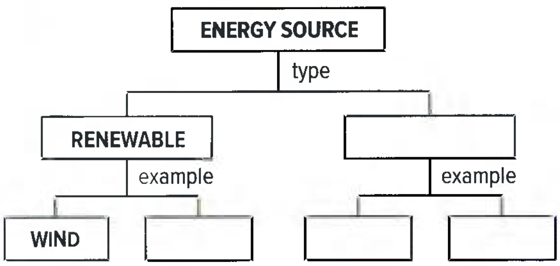
Review

What Do You Know?

Connecting to Concepts

Visualizing Ideas

1. Copy and complete the concept map.



2. Design a graphic organizer to compare a water circuit with an electrical circuit.

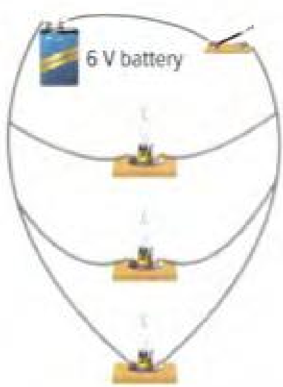
Using Key Terms

3. Below are four sets of terms from this unit. For each set, write one or two sentences that use all the terms correctly.

- **a)** law of electric charge, negative charges, positive charges
- **b)** voltage, current, Ohm's law, resistance
- **c)** current, closed circuit, load
- **d)** electrical energy, EnerGuide label, smart meter

4. Examine the diagram.

- **a)** Identify the load(s), source, switch, and direction of current flow.
- **b)** Identify the type of circuit.



Communicating Concepts

5. How does each of the following use electrical energy to perform a function?

- **a)** a maglev train to travel
- **b)** a tablet to carry out a command from your finger
- **c)** a neon sign to glow a specific colour
- **d)** a robot to frown like a human being

6. a) Describe the relationship among mechanical energy, potential energy, and kinetic energy.

- **b)** Explain how a geothermal generating station transforms thermal energy into electrical energy.

7. A generating system is sometimes referred to as simply a generator. Why is this technically incorrect?

8. Consider the terms nuclear fission and nuclear fusion.

- **a)** How do these two nuclear reactions differ?
- **b)** Which is currently used to generate electrical energy in Canada?

9. Describe the law of electric charge.

10. Use the analogy of a worker to explain how chemical energy does work to create an electrical potential difference in a cell.

11. Which "batteries" that you use in your daily life are not actually batteries? Explain.

12. A series circuit has a battery, a switch, and a load. Explain why the load goes off when you open the switch. Base your answer on the necessary conditions for circuits.

13. Use the terms "electrically charged" and "electrically neutral" to explain what has caused the phenomenon on the right.

14. Write out Ohm's law in your own words.
15. a) How does a short circuit form?
    b) Explain how a short circuit might be dangerous.
16. Describe one way that a series circuit is the same as a parallel circuit and one way that it is different.
17. Explain what happens to the current from a source when it encounters two branches of a parallel circuit.
18. Describe the danger associated with running too many appliances on the same parallel circuit in a building.
19. Explain why a radio might still use electrical energy when it is switched off.
20. In Canada, electrical energy is generated mainly by hydroelectric dams, nuclear reactors, and fossil fuel-burning generating stations. Which of these use renewable energy sources?
21. Identify three different ways that renewable energy sources are currently used to generate electrical energy in B.C.
22. a) How is the slogan "every kilowatt counts" relevant to you as a consumer of electrical energy?
    b) How is the slogan relevant to the environment?
23. Explain the ideas behind First Peoples Ecosystem Based Management in your own words.

What Do You Know?
Connecting to Competencies

Developing Skills

24. a) Design a procedure to investigate how the distance between buildings and wind turbines affects the amount of electrical energy generated by the wind turbine. Include a materials list and safety precautions.
    b) What might your results suggest about where wind turbines should be situated in urban centres?
    c) What other factors might you want to investigate in order to better answer question b?
25. Create a sketch that explains the role of electrodes and an electrolyte in a cell.
26. Draw a sketch and write a caption that explains the connections among the following as they apply to electrical potential difference: cell, electrons, protons, chemical energy, positive terminal, negative terminal.
27. You want to build a circuit with a source, a switch, a motor, and a lamp. You want the lamp to indicate if the motor stops working. Draw the circuit.
28. There are three light bulbs, A, B, and C, in a circuit. The circuit has only one switch which turns on all of the light bulbs. When A burns out, B and C remain on. When B burns out, A remains on but C goes out. When C burns out, A remains on but B goes out. Draw a circuit diagram with these three light bulbs that would give these results. Explain why each light bulb responds as described.

Thinking Critically and Creatively

29. A solid metal ball is sitting on a rubber mat. If it is given a negative charge, will the charge remain on the surface or spread through the ball? Use your understanding of conductors and the properties of charges to explain your answer.

30. Objects A and B are suspended from insulating threads. A positively charged balloon attracts Object A and repels Object B. Can you determine the charge of each object? Explain your reasoning.

31. An AA cell is smaller than an A cell. Does it necessarily have a smaller electrical potential difference? Explain.

32. A battery has an electrical potential difference of 6 V. A bulb with a resistance of 50 Ω is connected to the battery in series. The bulb burns out. What is the current through the bulb? Explain.

33. A hair dryer fan starts as soon as the switch is closed. The cord on the hair dryer is 100 cm long. However, electrons take about 1 minute to travel 3 cm. Explain the apparent contradiction.

34. A forensics team is investigating a fire. They find a burnt-out wall outlet with the remains of two extension cords plugged into it. Several appliances are plugged into each extension cord. Explain a possible cause of the fire.

35. A washing machine has a power rating that is many times greater than a television. However, a washing machine uses less electrical energy in a year in an average home than a television. Suggest why this is true.

Understanding Big Ideas

Making New Connections

Applying Your Understanding

36. Whenever a new hydroelectric dam is built, unavoidable flooding of plants and other organic materials results in the release of mercury compounds as they decompose. This leads to harmful mercury build-up in food chains and, in particular, in valuable fish stocks. Over a period of 10 to 30 years, decomposition rates slow and mercury in the environment decreases.

a) How should we value the electrical energy generated by a hydroelectric dam versus the damage caused by mercury pollution?

b) Many First Peoples depend on fish in B.C. rivers. If you depend on fish in a region where a dam is built and have to stop eating them, should you be compensated for your loss? Explain your reasoning.

c) In light of the environmental harm a dam can cause, can it be part of a sustainable energy system? Explain your reasoning.

37. Electric vehicles are common sights in British Columbia, especially in urban areas. These vehicles are often described as environmentally friendly. However, two people driving identical electric vehicles for the same distance each year can have very different environmental impacts depending on the energy source they use to charge their car batteries. Explain why this is the case.

38. Many scientists and environmentalists are opposed to drinking water from plastic bottles even though most bottled water is sold in bottles made out of recyclable plastic.

a) How might consuming bottled water waste electrical energy?

b) How might it affect the environment?

Thinking Critically and Creatively

39. B.C.'s forests could produce a large amount of biomass energy.

a) What are the pros and cons of using a natural forest as a source of biomass?

b) Do you think devoting large areas of forest to growing biomass to generate electrical energy is a good idea? What factors would you consider?

c) Suggest one benefit and one drawback of using farmland instead of forest to produce biomass for electrical energy.

40. Your family is trying to decide whether to install photovoltaic cells on your roof.

a) Identify one benefit of installing photovoltaic cells.

b) Identify one problem related to installing them.

c) Describe what other factors you would take into account when choosing whether to install this technology.

d) Many provinces offer subsidies that help homeowners pay for renewable energy technology they install in their homes. Others buy back excess electrical energy produced by the consumer. Do you think these programs will increase the number of people using this technology? Would it influence your decision? Explain.

Connecting to Self and Society

41. People living in different countries have very different rates of electrical energy consumption. In general, developed countries use the most electrical energy while developing countries use the least. How do you think this information should influence how much responsibility different countries have in moving to a sustainable energy system?

42. As shown below, Abbotsford Middle School has installed a wind turbine to generate electrical energy. The school also has solar panels and a bicycle generating system all linked up to the computer lab.

How is the school moving toward a sustainable energy system or following the principles of First Peoples Ecosystem Based Management?

43. Refer to "First Peoples Perspectives in Science" on page xxii near the start of the textbook.

a) Review and reflect on the four themes of interconnectedness, transformation, renewal, and connections with place.

b) In a journal or in small groups, share ideas about how the concepts you have been learning about in this unit relate to these four themes.

Unit Assessment

How can you "green" the electrical plan of a home?

A large-scale shift toward sustainable energy is taking place all around the world. For the first time, the development of renewable energy sources is surpassing that of nonrenewable sources. But small-scale change is taking place as well, as people conserve electrical energy in their daily lives. We can create greener rooms that use less electrical energy in any home or building. Understanding the electrical plan (how each room is wired and how much current each device or appliance draws) is a starting point. This can help people make decisions about nonessential loads, devices with phantom loads, and energy-efficient appliances. It can also help people assess electrical safety in the home.

Work as part of a group to do the following.

STEP 1 ► Reflect on the three options, their photos, and the question asked for each option.

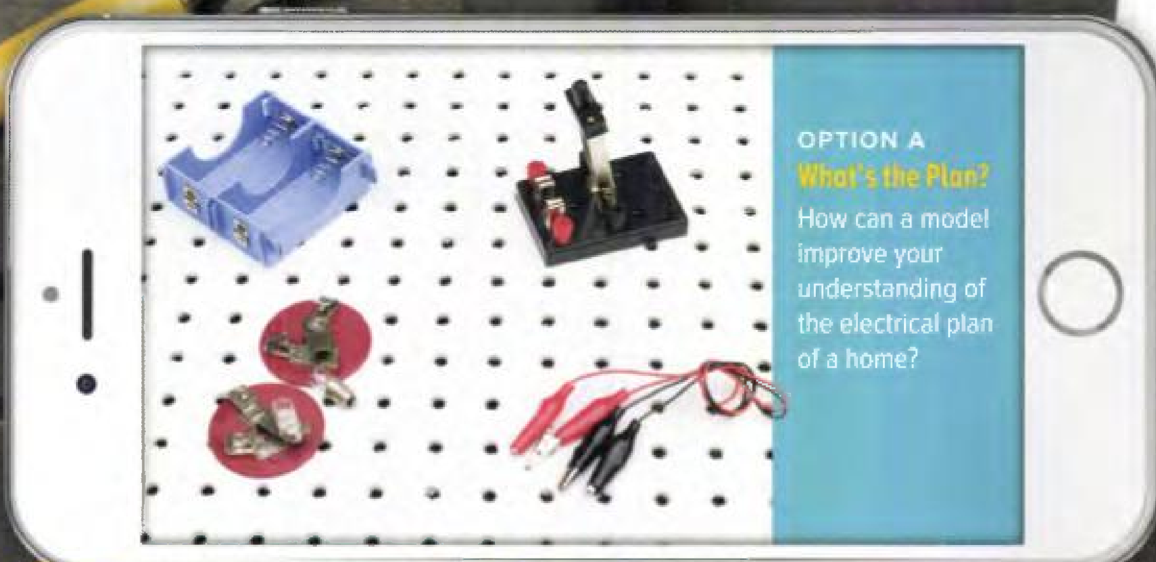
STEP 2 ► Brainstorm at least three more options and questions of your own about ways to green a home's electrical plan.

STEP 3 ► Decide on one of the six option questions to investigate.

STEP 4 ► Plan and conduct a scientific inquiry to explore your question.

STEP 5 ► Organize and analyze the data and information that you find and collect.

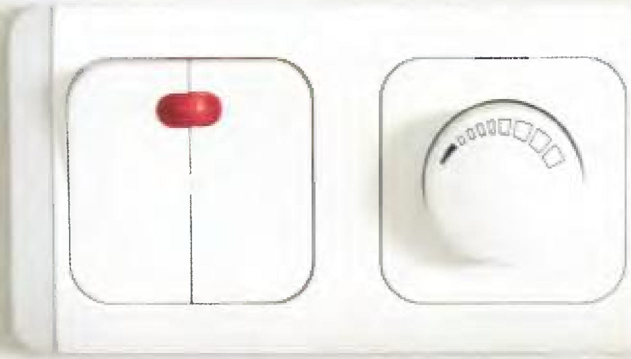
STEP 6 ► Communicate the results of your inquiry in a suitable manner.



OPTION C

Energy-efficient Technology

How can technology like solid state dimmers and TRIAC (triode for alternating current) switches be a part of a green electrical plan?



OPTION B

Current and Power Rating

What is the link between current drawn by appliances, their power rating, and use of electrical energy in a home?

Assessment Criteria

Did I and my group...

- Develop one or more questions that provided opportunities for rich investigation? QP
- Develop effective methods to collect and record reliable data and information? PC
- Analyze, reflect on, and draw meaningful conclusions as related to the inquiry? PA
- Evaluate the process and results of the inquiry, troubleshooting problems if they arose? E
- Propose alternatives that "green" the electrical plan of a home? AI
- Present the results of the inquiry using language, conventions, and representations appropriate for a specific purpose and audience? C

UNIT 4

Earth's spheres are interconnected

What would you think if you read the headline "Salmon help keep temperate rainforests of British Columbia healthy"? Salmon hatch in freshwater streams in the temperate rainforest. Then, they migrate and spend their adult lives in the Pacific Ocean, picking up nutrients from the marine ecosystem. Salmon return to their birthplace to reproduce. During this time, wolves, bears, and other organisms feed on the salmon. They move the salmon from the streambeds far into the forest. When the remains of the salmon decay in the forest, nutrients from their bodies, such as nitrogen, enter the soil.

> **"We must protect the forests for our children, grandchildren and children yet to be born. We must protect the forests for those who can't speak for themselves such as the birds, animals, fish and trees."**
>
> *Qwatsinas (Hereditary Chief Edward Moody), Nuxalk Nation*

- How does this story show that Earth's spheres (its systems) are interconnected?
- Why is it important to understand that Earth's spheres are connected?
- What questions do you have about—this photo? the introduction? the quotation? the title for this unit? ...?

UNIT 4

At a Glance

You will demonstrate what you know, can do, and understand by being able to

- Perform investigations and use other investigative methods to explore and represent Earth's four spheres
- Develop and use models and other methods to construct evidence-based explanations for energy flow and matter cycles within ecosystems
- Seek patterns and connections to describe and evaluate sustainability of Earth's systems
- Apply a variety of ways of knowing, including First Peoples perspectives and knowledge, to reflect on and interpret interconnectedness and sustainability

ESSENTIAL QUESTION

How do energy flow and matter cycling connect the living and non-living parts of Earth's spheres?

TOPIC 4.1:

How do the ideas of connection and sustainability help us think about Earth's spheres?

Some things you will do:

- make observations aimed at identifying your own questions
- apply skepticism and scientific knowledge to evaluate claims

Some things you will come to know:

- everything in, on, and beyond Earth is connected
- all organisms receive benefits (services) from the environment

TOPIC 4.2:

What is the role of the Sun's energy in Earth's spheres?

Some things you will do:

- seek and analyze patterns, trends, and connections in data
- transfer and apply learning to new situations

Some things you will come to know:

- the Sun provides and distributes warmth, winds, and water currents around the globe
- photosynthesis provides and cellular respiration releases energy for life

TOPIC 4.3:

What interactions supply energy to Earth's biosphere?

Some things you will do:

- Work collaboratively to collect reliable data
- Construct, analyze, and interpret models
- Experience and interpret the local environment

Some things you will come to know:

- food chains and food webs link living things through the transfer and flow of energy
- the biosphere requires a continual input and flow of energy

TOPIC 4.4:

What interactions cycle matter through Earth's spheres?

Some things you will do:

- connect scientific explorations to possible careers
- assess risks associated with proposed investigation methods
- generate new or refined ideas

Some things you will come to know:

- Water on Earth is renewed by the water cycle.
- Nutrients are cycled in Earth's spheres through the interactions of living and non-living things.
- Nutrient cycles can become unbalanced, causing harm.

TOPIC 4.5:

How can our actions promote sustainability?

Some things you will do:

- experience and interpret the local environment
- use scientific concepts to draw conclusions consistent with evidence
- describe ways to improve investigation methods

Some things you will come to know:

- Individuals can effect change in the world by making thoughtful, respectful, and responsible decisions and choices.

TOPIC 4.1

How do the ideas of connection and sustainability help us think about Earth's spheres?

Key Concepts

- We are all connected.
- Sustainability ensures balanced, healthy systems now as well as in the future.
- Being a scientifically literate citizen matters to you both locally and globally.

Curricular Competencies

- Demonstrate a sustained intellectual curiosity about a scientific topic or problem of personal interest.
- Apply First Peoples perspectives and knowledge, other ways of knowing, and local knowledge as sources of information.
- Critically analyze the validity of information in secondary sources and evaluate the approaches used to solve problems

The "ghost moose" shown in the photo has rubbed and scratched off its dark winter coat in an effort to remove ticks embedded in its skin. When tick infestations are high, moose can be severely, possibly fatally, affected. A single moose may carry thousands of ticks, all feeding parasitically on the moose's blood. The moose can be weakened by the loss of blood and unprepared for extreme weather due to the loss of hair. In an effort to learn more about how many moose are affected and how severely, the B.C. government began a study using reports from citizens in 2015. In 2016, scientists collected more than 500 reports from citizen scientists that showed an 11% increase in sightings of moose with visible hair loss compared to sightings in 2015.

Starting Points

Choose one, some, or all of the following to start your exploration of this Topic.

1. **Identifying Preconceptions** What do you think of when you hear the word *sphere*? Skim through the pages of this unit. Then, provide a definition for the word sphere related to how it is used in the unit.
2. **Making Connections** What do you think of when you hear the terms *sustainability* or *sustainable*? What about the term *interconnected*? How do you think the terms *sustainability* and *interconnected* could be related to each other?
3. **Questioning** The introduction on the previous page uses the term *citizen scientist*. A citizen scientist is a person who volunteers to assist scientists by collecting data to help answer real-world questions. What questions do you think the scientists are trying to answer about the moose and ticks described in the introduction? Why do you think someone might be interested in being a citizen scientist?
4. **Inferring** Reread the unit-opening quotation. How do you think protecting forests helps protect soil, fish, and the air you breathe? Think about how living and non-living things on Earth are interconnected as you answer these questions.

Key Terms

There are four key terms that are highlighted in bold type in this Topic:

- biotic
- abiotic

Flip through the pages of this Topic to find these terms. Add them to your class Word Wall along with their meanings. Add other terms that you think are important and want to remember.

CONCEPT 1

We are all connected.

Activity

Reflecting on Interconnections

The respected ethnobotanist, Dr. Nancy J. Turner, has written extensively on First Peoples traditional knowledge systems and land and resource management systems. The passage below has been edited slightly to make it easier to read by a general audience. As you read it, reflect on the following questions. (You might also find it helpful first to skim the At Issue feature back on page 34 in this textbook.)

> Both avalanche lily and balsamroot, as well as other food resources, depended upon the harvesting, processing, and preparation of a number of other resources. These included the woods used for making the digging sticks; the birch bark, red-cedar root, and cherry bark for the baskets needed to transport the roots; the maple bark used to string the bulbs or roots for drying; the Indian hemp fiber, silverberry, or other fibers used for weaving storage bags; and the fuel and vegetation used for cooking and flavoring them. (Turner 1996, 1997a, 1998)

1. What examples of interconnectedness can you identify in this passage?
2. How does this First Peoples approach to the extraction and use of natural resources support the idea of sustainability as you understand it? How does it differ from the ways that Western societies have tended to view resource extraction and use?

The idea of interconnections is at the heart of what it is to be First Peoples. A similar idea has been developing, slowly, among many other cultures and societies since the start of the modern environmental movement in 1970 (Figure 4.1) At that time, the western mindset of unbridled, infinite development and growth began to be challenged. Canadian Inuit leader Sheila Watt-Cloutier put it this way: "We must now speak environment, economy, foreign policy, health, and human rights in the same breath. Everything is connected."

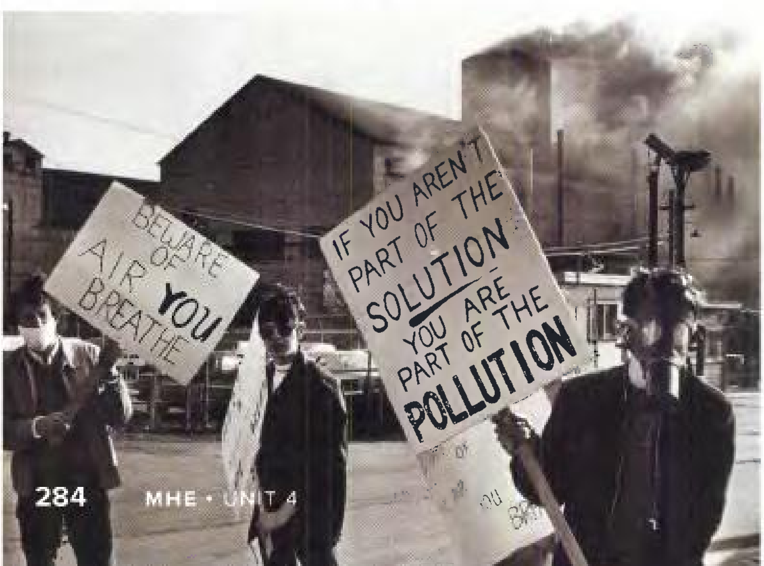


Figure 4.1 Although there were environmental movements in the early 1900s, the birth of the modern environmental movement is considered to be the first Earth Day on April 22, 1970. Earth Day has been observed on April 22 each year since.

In a petition that Watt-Cloutier made before the U.S. Senate back in 2004, she delivered a powerful message about interconnectedness (Figure 4.2) This message is as true today as it was then. She said:

> "Use what is happening in the Arctic—the Inuit story—as a vehicle to reconnect us all, so that we may understand that the planet and its people are one. The Inuit hunter who falls through the depleting and unpredictable sea ice is connected to the cars we drive, the industries we rely upon, and the disposable world we have become."

Figure 4.2 Sheila Watt-Cloutier received the Right Livelihood Award in 2015 in honour of her efforts to protect and defend Inuit livelihoods and culture in the face of threats posed by global climate change—notably the unprecedented melting of sea ice.

Activity

Make Connections

Re-read the quotation from Sheila Watt-Cloutier.

1. In what ways could a hunter falling through Arctic sea ice be connected to the activities of people—like you—who live south of the Arctic?
2. Many First Peoples talk about how all living and non-living things are connected to and depend on one another. What does "being connected" mean to you?
3. Do you think you are connected to everyone and everything in the world? Can you prove that you are not? Share your ideas with a partner or in small groups. See if your class can read a full or partial agreement on these questions.

biotic living parts of an environment

abiotic non-living parts of an environment

Biotic and Abiotic Parts of the Environment

All the living things in the environment are its **biotic** (living) parts. Within the Western science framework, some parts of the environment are considered to be not alive. All the non-living things are the **abiotic** parts of the environment. All the biotic and abiotic parts of the environment are connected through the ways in which they interact with one another. Figure 4.3 summarizes how biotic and abiotic parts of the environment can interact. Note that a population is a group of individuals of the same species living in the same geographical area at the same time. Populations of different species are part of a community in a particular habitat (environmental setting).

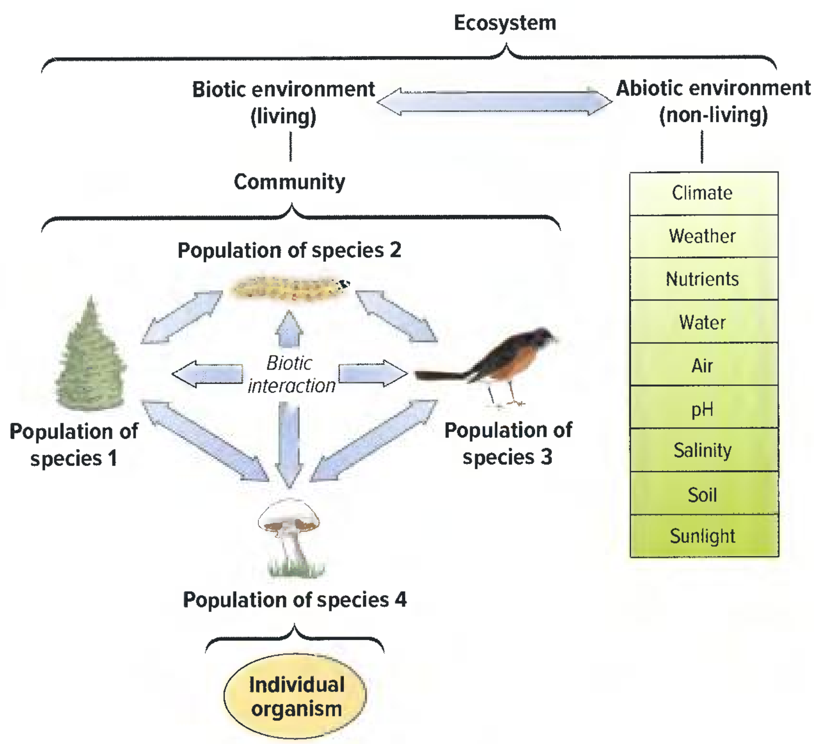


Figure 4.3 The interaction of biotic and abiotic parts of the environment is one example that shows how we are all connected. **How do the biotic components in the illustration interact with the abiotic components ?**

Earth's Spheres

Natural processes move matter in continuous cycles from the biotic and abiotic parts of the environment and back again. At any time, matter occupies one of Earth's four spheres (systems):

- *atmosphere*: the gaseous part of Earth, which is concentrated within about 10 km of the surface but also extends hundreds of kilometres higher
- *geosphere* (or lithosphere): the solid, mainly rocky part of Earth
- *hydrosphere*: all of the water (liquid, as well as solid and gaseous) that exists on and within the geosphere
- *biosphere*: all of the areas on and under the geosphere, in the atmosphere, and in the hydrosphere that are inhabited by and support life

Earth's spheres are interconnected. For example, the atmosphere interacts with the hydrosphere, resulting in weather. The hydrosphere interacts with the geosphere when floods wash away soil. The biosphere interacts with the geosphere when plant roots break apart rocks. Figure 4.4 shows examples of each of Earth's spheres and how they interact with each other. You will learn more about how matter cycles through Earth's spheres in Topic 4.3.

Figure 4.4 Earth's four spheres interact with and affect each other in many different ways. Understanding that Earth's spheres are interconnected is an important part of maintaining a sustainable Earth.

Ice storms are just one way the atmosphere interacts with Earth's other spheres. In January 2015, an ice storm hit Hope, B.C., bringing down trees and resulting in power outages and closed schools. **Which of Earth's spheres were affected by the ice storm?**

Landslides occur when soil and rock from the geosphere are pulled downward by gravity. **How do you think the biosphere may have been affected by this landslide?**

The hydrosphere includes solid and liquid water, as well as water vapour in the atmosphere. Bear Glacier ends in Strohn Lake near Stewart, B.C. **How does the cloudy sky in this photo represent an interaction between the hydrosphere and the atmosphere?**

Mountain goats and the grass they eat are part of the biosphere. **How do you think these mountain goats interact with or are impacted by Earth's other spheres?**

Before you leave this page . . .

1. How are First Peoples and Western science ideas of interconnectedness different and similar?
2. Which of Earth's spheres are involved when liquid water expands as it freezes and causes small cracks to form in rocks?

AT ISSUE How do clam gardens contribute to ecological and cultural landscapes?

What's the Issue?

For at least 2000 years, First Peoples along coastal B.C., Alaska, and Washington State have been building and maintaining stone-walled terraces in the intertidal zone—the part of a beach between low and high tide. These rock walls are called clam gardens in English. In Kwakwala, they are called *lúxʷxiwey*, which means "rolled rocks forming a wall." In Nuu-chah-nulth, they are *t'iimiik̲* ("move aside rocks"). In the Mainland Comox language, they are *wux̱wuthin* ("held back at the mouth").

Clam gardens transform sloping beaches or rocky shorelines into flat terraces that increase clam populations and habitat. Elders share that clams are an important traditional food and trade item, and that a garden must be tended to maintain a healthy beach. With guidance from elders, scientists are investigating ways that clam gardens contribute to ecological, as well as cultural, landscapes.

Dig Deeper

Collaborate with your classmates to explore one or more of these questions—or generate your own questions to explore.

1. The Nuu-chah-nulth term *Hiskuk ish tsawalk*, from Western Vancouver Island, translates as "everything is one and all is interconnected." In bordering on each of Earth's four spheres, how do clam gardens reflect this world view?
2. Western scientists only began to recognize the importance of clam gardens in the early 2000s. Why did it take so long?
3. Many First Nations communities are interested in restoring clam gardens in their territories. While some clam gardens are healthy and are still used today, many have fallen out of use. Why have some gardens been lying dormant for decades, and possibly centuries?

CONCEPT 2

Sustainability ensures balanced systems now and for the future.

Natural ecosystems are sustainable—they are able to continue to exist indefinitely, recycling their materials, as long as they have a continued and constant source of energy. Natural ecosystems are always changing, so what is sustainable for some organisms at some times might not be sustainable for them at other times. However, the system itself is always sustainable.

Connect to Investigation 4-B on page 294

Ecosystems also provide services that all living things, including humans, depend on. *Ecosystem services* are the benefits that organisms receive from the environment and its resources. Refer to Table 4.1. Keep in mind that these services are inseparably linked together on a global scale. Each one is as important as any other, and none is expendable or replaceable. If we do not take care of Earth and Earth's spheres or the cycles and subsystems within them, systems become unbalanced, break down, and become unsustainable.

Table 4.1 Examples of Ecosystem Services

Ecosystem Service	Example
Atmospheric gas supply	Regulation of carbon dioxide and oxygen
Climate regulation	Regulation of greenhouse gases
Cultural benefits	Aesthetic, spiritual, and educational value
Disturbance regulation	Storm protection, flood control, drought recovery, and other aspects of environmental response to disturbances
Food production	Crops, livestock, fish
Habitat (living space)	Habitat for migratory species and for locally harvested species, overwintering grounds, nurseries
Nutrient recycling	Carbon, nitrogen, and other nutrient cycles
Raw materials (natural resources)	Fossil fuels, timber, minerals
Soil erosion control	Retention of topsoil
Water supply	Supplying of water by reservoirs, watersheds, and wells

Before you leave this page . . .

1. Pick one example of an ecosystem service from Table 4.1. Identify which of Earth's spheres it affects, explain how, and explain how humans benefit from the service.

CONCEPT 3

Scientifically literate citizens are aware of bias in sources of information.

Activity

Can You Spot Bias?

Read at least two articles and watch one news report on the same science topic. Can you determine if the articles or news report are biased? If so, how do you know? After you read this page, re-examine the articles and news report to see whether your answer has changed and why.

Connect to Investigation 4-A on page 292

You are exposed to information of many different kinds from many different sources each day. Being able to recognize and evaluate bias in information is a vital part of being scientifically literate. Bias is a judgment that is based on a person's knowledge, understanding, and beliefs. For example, someone who is against processing Alberta's northern shale oil resources might call them "tar sands." A person in favour might call them "oil sands." The first term suggests a sense of an environmental problem. The second term suggests a sense of an economic opportunity. Either term indicates a bias. Now compare Figure 4.5 and Figure 4.6. Notice how the choice of photo can indicate a bias as well. It is valuable to recognize bias and understand what it might communicate about ideas, issues, or both.

Figure 4.5 Open-pit mining at Fort McMurray.
What do you think and feel when you look at this photo?

Figure 4.6 Open-pit mining at Fort McMurray.
What do you think and feel when you look at this photo?

Before you leave this page . . .

1. Define bias. Why it is important to be able to recognize bias when gathering information about a topic or issue?
2. Give an example of a time when you were able to identify bias when reading about or discussing a topic or an issue.

Check Your Understanding of Topic 4.1

QP Questioning and Predicting · PC Planning and Conducting · PA Processing and Analyzing · E Evaluating · AI Applying and Innovating · C Communicating

Understanding Key Ideas

1. Use Figure 4.3 to name two ways that biotic components and two ways that abiotic components of an environment interact. PA C

2. Describe how the term *connectedness* is interpreted by the following populations (in your discussion look for similarities and for differences): PA C
   a) First peoples
   b) Science community

3. Why is the concept of sustainability something that all people on Earth need to be aware of? PA

4. Select what you believe to be the top three ecosystem services. Justify your ranking with an explanation of your opinion. E C

5. Which of the ecosystem services listed in Table 4.1, if it were no longer available, would have the least impact on how the planet functions? Justify your answer. E C

6. How can you determine whether information is unbiased? PA

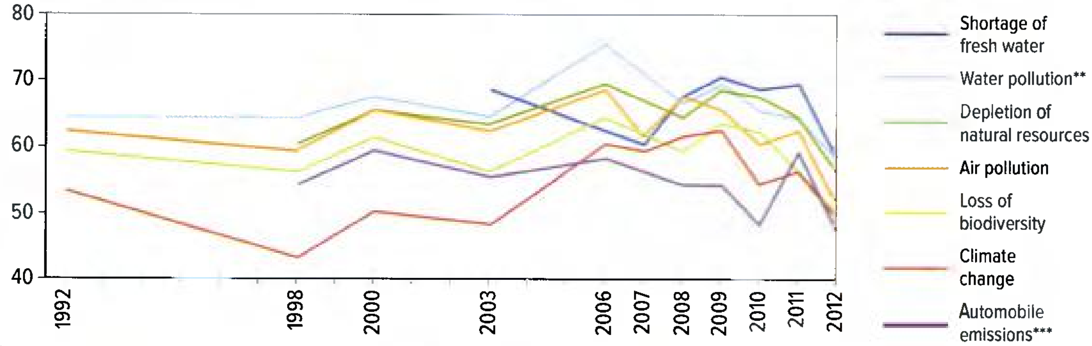
Connecting Ideas

7. Use a graphic organizer to show the interactions you have with the abiotic and biotic parts of a neighbourhood environment. AI C

Making New Connections

8. The graph below shows the results of a survey conducted in 12 countries between 1992 and 2012. The headline that accompanied the article about the results of the survey and the graph was "Public concern for the environment lowest in 20 years." AI C
   a) How would you rank the issues listed on the side of the graph in order of importance to you? Why? How would this order change if you looked at things from a "we are all connected" perspective? Why?
   b) Identify which of Earth's spheres is most affected by each issue. How are the other spheres affected by each issue? Why must we always approach an issue by thinking about how it affects all of Earth's spheres?

Relative Seriousness of Issues
"Very Serious," Average of 12 Countries,* 1992–2012



*Average of Brazil, Canada, China, France, Germany, India, Indonesia, Mexico, Nigeria, Turkey, UK, and USA. Not all questions were asked in all countries in all years.
**Not asked in Brazil, Canada, and France
***Not asked in Brazil and Canada

INVESTIGATION

4-A

GUIDED INQUIRY

Skills and Strategies

- Planning and Conducting
- Processing and Analyzing
- Evaluating
- Communicating

What You Need

- access to the Internet or print resources

How Do You Tell the News from the Noise?

Today, more than three billion people have access to the Internet, a source of news, blogs, and social networks. Many 24-hour news channels operate worldwide. Newspapers are published every day both in print and online. Magazines and academic journals are other sources of news. People always have access to the news, which sounds like a good thing. However, a study on the state of media by the Center for Journalistic Excellence at Columbia University concluded that the news is growing increasingly biased. Rumours and falsehoods fly across the Internet at light speed. More than two thirds of all TV news segments consist of reports or interviews in which only a single point of view is presented without any background or perspective. Using critical thinking skills, like those listed in Table 4.2, to analyze news stories is an important part of being an educated citizen. In this lab, you will practise using these skills.

Question

How can you determine the bias in a media report?

Procedure

1. Choose a media report about the environment to read (or watch) and analyze.
2. Use the critical thinking skills listed in Table 4.2 to detect whether or not the report contains bias.

Analyze and Interpret

1. Did the report you chose contain bias? Explain your reasoning.
2. What do you think of these bias-detecting questions? Which ones did you use? Which ones did you not use, and why? What other questions could be asked?
3. How many sources do you rely on for information? What could this mean about your understanding of a fact, situation, or issue?

Conclude and Communicate

4. What factors influence the ways you form your opinions from the news and other sources of information?

Table 4.2 Using Critical Thinking Skills

Critical Thinking Skill	Examples of Questions to Ask Yourself
Identify and evaluate statements and conclusions in an argument.	• What is the basis for the claims made? • What evidence is presented to support the claims, and what conclusions are drawn from this evidence? • If the statements and evidence are correct, does it necessarily follow that the conclusions are valid?
Acknowledge and clarify uncertainties, vagueness, and contradictions.	• Do the terms used have more than one meaning? • If so, are all participants in the arguments using the same meanings? • Are the uncertainties deliberate? • Can all the claims be true at the same time?
Distinguish among facts, opinions, and values.	• Are claims made that can be tested? (If so, they should be verified, when and where possible.) • Are claims made about the worth or lack of worth of something? (If so, these are value statements or opinions and probably cannot be verified objectively.)
Recognize and assess assumptions.	• Given the backgrounds and views of the people in the argument, what underlying reasons might exist for the statements, evidence, or conclusions they present? • Does anyone have a personal agenda? What do they think I know, need, want, or believe? • Are there underlying suggestions based on gender, ethnicity, economics, a belief system, or other factors that can affect the discussion?
Determine the reliability or unreliability of a source.	• What makes the experts qualified in this issue? • What special knowledge or information do they have? • What evidence do they present? • How can I determine whether their information is unbiased, accurate, and complete?
Recognize and understand the context in which things are presented.	• What are the basic beliefs, attitudes, and values that this person, group, or society holds? • How do these beliefs and values affect the way people view themselves and the world around them? • If there are conflicting beliefs or values, how can these differences be resolved?

INVESTIGATION
4-B

GUIDED INQUIRY

Skills and Strategies

- Planning and Conducting
- Processing and Analyzing
- Evaluating
- Communicating

What You Need

- access to the Internet or print resources

Effects of Arctic Ice Cap Melting

A polar ice cap is a high-latitude region of land or water that is covered in ice. Ice caps form as snow accumulates year after year. As part of a cyclical process, each year some of the ice melts in the summer, and then reforms in the winter. In the last several decades, scientists have tracked significant changes in the size of the Arctic ice cap. Data analyzed from satellite images show that the area of permanent ice cover is decreasing at a rate of 9% each decade. At this rate, scientists predict that summers in the Arctic will be ice-free by 2030. In this activity, you will investigate the impact of the melting Arctic ice cap on Earth's spheres and sustainability.

Question

How does the melting of the Arctic ice cap affect Earth's spheres and sustainability?

Procedure

PART A

1. Research why the Arctic ice cap is melting.
2. Summarize the results of your research from step 1. Use diagrams, illustrations, animations, or other formats as appropriate in your summary.

PART B

1. Research the effects of the melting of the Arctic ice cap on the hydrosphere. Use the following questions to guide your research. Use your critical thinking skills to evaluate sources of materials for bias or inaccuracies.
   - How will Greenland's ice sheet be affected by the Arctic ice cap melt? What effects will the changes to Greenland's ice sheet have on the hydrosphere?
   - Is the sustainability of the hydrosphere affected by the melting of the Arctic ice cap? If so, how?
2. Summarize the results of your research in a format approved by your teacher.

PART C

1. Research the effects of the melting of the Arctic ice cap on the atmosphere. Use the following questions to guide your research. Use your critical thinking skills to evaluate sources of materials for bias or inaccuracies.
   - How could the melting of the Arctic ice cap affect climate in other parts of the world?
   - Is the sustainability of the atmosphere affected by the melting of the Arctic ice cap? If so, how?
2. Summarize the results of your research in a format approved by your teacher.

PART D

1. Research the effects of the melting of the Arctic ice cap on the biosphere. Use the following questions to guide your research. Use your critical thinking skills to evaluate sources of materials for bias or inaccuracies.
   - How have animals such as polar bears, whales, walruses, and seals been affected?
   - How does the melting ice cap affect hunting and fishing by Aboriginal people?
   - Is the sustainability of the biosphere affected by the melting of the Arctic ice cap? If so, how?
2. Summarize the results of your research in a format approved by your teacher.

PART E

1. Research the effects of the melting of the Arctic ice cap on the geosphere. Use the following questions to guide your research. Use your critical thinking skills to evaluate sources of materials for bias or inaccuracies.
   - How does the melting ice cap affect the extraction of oil, natural gas, and minerals?
   - How does the melting ice cap affect the rate of erosion and weathering in coastal areas?
   - Is the sustainability of the geosphere affected by the melting of the Arctic ice cap? If so, how?
2. Summarize the results of your research in a format approved by your teacher.

Analyze and Interpret

1. How does the melting of the Arctic ice cap show that Earth's spheres are interconnected?
2. Do you think the melting of the Arctic ice cap could be considered a global problem? Why or why not?

Conclude and Communicate

3. Create an educational report that uses the melting of the Arctic ice cap to showcase how Earth's spheres are interconnected and how if sustainability is not maintained in one sphere it could affect sustainability in other spheres. You could write an editorial piece, make a short video, write a blog entry, or use another format approved by your teacher.

TOPIC 4.2

What is the role of the Sun's energy in Earth's spheres?

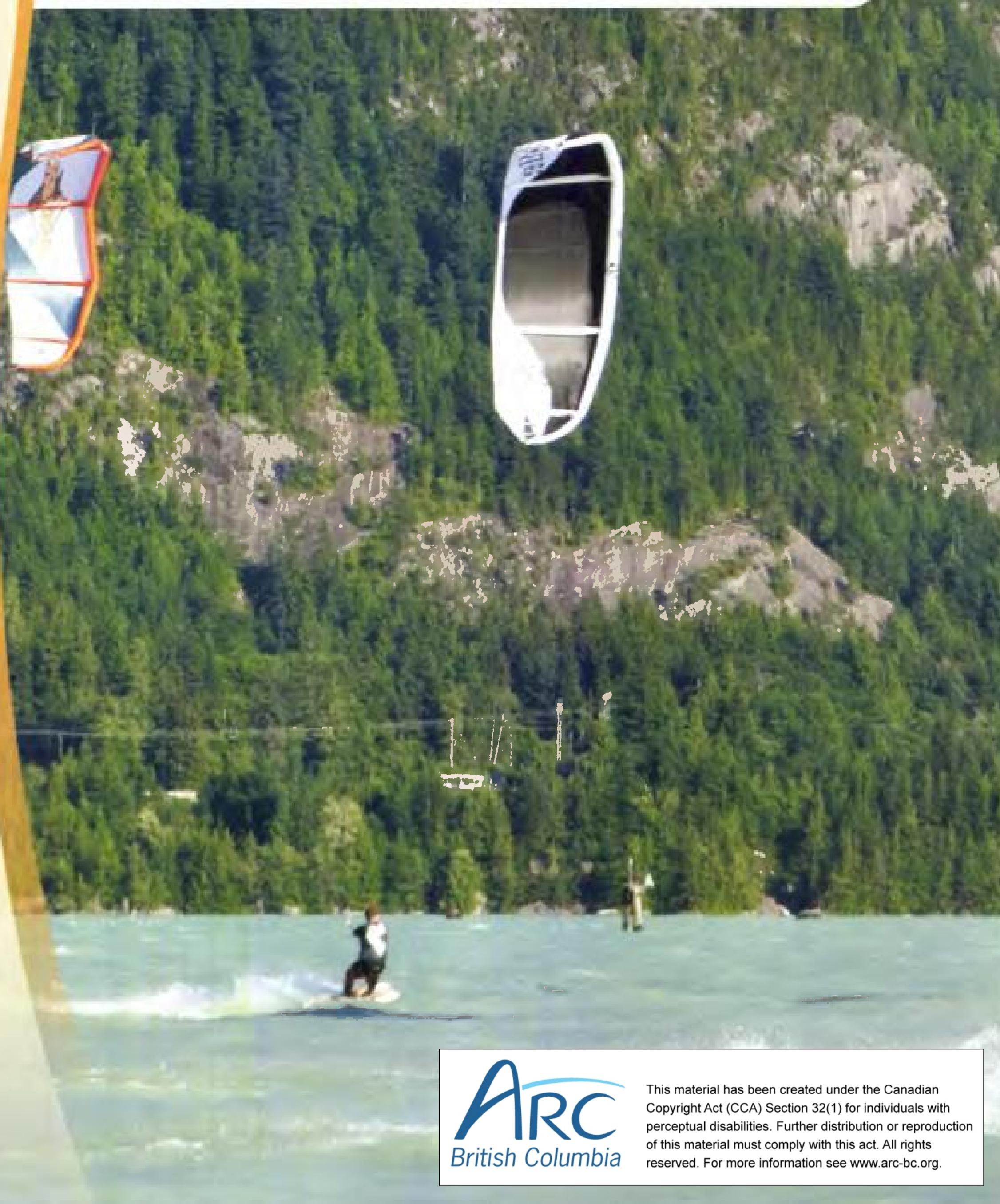
The photo of Squamish Spit, British Columbia shows a great scene. It's a beautiful sunny day. The breeze is blowing; the water is rippling and waves are kicking up. People are enjoying kiteboarding. People also come out to windsurf, sail, and paddleboard in this area. The water, wind, and waves are sources of recreation. But what's the source of energy for the wind and waves? How do they form? And what other roles do they have that are important to Earth's spheres?

Key Concepts

- Solar energy that reaches Earth is absorbed and reflected by Earth's atmosphere and Earth' surface.
- Solar energy heats Earth's surface unevenly and global winds help redistribute thermal energy around Earth.
- Ocean currents also redistribute thermal energy around Earth.
- Solar energy enters the biosphere through photosynthesis and cellular respiration.

Curricular Competencies

- Construct, analyze, and interpret graphs, models, and/or diagrams.
- Use knowledge of scientific concepts to draw conclusions that are consistent with evidence.
- Analyze cause-and-effect relationships



Starting Points

Choose one, some, or all of the following to start your exploration of this Topic.

1. **Identifying Preconceptions** Think about the questions in the introduction on the previous page. How do wind and waves form? What is the ultimate source of energy behind wind and currents and waves in large bodies of water? Explain your answer.
2. **Hypothesizing** As you read this Topic, you will learn that energy from the Sun is moved around Earth. Do you think wind and water currents are involved in moving energy around Earth? Why or why not? Form a hypothesis that explains how this happens. How could you test it?
3. **Making Connections** Many countries use wind as a form of sustainable energy. What do you think are some of the benefits and drawbacks of using wind as an alternative energy source (including benefits and drawbacks to Earth's spheres)?
4. **Applying First Peoples Perspectives** The Sun plays an important role in many First Peoples cultures. Find out the words for Sun and related words in a local First Nations language. How is the Sun represented in traditional stories?

Key Terms

There are two key terms that are highlighted in bold type in this Topic:

- greenhouse gases
- greenhouse effect

Flip through the pages of this Topic to find these terms. Add them to your class Word Wall along with their meanings. Add other terms that you think are important and want to remember.

CONCEPT 1

Solar energy that reaches Earth is absorbed and reflected by Earth's atmosphere and Earth's surface.

Activity

How a Greenhouse Works

People use greenhouses to grow plants during the winter or to plant seeds in the spring so they can germinate and be planted outside when the weather gets warmer. A greenhouse is a building whose walls and ceiling are made of glass or clear plastic. A greenhouse stays warm on the inside even when it is cold outside. Draw a diagram to show how this occurs. How is a greenhouse similar to Earth's atmosphere?

greenhouse gases gases that absorb solar energy in Earth's atmosphere

greenhouse effect process that absorbs outgoing solar energy in Earth's atmosphere

We are all familiar with the feeling of the Sun's energy warming up the ground, grass, or our skin as the Sun rises in the sky each day. But what happens to all of the energy from the Sun as it enters Earth's atmosphere? As shown in Figure 4.7, solar energy enters Earth's atmosphere. Most of that energy is absorbed by land and water on Earth's surface. Some of it is reflected by both Earth's surface and the atmosphere and passes through the atmosphere back out into space. Some of the reflected energy is absorbed by gases in the atmosphere and re-emitted in all directions. The gases that absorb solar energy in Earth's atmosphere are called **greenhouse gases**. The process that absorbs outgoing solar energy in Earth's atmosphere is called the **greenhouse effect**.

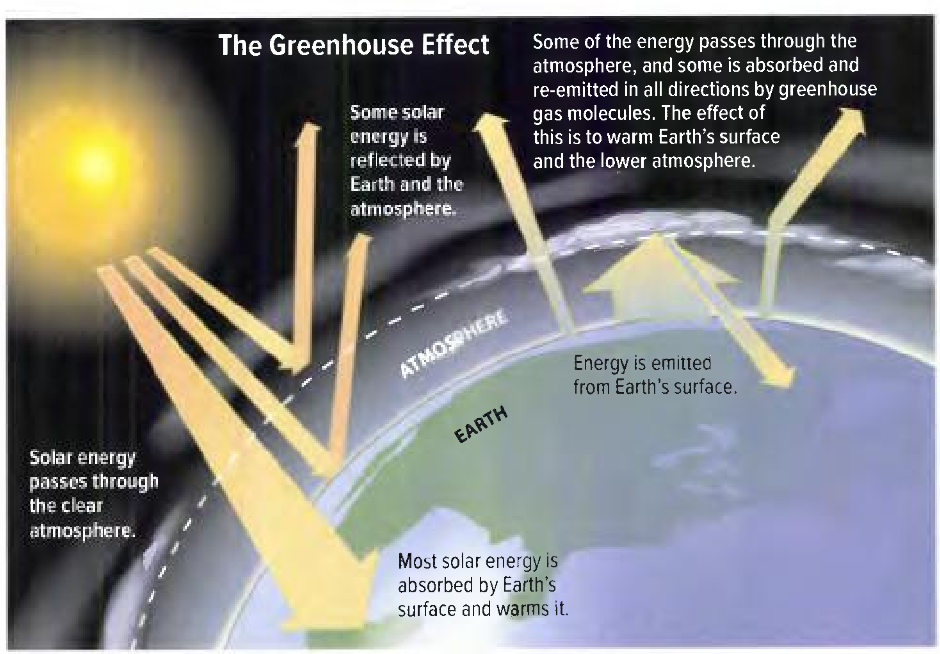


Figure 4.7 The greenhouse effect moderates Earth's temperature. Average global temperature would be a chilly –18°C if greenhouse gases were not naturally found in the atmosphere.

Greenhouse Gases

Many greenhouse gases occur naturally in the atmosphere. Table 4.3 lists four of these, and their sources.

Table 4.3 Natural Greenhouse Gases

Greenhouse Gas	Sources	Other Details
water vapour	• evaporation from water • given off by plants, animals, and other organisms	• most abundant greenhouse gas • produced during cellular respiration and certain plant processes
carbon dioxide	• living organisms • volcanoes, forest fires, decaying organisms, release from oceans	• second most abundant greenhouse gas • produced in and by the cells of most living organisms through cellular respiration
methane	• certain species of bacteria and other micro-organisms that live in and around bogs, wetlands, melting permafrost • certain species of bacteria that live in the gut of animals such as cows and termites • vents and other openings in Earth's crust on land and the ocean floor	• a by-product of cellular processes used by some micro-organisms to extract energy from food in the absence of oxygen
nitrous oxide	• bacteria that live in oceans and wet, warm soils such as those in the tropics	• produced when certain species of bacteria break down nitrogen-rich compounds for food

Greenhouse gases can also be released into the atmosphere as a result of human activities. For example, carbon dioxide is released when the fossil fuels oil, natural gas, and coal are burned for electricity, heat, and transportation. Nitrous oxide enters the atmosphere when fertilizer is applied to agricultural crops. Herds of cattle raised as livestock release large amounts of methane into the air. Later in this unit, you will read more about how the excess release of these gases affects nutrient cycles and impacts Earth's climate.

Connect to Investigation 4-C on page 308

Before you leave this page . . .

1. Explain the role that greenhouse gases play in the greenhouse effect.
2. Predict what would happen to Earth's other spheres if the concentration of greenhouse gases in the atmosphere increased.

CONCEPT 2

Solar energy heats Earth's surface unevenly, and global winds help redistribute thermal energy around Earth.

Activity

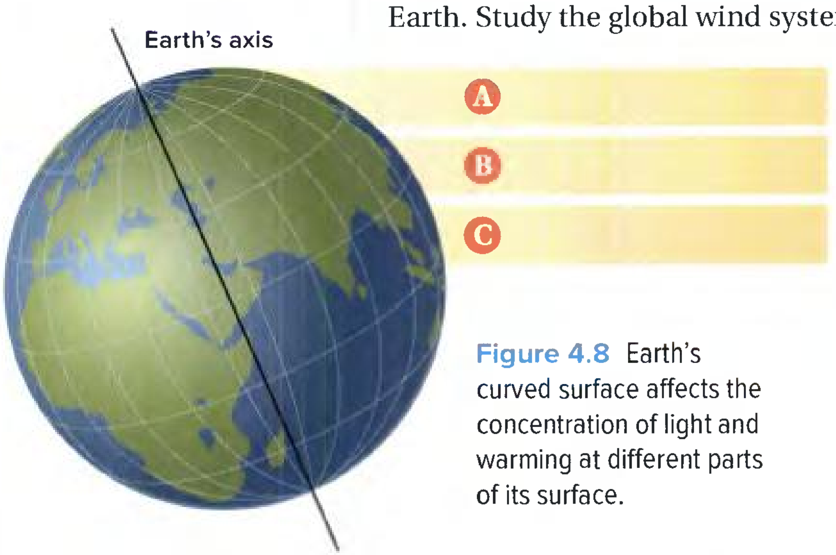
Three Types of Thermal Energy Transfer

Thermal energy is the total energy of the particles that make up an object. Thermal energy is transferred around Earth by radiation, conduction, and convection. Review the definition of each of these types of energy transfer and provide an example of each. Share your example with a classmate.

Even when the Sun's activity is constant, the amount of solar energy that reaches different regions of Earth varies. One reason it varies is that our planet is spherical. Solar energy strikes the curved surface at different angles, as shown in Figure 4.8. As a result, the concentration of light that warms Earth's surface is unequal. Earth receives more direct solar energy at lower latitudes (for example, in Mexico) than at higher latitudes (for example, in Canada). As a result, the atmosphere heats up unevenly. The lower latitudes become warmer than the higher latitudes.

Global Wind Systems

What does Figure 4.8 have to do with wind? Wind, or moving air, results from the unequal heating of Earth's surface. Wind plays an important role in redistributing thermal energy around Earth. Warm air near Earth's surface rises and cools. The cool air is denser and eventually sinks, creating wind that moves warm and cool air around Earth. Study the global wind systems shown in Figure 4.9.



A Sun's light is spread out over a large area, so warming is more diffuse (less concentrated).

B Sun's light is spread out over a smaller area, so warming is more concentrated than in A, but less than in C

C Sun's light is very concentrated over a small area, so warming is much more concentrated than at B and A

Figure 4.8 Earth's curved surface affects the concentration of light and warming at different parts of its surface.

The wind systems shown in the figure are wide zones of winds. Earth's major wind systems result from a combination of convection currents and the Coriolis effect. The Coriolis effect is a change in the direction of moving air, water, or other objects on or near Earth's surface due to Earth's rotation. Together, global wind systems move thermal energy around Earth and distribute it more evenly throughout the atmosphere.

- The trade winds move from east to west and occur between the equator and 30°N and 30°S latitudes. Air near the equator warms, rises, and travels to 30° north or south latitude. At 30° north or south latitude, the air cools, sinks, and moves west toward the equator.
- The westerlies are winds that move from west to east and occur between 30°N and 60°N and 30°S and 60°S latitudes. The westerlies are steady winds that move much of the weather across parts of North America.
- The polar easterlies move from east to west and occur between 60°N and 90°N and 60°S and 90°S latitudes. These winds move cold air from polar regions back toward the equator.

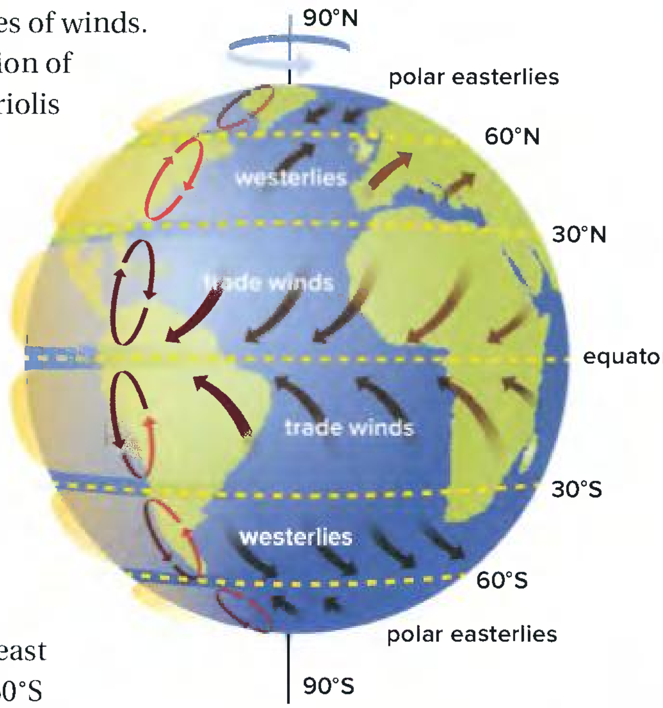


Figure 4.9 The directions of Earth's wind systems vary with the latitudes in which they occur.

Activity

Which Wind System Affects Your Weather?

Using a map that shows latitude, determine which wind system is moving air in your area. How do you think that wind system affects the weather in your area? Which spheres of Earth are interacting to produce wind and weather?

Extending the Connections

Winds and First Peoples Science

Knowledge of winds is an important part of First People's science. What are some examples of Traditional Ecological Knowledge that connect with the winds?

Before you leave this page . . .

1. Explain why Earth receives more direct energy at lower latitudes than at higher latitudes.
2. Write a summary about how the global wind systems move thermal energy around Earth.

CONCEPT 3

Ocean currents also redistribute thermal energy around Earth.

Activity

Ocean Currents Carry More Than Messages in Bottles

In May of 1990, boxes of Nike™ shoes spilled overboard from a container ship in the Pacific Ocean. By early 1991, the shoes were hitting the beaches up and down the coast of B.C. More recently, some of the debris from the 2011 earthquake and tsunami that occurred in Japan washed ashore on B.C. beaches. These are examples of things that we can see with the unaided eye that ocean currents carry. What else do ocean currents carry that is not as easily visible?

Like wind, ocean currents also move thermal energy around Earth. Surface currents, like the ones shown in **Figure 4.10**, are created by wind. There are five major sets of surface currents, one in each main ocean basin—the north Pacific basin, the south Pacific basin, the north Atlantic basin, the south Atlantic basin, and the Indian Ocean basin.

Notice in **Figure 4.10** that in all of the ocean basins, the warm water currents near the equator flow in a westerly direction. When these currents reach a landmass, they turn toward the poles. These poleward-flowing waters carry warm, tropical water into higher, colder latitudes. For example, the warm Kuroshio current moves heat toward the north pole in the north Pacific Ocean.

After these warm waters enter polar regions, they gradually cool. Eventually, they reach a landmass and begin flowing toward the equator. The resulting currents, such as the California current, bring cold water from higher latitudes to tropical regions.

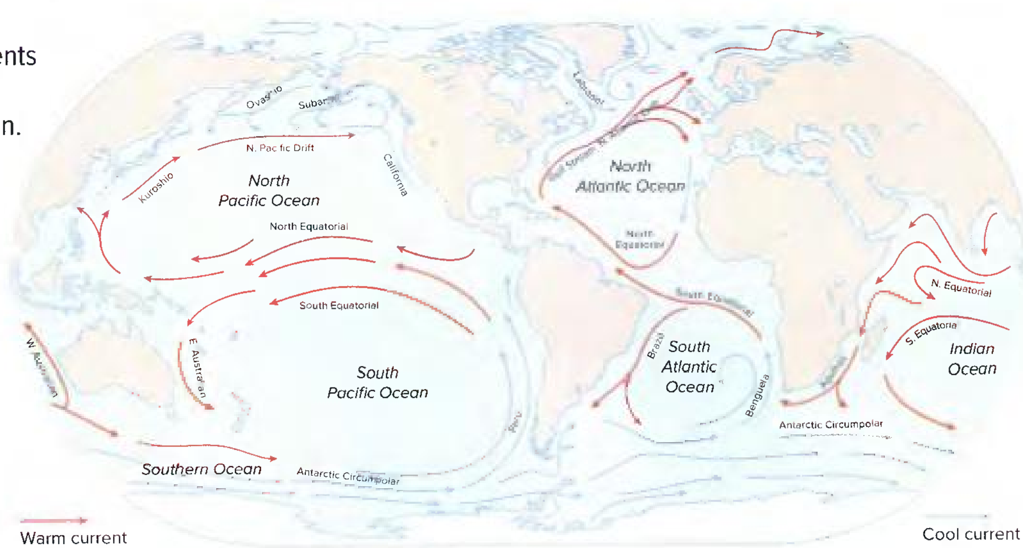


Figure 4.10 Surface currents circulate in predictable patterns in each ocean basin. The red arrows represent warm water currents and the blue arrows represent cold water currents.

Ocean water at the surface moves mostly due to winds. But deeper ocean water moves as a result of differences in the temperature and the salt content of water. Colder water is more dense than warmer water. So colder water sinks and displaces warmer water around it. In a similar way, saltier water is more dense than less salty water. So saltier water sinks and displaces the less salty water around it. Both of these motions produce a massive system of deep-water currents called the *great ocean conveyor belt*. Refer to Figure 4.11. This belt of moving water carries heat around the whole world.

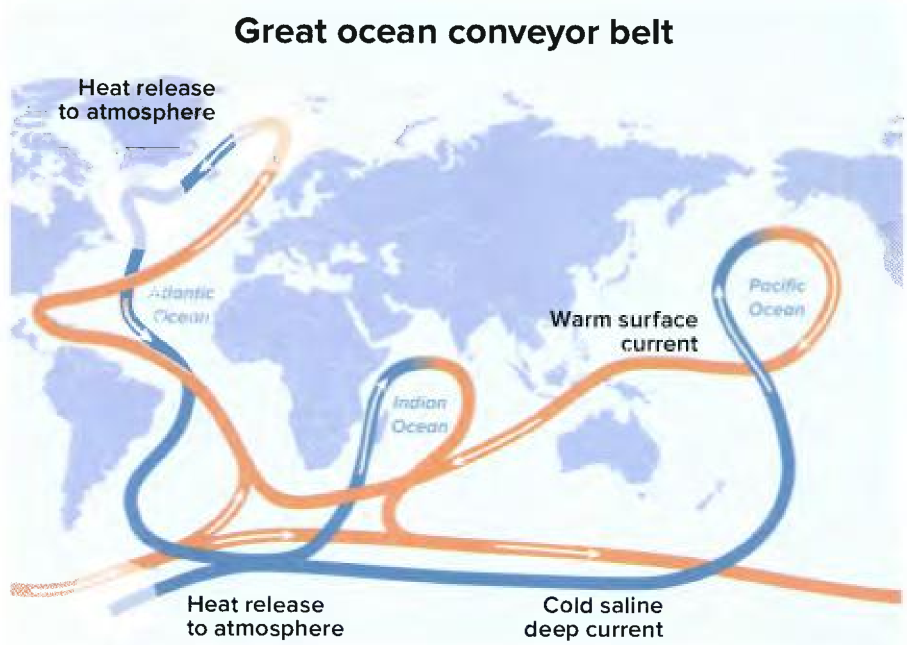


Figure 4.11 The great ocean conveyor belt moves water, nutrients, and thermal energy around Earth.

The great ocean conveyor belt also moves nutrients, such as nitrogen and phosphorus, around the ocean. The surface water that sinks does not contain high amounts of nutrients. After the water sinks, bacteria in deep water break down organic material and return nutrients to the water. When the deep water eventually returns to the surface, it has a high concentration of nutrients.

Activity

Additional Images and Animations

Find satellite images that show the temperature of ocean surface currents, such as the Gulf Stream or the Kuroshio current. How do these images help you understand more about the movement of thermal energy by ocean surface currents? Find an animation that shows the movement of the great ocean conveyor belt. How does the animation help you understand more about the movement of thermal energy by deep ocean currents?

Before you leave this page . . .

1. Describe how surface currents in ocean basins redistribute heat between the equator and the poles.
2. How does the great ocean conveyor belt move heat and nutrients around Earth?

CONCEPT 4

Solar energy enters the biosphere through photosynthesis and cellular respiration.

Activity

KWL Chart

Use a KWL chart to organize the ideas you have about photosynthesis and cellular respiration. Which organisms carry out each process, and for what purpose? How are the processes complementary? Record answers to these questions and anything else you know or want to know about photosynthesis and cellular respiration. After you finish Concept 4, fill in the "What I Learned" column of your chart.

The Sun is the direct source of energy for almost all living things on Earth. Green plants and single-celled plant-like organisms use the Sun's energy to make their own food. To do so, they carry out photosynthesis, in which they transform light energy into chemical energy. The chemical energy is stored in energy-rich food compounds such as glucose, which is a type of sugar. All living things need the chemical energy stored in glucose to live. Most living things use cellular respiration to break apart these compounds to release their stored energy. Once released, it can be used for life functions. **Table 4.4**, which runs across the bottom of these two pages, summarizes details about photosynthesis and cellular respiration.

Table 4.4 Comparing Photosynthesis and Cellular Respiration

	Photosynthesis
1. What is it?	A series of chemical changes in which green plants capture the Sun's light energy and transform it into chemical energy that is stored in energy-rich food compounds such as sugars
2. Which living things use it?	Green plants and certain kinds of single-celled organisms
3. How is energy changed?	Light energy is changed to chemical energy
4. What substances does it use?	• carbon dioxide (CO_2) • water (H_2O)
5. What substances does it produce?	• glucose ($C_6H_{12}O_6$) • oxygen (O_2)
6. How can it be represented?	light energy + carbon dioxide + water $\longrightarrow$ glucose + oxygen light energy from the Sun + CO_2 + H_2O $\longrightarrow$ $C_6H_{12}O_6$ + O_2
7. Why is it important?	• Photosynthesis transforms the Sun's energy into a form that living things can use to survive • Photosynthesis produces the oxygen that most living things need to survive

Photosynthesis and Cellular Respiration Balance Each Other

Notice in Table 4.4 that photosynthesis and cellular respiration are complementary processes—they balance each other.

- Photosynthesis stores energy. Cellular respiration releases energy.
- Photosynthesis uses carbon dioxide and water, and produces glucose and oxygen.
- Cellular respiration uses glucose and oxygen, and produces carbon dioxide and water.

So each process makes the raw materials that the other process needs to store energy or to release energy. In this way, each process sustains the other. Together, both processes sustain life.

Activity

The Sun and Earth's Spheres

Using a mind map, show how the Sun's energy affects each of Earth's spheres. Think about how the spheres interact as a result of the Sun's energy and represent those interactions in your final product as well.

Before you leave this page . . .

1. What forms of energy are transformed during photosynthesis and cellular respiration?
2. Which substances are used and produced by photosynthesis and by cellular respiration?

Cellular Respiration	
A series of chemical changes that let living things release the energy stored in energy-rich food compounds such as sugars to fuel all life functions	**1.** What is it?
Nearly all living things on Earth	**2.** Which living things use it?
Chemical energy is changed to other forms of energy such as kinetic (motion) energy and heat	**3.** How is energy changed?
• glucose ($C_6H_{12}O_6$) • oxygen (O_2)	**4.** What substances does it use?
• carbon dioxide (CO_2) • water (H_2O)	**5.** What substances does it produce?
glucose + oxygen ⟶ carbon dioxide + water + usable energy $C_6H_{12}O_6 + O_2 \longrightarrow CO_2 + H_2O$ + usable energy	**6.** How can it be represented?
• Cellular respiration releases the energy that living things use to survive • Cellular respiration produces the carbon dioxide that green plants need to carry out photosynthesis	**7.** Why is it important?

AT ISSUE

Could global warming bring a frosty future?

What's the Issue?

Could changes in global ocean currents cause mild temperatures in northwestern Europe to plunge, bringing winters that rival the Canada's worst? Some scientists say yes. They point to the Gulf Stream, which carries warmer ocean water (and warmer temperatures) to northwestern Europe. The Gulf Stream is driven mainly by winds, but the great ocean conveyor belt contributes to about 20% of its flow. Scientists think an influx of lower density water from melting sea ice could clog the conveyor belt, slowing or stopping the Gulf Stream and altering European climate dramatically.

Other scientists say the atmosphere plays a greater role than the hydrosphere in Europe's climate. They focus on patterns of atmospheric pressure and large-scale wind flow directed by mountain ranges like the Rockies. In this case, an abrupt change in Europe's climate due to a shutdown of the great ocean conveyor belt may be less likely.

Dig Deeper

Collaborate with your classmates to explore one or more of these questions—or generate your own questions to explore.

1. a) Imagine you are a science journalist interested in the issue you just read about. What questions would you pose to scientists?

   b) Find out more about the ideas discussed in this feature, and try to answer the questions you posed in part a. What do you think the future holds for Europe's climate and why?

2. None of Earth's spheres exist in isolation. How do you think changes in the great ocean conveyor belt might affect Earth's other spheres?

3. Winter air temperatures in Vancouver are around 20°C warmer than those at the southern tip of Russia's Kamchatka Peninsula, at nearly the same latitude. Use the information in this Topic and other sources to suggest a reason why.

Check Your Understanding of Topic 4.2

QP Questioning and Predicting PC Planning and Conducting PA Processing and Analyzing E Evaluating
AI Applying and Innovating C Communicating

Understanding Key Ideas

1. Explain why naturally occurring greenhouse gases are necessary for life to exist on Earth. PA C

2. Create an illustration to explain how the warming and cooling of air generates wind. PA C

3. Surface currents can affect coastal climates. Would the Gulf Stream and the Benguela current, both of which are surface currents, have the same effect on coastal climates? Explain. (Refer to Figure 4.10.) PA C

4. How does the great ocean conveyor belt help move dissolved gases, such as oxygen, and nutrients, such as nitrogen, from one area of the ocean to another? PA

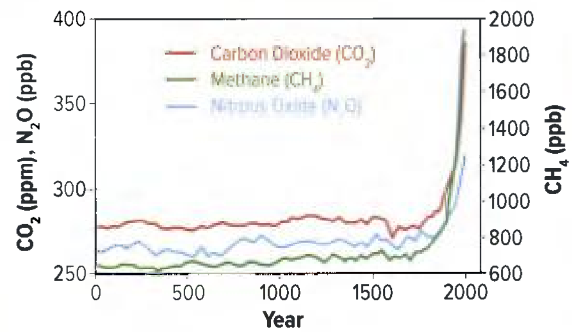
5. Using a format of your choice, compare photosynthesis and cellular respiration, including the organisms in which each process occurs and the substances involved in each process. E C

6. When two things are complementary, they balance each other. Explain why photosynthesis and cellular respiration are considered complementary processes. AI

Connecting Ideas

7. Refer to Table 4.4. Should photosynthesis win the Most Important Process on Earth Award? Write a supported opinion paragraph explaining your position. AI C

8. Examine the graph below. Provide reasons to account for the dramatic jump in the concentration of each greenhouse gas. PA E



Source: United States Environmental Protection Agency

Making New Connections

9. The term *greenhouse gases* has been used in the media to discuss the negative impacts of climate change. Are greenhouse gases bad for our climate or necessary? Justify your answer. PA C

10. As the average temperature of traditionally cooler regions increases, what does this do to the ability of winds to redistribute the energy evenly around the world? PA E

11. For many First Peoples, the Sun is a symbol of renewal. What are some ways in which the Sun brings about renewal?

12. From a First Peoples perspective, how are the ideas of transformation and balance reflected in the processes of photosynthesis and cellular respiration?

INVESTIGATION

4-C

STRUCTURED INQUIRY

How Does Melting Sea Ice Affect Global Temperature?

Find out how changes in the hydrosphere affect temperatures around the world in this activity.

Question

How can changes in the hydrosphere affect temperatures worldwide?

Procedure

1. Read all the steps, and create a data table to record your observations.
2. Line each tray with black plastic.
3. Label the trays A and B with the marker and masking tape. Cover three quarters of Tray A with ice. Cover one quarter of Tray B with ice.
4. Pour water in both trays to fill half the depth of the trays.
5. Set up two 150 W heat lamps about 20 cm from each tray.
6. Position thermometers in each tray to measure the temperature of the water.
7. Turn on the lamps, and make sure that the light shines over the entire tray.
8. Record the temperature of the water in each tray every 30 s for 10 min.

Analyze and Interpret

1. Create a line graph to represent your data.
2. In which tray did the water temperature warm the most? Why do you think this was the case?
   a) What did the black plastic represent in this activity? Hint: After sea ice melts, what lies beneath it?
   b) Why was this lining an important part of the experiment?
3. Use what you have learned in this activity to predict the effect of melting sea ice on average global temperature.

Skills and Strategies

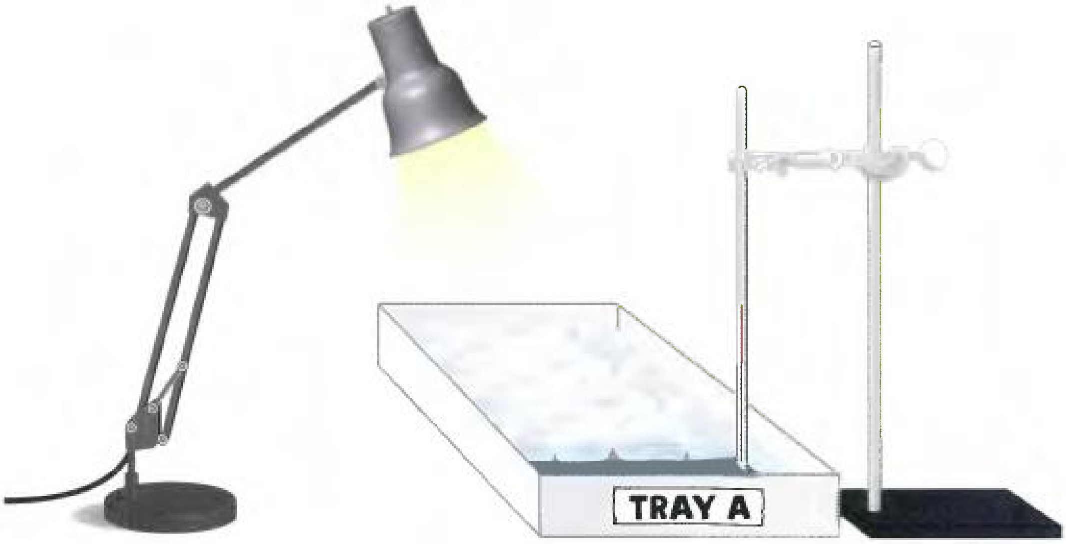
- Planning and Conducting
- Processing and Analyzing
- Evaluating
- Communicating

Safety

- Be careful when handling the glassware and thermometers to avoid breakage.
- Be careful when working near the hot bulb of the lamp.

What You Need

- 2 plastic trays
- black plastic
- cold water
- ice cubes
- 2 heat lamps
- 2 thermometers
- 2 clamps
- 2 retort stands with clamped thermometers
- masking tape
- waterproof marker
- timer



Conclude and Communicate

4. How do you think melting sea ice could affect Earth's other spheres? As you answer, think about how the atmosphere would be affected if areas of Earth's oceans normally covered by ice can now absorb more heat. Also consider how organisms in the biosphere may be affected by the loss of sea ice, and how the hydrosphere and the geosphere interact.

TOPIC

4.3

What interactions supply energy to Earth's biosphere?

Key Concepts

- Producers transfer energy to consumers and decomposers.
- Interactions are needed to provide a constant flow of energy to sustain the biosphere.

Curricular Competencies

- Construct, analyze, and interpret graphs, models, and/or diagrams.
- Apply First Peoples perspectives and knowledge, other ways of knowing, and local knowledge
- Formulate physical or mental theoretical models to describe a phenomenon.
- Communicate ideas, claims, and information using evidence-based arguments and appropriate language, conventions, and representations

Although the focal point of this photograph is the grasshopper, it really should be the Sun. The Sun is the ultimate source of energy for the biosphere. The Sun's energy is transferred from one organism to another organism when one organism consumes the other. You already know that the plant shown here makes its own food by carrying out photosynthesis. The grasshopper will use the energy it gets from eating the plant to jump, grow, and carry out other life functions. The grasshopper then may be eaten by a woodpecker, which in turn may be eaten by a hawk. The woodpecker uses the energy it gets from the grasshopper to fly, hunt for more food, and reproduce. The hawk uses the energy it gets from eating the woodpecker for the same types of activities and processes.

Starting Points

Choose one, some, or all of the following to start your exploration of this Topic.

1. **Identifying Preconceptions** Think about what you know about food chains. Does a food chain have an end? Why or why not?
2. **Inferring** How do the cows in the photo on the right depend on energy that comes originally from the sun? Is the dependency of the young calf different from the dependency of the adult cow?

3. **Relating** Think about the foods you have eaten during the past week. Write down three of these foods. Use words, pictures, or both to show how you think each of the foods is linked to the Sun.
4. **Applying First Peoples Perspectives** How does the energy transfer between organisms support the idea that everything is interdependent? How do humans fit in to this transfer of energy?

Key Terms

There are six key terms that are highlighted in bold type in this Topic:

- producers
- consumers
- decomposers
- food chain
- food web
- energy pyramid

Flip through the pages of this Topic to find these terms. Add them to your class Word Wall along with their meanings. Add other terms that you think are important and want to remember.

CONCEPT 1

Producers transfer energy to consumers and decomposers.

producers living things that make their own food to get the energy they need

consumers living things that eat producers or other consumers to get the energy they need

decomposers living things that break down dead organic material to get the energy they need

food chain a model that describes how food energy is passed from one living thing to another

Many interactions between living things in ecosystems involve food and feeding. Because of this, you can describe living things based on how they get energy from food.

- **Producers** produce (make) their own food to get the energy they need to live. Most producers use photosynthesis to do this. Only green plants and some kinds of single-celled living things can carry out photosynthesis. So these kinds of organisms are producers in most ecosystems.
- **Consumers** consume (eat) producers or other consumers to get the energy they need to live. Animals and most other kinds of living things are consumers.
- **Decomposers** break down dead organic material, such as dead plant or animal tissue, to obtain the energy they need to live.

Food Chains Chart the Flow of Energy from Producers to Consumers

A **food chain** is a model that describes how the stored energy in food is passed on from one living thing to another. You can use a food chain to show how energy flows in any ecosystem. An example of a food chain in a mountain ecosystem is shown in Figure 4.12. Notice that the flow of energy always goes from a producer to a consumer, and then on to one or more other consumers.

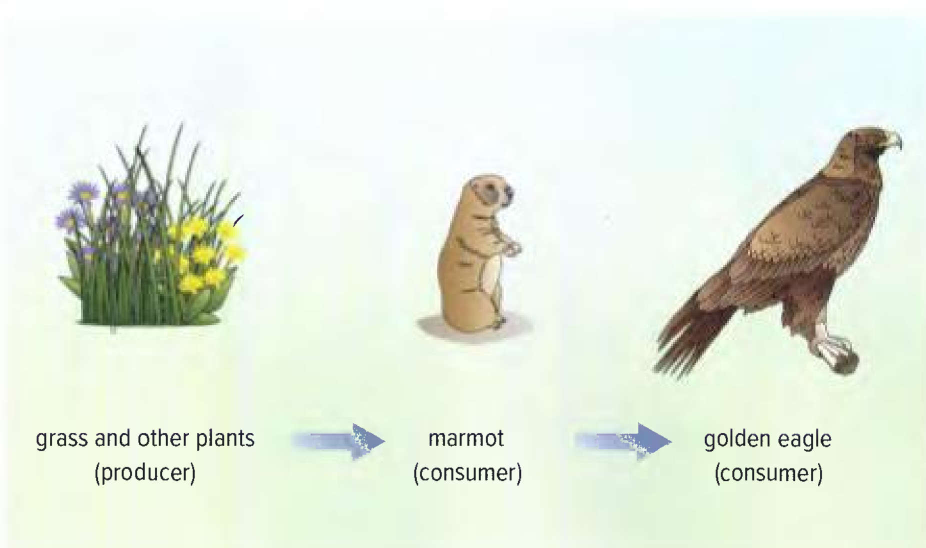


Figure 4.12 The terrestrial mountain ecosystem food chain has three links, with one producer and two consumers.

Food Webs Show How Food Chains Are Connected

You eat many different kinds of organisms that are producers and consumers. In other words, you are part of many different food chains. The same is true for other organisms. In any ecosystem, a more realistic model of feeding relationships shows a network of interacting and overlapping food chains. Such a model is called a food web. A **food web** weaves together two or more food chains within any given ecosystem. Refer to Figure 4.13. All organisms in a food web are connected to each other through their feeding relationships. As a result, a change in the number of one organism could affect several food chains within the food web. In this sense, all organisms in an ecosystem are connected to and depend on each other for survival. Their interactions are key factors to sustaining life in aquatic and terrestrial ecosystems.

food web a model of feeding relationships shows a network of interacting and overlapping food chains

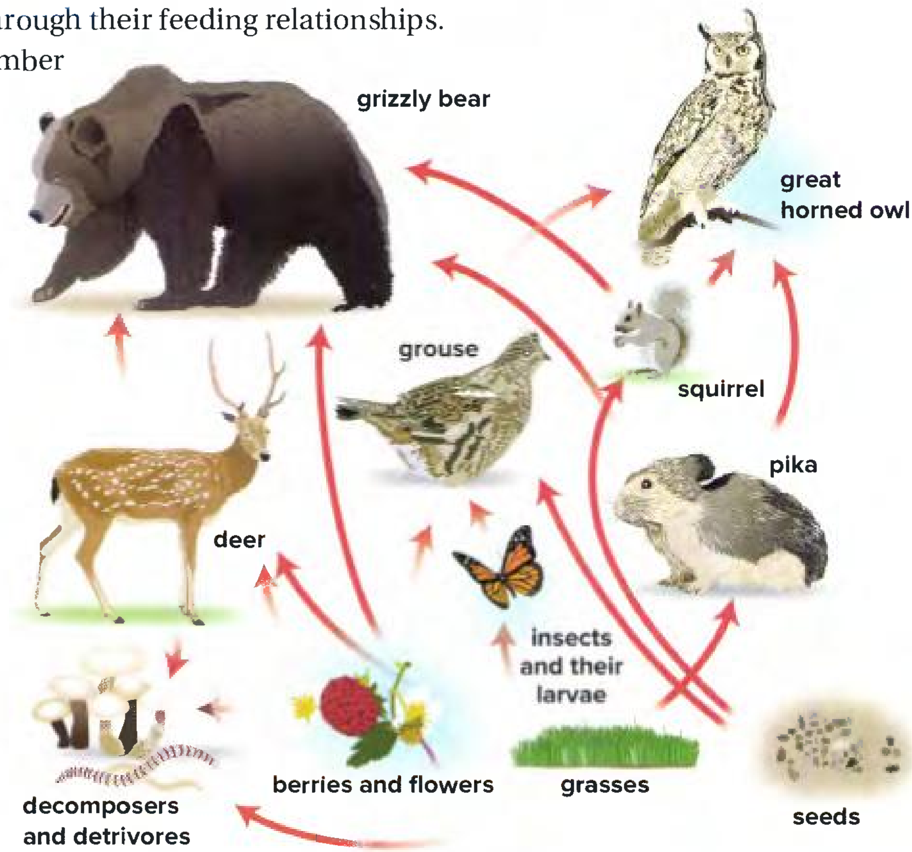


Figure 4.13 An example of a food web that might be found in B.C.'s alpine regions

Activity

Analyzing a Food Web

In Figure 4.13, what makes the grasses and other plants that make seeds, berries, and flowers different from other organisms in the food web? Identify four food chains in the food web in Figure 4.13.

Before you leave this page . . .

1. Compare and contrast producers, consumers, and decomposers.
2. A food web is a more realistic model for feeding relationships in an ecosystem than a food chain. Explain why.

CONCEPT 2

Interactions are needed to provide a constant flow of energy to sustain the biosphere.

Activity

Model a Food Chain

Start with a small paper cup containing five dried beans. With your classmates lined up in a row, start with the first person and have them remove one bean from the cup, then pass the cup to the next person in line. The next person should repeat the process, removing one bean and then passing the cup to the next person, and so on until there are no beans left. How many people were left without beans? Food chains in nature have between two and five levels. How does this fact relate to what happened in your food chain? Why do you think food chains have a limit to the number of levels in them?

Most food chains have three or four links. Some food chains might have as many as five or six links. Why are there limits to the length of a food chain? Limits exist because only about 10% of the food energy for a producer is available to a consumer that eats it. And only 10% of the food energy for that consumer is available to the next consumer. Here are some of the reasons why.

- Some of the original food energy has been used already to support life functions, such as growth and cellular respiration.
- Some energy is changed into heat that is given off into the environment. This energy cannot be used by other living things.
- Some energy is stored in wastes (urine and feces) that are excreted into the environment.

Bacteria, fungi, and other decomposers extract some of this energy, but most is lost to the environment as heat. The transfer of energy along a food chain is like a bucket-toss relay game. Figure 4.14 illustrates this idea. As each player tosses a bucket of water to the next player, some of the water spills from the bucket. There is only a little water left when the bucket reaches the last player, because some of the water spilled out each time the bucket was tossed. In a food chain, each time energy is transferred some of it is lost as unusable heat. The energy that is lost cannot be used by other living things. So a constant supply of energy is needed to sustain living things in terrestrial and aquatic ecosystems.

Connect to Investigation 4-D on page 318

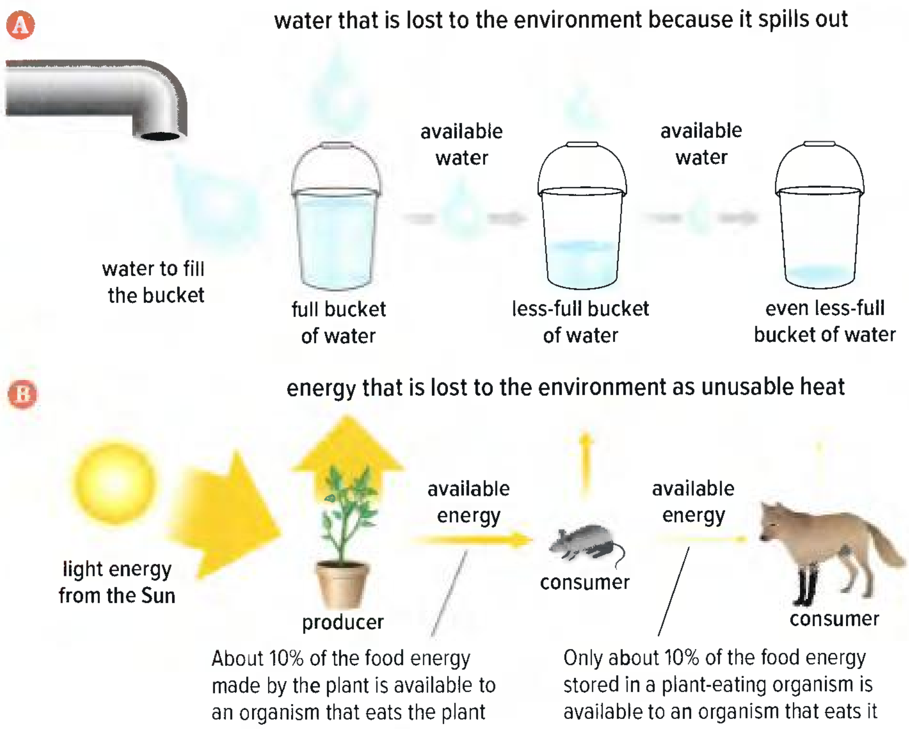


Figure 4.14 A Most of the water in the bucket that is transferred from one player to another in a bucket-toss relay game is lost to the environment. Less and less water is in the bucket for each player in the relay. B Most of the energy that is transferred from one organism to another in a food chain is lost to the environment as unusable heat. Less and less energy is available to each organism in the food chain.

The concept in **Figure 4.14** is also represented by an energy pyramid, shown in **Figure 4.15**. In an **energy pyramid**, each level represents the amount of energy that is available to that level of the food chain.

energy pyramid a model that shows the amount of energy available in each level of a food chain

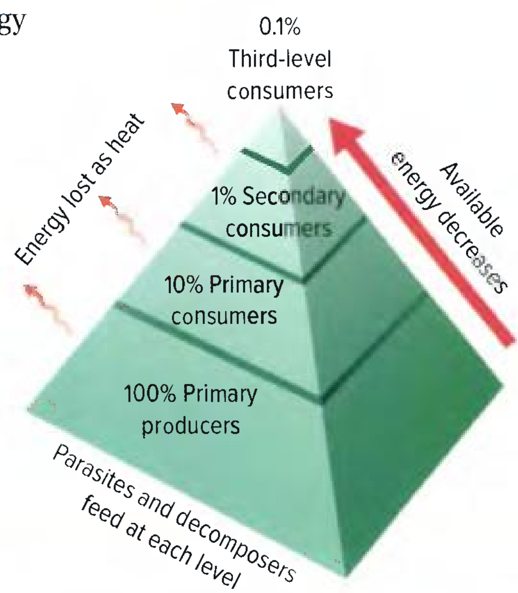


Figure 4.15 In a pyramid of energy, each level represents the amount of energy that is available to that trophic level. With each step up, there is an energy loss of 90%.

Before you leave this page . . .

1. When a mouse eats a plant, only about 10% of the plant's energy is transferred to the mouse. What happens to the rest of the energy?

2. In **Figure 4.14**, the analogy of a bucket-toss relay game is used to explain the transfer of energy through a food chain. Create your own analogy to explain this transfer of energy.

AT ISSUE What is happening to the once-mighty oolichan?

What's the Issue?

The oolichan (also spelled eulachon) may be small, but it is packed with nutritious oils. It is a key link in the transfer of energy in many aquatic ecosystems. The fish returns from the ocean to spawn in fresh water early in the spring. Hungry birds and mammals like eagles, seagulls, seals, and sea lions gorge on them. The timing is perfect. Food supplies are low, and the animals need nutrition as their bodies prepare for reproduction.

The oolichan has always been a significant source of energy for First Peoples as well. In the past, a number of major rivers along the Pacific coast supported huge numbers of the fish. First Peoples preserved them by drying and smoking, and they manufactured a rich oil known as "grease" that was traded throughout the province for thousands of years. However, oolichan numbers have been seriously declining in recent decades, and today the fish and oil delicacies are becoming rare.

Dig Deeper

Collaborate with your classmates to explore one or more of these questions—or generate your own questions to explore.

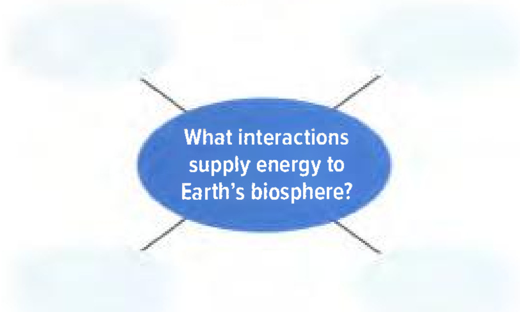
1. Predict some reasons for the decline in oolichan stocks. Research to find out Western science and First Peoples perspectives about the causes.
2. The oolichan is sometimes called both the "saviour fish" and the candlefish. Explain why each of these names is appropriate.
3. Understanding how to extract the nutritious oil from the fish is an example of Traditional Ecological Knowledge. Find out how coastal First Peoples make oolichan grease. In what ways is energy transformed through the process?

Check Your Understanding of **Topic 4.3**

QP Questioning and Predicting PC Planning and Conducting PA Processing and Analyzing E Evaluating
AI Applying and Innovating C Communicating

Understanding Key Ideas

1. Answer the question that is the title of this Topic. Copy and complete the graphic organizer below in your notebook. Fill in four examples using key terms as well as your own words. PA C

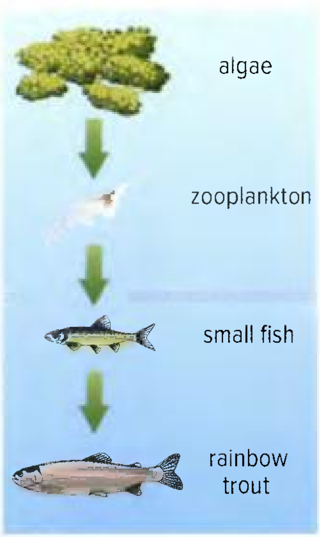


2. Why do food webs require a continual input of energy from the Sun? E

3. What role does the amount of energy available for transfer from one organism to the next play in the number of organisms in a food chain? PA

4. Why is a constant supply of energy needed to sustain life on Earth? PA

5. How many levels are in the aquatic ecosystem shown on the right? Which organisms are the producers? Which are the consumers? AI



6. Discuss whether a food chain can carry on after the removal of one of the organisms from the chain. PA C

7. Re-read the introduction to Topic 4.3. How can you represent the transfer of energy among the organisms mentioned in one diagram or illustration? Share your representation with a classmate. What questions do you have as a result of making your own representation and looking at your classmate's? AI C

Connecting Ideas

8. Think about everything that you ate yesterday. Draw a food web that includes you. AI C
   a) Look at your food web and determine how many links are in the longest food chain within it.
   b) What process did your body use to release the energy from the food you ate?

9. How might the ideas of "energy loss" and "unusable heat" be considered from a First Peoples perspective? Think about interconnectedness and balance.

Making New Connections

10. The plants in level 1 of a food pyramid obtain 30 000 units of energy from the Sun. How much energy is available for consumers in level 2? level 3? level 4? AI

11. Are some organisms more important to the food chain than others? If yes, where would they be found in the food chain? If no, justify your answer. E C

INVESTIGATION

4-D

GUIDED INQUIRY

Skills and Strategies

- Planning and Conducting
- Processing and Analyzing
- Evaluating
- Communicating

What You Need

- access to the Internet and print resources

Plot the Pathway

Interactions between biotic and abiotic parts of an ecosystem provide a constant flow of energy through it. Recall that an ecosystem is all of the living things and non-living things in a given area. You will investigate a possible pathway of energy flow through a British Columbian ecosystem of your choice to better understand how these interactions affect energy transfer.

Question

How can you trace the pathway of energy through a food web?

Procedure

1. Choose an ecosystem in British Columbia.
2. In a format of your choice, represent a food web from the ecosystem.
3. Decide how you can trace a pathway or multiple pathways of energy through the food web.
4. Represent the pathway(s) in your food web.

Process and Analyze

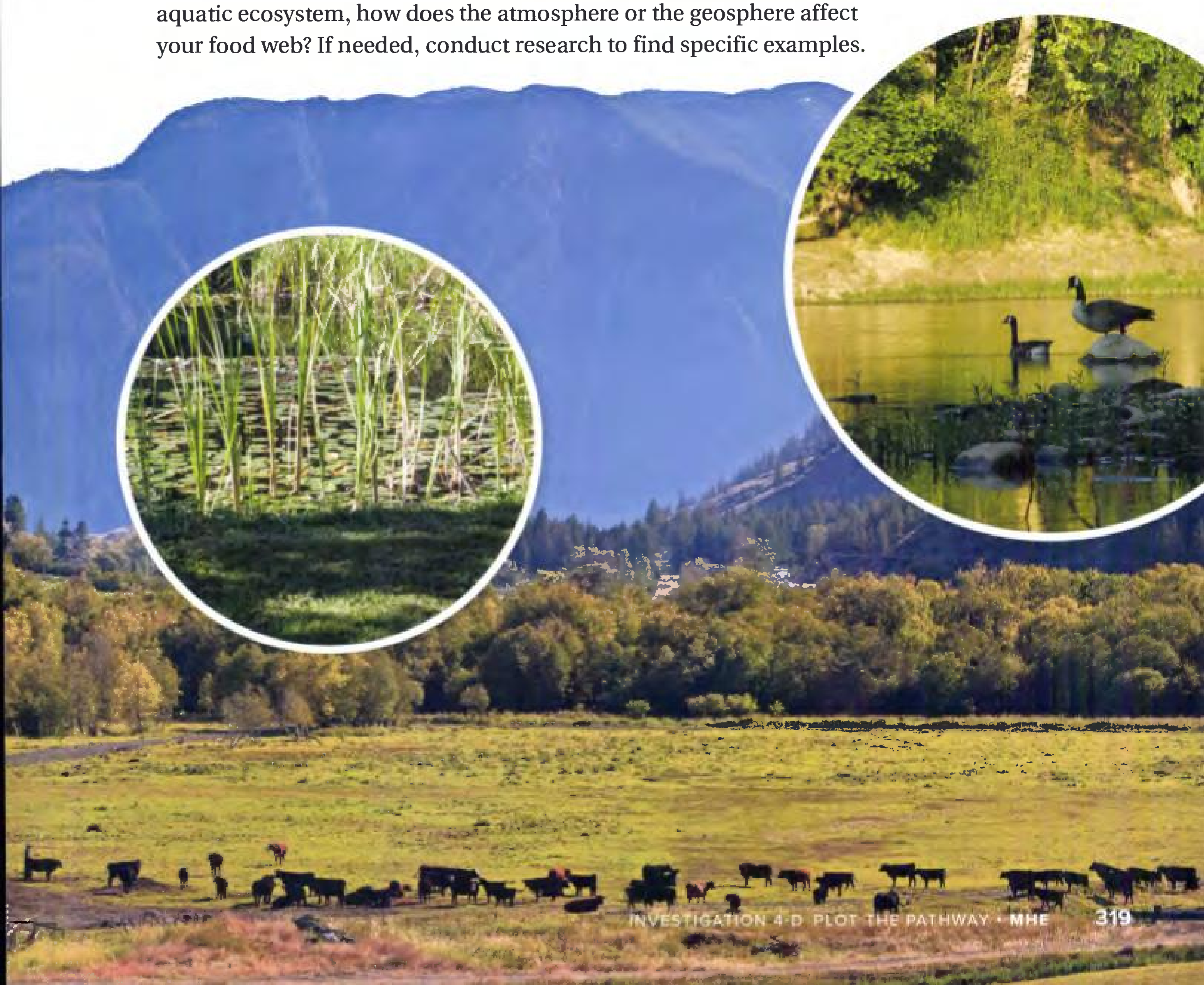
1. Identify the following ecosystem components in your food web:
   a) abiotic parts
   b) biotic parts
   c) producers
   d) consumers
2. a) Which of the organisms in your food web store energy through photosynthesis?
   b) Which of the organisms in your food web release energy through cellular respiration?
   c) What would happen to your food web if the organisms that carry out died out? Explain your answer.
3. How many organisms are in your food web? How many levels were there in each of your food chains? Why are all food chains limited in length?

Evaluate and Communicate

4. Suppose one of the consumers in your food web is a threatened species in British Columbia, meaning its numbers are low enough that it could die out at some point in the near future. How might a food chain that includes this consumer be affected if its population numbers continue to decline? Why would this be the case? How would its decline affect the food web as a whole?

Apply and Innovate

5. How is your food web connected to Earth's spheres? Be specific to the ecosystem you chose in your answer. For example, if you chose a mountain ecosystem, how does the geosphere interact with your food web? What about the hydrosphere and atmosphere? If you chose an aquatic ecosystem, how does the atmosphere or the geosphere affect your food web? If needed, conduct research to find specific examples.



TOPIC 4.4

What interactions cycle matter through Earth's spheres?

Key Concepts

- The water cycle is a continuous cycle driven by solar energy and gravity.
- Carbon is cycled through interactions between living and non-living things.
- Nitrogen is cycled through interactions between living and non-living things.
- Phosphorus is cycled through interactions between living and non-living things.

Curricular Competencies

- Formulate multiple hypotheses and predict multiple outcomes.
- Analyze cause-and-effect relationships
- Demonstrate an awareness of assumptions, question information given, and identify bias

Methane (CH_4) is one of the more powerful greenhouse gases, and it comes from a perhaps unexpected source: cows. As you read in Topic 4.2, the true source of the methane in this case is the bacteria that live in the cows' guts. The cows release methane when they burp and "pass gas." Burping and windy cows might seem funny, but where the carbon cycle and climate change are concerned it's no laughing matter. Scientists in Argentina did an experiment in which they strapped plastic bags to the backs of cows (such as the one in the photo), ran tubes from the bags to the cows' stomachs, and collected the gases produced. The scientists discovered that one 550 kg cow produces 800 L to 1000 L of methane and other greenhouse gases per day. That's a lot when you consider that Canada has about 13 million cows!

Starting Points

Choose one, some, or all of the following to start your exploration of this Topic.

1. **Identifying Preconceptions** When you hear the word "recycling," what do you think of? Would it surprise you to know that Earth has been recycling water and other nutrients for billions of years? Explain how human recycling of plastic and paper is analogous to Earth recycling water, carbon, nitrogen, and phosphorus.
2. **Checking for Bias** Is corn sweat a real thing? Research more about corn sweating and the formation of "heat domes." What are the supposed effects of a heat dome? Evaluate your sources for bias. Do you think that corn sweat is responsible for an increase in temperature in certain areas? Why or why not?
3. **Applying First Peoples Perspectives** For First Peoples, Place is a relationship with their traditional lands. What are some ways that the interactions of the Earth's spheres might contribute to a sense of place?

Key Terms

There are six key terms that are highlighted in bold type in this Topic:

- transpiration
- bioaccumulation
- global warming
- water pollution
- biomagnification
- global climate change

Flip through the pages of this Topic to find these terms. Add them to your class Word Wall along with their meanings. Add other terms that you think are important and want to remember.

CONCEPT 1

The water cycle is a continuous cycle driven by solar energy and gravity.

Activity

Amount of Water on Earth

On a map of Canada or British Columbia, locate Vancouver and the Tsay Keh Dene Nation at the north end of Williston Lake. The distance between these two locations is nearly 1400 km. Now picture a ball with a diameter of 1400 km. (In other words, the ball is 1400 km across.) All the water on Earth could fit into that ball. Do you think that is a lot or not? Explain.

When you study Figure 4.16, you can see that there is water on Earth's surface in the form of ponds, lakes, rivers, the ocean, snow, and ice. There is water under Earth's surface in the form of ground water. And there is water in the air in the form of water vapour. All this water continuously cycles through ecosystems by means of the interaction of three main processes: evaporation, condensation, and precipitation.

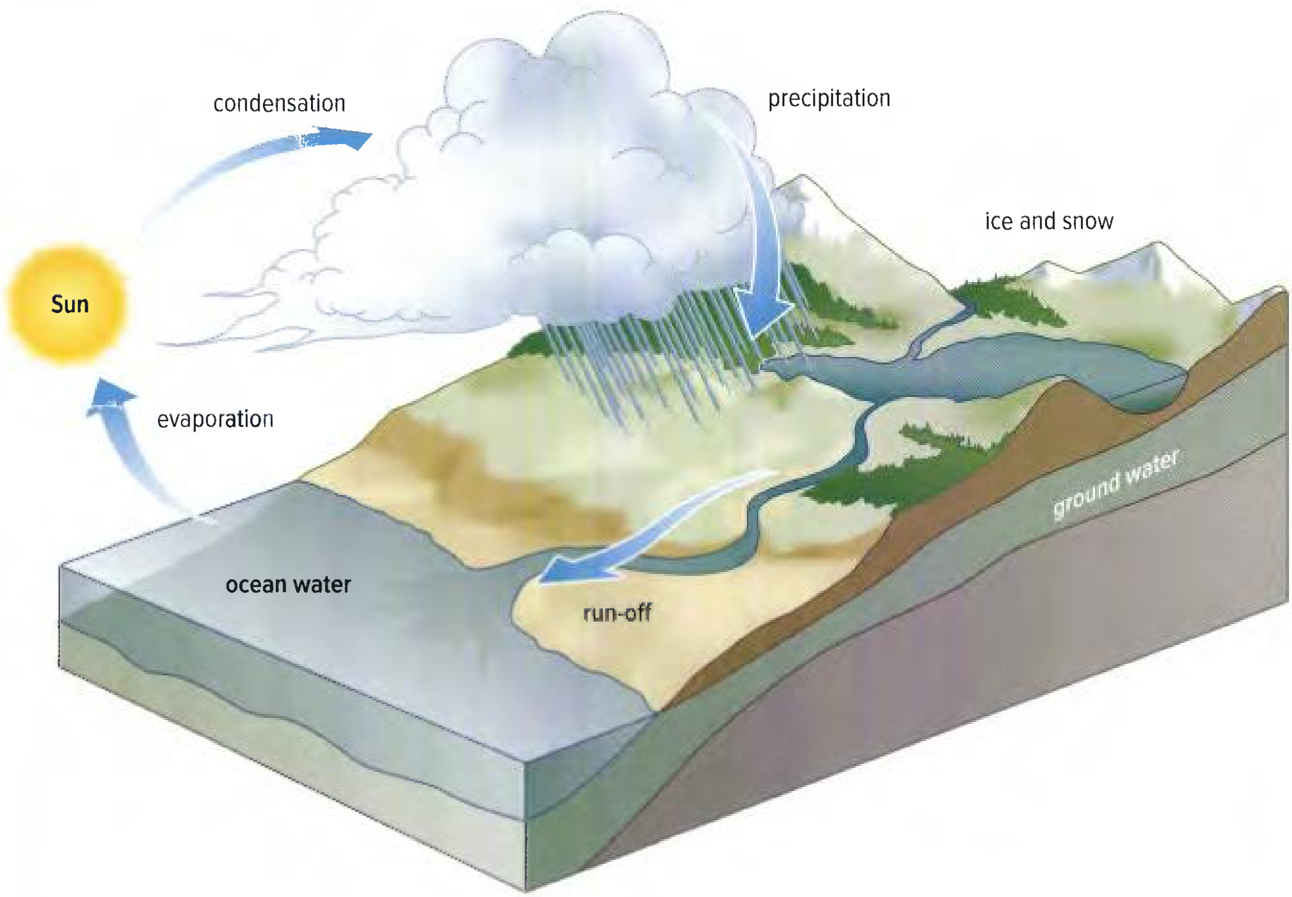


Figure 4.16 During the water cycle, water is exchanged among the hydrosphere, atmosphere, and geosphere.

The Water Cycle

Heat from the Sun causes water at Earth's surface to evaporate. As the warm air rises, it cools and condenses, forming clouds. Water falls back to Earth's surface when it rains, snows, sleets, or hails. Water that moves over Earth's surface is called run-off and moves downhill toward the lowest point due to gravity.

So far, you've seen that water moves through the hydrosphere, the atmosphere, and the geosphere. What about the biosphere? One process that involves water moving through the biosphere is transpiration. **Transpiration**, shown in Figure 4.17, is the process by which water is absorbed by the roots of plants, carried through the plant, and lost as water vapour through small pores in the leaves.

transpiration process by which water is absorbed by the roots of plants, carried through the plant, and lost as water vapour through small pores in the leaves

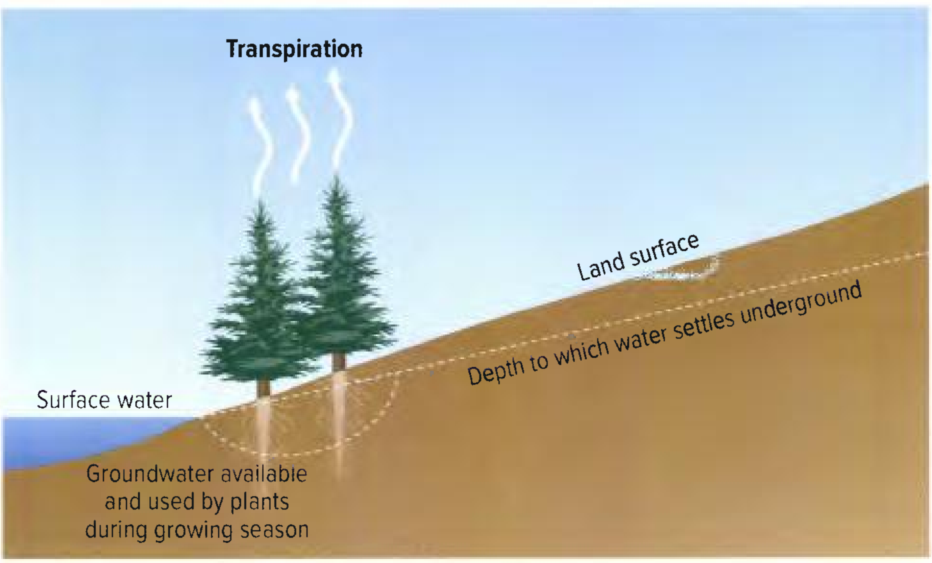


Figure 4.17 Studies show that about 10% of water vapour in the atmosphere is released by plants.

Activity

Model the Water Cycle

Use materials provided by your teacher to model the water cycle. Trace a single drop of water through your model.

Connect to Investigation 4-F on page 337

Extending the Connection

Water Conservation

The water cycle ensures that Earth will never run out of water. In fact, the total amount of water on Earth (the amount in that 1400-km-diameter ball) always stays the same. So why are we concerned about conserving water resources? (Hint: What is the difference between the total amount of water on Earth and the amount of water that is available in any one place at any one time?)

Human Impact on the Water Cycle

water pollution any physical, biological, or chemical change in water quality that has an adverse effect on organisms or that makes water unsuitable for desired uses

Water pollution is any physical, biological, or chemical change in water quality that has an adverse effect on organisms or that makes water unsuitable for desired uses. Water may be polluted by natural sources such as volcanoes and landslides. However, human activities can affect water quality as well.

Point sources of water pollution, such as the one shown in Figure 4.18, include factories, power plants, sewage treatment plants, and oil wells. These sources are fairly easy to monitor and regulate. Non-point sources of water pollution, also shown in Figure 4.18, include run-off from farm fields and feedlots, lawns, construction sites, logging areas, roads, and parking lots. Pollution from non-point sources tends to be periodic. As a result, it is more difficult to monitor, regulate, and treat non-point sources of water pollution.

Perhaps the most challenging non-point source to address is the atmosphere itself. Pollutants may be carried great distances by winds and then eventually fall to the ground in rain or snow. As a result, pollutants from one location may turn up in watersheds and surface waters far from their point of origin.

Figure 4.18 Industrial pipes that discharge waste are a point source of water pollution. Run-off from construction sites is a non-point source of water pollution.

Activity

Write Your Own Take a Stand Feature

Use the Internet and other resources to research water pollutants in your area. Choose one water pollutant that interests you. Find a specific instance where it has caused a problem in your area. Use the Take a Stand feature in this textbook as a model to write your own feature. At a minimum, your feature should include

- a description of the problem, including the pollutant involved, its source, and its effect on the environment and/or human health
- solutions as to how the problem can be dealt with

Organisms Magnify Water Pollutants

Some pollutants do not degrade easily so they stay in the environment for a long time. These include the pesticide DDT, heavy metals such as mercury, and PCBs. PCBs are chemicals that were used in hundreds of different products, from plastics to paints. Production of both DDT and PCBs is now banned in Canada. Why is this the case?

DDT and PCBs, along with heavy metals, enter waterways and are taken up by microscopic organisms such as phytoplankton and bacteria. The pollutants collect in the cells and tissues of these organisms. This process is called **bioaccumulation**. When predators, such as zooplankton and fish, eat these organisms, the pollutants build up further in the predators' fatty tissues. Because predators consume a lot of prey, the pollutants become concentrated in their tissues. This effect is called **biomagnification**. Figure 4.19 explains how these two processes occur. Notice how the organisms that are highest in the food chain accumulate the greatest levels of the pollutant. Large fish such as sharks, fish-eating birds, and humans all fall into this category. At high levels, these pollutants are extremely harmful.

bioaccumulation the process by which pollutants collect in the cells and tissues of organisms

biomagnification the increase in concentration of pollutants in tissues of organisms that are at successively higher levels in a food chain or food web

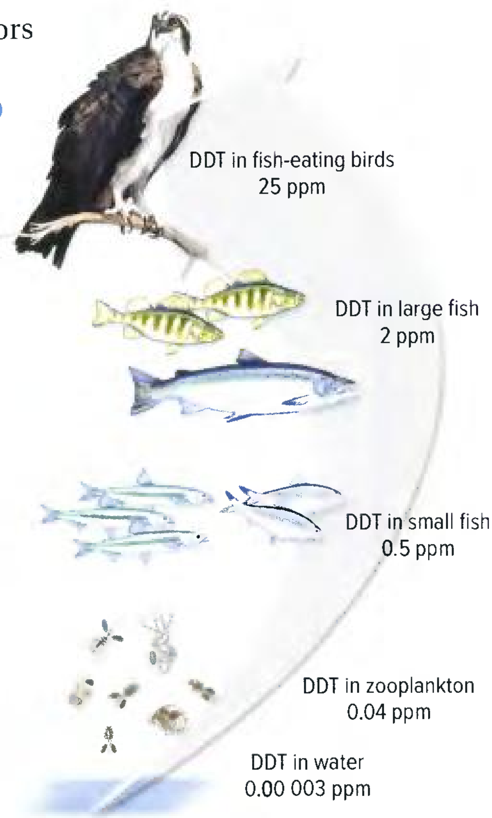


Figure 4.19 Bioaccumulation and biomagnification work together to magnify certain water pollutants in large predators. The unit ppm means "parts per million" of the pollutants. One part per million (1 ppm) is like one second in 11.5 days, or one minute in two years, or one car in bumper-to-bumper traffic from Vancouver, British Columbia, to Toronto, Ontario. **Would someone who eats small fish such as sardines consume as much DDT as someone who eats large fish such as tuna? Why or why not?**

Activity

Pass It On

Design an activity to explain bioaccumulation and biomagnification to a class of younger students. Create your activity, and then test it on a group of students. Improve the activity based on any feedback you receive.

Before you leave this page . . .

1. A cycle is a pattern of change that repeats itself forever. In what way does the water cycle demonstrate the features of a cycle?
2. Describe how transpiration ties the hydrosphere and the biosphere together.
3. Make a T-chart to list the differences between point source and non-point source water pollution.
4. Compare and contrast bioaccumulation biomagnificationt.

CONCEPT 2

Carbon is cycled through interactions between living and non-living things.

Activity

Sources and Sinks

In each of the nutrient cycles you will read about next, the carbon cycle, the nitrogen cycle, and the phosphorus cycle, there are sources of each nutrient and sinks for each nutrient. A source is any process that releases more of the nutrient than it absorbs. A sink is just the opposite, any process that absorbs and stores more of the nutrient than it releases. As you read about each nutrient cycle, identify the sources and sinks for the nutrient. Record the information in a table that you create.

Figure 4.20 shows how carbon moves through Earth's spheres. Carbon dioxide gas moves from the atmosphere into the biosphere and back again through the processes of photosynthesis and cellular respiration. Carbon dioxide also moves back to the atmosphere when organisms die and their bodies decompose. Carbon enters the geosphere when the remains of organisms are trapped under layers of sediment.

Not all the carbon involved in the carbon cycle is used immediately by living things. Some is stored in the woody tissues of long-living trees. Some is stored in the slowly decomposing remains of organisms, which become buried deeply in the ground. With the passage of time, some of this stored carbon will eventually be transformed into the carbon-rich fuels that we know as coal, oil, and natural gas. This is what happened about 300 million years ago to form the coal, oil, and natural gas that we use today as fuel.

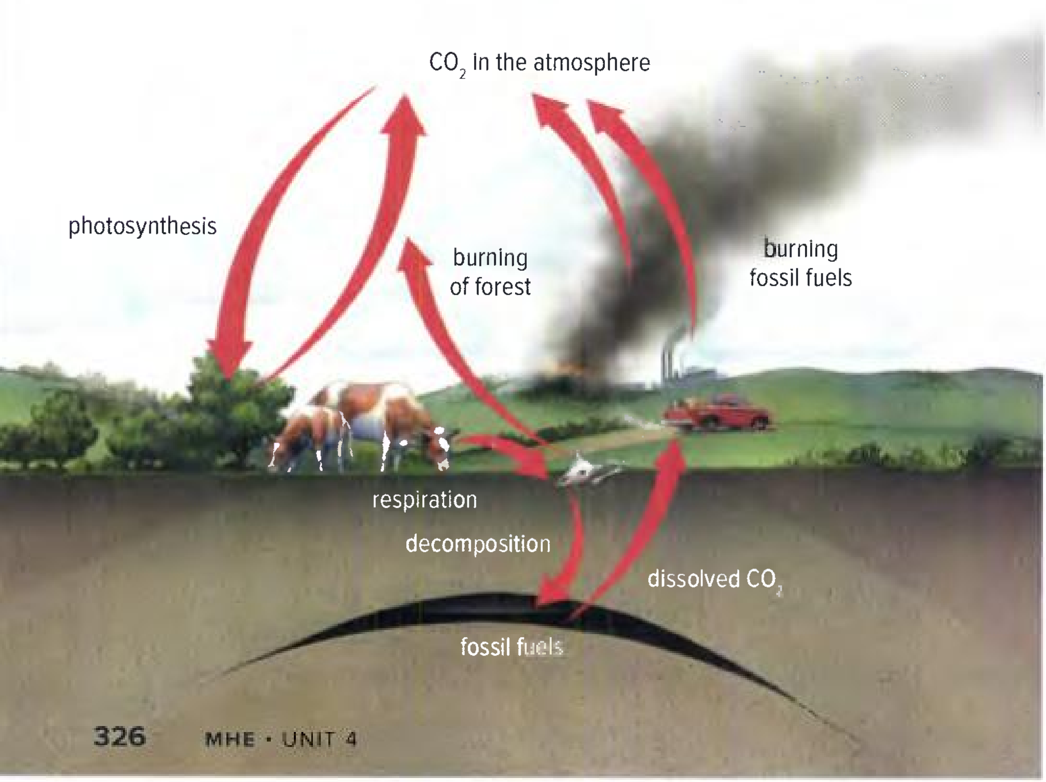


Figure 4.20 During the carbon cycle, carbon is exchanged among the biosphere, atmosphere, and geosphere.

Upsetting the Balance

The amount of carbon dioxide that is used by photosynthesis and given off by cellular respiration is nearly the same. In this way, the amount of carbon dioxide is balanced. However, when we burn trees, coal, oil, and natural gas for fuel, the carbon stored long ago is released into the air in the form of carbon dioxide. This upsets that balance. As well, human activities have removed huge numbers of trees to make space for homes, buildings, and farmland, and to make products such as furniture and paper. So, there are fewer trees available to use the extra carbon dioxide in the atmosphere. As a result, the extra carbon dioxide builds up in the air and helps to trap heat in the atmosphere. This is one of the sources of the extra carbon dioxide that adds to the processes known as **global warming** and **global climate change**.

global warming an increase in the average temperature of Earth's surface

global climate change a long-term change in Earth's climate

Climate change can be caused by either natural factors or human activity. Earth has experienced many periods of climate change due to natural processes such as natural variations in greenhouse gases, changes in ocean and atmospheric circulation, and changes in Earth's orbit. For example, during the Cretaceous period, around 90 million years ago, high levels of volcanic activity released large amounts of carbon dioxide into the atmosphere, quadrupling the concentration of carbon dioxide in the atmosphere compared to today's values. Carbon dioxide is a significant greenhouse gas. As a result, global temperatures rose well above average. The graph in Figure 4.21 shows that scientists estimate that the temperature of water at the bottom of the ocean during that time was about 19°C. Today water near the bottom of the ocean is around 3°C.

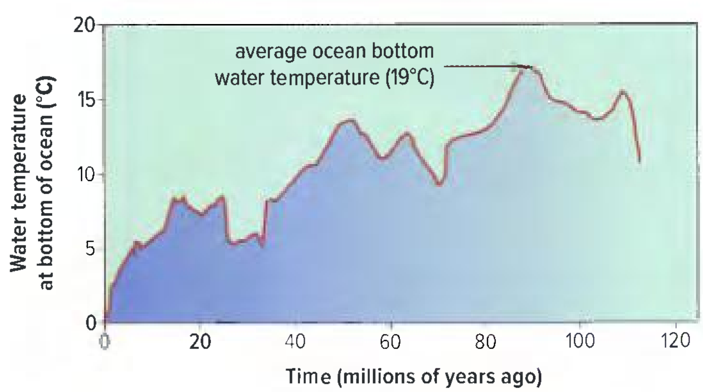


Figure 4.21 High levels of volcanic activity released greenhouse gases that warmed global temperature significantly during the late Cretaceous period. As a result, scientists estimate that the temperature of water at the bottom of the ocean was near 19°C.

Unlike events in the past, current climate change is the result of human actions. There is a solid relationship between the recent increase in greenhouse gases (at least 70% in the last 40 years) and rapidly increasing global temperatures. This increase in greenhouse gases is mainly due to human activities that burn fossil fuels. These activities release carbon dioxide and other greenhouse gases, such as methane, chlorofluorocarbons, and nitrous oxide.

The Effects of Excess Carbon in the Carbon Cycle

Earth's surface temperature has increased by between 0.56°C and 0.92°C in the past 100 years. This small change may not seem like a big deal. However, it is important to keep in mind that Earth's climate is a system. This means that a change in one aspect of climate, such as temperature, can result in changes to other aspects, such as precipitation levels, wind patterns, and storm severity. Climate change is expected to affect conditions in all of Earth's spheres. Some of these changes are already evident, as you will read below. The flowchart in Figure 4.22 explores some relationships between warming global temperatures and their effects around the world.

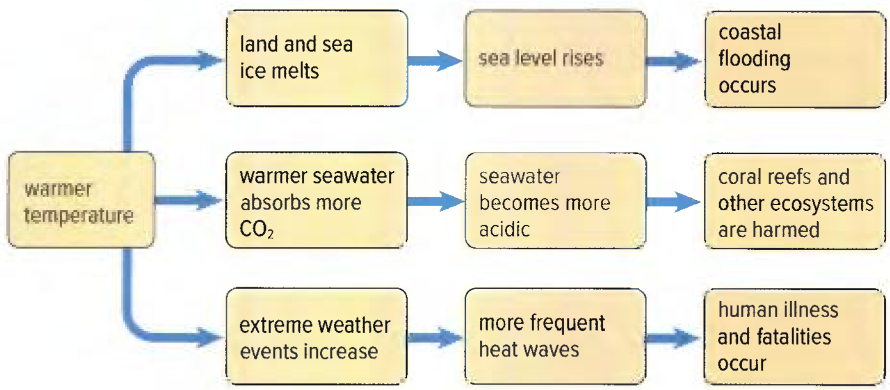


Figure 4.22 Warmer global temperatures are linked to changes in Earth's environment.

Melting Sea Ice—Warmer temperatures are causing sea ice to melt in the Arctic and Antarctic. Between 2005 and 2007, sea-ice levels in the Arctic Ocean decreased by 20%. This is the largest change in sea-ice levels recorded since scientists began taking these measurements in 1978. Many polar organisms that rely on sea ice for survival, such as polar bears, are negatively affected by this change. In the Arctic, decreasing sea-ice levels also affect Aboriginal people who hunt marine organisms as a food source.

Melting Land Ice—Warmer temperatures are melting glaciers around the world. Figure 4.23, on the next page, shows changes in the Bear Glacier in Alaska between 2002 and 2007. Glacial melting changes the volume and flow of rivers. These changes affect local flooding, sea level, and water available for human use, such as irrigation. As temperatures continue to warm, permafrost (permanently frozen ground) in the higher latitudes is also at risk of melting. Permafrost covers one quarter of the northern hemisphere to a depth of 700 m. When it melts, it is expected to release large amounts of methane gas that will accelerate climate change.

Rising Sea Level—Sea level is rising at a rate of about 2 mm to 3 mm per year. Already, two uninhabited islands in the Pacific Ocean have slipped beneath the waves. Salt water is also intruding into underground supplies of drinking water. In addition to coastal flooding, sea-level rise destroys wetlands, mangroves, and salt marshes. These are important habitats for aquatic organisms and birds. Melting land ice is linked to this rise in sea level, and its effects will increase as the planet warms. For instance, the Antarctic Ice Sheet contains 90% of Earth's ice. Scientists predict that complete melting of the ice sheet will raise sea level by 50 m.

Changing Ocean Chemistry—Sea surface temperature has increased over the last 100 years and is continuing to rise. As oceans warm, seawater absorbs more carbon dioxide from the air. When this gas dissolves in ocean water, the water becomes more acidic. This has a harmful effect on ocean ecosystems, as explained below.

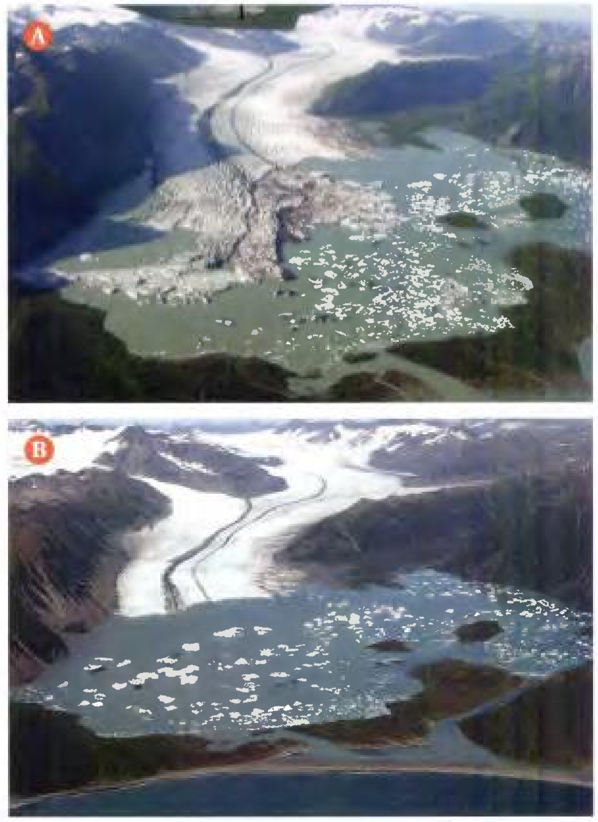


Figure 4.23 Bear Glacier can be viewed from northern British Columbia. Photo A of the glacier was taken in 2002. Photo B shows the glacier in 2007. Between 2002 and 2007, the glacier retreated by several kilometres and decreased significantly in height.

Changing Ecosystems—Changes in temperature, ocean chemistry, and sea level are altering global ecosystems. When possible, organisms are relocating their habitats and moving out of these danger zones. Plant growth patterns have shifted north over the last 30 years due to warmer temperatures. When a move is not possible species may not be able to survive. Corals that form reefs are one example of temperature-sensitive organisms that are unable to move. Corals, as well as shelled organisms, are also threatened by increased ocean acidity. This acidity dissolves calcium in the organisms' skeletons and shells.

Extending the Connection

Climate Change and Human Illness

Conduct research to find out more about how excess carbon in the carbon cycle leads to human illness and fatalities. Create an infographic to display the results of your research. Be sure to include any relevant facts or statistics in your product.

Before you leave this page . . .

1. How does burning fossil fuels upset the balance of the carbon cycle?
2. Make a table to describe the effects of excess carbon in the carbon cycle on each of Earth's spheres.

CONCEPT 3

Nitrogen is cycled through interactions between living and non-living things.

Activity

Fertilizer Ingredients

Read the ingredients on the bag of fertilizer provided by your teacher. Do you think fertilizer is a source or a sink for nitrogen in the nitrogen cycle? How do you think applying fertilizer to agricultural crops and gardens could affect the nitrogen cycle? How might it affect the hydrosphere and the biosphere?

Nitrogen is another nutrient that cycles in ecosystems. It is a major part of all cells and a key building block for proteins, which all cells need. Nitrogen makes up 78% of air, but most living things cannot use nitrogen from the air. Instead, they depend on certain kinds of bacteria, called nitrogen-fixing bacteria, in the soil and water to change the nitrogen into forms that plants can use. These forms include ammonium (NH_4^+), nitrite (NO_2^-), and nitrate (NO_3^-). Figure 4.24 shows how nitrogen moves through Earth's spheres.

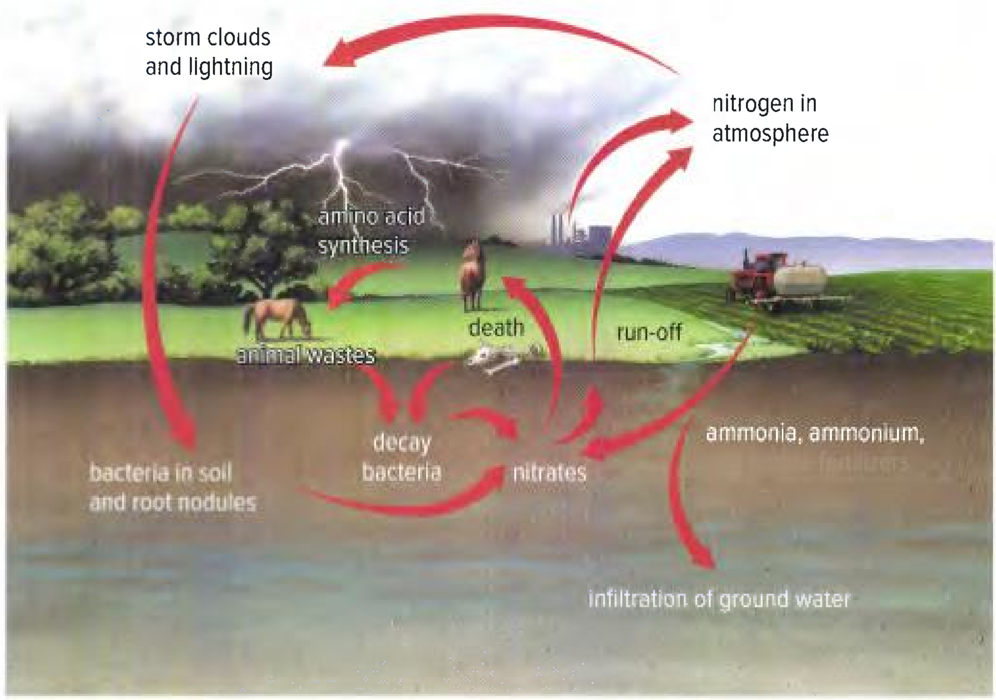
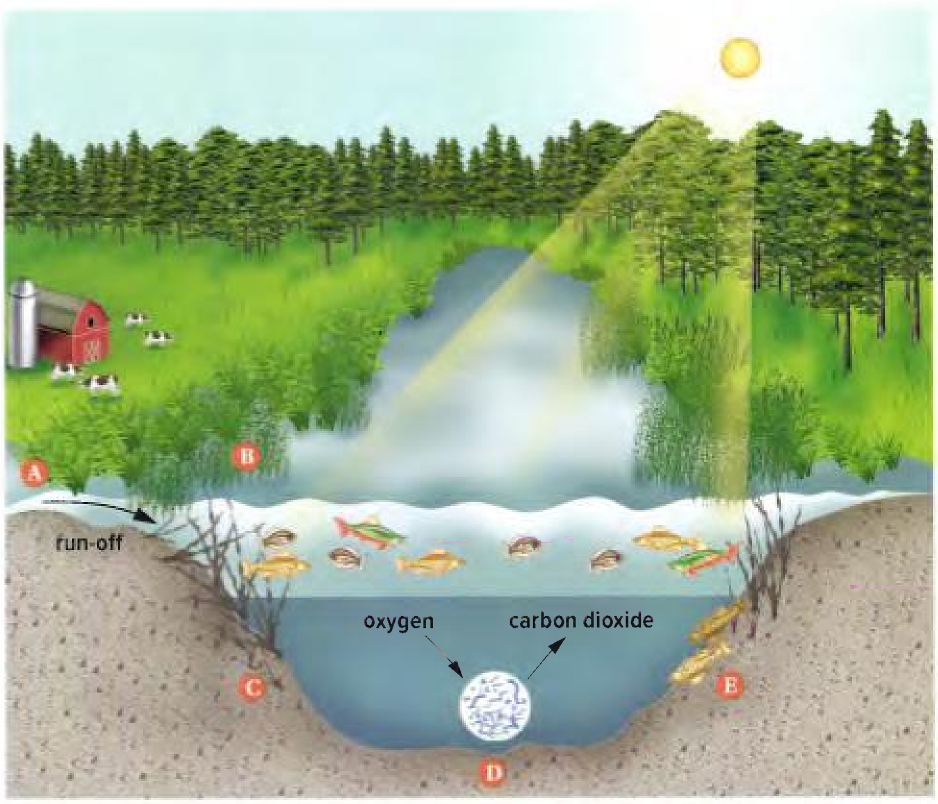


Figure 4.24 During the nitrogen cycle, nitrogen is exchanged among the atmosphere, biosphere, and geosphere.

Excess Nitrogen

Human activities dramatically increase the concentration of nitrogen in the atmosphere and the biosphere through the use of fertilizers (which contain nitrates), combustion of fossil fuels (which emits gaseous nitrogen oxides), and the clearing of forests and grasslands. For example, farmers and gardeners use fertilizers to enhance the growth of their plants. However, not all the nitrogen in the fertilizers is used by the plants. Some stays in the soil. When it rains, or when fields are watered, some of the nitrogen is carried into aquatic ecosystems. This excess nitrogen can cause an overgrowth of algae called an algal bloom. Figure 4.25 shows how an algal bloom can affect an aquatic ecosystem.

Figure 4.25 An algal bloom is caused by too much of a nutrient, such as nitrogen, entering an aquatic ecosystem.



A Rain carries nitrogen from farms, gardens, and lawns into aquatic ecosystems.

B Algae and plants at the water's surface grow quickly. This blocks sunlight from reaching deeper water.

C Deep-water plants get no sunlight. They cannot carry out photosynthesis, so they no longer give off oxygen, and they soon starve to death.

D When the plants die, decomposers have lots of food. The number of decomposers increases quickly. They use up the oxygen in the water as they carry out cellular respiration.

E As oxygen in the water is used up, aquatic organisms that need the oxygen suffocate and die.

Before you leave this page . . .

1. Why are bacteria an important part of the nitrogen cycle?
2. How does excess nitrogen in the nitrogen cycle affect the biosphere?

CONCEPT 4

Phosphorus is cycled through interactions between living and non-living things.

Activity

Algal Blooms

Have you ever been near a body of water that is experiencing an algal bloom? If so, use your observations to help answer the questions in this activity. Whether you have or have not seen an algal bloom in real life, locate and study photos of algal blooms. How do you think the air smells during an algal bloom? Would you go swimming or fishing in water experiencing an algal bloom? Why or why not? How do you think an algal bloom might affect drinking water? What do you think happens after the bloom and fish kill are over? What happens to all of the dead fish? How does the body of water recover from an algal bloom?

Phosphorus is another nutrient that cycles in ecosystems. Phosphorus is essential for the growth and development of organisms. Figure 4.26 shows that phosphorus is stored in the geosphere. When rock material is broken down through natural weathering processes, phosphorus is released into soil and water. Plants and plant-like organisms in water absorb the phosphorus, and animals obtain it when they eat plants, plant-like organisms, and other animals. Decomposers return phosphorus to soil and water as they break down dead organisms. Human activities also release phosphates into soil and water.

Connect to Investigation 4-G on page 338

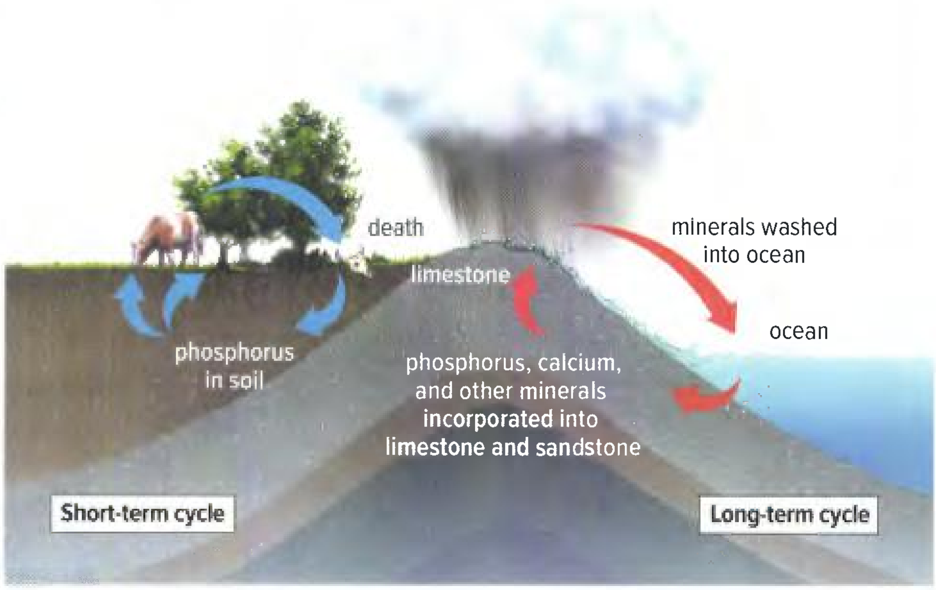


Figure 4.26 During the phosphorus cycle, phosphorus is exchanged among the biosphere, hydrosphere, and geosphere.

Excess Phosphorus

Along with nitrogen, phosphorus is also a main ingredient in fertilizer. Excess phosphorus in run-off from agricultural fields contributes to algal blooms, like the one shown in Figure 4.27, and subsequent death of aquatic organisms. Phosphorus is also found in household cleaners and dishwashing and laundry detergents. Although that may sound like a minor source, scientists estimate that removing phosphorus from dishwasher detergents alone could reduce the amount of phosphorus in run-off by 10%. In 2010, Canada banned any household cleaners and detergents that contain more than 0.5% of phosphorus by weight.

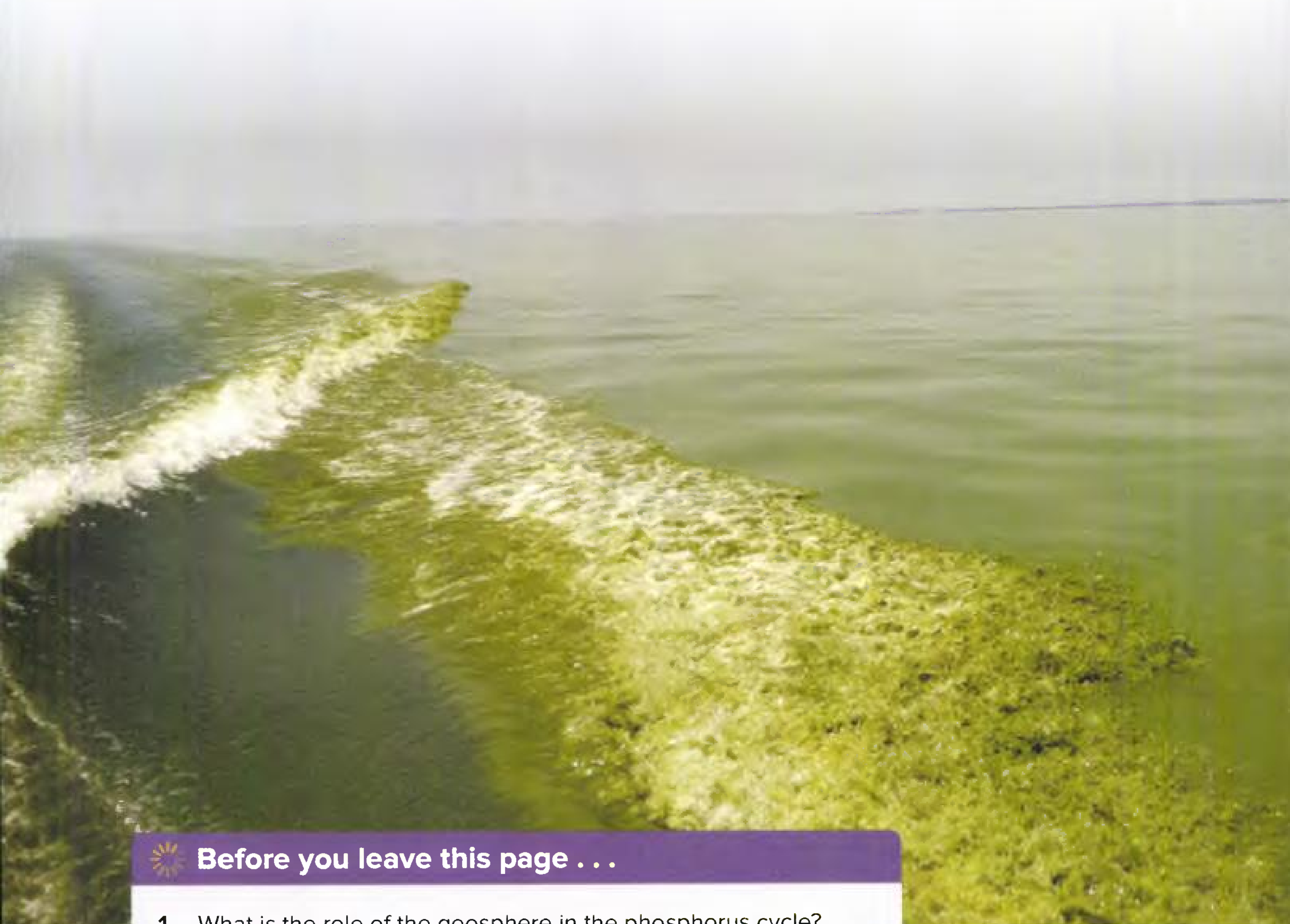


Figure 4.27 One kilogram of phosphorus can produce up to 500 kilograms of algae in a marine environment.

Before you leave this page . . .

1. What is the role of the geosphere in the phosphorus cycle?
2. What are some sources of excess phosphorus?
3. What actions could you take to help reduce the amount of excess phosphorus entering the phosphorus cycle?

Connect to Investigation 4-E on page 336

SCIENCE AT WORK

Focus on Sustainability of Systems

What kinds of jobs are there for people interested in sustainability?

Organic Farmer

Landscape Architect

Solar Engineer

Wetland Specialist

Energy Manager

Climatologist

What do mud, ice cores, satellites, and landscape paintings all have in common? They are the tools of the trade for climatologists, who study climate change and its effects on the biosphere.

Energy Sustainability Engineering Technologist (ESET)

How many ESETs does it take to screw in a filament light bulb? None—they are all too busy noting its inefficiency and suggesting greener ways to brighten your home.

Environmental Educator

If you love updating friends about sustainability issues, consider getting paid to indulge your passion for the environment by explaining the importance of sustainability to broader audiences.

Questions

1. What other jobs and careers do you know or can you think of that involve sustainability?
2. Research a job or career related to Unit 4 that interests you. Explain what attracted you to it. What kinds of things do you have to know, do, and understand for this job or career?

Check Your Understanding of Topic 4.4

QP Questioning and Predicting PC Planning and Conducting PA Processing and Analyzing E Evaluating AI Applying and Innovating C Communicating

Understanding Key Ideas

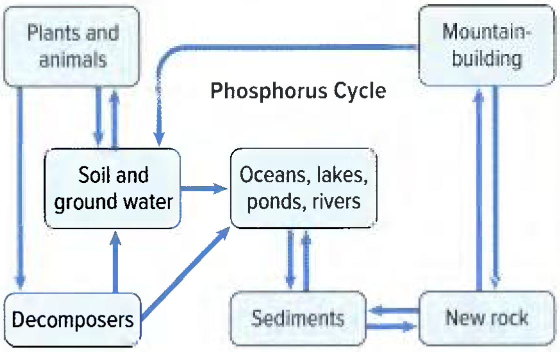
1. Explain why the Sun and gravity are considered the driving forces of the water cycle. PA
2. Describe the path a drop of rain might follow through the water cycle. PA
3. Describe how cutting down trees increases the amount of carbon dioxide in the atmosphere. PA
4. How is the melting of permafrost related to the release of greenhouse gases? PA
5. Give two examples of how nitrogen moves from the abiotic portion of the environment into living things and back. PA
6. Predict what might happen if there were no nitrogen-fixing bacteria on Earth. QP
7. Use a Venn diagram to compare and contrast the nitrogen cycle and the phosphorus cycle. PA C
8. Make a table that explains how excess carbon, nitrogen, and phosphorus in each cycle can affect ecosystems. PA C

Connecting Ideas

9. Would biomagnification be possible without bioaccumulation occurring? Explain. E C
10. According to the law of conservation of matter, matter can be neither created nor destroyed. Show a relationship between this statement and the recycling of carbon, nitrogen, or phosphorus in the environment. AI C
11. Explain how fertilizer in run-off could affect at least three of Earth's spheres. PA AI

Making New Connections

12. Phosphorus enters the cycle from sediments. Using evidence from the diagram below, explain why and how the mountains are related to the cycle. AI E



13. How can there be so much water on Earth, yet every year there are droughts and water shortages around Canada and the world? AI
14. Write a letter to the head of your local school board explaining how a single change could significantly reduce the amount of greenhouse gases your school releases into the atmosphere. AI C
15. How do you think ideas about renewal and transformation can be applied to natural cycles such as those that involve water, carbon, nitrogen, and phosphorus? E AI C

INVESTIGATION

4-E

OPEN INQUIRY

Skills and Strategies

- Planning and Conducting
- Processing and Analyzing
- Evaluating
- Communicating

What You Need

- access to online or print resources
- computer software for drawing or creating animations
- drawing materials, such as coloured markers, pens, or pencils, posterboard, and/or construction paper
- scissors
- tape

Where Do You Fit into the Nutrient Cycles?

You have just read about the water, carbon, nitrogen, and phosphorus cycles—the sources and sinks in each and how humans and excess nutrients can affect the balance of the cycles. In this investigation, you will think about these cycles and your role in them on a more personal level.

Question

How do you fit into and affect each nutrient cycle?

Procedure

1. Your goal for this investigation is to create a representation of each of the four cycles listed above and show how you fit into each cycle and how you impact it.
2. Determine how you would like to represent each cycle.
3. Determine how you fit into each cycle. Decide how you will show that in your representation.
4. Determine how you impact each cycle. Decide how you will show that in your representation.
5. Share your ideas with your teacher.
6. Once approved, create your representations of each cycle.
7. Share your representations with other students.

Process and Analyze

1. What realizations did you make about your actions in relation to the cycles while completing this investigation?
2. How did your representations compare to other students? What did you learn from studying their representations?

Evaluate and Communicate

3. How could you change your actions to reduce your impact on each cycle? How could you show this in your representations?

Apply and Innovate

4. How could you use your representations to raise awareness about the impact of humans on each cycle?

INVESTIGATION

4-F

GUIDED INQUIRY

Skills and Strategies

- Planning and Conducting
- Processing and Analyzing
- Evaluating
- Communicating

Greywater: Recycling Household Wastewater

Greywater is household wastewater except for water from toilets and kitchen sources. Although not yet approved in all jurisdictions in Canada, there is a growing trend to recycle greywater for certain uses.

Question

What are important features of a greywater recycling system?

Procedure

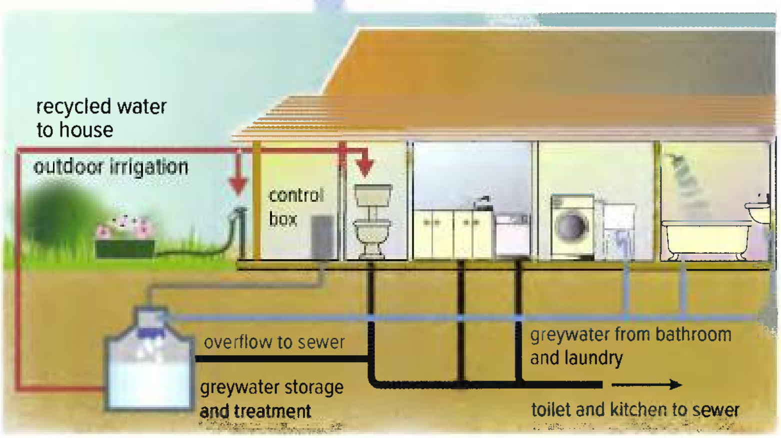
1. Analyze the schematic below, which shows a complete household system that uses greywater from all suitable sources.
2. Make a list of the key features of the system. For example, identify the sources of greywater, what is done with the greywater, and how it is used.

Analyze and Interpret

1. What is the recycled greywater used for?
2. For the system shown, is the recycled greywater used directly or is some type of treatment performed first? Why do you think it is set up this way?

Conclude and Communicate

3. In a chart format, list some benefits and risks of using recycled greywater.
4. Explain how greywater recycling fits into and benefits the water cycle.



5. Research the status of greywater use in your area. Is it legal? If so, what regulations are in place for its use?
6. Develop a design for a bathroom-specific system that uses greywater from the sink as a source of water to flush the toilet. Include a labelled sketch of your design to explain how it works.

INVESTIGATION

4-G

GUIDED INQUIRY AND OPEN INQUIRY

Skills and Strategies

- Planning and Conducting
- Processing and Analyzing
- Evaluating
- Communicating

Safety

- Handle the glass rod carefully.
- Do not use a chipped or broken glass rod.

What You Need

- 5 Erlenmeyer flasks or beakers
- fertilizer solutions (five different concentrations)
- dropper
- well-lit space or grow light
- algae
- graph paper

Investigating Limiting Factors for Algae Growth

Algae are microscopic plant-like organisms commonly found in aquatic ecosystems. As is the case with all living things, the growth of an algae population is limited by abiotic and biotic factors. In this investigation, you will plan and conduct an experiment to explore how fertilizer affects the size of an algae population.

Question

How does fertilizer affect the growth of algae?

Procedure

1. Design a procedure to determine how different concentrations of fertilizer solutions affect the growth of algae. Use this checklist to help you plan your procedure.
   - ✓ Because algae are producers, they need light for photosynthesis. Ensure that the algae have enough light.
   - ✓ You will need to design a way to describe and compare the amount of algae growth in each test tube.
   - ✓ Be sure to consider safety precautions and proper clean-up and disposal in your procedure. Why must you not pour the material in your flasks down the sink?
   - ✓ Ensure that you design an experiment to test only one variable.
   - ✓ What are the controlled variables (the ones that must be kept the same)? Hint: Consider any factors that might affect the outcome of the experiment. Examples include air temperature, water temperature, amount of light, and volume of pond water.
2. Create a table to record your observations. Give your table a suitable title.
3. Ask your teacher to approve your procedure. Then carry it out.

Process and Analyze

1. Create a graph that compares the concentration of fertilizer solution to algae growth. Give your graph a suitable title.
2. What was the factor that limited growth in your investigation? Was it biotic or abiotic? Explain.
3. Explain how you controlled your experiment. As part of your answer, state your independent variable and your dependent variable. Also state the variables that you controlled.
4. How did you minimize risks in order to maximize safety?

Evaluate and Communicate

5. Using your graph, what can you conclude about the effect that different concentrations of fertilizer solution have on algae growth?
6. If algae have access to unlimited nutrients for growth, will an algae population keep growing forever? What other abiotic and biotic factors might limit the growth of the population?
7. If you were able to design your experiment again, what would you do differently? Why?

Apply and Innovate

8. Many people believe that organic fertilizers such as manure and compost are better for the environment than synthetic (human-made) fertilizers. What questions do you have about this idea? What kinds of inquiries could you develop based on your questions? Pick one question and design an inquiry to investigate it.

TOPIC 4.5

How can our actions promote sustainability?

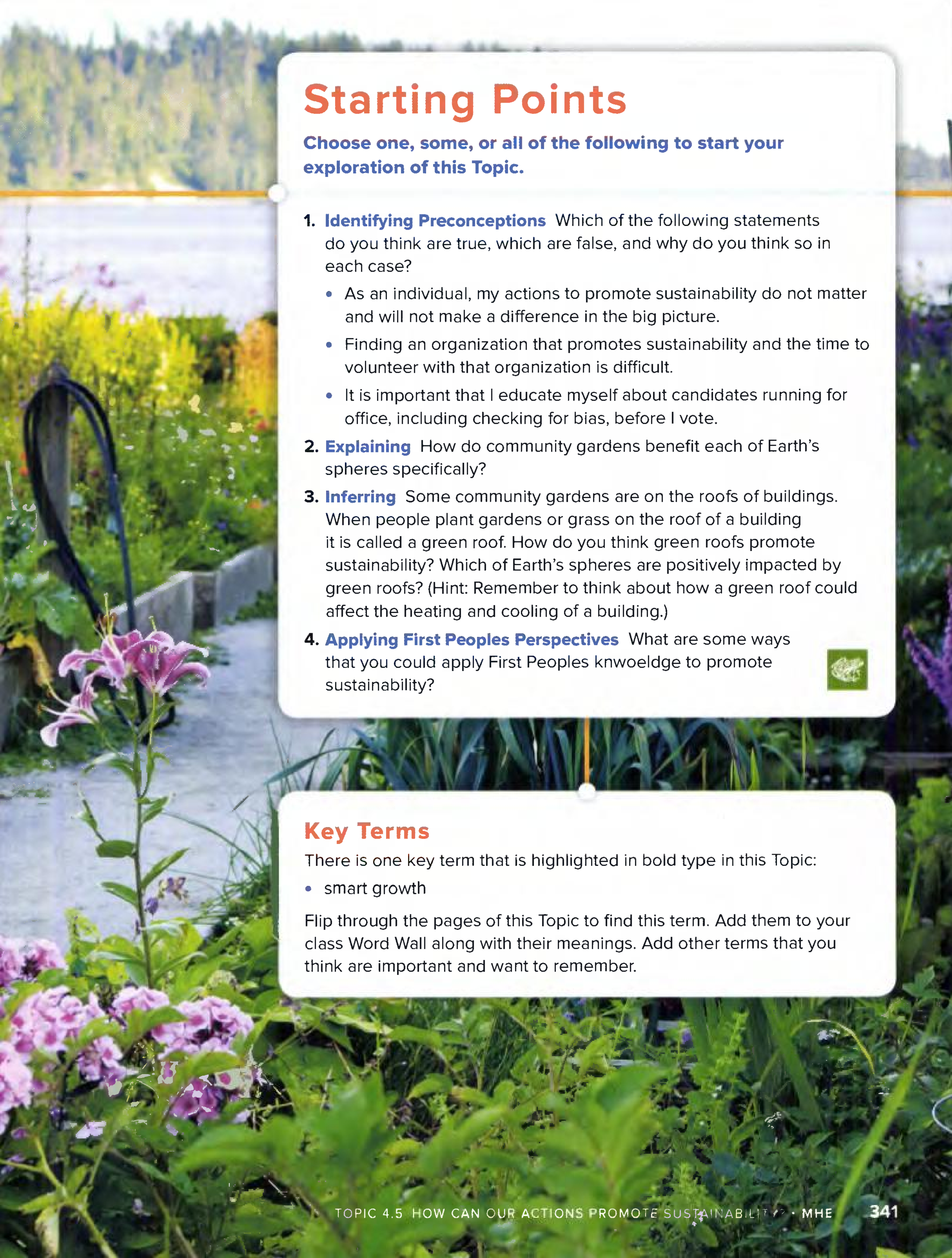
Key Concepts

- Inquiring individuals can make a difference.
- Responsible decision making and choices can lead to sustainable practices that benefit all life.

Curricular Competencies

- Contribute to care for self, others, community, and world through individual or collaborative approaches
- Transfer and apply learning to new situations
- Generate and introduce new or refined ideas when problem solving
- Contribute to finding solutions to problems at a local and/or global level through inquiry
- Express and reflect on a variety of experiences, perspectives, and worldviews through place

Community gardens are popping up all over the place. People may grow fruits and vegetables, herbs, flowers, or a mix of everything. Community gardens are a great way to promote sustainability. They benefit the biosphere, atmosphere, geosphere, and hydrosphere. Community gardens increase biodiversity, and they reduce run-off after it rains. Because people are growing food locally, it reduces the amount of food that needs to be transported to an area. Community gardens also help bring people of different backgrounds together and allow them to share aspects of their culture with each other.



Starting Points

Choose one, some, or all of the following to start your exploration of this Topic.

1. **Identifying Preconceptions** Which of the following statements do you think are true, which are false, and why do you think so in each case?
   - As an individual, my actions to promote sustainability do not matter and will not make a difference in the big picture.
   - Finding an organization that promotes sustainability and the time to volunteer with that organization is difficult.
   - It is important that I educate myself about candidates running for office, including checking for bias, before I vote.
2. **Explaining** How do community gardens benefit each of Earth's spheres specifically?
3. **Inferring** Some community gardens are on the roofs of buildings. When people plant gardens or grass on the roof of a building it is called a green roof. How do you think green roofs promote sustainability? Which of Earth's spheres are positively impacted by green roofs? (Hint: Remember to think about how a green roof could affect the heating and cooling of a building.)
4. **Applying First Peoples Perspectives** What are some ways that you could apply First Peoples knwoeldge to promote sustainability?

Key Terms

There is one key term that is highlighted in bold type in this Topic:

- smart growth

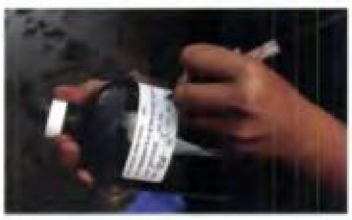
Flip through the pages of this Topic to find this term. Add them to your class Word Wall along with their meanings. Add other terms that you think are important and want to remember.

CONCEPT 1

Inquiring individuals can make a difference.

Although it may seem like an overwhelming goal, individuals can make a difference in moving toward sustainability. Table 4.5 outlines examples of how individuals can be empowered.

Table 4.5 Examples of Individual Empowerment

Role or Action	Empowerment
	**Consumers have power.** • What choices do you make about the products you will and will not buy? • What reasons lie behind, or motivate, your choices? • How can you find out more about the manufacturing conditions and materials used to make a product?
	**Volunteers inspire through their commitment and example.** • Where do you, or can you, volunteer your time? • Who benefits from your willingness to share a part of yourself? • How can volunteering locally have global effects?
	**Citizens have responsibility.** • In what ways are you a citizen of your community? your province? your country? your planet? • What responsibilities do you have as a citizen? • How can you educate yourself about candidates before you vote?
	**Citizen scientists can make important contributions to science.** • How can you find out more information about local projects you could participate in, such as vernal pool, butterfly, or wildflower surveys? • What local projects interest you? • How can your local data be used nationally or internationally to help scientists learn more about sustainability?
	**Science-minded advocacy groups can affect change, and increase sustainability and stewardship.** • How can you find out more about advocacy groups their motives, backing, and the causes they represent? • How can the work you do as a member of an advocacy group lead to changes in legislation that help protect ecosystems and ecosystem services?

Before you leave this page . . .

1. Identify one way that you can promote sustainability as a consumer.
2. What does it mean to be a citizen scientist?

TAKE a Stand

Make a Difference

You Can Make a Difference as a Consumer

EcoLogo, ENERGY STAR®, Fair Trade, SeaChoice, B.C. Certified Organic—going shopping can be a confusing experience with so many different labels to consider. For instance, many consumers are unaware of what the Leaping Bunny logo on a household cleaner stands for, or what a tree marked with FSC on a pack of printer paper means. However, these and other labels can help you make informed choices as a consumer, if you understand the claims behind them.

It is also important to know if claims are valid and regulated, or if they may be false and misleading to the consumer. A technique called greenwashing refers to how some companies or organizations promote themselves and their products as environmentally responsible, but do not live up to their claims. It is important for consumers to recognize this strategy and develop a healthy skepticism for any claims that a company makes before making a purchase based on them.

Analyze and Evaluate

1. Labels are important tools for consumers. Find out more about one of the labels mentioned in this feature, or another that interests you. Write down any questions you have about the label. Use online resources and other information sources to answer your questions. Use your answers to inform consumers about the label, using a medium of your choice.

Apply and Innovate

2. Making a difference as a consumer applies not only to what you purchase, but also to what you choose not to purchase. How much of what you purchase do you actually need? Track your purchases for a week to find out. After a week, assess your consumption. Write an opinion piece to advise other consumers about their power as consumers, based on your experiences.

CONCEPT 2

Responsible decision making and choices can lead to sustainable practices that benefit all life.

Activity

Community Gardens

Is there a community garden in your area? If so, where is it? What is grown there? How does it benefit Earth's spheres on a local level? What other questions do you have about the garden? If not, how could you start one? Make a list of what you would need to establish a community garden in your area.

Connect to Investigations 4H, 4I, and 4J on pages 348, 350, and 352

In this unit, you have read about the importance of maintaining sustainability and the interconnectedness of Earth's spheres. You have also read how human actions can negatively impact Earth's spheres and nutrient cycles. However, human actions can also restore sustainability and balance to Earth. Figure 4.28 shows a sample of the many ways that human activities are promoting sustainability.

Figure 4.28 Examples of promoting sustainability

Urban sprawl happens as cities with growing populations increase their size by spreading into natural areas and farmland. A strategy called **smart growth** helps by concentrating growth in the centre of a city, rather than in outlying areas. Homes and businesses are intermixed, while green spaces are preserved. Smart growth also enhances public transit, which reduces air pollution from traffic, a benefit to the atmosphere.

smart growth strategy focussed on concentrating growth in the centre of a city, rather than in outlying areas

McDonald Park in Abbotsford, B.C. was designated as a Dark Sky Preserve by the Royal Astronomical Society of Canada in 2003. Being a Dark Sky Preserve means that the park is dedicated to reducing the effects of artificial lighting on the nighttime environment. This not only increases the aesthetic ecosystem service the park offers to its stargazing patrons, but also helps protect the wildlife that use the park as their habitat. Animals that rely on darkness to forage for food, mate, or migrate are negatively affected by light pollution.

The use of solar panels on a small scale can help reduce the use of fossil fuels. The Grand Forks Aquatic Centre in Grand Forks, B.C. uses 18 solar panels to heat pool water and hot tubs. The St. Hubertus winery in Kelowna, B.C. recently installed 42 solar panels that supply 100% of its power during summer days. In East Vancouver, Vancouver Cohousing's Community Solar Project opened a multi-family residential development that is equipped with 90 solar panels to provide electricity to the development's common areas.

From 2008 to 2011 trips made by bicycle increased by 40%, making bicycling the fastest growing mode of transportation in Vancouver. The city responded by increasing the number of protected two-way bike lanes in the downtown area. In 2016, the city started a bike-sharing program as well. People can purchase daily or monthly passes to ride the bicycles instead of using an automobile. The bike-sharing program is part of Vancouver's Greenest City Action Plan.

Waste Reduction Week for Schools is a nationwide program in which students can learn more about how to reduce the waste their schools produce. Students are challenged to have a waste-free lunch, as well as to reduce, reuse, and recycle while at school. Students conduct a waste assessment to determine which materials may be recycled, reused, or composted. Then, they create a waste reduction action plan for their school.

The Scia'new First Nation on Beecher Bay in East Sooke, B.C., in partnership with the Trust for Sustainable Development, are building a sustainable housing development as a community. They are incorporating ecologically sustainable technologies including the use of a geothermal heating system to provide heat to homes. Trees removed as part of construction will be used on site, such as to make fireplace mantels for the homes.

Before you leave this page . . .

1. Choose one of the examples from these two pages and explain how it affects you personally.
2. Choose a different example from these two pages and explain how Earth's spheres benefit from it.

TAKE Action

Make a Difference

Respecting and Protecting Earth's Spheres

All of Topic 4.5 represents ideas for how you can do something meaningful to make a difference for Earth—your home, our home. What can you do, what would you like to do to take action and make a difference for one or more of Earth's spheres?

- It can be something small, like using stainless steel water bottles instead of plastic.
- It can be something huge, like organizing a battery recycling drive for your school or local community.
- It can be something collaborative or personal.
- It can be something that serves to inspire others.
- It can be something private.

Apply and Innovate

1. How would you like to respect and protect Earth's spheres today?
2. What will you do tomorrow?
3. ..?

Check Your Understanding of **Topic 4.5**

QP Questioning and Predicting PC Planning and Conducting PA Processing and Analyzing E Evaluating
AI Applying and Innovating C Communicating

Understanding Key Ideas

1. Answer the question that is the title of this Topic. Copy and complete the graphic organizer below in your notebook. Fill in four examples from the topic using key terms as well as your own words. PA C

2. Explain what is meant by the phrase "sustainable practice." PA

3. What role can the development of a community garden in your community play in ensuring the sustainability of your community? PA E

4. Identify some of the actions you can take in your home to encourage the development of a sustainable household. AI

5. Describe what sustainability means to you.

a) What does "urban sprawl" mean?

b) Provide an example of urban sprawl that you may be familiar with.

c) Use a cause-and-effect map to show possible effects on a city of using the strategy known as "smart growth." AI C

6. Converting a strip mall to condominiums instead of building on a field is an example of smart growth. Explain why. PA C

Connecting Ideas

7. List and describe three actions that you as an individual could take to increase sustainability on Earth. How would your actions positively impact each of Earth's spheres? AI

Making New Connections

8. Use the Internet to find examples of different online campaigns that people have launched to promote sustainability. Present one example to the class and discuss whether or not you think the campaign has been effective. E AI C

9. Read the information in **Table 4.5** and think about the following statement: "Instead of waiting for the change that might never come, many people are choosing to become the change they are waiting for." Which of the actions in the table can or do you take to ensure sustainability? Explain how. E AI C

10. In the news, you often find complex issues presented in polarized ways, where each side represents an extreme position. When this happens, people become stereotypes—they become their opinions or their jobs, instead of real people. For example, "environmentalists" are pitted against "loggers", or "developers" are pitted against "activists." What happens to dialogue and communication when people who are engaged on both sides of complex issues are reduced to stereotypes? AI C

INVESTIGATION

4-H

OPEN INQUIRY

Skills and Strategies

- Planning and Conducting
- Processing and Analyzing
- Evaluating
- Communicating

What You Need

- access to online and/or print resources

Investigating a Local Environmental Project

Do you have a friend who is part of a group that is working to preserve a local bog? Is your neighbour involved in a spring riverbank clean-up each year? Do you help out with a local frog count? In this investigation, you will research an environmental program or project to find out how it is linked to the sustainability of a local environment.

Question

How is a local environmental program linked to sustainability?

Procedure

1. With your class, identify sources of information that could be used to discover local projects that promote the sustainability of a terrestrial or aquatic environment in your area.
2. With your group, use these resources to choose a local project that interests you. Ask your teacher for permission to research this project before you continue.
3. As a group, write a list of questions that you would like to answer about your chosen project. Your goals are to learn more about the project in general and find out why it is important to the sustainability of the environment it is targeting. Below are examples of questions that your group could ask.
   - Is there a program that is working to reduce the amount of greenhouse gases being released into the atmosphere? What impact has this program had on the local area? What other plans could be put in place to help this program succeed?
   - Is there a project in your community to reduce the amount of pollution released into a nearby river or lake? How has this aquatic environment become more sustainable as a result of the project? What other actions could be taken to improve the sustainability of the hydrosphere and biosphere in this environment?

- Is there a project in your community working to make agriculture more sustainable on a farm near your community? What changes have been made? How have these changes affected the sustainability of each of Earth's spheres locally?

Analyze and Interpret

1. How has the project you investigated improved the sustainability of a local environment?
2. Suggest another way the project could make the environment and Earth's spheres more sustainable. How would your suggestion do this?

Conclude and Apply

3. Use your research to design a website, blog, poster, or brochure to inform other community members about the project.

INVESTIGATION

4-I

OPEN INQUIRY

I Remember When...

The environments in and around your community have experienced a great deal of change over the last few decades. Many of these changes are due to human activities. In this activity, you will interview seniors or Elders who have lived in your community for a long time to learn what changes they have observed.

Skills and Strategies

- Planning and Conducting
- Processing and Analyzing
- Evaluating
- Communicating

What You Need

- writing materials
- audio/visual equipment, such as a video camera, tape recorder, or camera (optional)

Question

What changes have occurred in environments in your community in the last several decades?

Procedure

1. Your teacher will help you make arrangements to interview a local senior or Elder, either at your school or in the community.
2. Prepare a list of questions you would like to ask during this interview. Here are a few examples of questions you could ask.
   - How long have you lived in this area?
   - What was it like when you were a child (or when you first came here)?
   - How has the city (or town, or village, or area) changed since then?
   - Are there more or fewer animals around than there were in the past? What about trees or other plants?
   - What kinds of work and other activities did people do in the past? How did their work and other activities affect the land and living things in the area?
   - Has the quality of the air and/or water changed? How?
   - Have you noticed changes in local ponds, rivers, or lakes? What has caused them?
3. Show your list of questions to your teacher for approval before you begin your interview. Your teacher will discuss guidelines for the interview process with you before you begin.
4. Take notes during the interview. You could also use audio/visual equipment, such as a video camera, tape recorder, or camera, to capture the interview.

Seniors and Elders share knowledge and wisdom that come from experience. Connecting with them also provides opportunities to develop or strengthen familial and social bonds.

5. Use the material you gathered in your interview to prepare a newspaper article, a blog post, or a film documentary of your research findings.

Analyze and Interpret

1. Did the local environment change as much as you expected over the years? Explain.
2. How was each of Earth's spheres affected?
3. What part of your research surprised you the most? Why was this the case?

Conclude and Communicate

4. How did you feel about the information you found out? Do you think the changes were positive, negative, or both? Can the changes be reversed? How?
5. Develop a plan to share your findings with the senior or Elder whom you interviewed and the broader community. With the support of your teacher, carry out the plan.

INVESTIGATION
4-J

OPEN INQUIRY

Skills and Strategies

- Questioning and Predicting
- Planning and Conducting
- Processing and Analyzing
- Evaluating
- Applying and Innovating
- Communicating

What You Need

- access to the Internet and/or library materials

Local Human Activity and Earth's Spheres

Do you know what's happening in your community and how any actions are affecting Earth's spheres? In this activity, you will find out more about projects and/or activities in your community that may be affecting the sustainability of Earth's spheres.

Question

In what ways are human activities affecting Earth's spheres in your community?

Procedure

1. With your class, gather stories from newspapers, TV, radio, and the Internet about actions that affect Earth's spheres in or near your community. Here are some examples of actions that might affect Earth's spheres.
   - Diverting water for a construction project lowers the water level.
   - Adding fertilizers to a local field changes the make-up of the soil.
   - The shoreline of a lake is being developed for a new recreation area.
   - The growing human population is filling a landfill site with wastes faster than originally planned. The site must be expanded, or another solution must be developed.
   - Forests are being cut for timber or cleared for land development.
   - Identifying and extracting oil and natural gas deposits from under the ground.
   - Mining commercially important minerals.
2. Work in a group. Choose an issue to study.
3. Identify which of Earth's spheres is being immediately affected and how other spheres may be affected because they are interconnected.

4. With your group, create a list of sources of information to help you learn about the issue and predict possible consequences for Earth's spheres. Analyze all information for reliability and bias before using it. Create a "References Cited" page to record your sources of information.
5. Create a presentation to communicate your ideas and your findings.

Analyze and Interpret

1. What did you learn about the ways that human activities are affecting Earth's spheres in your community?

Conclude and Communicate

2. What actions could be taken to reduce the impacts? How could these activities be carried out sustainably?

UNIT 4

Summary

ESSENTIAL QUESTION

How do energy flow and matter cycling connect the living and non-living parts of Earth's spheres?

TOPIC 4.1:

How do the ideas of connection and sustainability help us think about Earth's spheres?

- We are all connected.
- Sustainability ensures balanced systems now and for the future.
- Being a scientifically literate citizen matters to you both locally and globally.

Key Terms

biotic   abiotic

TOPIC 4.2:

What is the role of the Sun's energy in Earth's spheres?

- Solar energy that reaches Earth is absorbed and reflected by Earth's atmosphere and Earth' surface.
- Solar energy heats Earth's surface unevenly and global winds help redistribute thermal energy around Earth.
- Ocean currents also redistribute thermal energy around Earth.
- Solar energy enters the biosphere through photosynthesis and cellular respiration.

Key Terms

greenhouse gases   greenhouse effect

TOPIC 4.3:
What interactions supply energy to Earth's biosphere?

- Producers transfer energy to consumers and decomposers.
- Interactions are needed to provide a constant flow of energy to sustain the biosphere.

Key Terms

producers	consumers	decomposers
food chain	food web	energy pyramid

TOPIC 4.4:
What interactions cycle matter through Earth's spheres?

- The water cycle is a continuous cycle driven by solar energy and gravity.
- Carbon is cycled through interactions between living and non-living things.
- Nitrogen is cycled through interactions between living and non-living things.
- Phosphorus is cycled through interactions between living and non-living things.

Key Terms

transpiration	water pollution
bioaccumulation	biomagnification
global warming	global climate change

TOPIC 4.5:
How can our actions promote sustainability?

- Inquiring individuals can make a difference.
- Responsible decision making and choices can lead to sustainable practices that benefit all life.

Key Term

smart growth

UNIT 4 Review

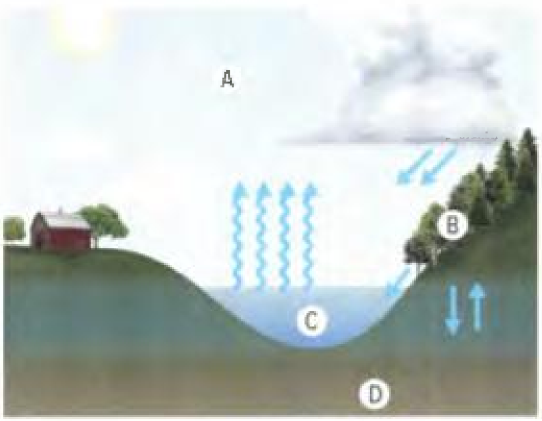
What Do You Know?
Connecting to Concepts

Visualizing Ideas

1. The photo below appeared in many different newspapers.

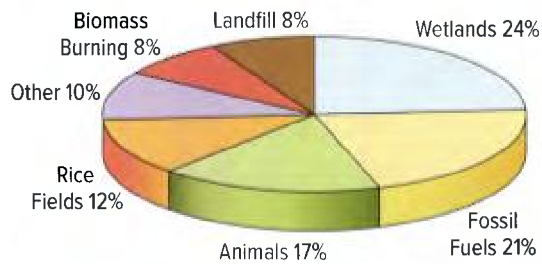
   a) What "story" does the photo tell?
   b) What "story" or part of a story does the photo not tell?
   c) Is a single picture or a single source of information (such as a news article that goes with the photo) enough for you to form a meaningful opinion about an environmental issue? Explain your thinking.

2. Identify each of Earth's spheres represented by the letters A, B, C, and D in the diagram below.



3. Methane is a substance that is made up of carbon and hydrogen. It is a greenhouse gas that is about 21 times more potent than carbon dioxide. The circle graph below shows sources of methane emissions around the world. Use the graph to answer the following questions.
   a) Which nutrient cycle is methane part of?
   b) What percentage of methane emissions come from human activities, as opposed to natural sources?

Sources of Global Methane Emissions



Environment Canada, 2000

Using Key Terms

4. Create a table with three columns. In the first column, list all the key terms from this unit. In the second column, record a definition for each term, written in your own words. In the third column, sketch or draw a small picture that will help you remember the key term.

5. In a format of your choice, show how the terms *interconnected* and *sustainability* relate to the following terms from this unit:
   - food chain
   - food web
   - energy pyramid
   - water pollution
   - global climate change
   - biomagnification
   - global warming
   - urban sprawl
   - bioaccumulation

Communicating Concepts

6. Suppose you have to give a short presentation to a group of grade 3 students on Earth's spheres. How would you explain the concept of Earth's spheres to them? What examples would you use represent each sphere?
7. Choose an organism, and use it to explain how Earth's spheres are connected.
8. What are some ways you and your family and friends affect nutrient cycles? Use a graphic organizer to demonstrate the cause-and-effect relationships in the examples you provide.
9. Use words or diagrams to illustrate how a carbon atom that was part of a dinosaur 70 million years ago could be part of you today.
10. Use a Venn diagram to compare these two models of energy flow in ecosystems: food chains and food webs.
11. Decomposers are an essential part of the cycling of matter. Imagine that all of the decomposers on Earth became extinct. Write a story or draw a comic strip that describes the effects of this extinction on the carbon, nitrogen, and phosphorus cycles, as well as on the biosphere, geosphere, atmosphere, and hydrosphere.
12. Use a flowchart to explain how fisheries in the Arctic Ocean could be affected by global warming.
13. Show your understanding of the link between the Sun and the transfer of energy from one area to another or one organism to another in each of the following four cases. Communicate your answer by drawing a labelled diagram, writing a descriptive paragraph, or quietly speaking to a partner or your teacher.
    a) the polar easterlies move cold air from polar regions back toward the equator
    b) the Kuroshio current moves heat toward the north pole
    c) the great ocean conveyor belt moves cold water from high latitudes to lower latitudes
    d) a bear eats salmon
14. Describe three human activities that enhance the natural greenhouse effect.
15. Describe the role that evaporation and condensation play in Earth's water cycle.
16. Explain the processes that prevent polar regions from steadily cooling off and areas on or near the equator from heating up over time.
17. Distinguish among the three main wind systems.
18. Use a Venn diagram to compare and contrast ocean surface currents and the great ocean conveyor belt.

What Do You Know?
Connecting to Competencies

Developing Skills

19. Global climate change is resulting in a relatively modest overall increase in average global temperatures. How can such a change have serious consequences for the carbon cycle and Earth's spheres?
20. Make an analogy not already used in this unit to describe the transfer of energy along a food chain.
21. Consider the statement "Nothing is more important to Earth than the Sun." Write an argument that supports the statement using concepts presented in this unit.

Thinking Critically and Creatively

22. Plan (but do not actually conduct) an investigation to find answers to one of the questions below. Be sure to identify all variables, the data you will need to collect, and what method you will use to collect your data. Decide which format you will use to record your findings—for example, a chart.

a) What are the abiotic and biotic parts of your schoolyard environment?

b) How do the abiotic and biotic parts interact with each other?

c) What human activities have had an impact on the environment?

23. The amount of carbon dioxide used by producers and given off by producers and consumers is balanced.

a) Name two ways that human activities upset that balance.

b) Think about three human activities that could help to restore this balance. Use a cause-and-effect map to explain in each case.

24. Wolverines are strict carnivores (they don't eat plant material at all). Explain how the nutrients in a living plant might become part of the body tissue of a wolverine.

Understanding Big Ideas

Making New Connections

Applying Your Understanding

25. Sometimes people change an area to enhance its ecosystem services. For example, wildlife officials may stock a lake with fish to provide recreation for fishing enthusiasts. In California, environmental scientists conducted a four-year study to learn more about the effects of the introduction of non-native trout to mountain lakes in the western United States. A non-native species is a species that historically has not been found in an area. The results of the study showed that, after the introduction of the trout, there were reduced population numbers of several amphibian species and changes in the number and variety of aquatic insect species. In particular, the trout consumed aquatic insects in their very early, larval stages. Other organisms, including amphibians and other fish, also rely on insect larvae as a food source. As well, birds and bats that live near the lakes eat adult insects. The scientists concluded that all of these species must now compete with the non-native trout for food.

a) Infer how the introduction of the non-native trout affected the sustainability of the lake ecosystem.

b) Should one or two ecosystem services of an ecosystem be enhanced at the cost of some of its other services? Explain why or why not.

c) As an empowered individual, how would you respond if you knew this was happening in a lake near your home?

26. Scientists have confirmed that the blood of certain shark populations contains common prescription drugs. Using your knowledge of how pollutants travel within ecosystems and among Earth's spheres, make a hypothesis that could account for this phenomenon.

27. A gardener left grass clippings on her lawn after mowing it. She discovered that the lawn looked healthier than it did when she raked up and removed the clippings. Using your knowledge of nutrient cycles, write an explanation, supported by diagrams, of her observations.

28. Oceans are considered a sink for carbon. Think about what you know about life in the ocean and photosynthesis and make a diagram that shows how the ocean acts as a sink for carbon.

Thinking Critically and Creatively

29. Cattle and sheep ranching contribute to global warming. These animals produce and release large amounts of methane as they digest their food. Overgrazing of pasturelands can deplete the ground cover over large areas, which reduces the amount of vegetation that would take in carbon dioxide. Propose a way to reduce greenhouse gas emissions from cattle and sheep ranching. Keep in mind the importance of cattle and sheep ranching in providing jobs, food, and clothing.

30. Nitrogen from fertilizer used by farmers and gardeners can reach bodies of water and cause algal blooms.

- **a)** Determine a way to reduce the amount of nitrogen reaching water bodies.
- **b)** How could your idea be implemented? Who would have to be involved in the implementation?
- **c)** How could you raise awareness about your idea?

Connecting to Self and Society

31. What other cultures and traditions do you know of (or are you a part of) that express ideas related to interconnectedness and sustainability? Describe your awareness and understanding of these ideas. Do research if necessary to enhance your answer.

32. Suppose that your community is looking for ideas to promote sustainable development in the region where you live.

- **a)** Describe an activity that is sustainable in your community.
- **b)** Describe an activity that is unsustainable in your community.
- **c)** Explain how the sustainable activity is beneficial to each of Earth's spheres.

33. Research an upcoming election on a local, provincial, or national level.

- **a)** What are the candidates' stances on sustainability and other environmental issues?
- **b)** What questions do you have for the candidates based on your answer to part a?
- **c)** How would you decide which candidate you would vote for?
- **d)** Why is it important to learn about candidates during an election?

34. Refer to "First Peoples Perspectives in Science" on page xxii near the start of the textbook.

- **a)** Review and reflect on the four themes of interconnectedness, transformation, renewal, and connections with place.
- **b)** In a journal or in small groups, share ideas about how the concepts you have been learning about in this unit relate to these four themes.

Unit Assessment

Has our impact on Earth's spheres reached a tipping point?

Ecosystems experience change from year to year, day to day, moment to moment. Spring gives way to summer. Air temperatures rise and fall. Organisms die and are born. The blowing wind strips leaves from branches and disperses seeds. Burrowing animals dig channels through soil that aid the flow of air and water. Lightning sparks fires that sweep through forests and meadows. And yet ecosystems display *resilience.* They are able to stay functional and stable in the face of disturbances to their parts.

Sometimes, though, changes can occur that cause one or more parts of an ecosystem to "tip" or shift from one state to another. The threshold or point at which this shift takes place is called a tipping point. The new state presents changes that are more significant than those from before. These changes can be local, regional, or global. They may last a long time. They may be hard or impossible to reverse. The precise impacts may be hard to predict. The same is true of their consequences.

Work as part of a group to do the following.

STEP 1 ► Reflect on the three options, their photos, and the question asked for each option.

STEP 2 ► Brainstorm at least three more options and questions of your own about a situation that involves a tipping point.

STEP 3 ► Decide on one of the six option questions to investigate.

STEP 4 ► Plan and conduct a scientific inquiry to explore your question.

STEP 5 ► Organize and analyze the data and information that you find and collect.

STEP 6 ► Communicate the results of your inquiry in a suitable manner.

OPTION B

Global Climate Change

How do human activities affect Earth's spheres at home and beyond?

Product Life Cycle

OPTION C

Product Life Cycle Analysis

How can a cradle-to-grave approach to product development take into account costs and impacts on Earth's spheres?

Assessment Criteria

Did I and my group...

- Develop one or more questions that provided opportunities for rich investigation? OP
- Develop effective methods to collect and record reliable data and information? PC
- Apply different ways of knowing to analyze, reflect on, and draw meaningful conclusions that are consistent with evidence? PA
- Consider and demonstrate an awareness of assumptions, bias, and social, ethical, and environmental implications over the whole process of our inquiry? E
- Propose alternative courses of thought and/or action that contribute to care for self, others, community, and world? AI
- Construct evidence-based arguments using language, conventions, and representations appropriate for a specific purpose and audience? C

Guide to the Appendices

Appendix A: Science Skills

Scientific Notation

An exponent is the symbol or number denoting the power to which another number or symbol is to be raised. The exponent shows the number of repeated multiplications of the base. In 10^2, the exponent is 2 and the base is 10. The expression 10^2 means 10×10.

Powers of 10

Digits	Standard Form	Exponential Form
Ten thousands	10 000	10^4
Thousands	1 000	10^3
Hundreds	100	10^2
Tens	10	10^1
Ones	1	10^0
Tenths	0.1	10^{-1}
Hundredths	0.01	10^{-2}
Thousandths	0.001	10^{-3}
Ten thousandths	0.0001	10^{-4}

Why use exponents? Consider this:
One molecule of water has a mass of 0.000 000 000 000 000 000 000 029 9 g. Using such a number for calculations would be quite awkward. Adding or omitting a single zero by mistake would make the number either 10 times larger or 10 times smaller than it actually is. Scientific notation lets scientists express very large and very small numbers more easily, avoid mistakes, and clarify the number of significant digits.

Scientific Notation

In scientific notation, a number has the form $x \times 10^n$, where x is greater than or equal to 1 but less than 10, and 10^n is a power of 10.
To express a number in scientific notation, use the following steps:

1. To determine the value of x, move the decimal point in the number so that only one non-zero digit is to the left of the decimal point.
2. To determine the value of the exponent n, count the number of places the decimal point moves to the left or right. If the decimal point moves to the right, express n as a negative exponent. If the decimal point moves to the left, express n as a positive exponent.
3. Use the values you have determined for x and n to express the number in the form $x \times 10^n$.

Examples

Express 0.000 000 000 000 000 000 000 029 9 g in scientific notation.

1. To determine x, move the decimal point so that only one non-zero number is to the left of the decimal point:
   2.99
2. To determine n, count the number of places the decimal moved:
   0.000 000 000 000 000 000 000 02.99 g
   3 6 9 12 15 18 21 23
   Since the decimal point moved to the right, the exponent will be negative.
3. Express the number in the form $x \times 10^n$:
   2.99×10^{-23} g

Express 602 000 000 000 000 000 000 000 in scientific notation.

1. To determine x, move the decimal point so that only one non-zero number is to the left of the decimal point:
   6.02
2. To determine n, count the number of places the decimal moved:
   6.02 000 000 000 000 000 000 000.
   23 21 18 15 12 9 6 3
   Since the decimal point moved to the left, the exponent will be positive.
3. Express the number in the form $x \times 10^n$:
   6.02×10^{23}

The Metric System

Throughout history, people have developed systems of numbering and measurement. When different groups of people began to communicate with each other, they discovered that their systems and units of measurement were different. Some groups within societies created their own unique systems of measurement.

Today, scientists around the world use the metric system of numbers and units. The metric system is the official system of measurement in Canada.

The Metric System

The metric system is based on multiples of 10. For example, the basic unit of length is the metre. All larger units of length are expressed in units based on metres multiplied by 10, 100, 1000, or more. Smaller units of length are expressed in units based on metres divided by 10, 100, 1000, or more.

Each multiple of 10 has its own prefix (a syllable joined to the beginning of a word). For example, *kilo-* means multiplied by 1000. Thus, one kilometre is 1000 metres.

$$1 \text{ km} = 1000 \text{ m}$$

The prefix *milli-* means divided by 1000. Thus, one millimetre is one thousandth of a metre.

$$1 \text{ mm} = \frac{1}{1000} \text{ m}$$

In the metric system, the same prefixes are used for nearly all types of measurements, such as mass, weight, area, and energy. A table of the most common metric prefixes is given at the top of the next column. Notice the use of scientific notation to represent the very large and very small numbers.

Commonly Used Metric Prefixes

Prefix	Symbol	Relationship to the Base Unit
giga-	G	$10^9 = 1\,000\,000\,000$
mega-	M	$10^6 = 1\,000\,000$
kilo-	k	$10^3 = 1000$
hecto-	h	$10^2 = 100$
deca-	da	$10^1 = 10$
–	–	$10^0 = 1$
deci-	d	$10^{-1} = 0.1$
centi-	c	$10^{-2} = 0.01$
milli-	m	$10^{-3} = 0.001$
micro-	µ	$10^{-6} = 0.000\,001$
nano-	n	$10^{-9} = 0.000\,000\,001$

Example

A student measures 459 mL of water. Express this value in L.

Solution

$$1 \text{ L} = 1000 \text{ mL}$$

$$\text{volume of water} = 459 \text{ mL}$$

$$459 \cancel{\text{mL}} \times 1 \text{ L}/1000 \cancel{\text{mL}} = 0.459 \text{ L}$$

Instant Practice

1. The amount of energy used by an appliance is 250 W. Express this in kW.
2. The volume of water that is needed to fill a holding tank is 357 L. Express this in mL.
3. A student needs to measure 0.4 kg of salt. Express the mass in g.
4. The atomic radius of an atom of an element is 0.112 nm. Express this in m.

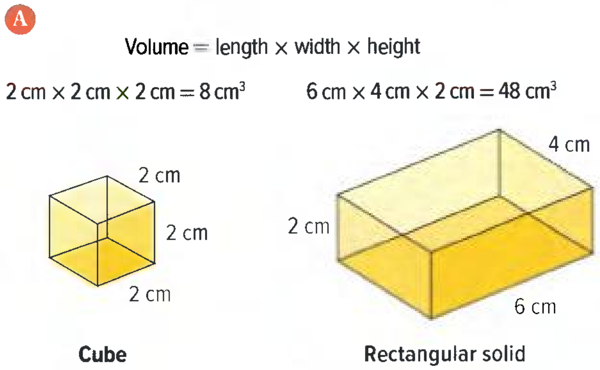
Measuring

Measuring Volume

The volume of an object is the amount of space that the object occupies. There are several ways of measuring volume, depending on the kind of object you want to measure.

As you can see in Diagram A below, the volume of a regularly shaped solid object can be measured directly. You can calculate the volume of a cube by multiplying its sides, as shown on the left in Diagram A You can calculate the volume of a rectangular solid by multiplying its length ×width × height, as shown on the right in Diagram A

A



Measuring the volume of a regularly shaped solid

If all the sides of a solid object are measured in millimetres (mm), the volume will be in cubic millimetres (mm^3). If all the sides are measured in centimetres (cm), the volume will be in cubic centimetres (cm^3). The units for measuring the volume of a solid are called cubic units.

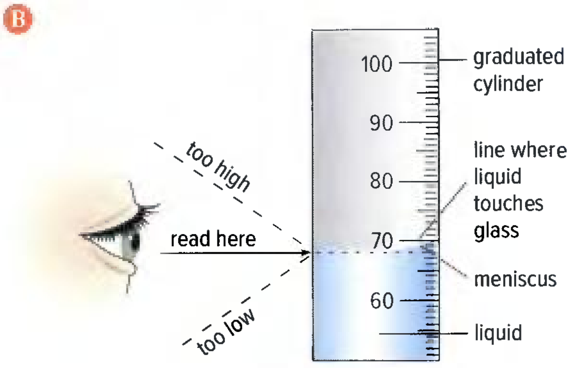
The units used to measure the volume of liquids are called capacity units. The basic unit of volume for liquids is the litre (L). Recall that 1 L = 1000 mL.

Cubic units and capacity units are interchangeable. For example,

$1\ cm^3 = 1\ mL$
$1\ dm^3 = 1\ L$
$1\ m^3 = 1\ kL$

The volume of a liquid can be measured directly, as shown in Diagram B. Make sure you measure to the bottom of the *meniscus*, the slight curve where the liquid touches the sides of the container. To measure accurately, make sure your eye is at the same level as the bottom of the meniscus.

B



Measuring the volume of a liquid

Instant Practice

1. Determine the volume of liquids present in the graduated cylinders shown here.
2. You want to determine how much water is needed to fill a tank that is 8 m by 3 m by 2 m.
   a) How can you do this?
   b) How much water will you need? Give the value in cubic metres and litres.

The volume of an irregularly shaped solid object, however, must be measured indirectly, as shown in Diagram C below. This is done by measuring the volume of a liquid it displaces.

When a solid object is placed in liquid, the liquid level will rise. The liquid is displaced, or moved from the place it was originally. The volume of the displaced liquid is equal to the volume of the solid.

C

1. Record the volume of the liquid.
2. Carefully lower the object into the cylinder containing the liquid. Record the volume again.
3. The volume of the object is equal to the difference between the two volumes of the liquid. The equation below the photographs shows you how to calculate this volume.

Measuring the volume of an irregularly shaped solid

volume of object
= volume of water with object − original volume of water
= 72 mL − 60 mL
= 12 mL

Instant Practice

A student needs to determine the volume of a pebble. Describe how she can do this using a graduated cylinder and water.

Measuring Mass

The mass of an object is the amount of matter in a substance or object. Mass is measured in milligrams, grams, kilograms, and tonnes. You need a balance for measuring mass.

How can you find the mass of a certain quantity of a substance, such as table salt, that you have added to a beaker? First, find the mass of the beaker. Next, pour the salt into the beaker and find the mass of the beaker and salt together. To find the mass of the salt, simply subtract the beaker's mass from the combined mass of the beaker and salt.

If you are using an electronic balance, you will not need to do any calculations to subtract the mass of the beaker. The balance will do the calculation for you. To measure the contents of a beaker, you can place the empty beaker on the balance and hit the "Tare," "Zero," or "Re-Zero" button to reset the balance to zero. Then add the material to be measured into the beaker. The balance subtracts the mass of the beaker before the contents are even added, so it reports only the mass of the contents.

Instant Practice

1. A student needs to measure 25 g of sodium chloride. Describe how he should do this using a beaker and a non-electronic balance.
2. Describe how he would measure 25 g of sodium chloride using an electronic balance.

Measuring Angles

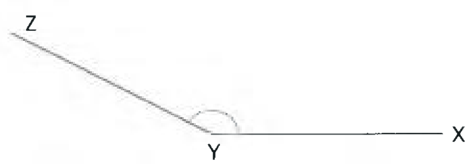
You can use a protractor to measure angles. Protractors usually have an inner scale and an outer scale. The scale you use depends on how you place the protractor on an angle (symbol = ∠). Look at the following examples to learn how to use a protractor.

Example 1

What is the measure of ∠XYZ?

Solution

Place the centre of the protractor on point Y. The 0°–180° line should lie along the line YX so that YX crosses 0° on the inner scale. YZ crosses 150° on the outer scale. So ∠XYZ is equal to 150°.

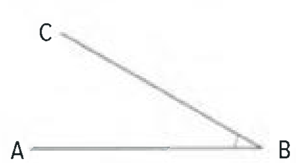


Example 2

Draw ∠ABC = 30°.

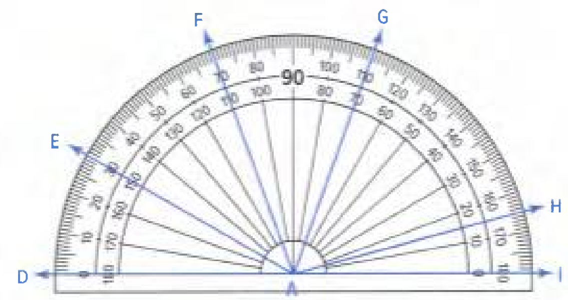
Solution

First, draw a straight line, AB. Place the centre of the protractor on B and line up AB with 0°. Mark C at 30°. Join BC. The angle you have drawn, ∠ABC, is equal to 30°.



Instant Practice

1. State the measure of each of the following angles using the following diagram.
   a) DAF
   b) DAH
   c) IAG
   d) HAF
   e) GAD
   f) DAI
   g) EAG
   h) EAI



2. Use a protractor to draw angles with the following measurements. Label each angle.
   a) ABC 90°
   b) QRS 110°
   c) XYZ 14°
   d) JKL 65°
   e) HAL 145°

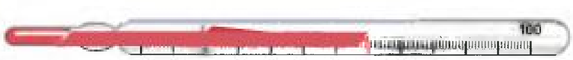
Measuring Temperature

Temperature is a measure of the thermal energy of the particles of a substance. In the very simplest terms, you can think of temperature as a measure of how hot or how cold something is. The temperature of a material is measured with a thermometer.

For most scientific work, temperature is measured on the Celsius scale. On this scale, the freezing point of water is zero degrees (0°C) and the boiling point of water is 100 degrees (100°C). Between these points, the scale is divided into 100 equal divisions. Each division represents one degree Celsius. On the Celsius scale, average human body temperature is 37°C, and a typical room temperature may be between 20°C and 25°C.

Sometimes scientists use a different unit of temperature called the kelvin (K). Zero on the Kelvin scale (0 K) is the coldest possible temperature. This temperature is also known as absolute zero. It is equivalent to –273°C, which is about 273 degrees below the freezing point of water. Notice that degree symbols are not used with the Kelvin scale.

Most thermometers are marked only with the Celsius scale. Because the divisions on the two scales are the same size, the Kelvin temperature can be found by adding 273 to the Celsius reading. This means that on the Kelvin scale, water freezes at 273 K and boils at 373 K.



Tips for Using a Thermometer

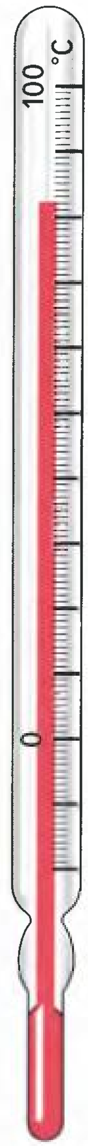
When using a thermometer to measure the temperature of a substance, here are three important tips to remember.

- Handle the thermometer extremely carefully. It is made of glass and can break easily.
- Do not use the thermometer as a stirring rod.
- Do not let the bulb of the thermometer touch the walls of the container.

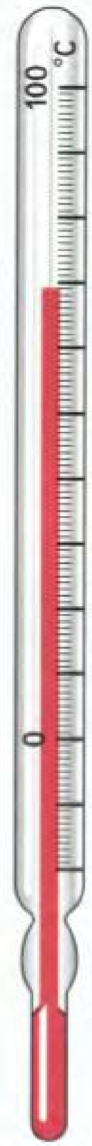
Instant Practice

Read the temperature, in °C, from the thermometer in each question. Convert your Celsius reading into Kelvin units.

1.



2.



Organizing Data in a Table

Scientific investigation is about collecting information to help you answer a question. In many cases, you will develop an hypothesis and collect data to see if your hypothesis is supported. An important part of any successful investigation includes recording and organizing your data.

Planning to Record Your Data

Suppose you are doing an investigation on the water quality of a stream that runs near your school. You will take samples of the numbers and types of organisms at two different locations along the stream. You need to decide how to record and organize your data. Begin by making a list of what you need to record. You will need to record the sample site, the temperature of the water at each sample site, the types of organisms found at each sample site, and how many of each type of organism you collected.

Creating Your Data Table

Your data table must allow you to record your data neatly. To do this you need to create

- headings to show what you are recording
- columns and rows that you will fill with data
- enough cells to record all the data
- a title for the table

In this investigation, you will find multiple organisms at each site, so you must make space for multiple recordings at each site. This means every row representing a sample site will have at least three rows associated with it for the different organisms.

If you think you might need extra space, create a special section. In this investigation, leave space at the bottom of your table, in case you find more than three organisms at a sample site. Remember, if you use the extra rows, make sure you identify which sample site the extra data are from.

Finally, give your table an appropriate title. The title should appear above your table. Your data table might look like the one below.

Observations Made at Two Sample Stream Sites

headings show what is being recorded

columns and rows contain data

Site	Temperature	Type of Organism	Number of Organisms
1	18°C	beetle	3
		snail	1
		dragonfly larva	8
2	20.2°C	beetle	6
		dragonfly larva	7

extra rows to collect data in case you need to add observations

Instant Practice

1. You are collecting data to compare the total rainfall per month in the capital city of each Canadian province and territory. Design and draw a data table that you could use to record the data. Make sure to give your table a title.
2. In an investigation, you are studying the effect of temperature on the reproduction of yeast. You are monitoring reproduction by measuring the amount of carbon dioxide produced by a population of yeast. Design and draw a data table that could be used for this investigation.

Constructing Graphs

In your investigations, you will collect information, often in numerical form. To analyze and report the information, you will need a clear, concise way to organize and communicate the data.

A graph is a visual way to present data. A graph can help you to see patterns and relationships among the data. The type of graph you choose depends on the type of data you have and how you want to present them. You can use line graphs, bar graphs, and pie graphs (pie charts).

The instructions given here describe how to make graphs using paper and pencil. Computer software provides another way to generate graphs. Whether you make them on paper or on the computer, however, the graphs you make should have the features described in the following pages.

Drawing a Line Graph

A line graph is used to show the relationship between two variables. The following example will demonstrate how to draw a line graph from a data table.

Example

The data in the table show the volume of a gas at different temperatures. Compare the steps in the procedure with the graph on the next page to learn how to make a line graph to display this information.

Volume and Temperature of a Gas

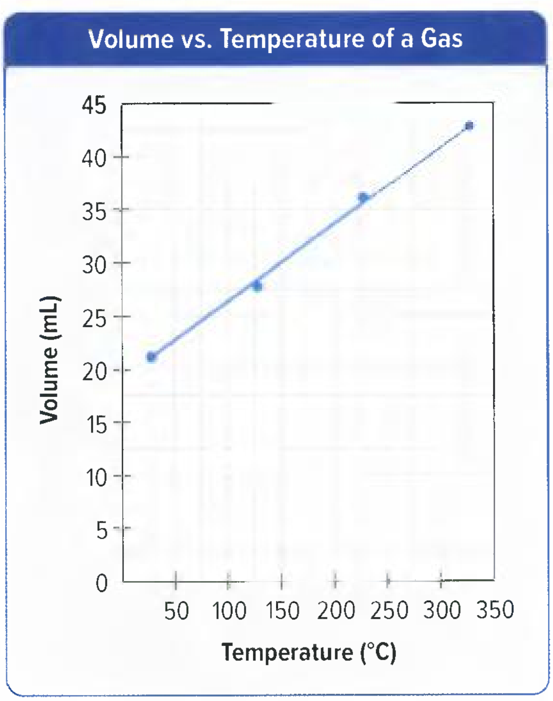
Volume (mL)	Temperature (°C)
21	26
28	126
36	226
43	326

Procedure

1. With a ruler, draw an *x*-axis and a *y*-axis on a piece of graph paper. (The horizontal line is the *x*-axis, and the vertical line is the *y*-axis.)
2. The independent (manipulated) variable is usually shown on the *x*-axis, while the dependent (responding) variable is shown on the *y*-axis. To label the axes, write "Temperature (°C)" along the *x*-axis and "Volume (mL)" along the *y*-axis.
3. Now you have to decide what scale to use. You are working with two numbers. You need to show the temperature range that was studied and the volume of the gas at each temperature. The scale on the *x*-axis will go from 0 to 350. The largest volume is 43 mL and the lowest is 21 mL. You might want to use intervals of 5 mL for the *y*-axis. That means every space on your *y*-axis represents 5 mL.
4. You want to make sure you will be able to read your graph when it is complete, so make sure your intervals are large enough.
5. To plot your graph, gently move a pencil up the *y*-axis until you reach a point just above 20 (you are representing 21 mL). Now move along the line on the graph paper until you reach the vertical line that represents the lowest temperature. Place a dot at this point. Repeat this process for all of the data.
6. If it is appropriate, draw a line that connects all of the points on your graph. A graph showing yearly data that rise and fall without a predictable pattern might have a jagged line connecting all of the points. However, this is not always appropriate. Scientific experiments often involve quantities that change smoothly. In addition, experimental data points usually have some error.

On a graph, this means that you should draw a smooth curve (or straight line) that has the general shape outlined by the points. This is called a line of best fit. If the points are almost in a straight line, draw a straight line as close to most of the points as possible. There should be about as many points above the line as there are below the line. If the data points do not appear to follow a straight line, then draw a smooth curve that comes as close to the points as possible. Think of the dots on your graph as clues about where the perfect smooth curve (or straight line) should go. A line of best fit shows the trend of the data. It can be extended beyond the first and last points to indicate what might happen.

7. Give your graph a title. Based on these data, what is the relationship between temperature and the volume of a gas?



Instant Practice

Using the information in the table below, create a line graph showing the relationship between atomic size and atomic number of elements within the same period of the periodic table.

Atomic Size of Period 3 Elements

Atomic Number	Atomic Radius (nm)
11	0.191
12	0.160
13	0.130
14	0.118
15	0.110
16	0.102
17	0.099
18	0.095

Constructing a Bar Graph

Bar graphs help you to compare a numerical quantity with some other category at a glance. The second category may or may not be a numerical quantity. It could be places, items, organisms, or groups, for example.

Example

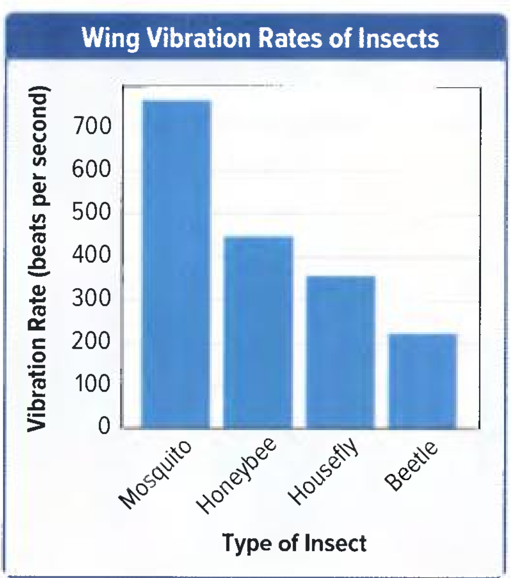
To learn how to make a bar graph to display the data below, examine the graph in step 5 (on the next page) as you read the steps that follow. The independent variable is the type of insect. The dependent variable is the number of wing vibrations per second.

Wing Vibration Rates of Insects

Type of Insect	Vibration Rate (beats per second)
Mosquito	760
Honeybee	440
Housefly	350
Beetle	220

Procedure

1. Draw your x-axis and y-axis on a sheet of graph paper. Label the x-axis "Type of Insect" and the y-axis "Vibration Rate (beats per second)."
2. Look at the data carefully in order to select an appropriate scale. Write the scale of your y-axis.
3. Using "Mosquito" and "760" as the first pair of data, move along the x-axis the width of your first bar, then go up the y-axis to 760. Use a pencil and ruler to draw in the first bar lightly. Repeat this process for the other pairs of data.
4. When you have drawn all of the bars, add labels on the x-axis to identify the bars. Alternatively, use colour to distinguish among them.
5. If you are using colour to distinguish among the bars, you will need to make a legend or key to explain the meaning of the colours.
6. Write a title for your graph.



Instant Practice

Make a vertical bar graph that shows each mammal's gestation period (the time between fertilization and birth).

Gestation Periods of Some Mammals

Mammal	Gestation Period (Days)
Chipmunk	31
Hamster	20
Beaver	122
Human	270
Elk	245
Kangaroo	42
Gorilla	257
Rhinoceros	450

Constructing a Pie Graph

A pie graph (sometimes called a pie chart) uses a circle divided into sections (like pieces of pie) to show the data. Each section represents a percentage of the whole. All sections together represent all (100 percent) of the data.

Example

To learn how to make a pie graph from the data below, study the corresponding pie graph on the next page as you read the following steps.

Trees in a Park

Type of Tree	Number of Trees	Percent of Total	Degrees in Section
Fir	36	9.0	32
Dogwood	19	4.8	17
Spruce	71	17.7	64
Cedar	14	3.5	13
Pine	180	45.0	162
Other	80	20.0	72

Procedure

1. Use a mathematical compass to make a large circle on a piece of paper. Make a dot in the centre of the circle.
2. Determine the percent of the total number of trees that each type of tree represents by using the following formula.

$$\text{Percent of total} = \frac{\text{Number of trees within the type}}{\text{Total number of trees}} \times 100\%$$

For example, the percent of all trees that are fir is

$$\text{Percent that are fir} = \frac{36 \text{ fir}}{400 \text{ trees}} \times 100\% = 9\%$$

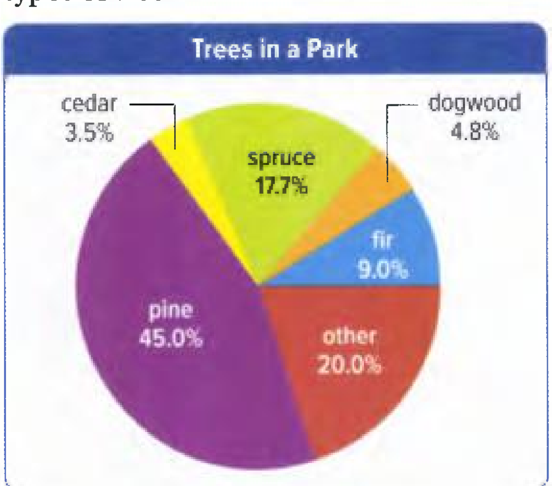
3. To determine the number of degrees in the section that represents each type of tree, use the following formula.

$$\text{Degrees in ``piece of pie''} = \frac{\text{Percent for a type of tree}}{100\%} \times 360°$$

Round your answer to the nearest whole number. For example, the section for fir trees is

$$\text{Degrees for fir} = \frac{9.0\%}{100\%} \times 360° = 32.4° \text{ or } 32°$$

4. Draw a straight line from the centre to the edge of the circle. Use your protractor to measure 32° from this line. Make a mark, then use your mark to draw a second line 32° from the first line.
5. Repeat steps 2 to 4 for the remaining types of trees.



Instant Practice

Use the following data to develop a pie chart to visualize world carbon dioxide emissions from use of different fuel types in 2014.

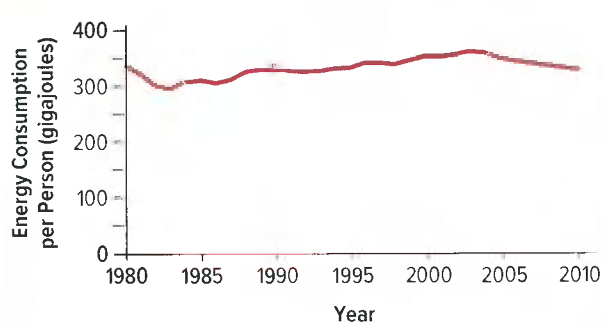
Carbon Dioxide Emissions from Fuels

Fuel Type	Emission Amount (million tonnes)
Coal	14 863
Oil	10 977
Natural gas	6 379
Other	162

Choosing the Right Graph for the Job

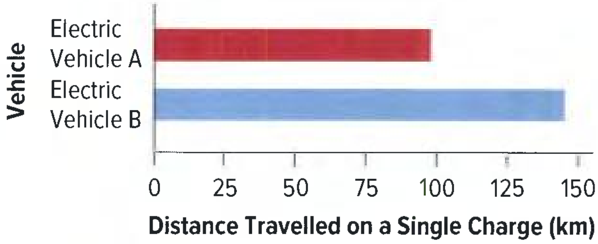
Line graphs are useful for

- making comparisons among a large number of categories or across a range of values for the variable that is being tested. For example, the graph below shows the annual energy usage per person from 1980 to 2010. Time is the variable being tested or considered.
- showing general trends in the relationship between variables. Does an increase in the manipulated (independent) variable cause an increase or a decrease in the responding (dependent) variable?
- finding the mathematical relationship between two variables. Rates and ratios can be calculated from a line showing how a variable changes over time.

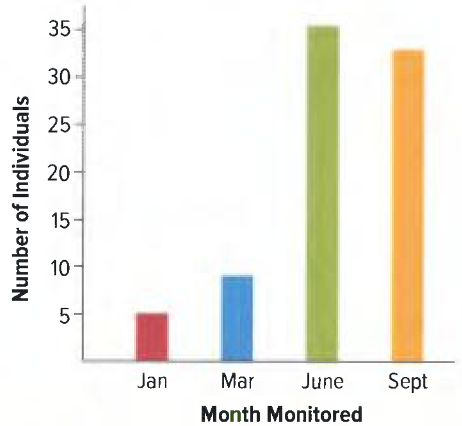


Bar graphs are useful for

- comparing a responding (dependent) variable between two distinct types of things, such as plant cells and animal cells, or between competing things, such as brands of a product. For example, this graph compares the distance travelled on a single charge by two different electric cars.



- comparing a responding (dependent) variable among categories within a group, such as provinces in Canada, months in a year, or phases of mitosis.
- reporting the results of surveys. For example, you might want to show how many people said "Yes" and how many said "No" to each question on a survey.
- showing changes using a small number of data points. For example, you might use a bar graph to show how the size of a population in a certain area has changed over a year, when monitored four times during the year. Note, however, that if the comparison is over a long period of time or there are many data points, it would be better to use a line graph.

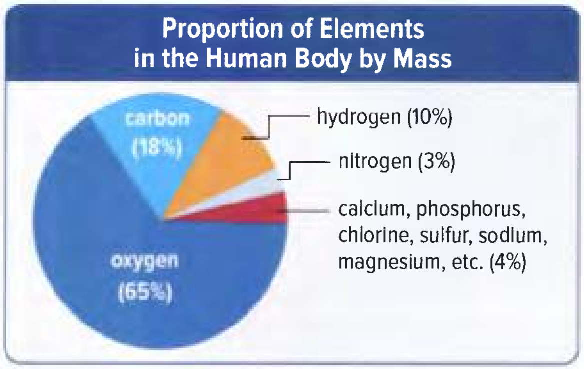


Pie graphs are useful for

- quick visual comparisons of proportions between segments of a whole.
- showing, at a glance, the most common category within a fixed set of categories.

Limitations of pie graphs include the following:

- They cannot be used to show change over time. They are a snapshot of data collected at one specific time.
- They cannot be used to show complex relationships among variables.
- They must represent categories as percentages of a whole.
- It is difficult to compare similar categories unless the percentages represented by each slice of the pie are clearly labelled, as they are in this example.



Instant Practice

What would be the best type(s) of graph to use for each purpose?

1. comparing the energy efficiency of four different types of heaters
2. showing how the amount of material that is recycled has changed over the last 30 years
3. comparing how much sulfur dioxide is emitted into the atmosphere from different sources
4. showing the total energy use in each province
5. showing the relationship between world population and degree of global warming

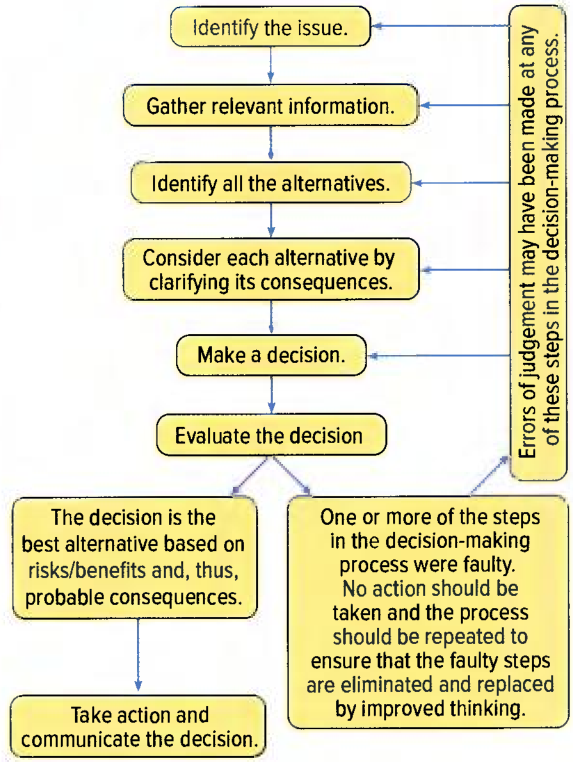
Analyzing Issues

An *issue* is a topic that can be seen from more than one point of view. How about the use of pesticides on private lawns and on golf courses? Many people prefer grass that has no weeds and is free of insects.

In a conversation with a friend, however, you find out that the cosmetic use of pesticides on grass can damage ecosystems. How might you use science and technology to think about this problem?

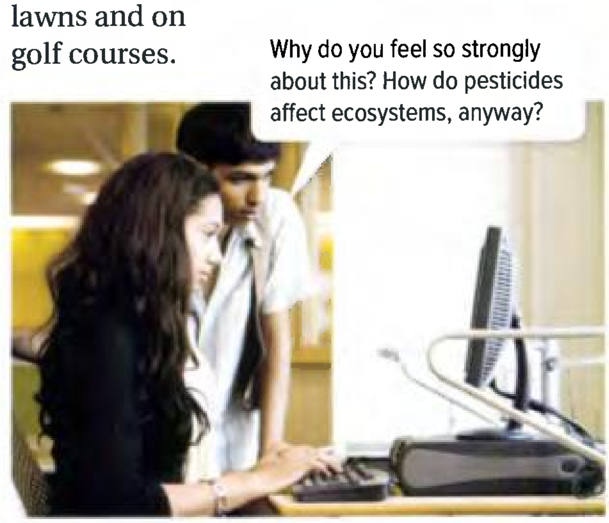
Suppose your town council is in the process of deciding whether to allow the cosmetic use of pesticides on lawns and golf courses. How will you analyze this issue and determine what action to take? The concept map on this page shows a process to help you focus your thinking and stay on track.

A Process for Analyzing Issues

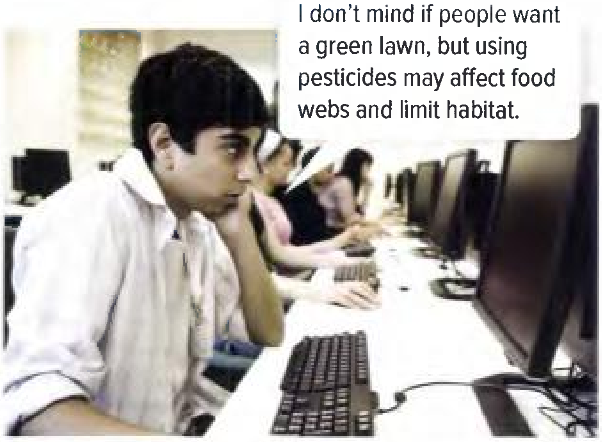


Identifying the Issue

Soon after talking with your friend about the cosmetic use of pesticides on grass, you find your friend sitting in front of the computer, writing a letter to the town council. In it, your friend is asking that they vote against allowing the use of pesticides on residential lawns and on golf courses.

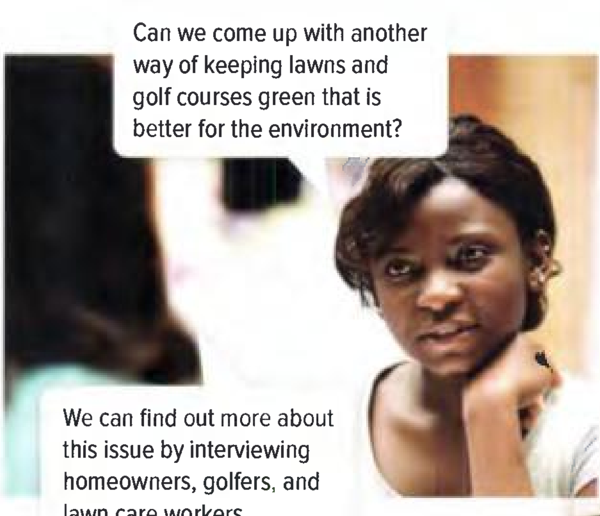


Gathering Information



Once you have identified the issue, you will need to find out more information.

The Internet and other sources, such as books or experts, are great places to find information about an issue. One thing that is important to do when gathering information is to look for bias.



Bias is a personal and possibly unreasonable judgement of an issue. For example, a person who makes his or her living running a lawn maintenance service may have a bias that pesticides do not harm the environment. It is important to check the source of information to determine whether it is unbiased. See How To Do a Research-Based Project in Appendix A for more information about how to research information.

Another important part of gathering information is taking notes so that you can analyze what you have learned. You may read about different viewpoints or solutions and advantages and disadvantages for each one. It is helpful to be able to organize your notes in the form of a graphic organizer such as a concept map, a flowchart, or a Venn diagram. See Using Graphic Organizers in Appendix A for more information.

Identifying and Considering Alternatives

Your research may lead you to ask new questions about alternative solutions and how successful they might be. For example, you might think about how a combination of pesticides and planting practices would keep grassy areas free of weeds. Would this be a safer environmental alternative? Answering these questions often leads to more research or possibly doing your own scientific inquiry.

Making a Decision

When you have all of the information that your research can provide, you will need to weigh the pros and cons of each option and make a decision. Sometimes it helps to organize your thoughts in a PMI chart that lists the pros and cons of an issue, or a t-chart that compares two possible solutions. You will find more information on using these charts in Using Graphic Organizers. It might even be helpful to rate how important you feel each point (pro or con) is.

PMI Chart for Cosmetic Pesticide Use

Plus	Minus	Interesting
• very effective • relatively inexpensive • •	• may cause habitat loss for endangered or useful species • •	• •

t-chart Comparing Pesticides and Biological Control

Pesticides	Biological Control
• more effective than biological control • •	• maintains higher level of biodiversity • •

Your decision will still involve some very human and personal elements. People have strong feelings about the social and environmental issues that affect them. Depending on their point of view, other people may feel differently than you do about an issue. Something that seems obvious to you might not be so obvious to them, and vice versa. Even the unbiased scientific evidence you found during your research might not change people's minds. If you are going to encourage a group to make what you consider a good decision, you have to find ways to persuade the group to think as you do.

Evaluating the Decision

After you have made a decision, it is important to evaluate your decision. Is the decision the best alternative considering the risks and benefits? Have you thought about the possible consequences of the decision and how you might respond to them? If you determine that your decision-making process was faulty—if, for example, you based your decision on information that you later learned was false— you should begin again. If you find that you are comfortable with your decision, the next step is to take action.

Taking Action

Issues rarely have easy answers. People who are affected have differing, valid points of view. It is easier for you to act as an individual, but if you can persuade a group to act, you will have greater influence. In the issue discussed here, you might write a letter to your town council. As a compromise, you might suggest a combination of pesticide use and biological control for cosmetic weed and insect control. Your research can provide you with appropriate statistics. As a group, you could attend a town council meeting or sign a petition to make your views known.

Over time, you can assess the effects of your actions: Are people beginning to accept a few weeds in their lawns? Is there any change in the populations of other species in the ecosystem?

Sometimes taking action involves changing the way you do things. It is not only up to the town council or any other group to act responsibly; it is also up to you and your friends.

How to Do a Research-Based Project

Imagine if your teacher simply stated that he or she wanted you to complete a research-based project on endangered species.

How can you get started?

This is a really big topic, and it is now your job to decide which smaller part of the topic you will research. One way to approach a research project is to break it up into four stages—exploring, investigating, processing, and creating.

Explore—Pick a Topic and Ask Questions

You need to start by finding out some general things about endangered species. Make a list of questions as you conduct your initial research, such as, What factors cause species to become endangered? Why does it matter? What types of species are endangered? Once you've done some research, you need to focus your topic into a research question.

What is a good research question?

Your research question needs to be specific enough that you can provide a thorough answer within the limits of your project (and in the time you have available). But it should not be so specific that you can answer it in one paragraph!

Suppose, in the course of your research, you decided to learn more about polar bears. There are many questions that can be asked about polar bears, such as, Why are polar bears endangered? or, What can I do to help prevent polar bear extinction? Both of these questions are deep and can be subdivided into many subtopics.

Investigate—Research Your Topic

When putting together a research project, it is important to find reliable sources to help you answer your question. Before you decide to use a source that you find, you should consider whether it is reliable or whether it shows any bias.

Find Sources of Information There are many sources of information. For example, you can use a print resource, such as an encyclopedia from the reference section of the library.

Another approach is to go online and check the Internet. When you use the Internet, be careful about which sites you choose to search for information. You need to be able to determine the validity of a website before you trust the information you find on it.

How do you decide which websites to use?

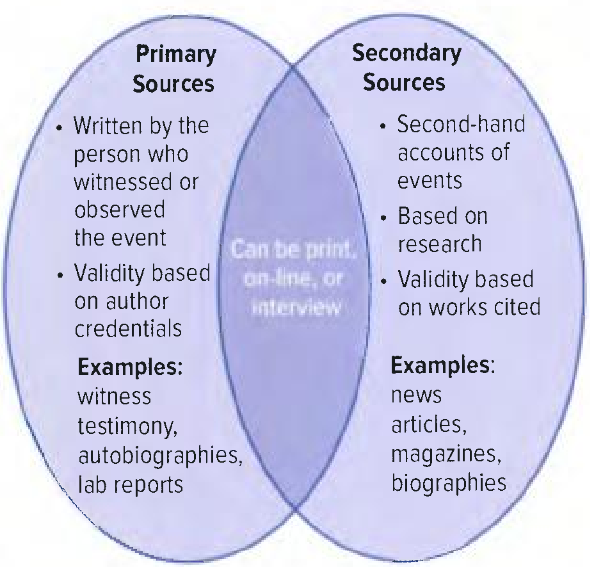
To do this, check that the author is identified, a recent publication date is given, and the source of facts or quotations is identified. It is also important that the website is published by a well-known company or organization, such as a college, university, or government agency.

What if you can't find any sources of information?

If you are having trouble finding any information about your topic, or if the only information you can find is on personal sites, you may want to consider changing your topic. You may also want to contact an expert on your topic. A credible expert has credentials showing his or her expertise in an area. For example, an expert may be a doctor or have a master's degree. Alternatively, an expert could have many years of experience in a specific career or field of study.

No matter which sources you use, it is your responsibility to be a critical consumer of information and to find trustworthy sources for your research.

You should also ask yourself if the sources you are using are primary or secondary. It is okay to use secondary sources, but you should try to include information from primary sources wherever possible.



How do you decide whether a source is reliable and unbiased?

Two other things to check for in a source are reliability and bias. To check for reliability, try to find the same "fact" in two other sources. But keep in mind that even if you cannot find the same idea somewhere else, the source may still be reliable if it is a research paper or if it was written by an author with strong credentials. To check for bias, look for judgemental statements. Does the author tend to favour one side of an issue more than another? Are all sides of an issue treated equally? A good source shows little bias.

How can you stay safe on the Internet?

When you copy or save something from a website, you could be saving more than information. Be aware that information you pick up could also include hidden, malicious code that could damage your computer system or destroy data.

Avoid sites that contain material that is disturbing, illegal, harmful, and/or was created by exploiting others. If you see any on-line content or activity that you suspect is inappropriate or illegal, report it to your teacher. Never give out personal information on-line during research. Protect your privacy, even if it means not registering to use a site that looks helpful. Discuss with your teacher ways to use the site while protecting your privacy.

Polar Bear Research

Source	Information	Reliability	Bias	Questions I Have
The Canadian Encyclopedia website	Polar bears inhabit ice and coastlines of Arctic seas.	• author: Brian Knudsen • secondary source • has links to external sites that are reliable	only lists facts	• Why do they live on ice? • Why don't they move south?
Polar Bears International website	shrinking sea ice habitat	• date at bottom of page 2009 • non-profit organization	designed to save the polar bear	• Why is the ice shrinking?

How can you organize your research?

As you find information, whether you're using paper or a computer, jot it down on sticky notes or use a chart similar to the one shown above. Both paper and electronic sticky notes are useful because you can move them around, group similar ideas together, and reorganize your ideas easily. Using a different colour for each sub-question is even better! Remember to write the source of your information on each sticky note. In addition to writing down information that you find as you research, you should also write down any questions you think of as you go along.

Process—Ask More Questions and Revise Your Work

Now that you have done some research, what subquestions have you asked? These are the subtopics of your research. Use the subtopics to find more specific information.

What if you have too much information—or not enough?

If you find that you have two or three subquestions that have a lot of research supporting them and a few that do not have much research, do not be afraid to "toss out" some of the less important questions or ideas.

Don't steal ideas!

Avoid Plagiarism Copying information word-for-word and then presenting it as though it is your own work is called *plagiarism*. When you refer to your notes to write your project, put the information in your own words. It is also important to give credit to the original source of an idea.

Reveal your source!

Record Source Information Research papers always include a bibliography—a list of relevant information sources the authors consulted while preparing them. Bibliographic entries give the author, title, and facts of publication for each information source. Facts of publication include the publication year, the name of the publisher, and the city in which the publisher is located. For online resources, you should also record the site URL, the name of the site, and the date on which you retrieved the information.

Remember to record source information while you are taking notes so you will not need to go back and search it out again! Ask your teacher about the preferred style for your references.

What if your research does not answer your question?

Before you choose a format for your final project, consider whether your researched information has answered the question you originally asked.

If you have not answered this question, you need to either refine your original question or do some more research! As long as your question still meets the criteria of your original assignment, it is okay to change the question so it focuses on the research you have already done. After all, you do not want your hard work to go to waste!

Create—Decide How to Present Your Work

Check the guidelines that your teacher gave you. There may be specific instructions or criteria that will help you decide how to present your work. You also need to consider who the audience is for your project. How you format your final project will be very different if it is meant for a Grade 2 class compared to the president of a company or a government official. You could present your project as a poster, graphic organizer, blog, graphic novel, video, or research paper.

Instant Practice

1. Describe the steps you should follow in preparing a project on the topic of chemical contamination of water supplies.
2. The following example is not an effective question on which to base a research project: *What is sustainability?* Modify the question to make it an effective research question.
3. Assume that the target audience for your project is a group of parents. What aspects of your project would you need to modify so that you are reaching the intended audience? What would be the best format to use to present your project to your audience?

Using Models and Analogies in Science

Scientists often use models and analogies to help communicate their ideas to other scientists or to students.

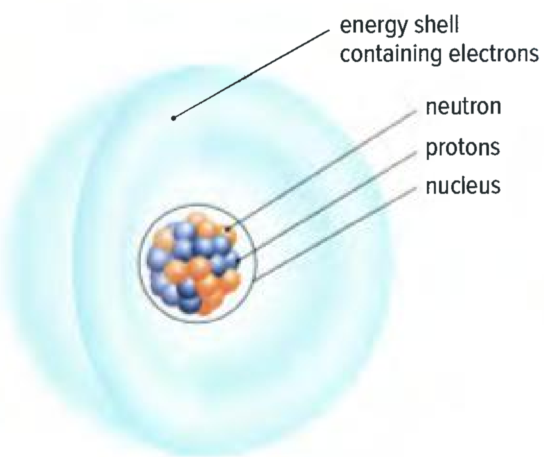
Using Models

When you think of a model, you might think of a toy such as a model airplane. Is a model airplane similar to a scientific model? If building a model airplane helps you learn about flight, then you could say it is a scientific model.

In science, a model is anything that helps you better understand a scientific concept. A model can be a picture, a mental image, a structure, or even a mathematical formula.

Sometimes, you need a model because the objects you are studying are too small to see with the unaided eye.

Atoms are so tiny that you cannot see them, even with the strongest of microscopes. A model of an atom can help you to form a mental picture that helps you understand the parts of the atom, even though it does not show exactly what an atom looks like.



Sometimes a model is useful because the objects you are studying are extremely large—the planets in our solar system, for example. In other cases, the object may be hidden from view, like the interior of Earth or the inside of a living organism.

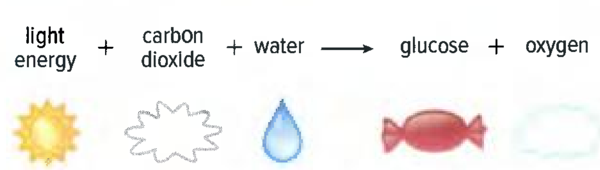
A mathematical model can show you how to perform a calculation. If you wanted to explain addition and subtraction to a young child, you might use carrots as a model. By eating a carrot, you could demonstrate subtraction.

Chemical equations are models that are often used in science to help explain how a chemical reaction or series of reactions takes place. An equation is often used to represent the process of photosynthesis. Photosynthesis is a complex process that involves many chemical changes. An equation helps you to think about the starting materials and end products of the process.

carbon dioxide + water ⟶ glucose + oxygen

Scientists often use models to test an idea, to find out if an hypothesis is supported, and to plan new experiments in order to learn more about the subject they are studying. Sometimes, scientists discover so much new information that they have to modify their models.

Examine the model shown below. How can this model help you learn about science?



Instant Practice

Describe a model that you could use to represent each of the following:

a) $5 - 2 = 3$

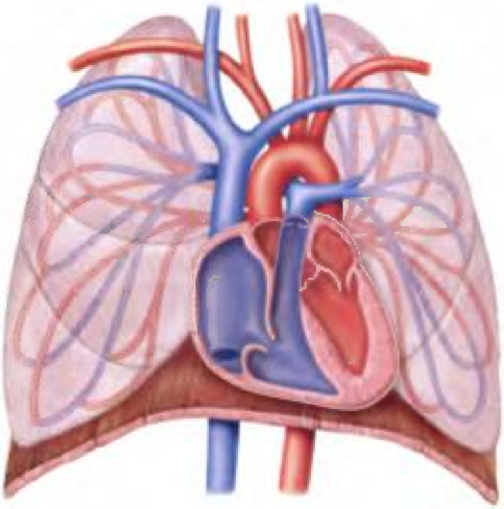
b) an atom

c) the path of light as it travels away from a source

Using Analogies

An analogy is a comparison between two things that have some characteristic in common. Scientists use analogies to help explain difficult concepts. For example, scientists sometimes refer to plants as the lungs of Earth. Plants take in carbon dioxide from the atmosphere to use during photosynthesis. Plants then release the oxygen produced by photosynthesis back into the atmosphere.

In a sense, the plants are "breathing" for Earth. When animals breathe, they take oxygen into their lungs and give off carbon dioxide.



Trees remove carbon dioxide from the atmosphere and release oxygen, just as lungs remove carbon dioxide from blood and add oxygen.

Thinking about photosynthesis in this way may help you to understand the function that plants have in the environment. This analogy will only work, though, if you have an idea of what lungs do. If you don't know anything about lungs or what they do, an analogy involving lungs will not help you to understand photosynthesis.

Negative charges are pushed through a circuit in a similar way to how water is pushed through a hose.

Analogies use familiar situations to help explain unfamiliar situations. Picturing an everyday situation, such as the way water moves through a hose, may help you to picture an unfamiliar concept, such as how electric charge flows through an electric circuit. This is a useful analogy because most people have seen or used a hose, and have an understanding of how water moves through it.

Instant Practice

1. Find an analogy that is used in this textbook. Explain how the analogy helped you in your understanding.

Using Graphic Organizers

When deciding which type of graphic organizer to use, consider your purpose: to brainstorm, to show relationships among ideas, to summarize a section of text, to record research notes, or to review what you have learned before writing a test. Eleven different graphic organizers are shown here. A chart at the end of this section summarizes the function of each organizer to help you decide on the best one for the information you are working with.

T-Chart

A *t-chart* is a simple two-column chart that can be used to compare or show a relationship between two things.

Prokaryote	Eukaryote
• type of cell • does not have a nucleus • organisms are single-celled	• type of cell • has a nucleus • organisms can be single-celled or multi-celled

PMI Chart

A *PMI chart* has three columns. PMI stands for "Plus," "Minus," and "Interesting." A PMI chart can be used to state the good and bad points about an issue. The third column in the PMI chart is used to list interesting information related to the issue. PMI charts help you to organize your thinking after reading about a topic that is up for debate or that can have positive or negative effects.

Citizen science describes cooperation between scientists and volunteers who help collect scientific data.

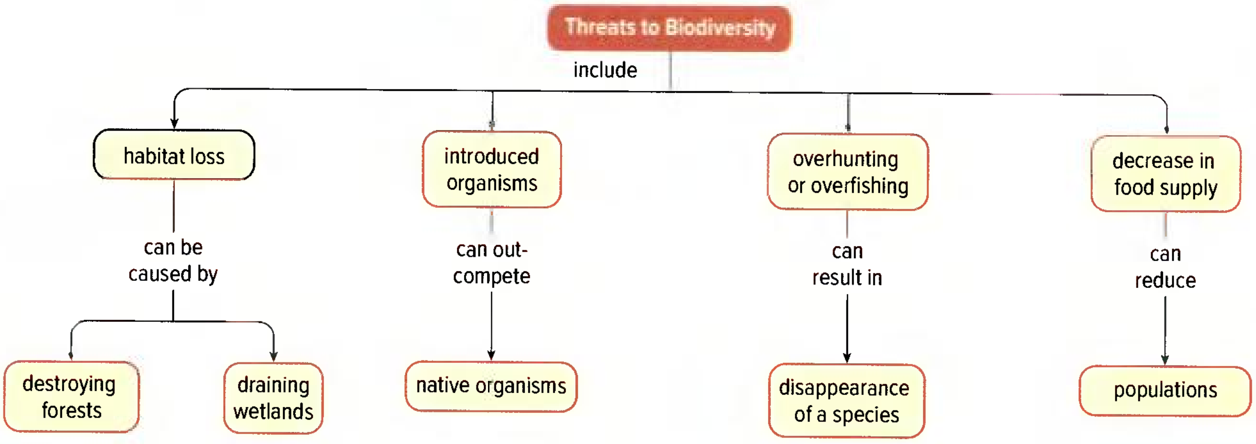
P	M	I
• Volunteers can increase the amount of data collected. • The amount of funding needed for research is reduced.	• Volunteer data may be inaccurate. • Inconsistencies in methodology could occur.	• Environment Canada's NatureWatch program enlists citizen scientists to monitor frogs, earthworms, plants, and ice formation. • Students have been collecting plant data in Canada for over 100 years.

Main Idea Web

A *main idea web* shows a main idea and several supporting details. The main idea is written in the centre of the web, and each detail is written at the end of a line coming from the centre.

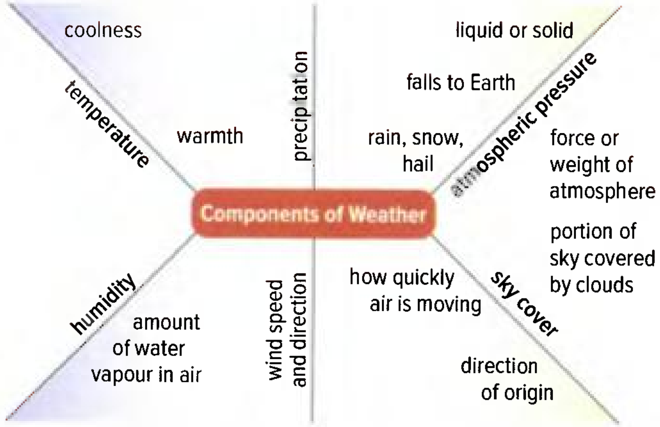
Concept Map

A *concept map* uses shapes and lines to show how ideas are related. Each idea, or concept, is written inside a circle, a square, a rectangle, or another shape. Words that explain how the concepts are related are written on the lines that connect the shapes.



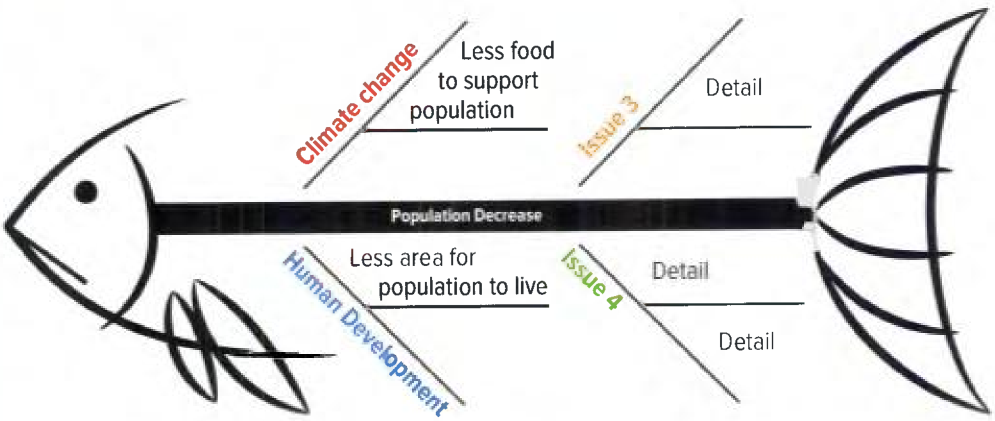
Spider Map

A *spider map* shows a main idea and several ideas related to the main idea. It does not show the relationships among the ideas. A spider map is useful when you are brainstorming or taking notes.



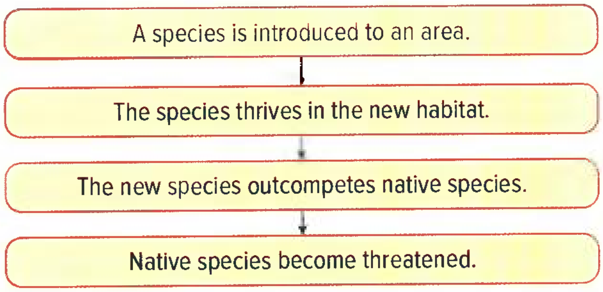
Fishbone Diagram

A *fishbone* diagram looks similar to a spider map, but it organizes information differently. A main topic, situation, or idea is placed in the middle of the diagram. This is the "backbone" of the "fish." The "bones" (lines) that shoot out from the backbone might be used to list reasons that the main situation exists, issues that affect the main idea, or arguments that support the main idea. Finally, supporting details shoot outward from these issues. Fishbone diagrams are useful for planning and organizing a research project. You can clearly see when you do not have enough details to support an issue. Then you can do more research.



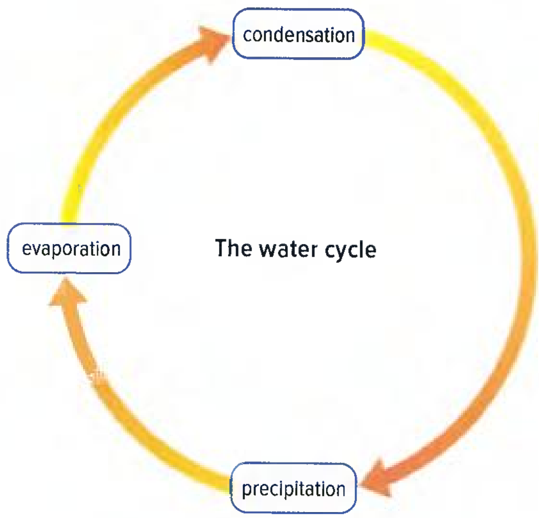
Flowchart

A *flowchart* shows a sequence of events or the steps in a process. A flowchart starts with the first event or step. An arrow leads to the next event or step, and so on, until the final outcome. All the events or steps are shown in the order in which they occur.



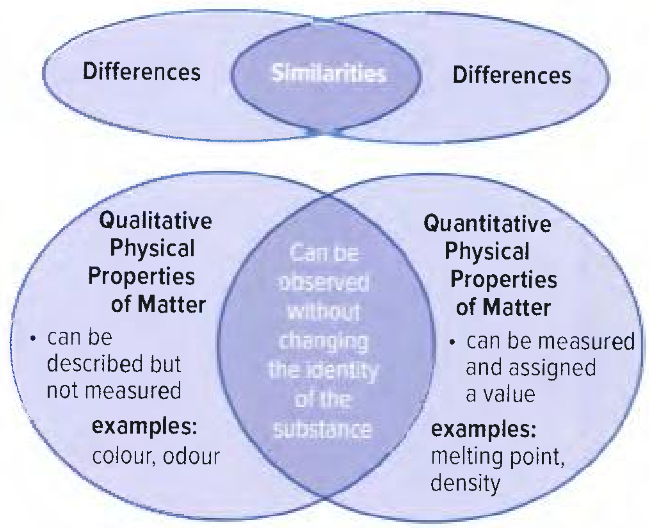
Cycle Chart

A *cycle chart* is a flowchart that has no clear beginning or end. All the events are shown in the order in which they occur, as indicated by arrows, but there is no first or last event. Instead, the events occur again and again in a continuous cycle.



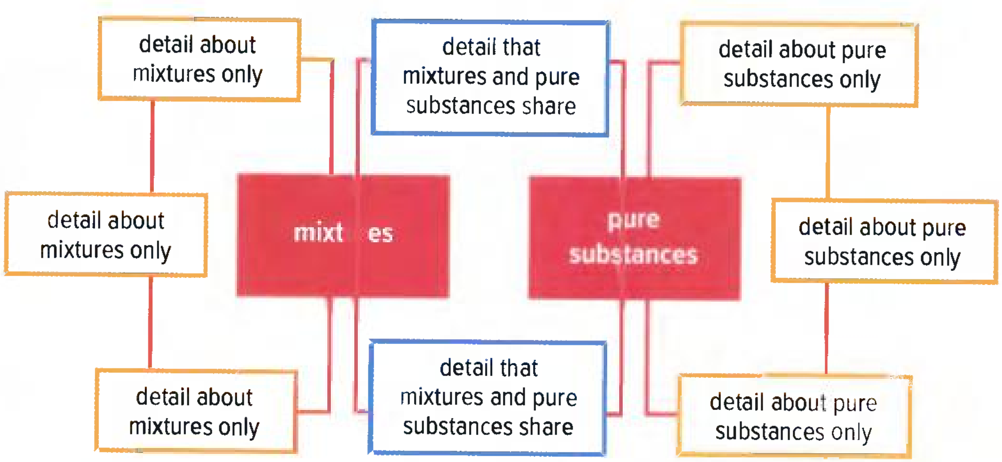
Venn Diagram

A *Venn diagram* uses overlapping shapes to compare concepts (show similarities and differences).



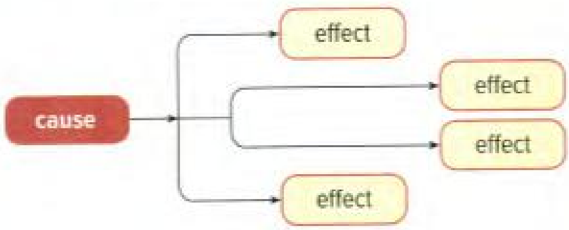
Double Bubble Organizer

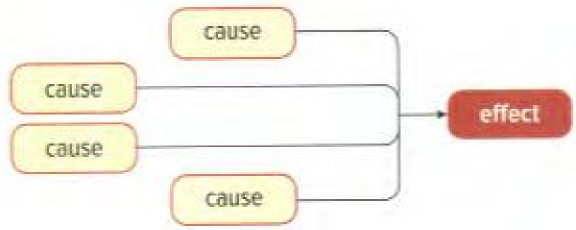
Like a Venn diagram, a *double bubble organizer* is used to compare concepts (show similarities and differences). It separates the details that two concepts share and the details that they do not share.



Cause-and-Effect Map

The first *cause-and-effect map* below shows one cause that results in several effects. The second map shows one effect that has several causes.





Which Organizer Should I Choose?

When you are trying to decide how to organize information, you can use the following chart to help you.

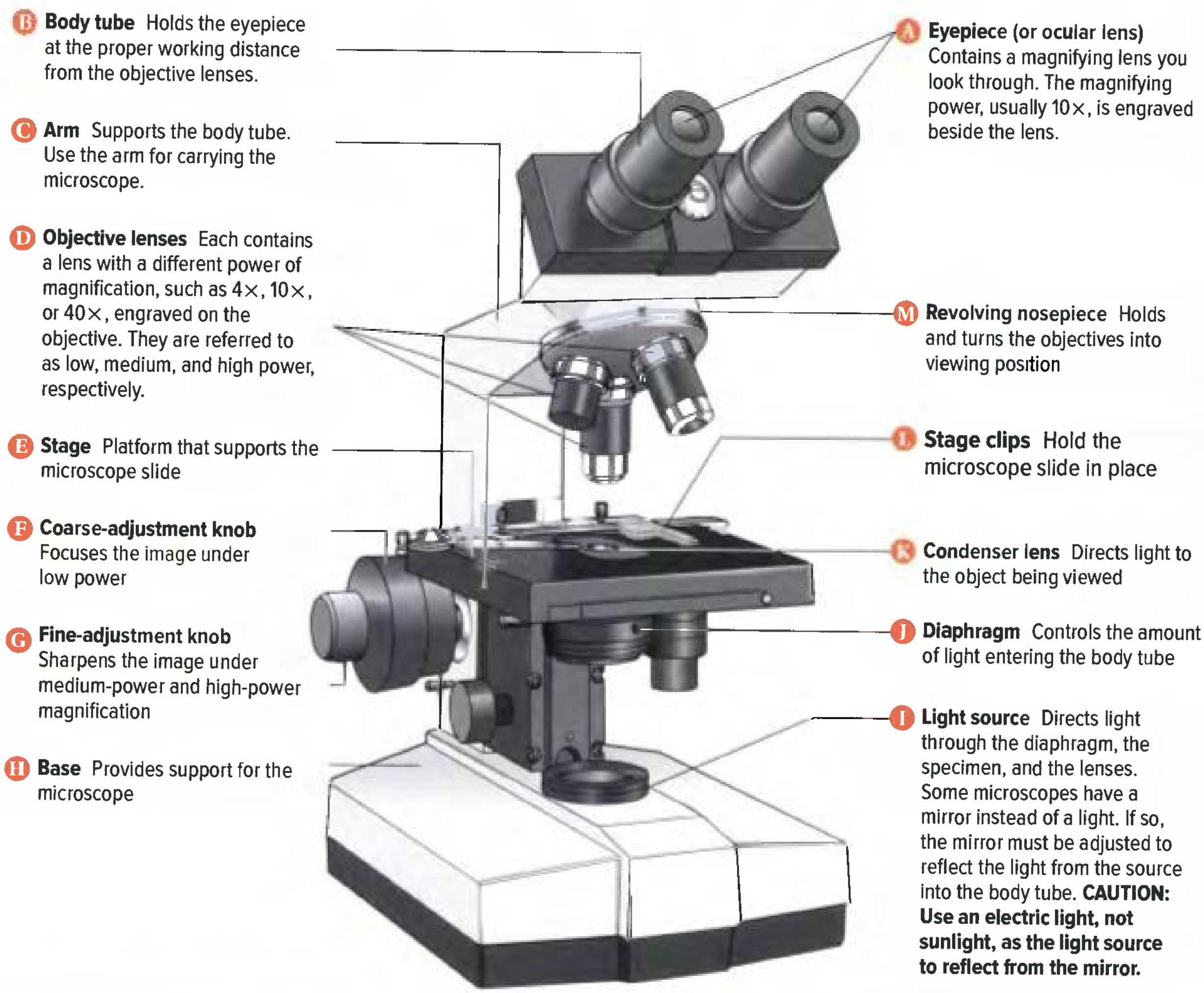
What are you trying to do with your graphic organizer?	t-Chart	PMI Chart	Main Idea Web	Concept Map	Spider Map	Fishbone Diagram	Flowchart	Cycle Chart	Venn Diagram	Double Bubble Organizer	Cause-and-Effect Map
Brainstorm			X	X	X						
Show relationships among ideas or words			X	X		X					
Check your understanding						X	X	X	X	X	X
Compare (show similarities and differences)	X								X	X	
Examine the pros and cons of an issue	X	X									
Examine the causes and/or effects of an action or issue				X		X	X				X
Take notes		X	X	X	X	X					
Plan your research						X	X				
Show a process or series of events							X	X			
Show a continuous series of events								X			

Care and Use of the Microscope

A compound light microscope is an instrument with a series of lenses that greatly magnify objects too small to be seen with the unaided eye. The diagram below shows the major parts of the microscope and their functions. Follow these tips to keep your microscope in good working condition.

1. Always use two hands to carry a microscope: one hand to hold the arm and the other hand to support the base.
2. Do not allow the electrical cord to become a trip hazard while working with your microscope.
3. Do not touch the lens surfaces with your fingers.
4. Use only lens tissue to clean the lens surfaces. Other kinds of paper can scratch the lenses.
5. Do not adjust any of the focusing knobs until you are ready to use the microscope.
6. Always focus using the coarse adjustment knob first, with the low-power objective lens in position.
7. Do not use the coarse adjustment knob with either the medium-power or high-power objective lens.
8. Always store the microscope with the low-power objective lens in place. Cover the microscope when not in use.

Compound Light Microscope



Troubleshooting Tips

The table below gives helpful tips for handling some problems you may have when you use a microscope.

Problem	How to Solve the Problem
You cannot see anything.	Make sure the microscope is plugged in and the light is turned on. If the microscope has no electric light, adjust the mirror.
You have trouble finding anything on the slide.	Be patient. Make sure the object being viewed is in the middle of the stage opening. While watching from the side, lower the low-power objective lens as far as it will go. Then look through the eyepiece. Slowly raise the stage using the coarse adjustment knob.
You have trouble focusing, or the image is very faint.	Try closing the diaphragm slightly. Some objects are almost transparent. If there is too much light, a specimen may be difficult to see or it will appear "washed out."
You see lines and specks floating across the slide.	These are probably structures in the fluid of your eyeball that you see when you move your eyes. Don't worry; this is normal.
You see a double image.	Check that the objective lens is properly clicked into place.
Your eyes feel tired or you find it difficult to sketch an object.	Keep both eyes open. This will help prevent eye fatigue. It also lets you sketch an object while you are looking at it.
You no longer see the object when you turn from low power to medium or high power.	Always place the part of the slide you are interested in at the centre of the field of view before changing to a higher-power objective lens. Otherwise, when you turn to medium and high power, you may not see the object you were viewing under low power.

Finding Total Magnification

When you look through a microscope, you are actually looking through two lenses at once. These lenses are 1) the lens in the eyepiece and 2) the objective lens you have chosen (low-, medium-, or high-power). Each of the lenses (the eyepiece lens and the objective lens) adds to the total magnification. The table on the right shows how to calculate the total magnification you actually see when you look through each objective lens. The eyepiece usually has a magnification of 10×. The table shows typical magnifications for the objective lenses. Your teacher will tell you if the microscope you are using has different magnifications.

Total magnification =
(eyepiece magnification) ×
(objective lens magnification)

Magnification and Total Magnification of Each Objective Lens

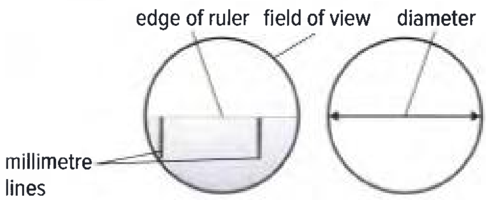
Objective Lens	Magnification	Total Magnification
Low-power	4×	10 × 4 = 40×
Medium-power	10×	10 × 10 = 100×
High-power	40×	10 × 40 = 400×

For example, suppose you are viewing an object under the medium-power lens. The object is magnified by the eyepiece lens (10×) and by the medium-power objective lens (10×). Therefore, the total magnification is 10 × 10 = 100×.

Finding the Diameter of the Field of View

The *field of view* is the circular area you can see when you look through the microscope. The diameter of the field of view is different depending on which lens you are using. For example, if you are using the medium-power lens (magnification 100×), then the area you can see is actually smaller than if you were using the low-power lens (magnification 40×).

1. Place a clear plastic ruler on the microscope stage.
2. Use the coarse-adjustment knob to focus on the ruler. Position the ruler so that one of the millimetre markings is at the left edge of the field of view, as shown below.



The diameter of the field of view under low power illustrated here is about 1.5 mm.

3. Measure and record the diameter of the field of view in millimetres (mm) for the low-power objective lens.
4. Use the following formula to calculate the field of view for the medium-power objective:

   Medium-power field of view =

   $$\text{low-power field of view} \times \frac{\text{magnification of low-power objective}}{\text{magnification of medium-power objective}}$$

   For example, if the low-power objective lens has a magnification of 4× and a field of view of 2 mm, and the medium-power objective has a magnification of 10×, then

   Medium-power field of view

   $$= 2\text{ mm} \times \frac{4}{10}$$
   $$= 2\text{ mm} \times 0.4$$
   $$= 0.8\text{ mm}$$

Calculating the Size of an Object under the Microscope

Once you know the diameter of your microscope's field of view, you can calculate the size of an object.

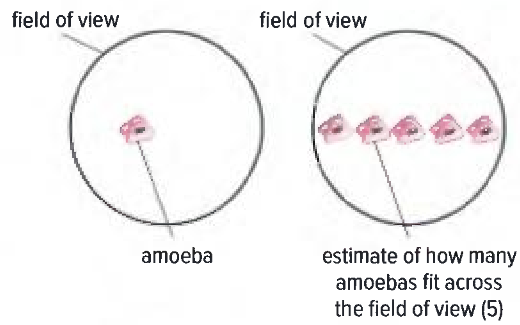
Objects in the field of view of a microscope are usually measured in micrometres (μm). One micrometre equals 0.001 mm (millimetres); or 1000 μm equals 1 mm (millimetre). For example, if the field of view under the medium-power objective is 0.8 mm, this is equal to 800 μm.

$$0.8\text{ mm} \times 1000 = 800\ \mu\text{m}$$

Steps in Calculating the Size of an Object under the Microscope

This example shows you how to calculate the size of an amoeba that you are viewing under a microscope.

1. Estimate how many amoebas could fit end to end across the field of view. (See the diagram below.)



2. Calculate the size of one amoeba using the following formula:

   Size of object =
   (field of view diameter) ÷ (number of specimens)

   Size of amoeba = 1500 μm ÷ 5
   = 300 μm

   Therefore, one amoeba measures about 300 μm across.

Important Features of Biological Drawings

The drawing of a human skin cell is from a student's notebook. The following are important features of biological drawings that you can see in this example.

- Use a pencil for drawing, not a pen.
- Use stippling (point-like pencil marks) to show darker areas instead of sketch lines or shading.
- Give your drawing a title.
- If possible, place all labels on the right-hand side of the drawing, with straight lines extending from the area you are labelling.
- Include the magnification used to view the specimen at the bottom of the drawing.

Instant Practice

PART 1

Viewing a Prepared Slide

CAUTION: Be sure your hands are dry when handling electrical equipment. Handle microscope slides carefully, since they can break easily and cause cuts.

1. Set up your microscope. Be sure to follow the tips just described.
2. Make sure that the low-power objective lens is in position. If not, rotate the nosepiece until the low-power objective lens clicks into place.
3. Look through the eyepiece and adjust the diaphragm until the view is as bright as possible.
4. Place a prepared slide on the stage and secure it in place with the stage clips. Make sure the object you want to view is centred over the opening in the stage.
5. Look through the eyepiece. Slowly turn the coarse adjustment knob until the object is in focus. Use the fine adjustment knob to sharpen the focus.
6. Once the object is in focus using low power, carefully rotate the nosepiece to the medium-power objective. Look at the objective from the side as you rotate the nosepiece to be sure the objective lens does not strike the surface of the slide. Adjust the focus using ONLY the fine adjustment knob. DO NOT use the coarse adjustment knob with the medium- or high-power objective lens.
7. To view the object under high power, follow the same process as in step 6.
8. Draw a sketch of what you are viewing. Use the tips provided about biological drawings.
9. Once you have finished, carefully rotate the nosepiece until the low-power objective is in position. Remove the slide from the stage and return it to its proper container. Unplug the light source and return the microscope to its storage area.

CAUTION: Never tug on the electrical cord to unplug it.

PART 2

Looking at the Letter "e" in a Wet Mount Slide

CAUTION: Be careful when using sharp objects such as tweezers. Handle microscope slides and cover slips carefully, since they can break easily.

Materials

newspaper	microscope slide
tweezers	water dropper
cotton ball	microscope
cover slip	

Procedure

1. Begin with a clean slide and cover slip. Hold the slide and cover slip by their edges to avoid getting your fingerprints on their surfaces.
2. Cut out a small piece of newspaper containing a single letter "e." Use the tweezers to position the letter in the centre of the slide.
3. Use the dropper to place one drop of water on the letter.
4. Hold a cover slip over the sample at a 45° angle. Lower the cover slip until one edge touches the surface of the slide at the edge of the water drop.
5. Slowly lower the opposite edge of the cover slip over the sample. Be sure no bubbles form beneath the cover slip. If bubbles do form, repeat the procedure. This type of sample preparation is called a *wet mount*.
6. Make sure the low-power objective lens is in position. Place the slide on the stage and secure it with the stage clips. Centre the sample over the opening.
7. Look though the eyepiece. If necessary, reposition the slide until you can see the letter. Use the coarse adjustment knob to focus on the letter. Then adjust the focus with the fine adjustment knob.
8. Draw the letter "e" as it appears under low-power magnification.
9. Move the slide in different directions (left, right, away from you, and toward you). Record how the image moves in each case.
10. Move the letter back to the centre of the field of view. Rotate the nosepiece so that the medium-power objective lens is in position. At higher magnification, use ONLY the fine adjustment knob to focus the image. You may need to adjust the light level at this higher magnification.
11. Draw the letter "e" as it appears at medium-power magnification.
12. Rotate the nosepiece so that the high-power objective lens is in position. Remember: use ONLY the fine adjustment knob to focus the image.
13. Draw the letter "e" as it appears at high-power magnification.

Observations

Use a table like this to record your observations in step 9.

Letter "e" as Viewed under the Microscope

Direction of Slide Movement	Observed Direction of Movement
Left	
Right	
Away from you	
Toward you	

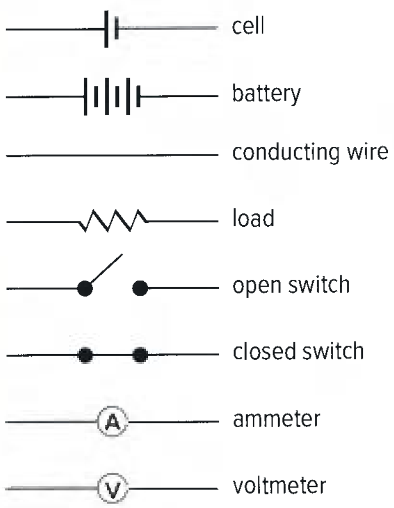
Look at your drawings of the letter "e" under low-, medium-, and high-power magnification.

a) How does the size of the field of view compare under each level of magnification?

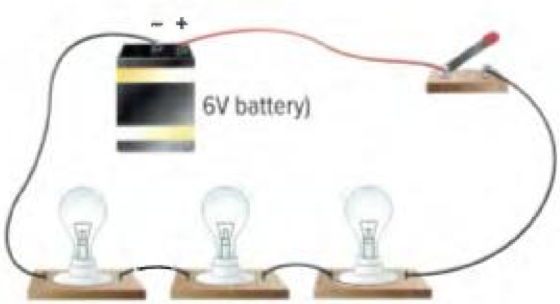
b) How does the appearance of the printed letter change as you increase the magnification?

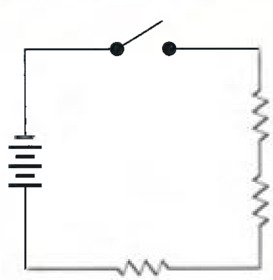
Drawing Circuit Diagrams

The symbols below are used to represent different components when drawing circuit diagrams. In the symbols for cell and battery, the long line represents the positive terminal. The short line represents the negative terminal.

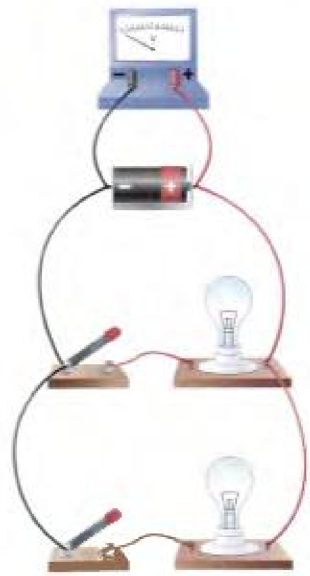


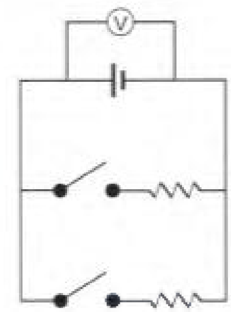
Circuit diagrams are usually drawn in the form of one or more rectangles with symbols placed in the sides of the rectangles. To draw a circuit diagram, choose a starting point such as the source. Then follow the wires and insert symbols as you locate circuit components. An example is shown below.





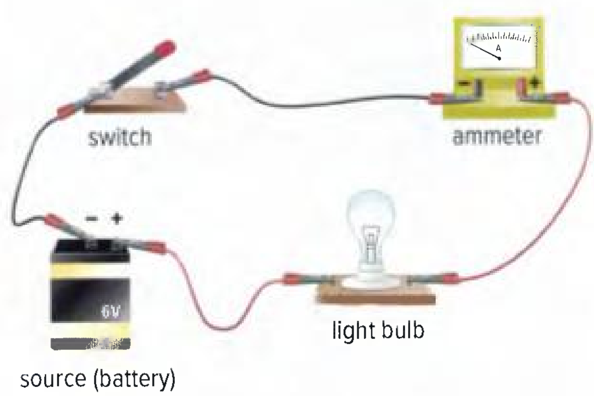
Notice that three rectangles are needed to draw a diagram for the parallel circuit below.





Instant Practice

1. Draw a circuit diagram for a circuit that has a cell, a closed switch, and a buzzer. All components are connected in series.
2. Draw a circuit diagram for a circuit that has three light bulbs that are connected in parallel. This combination is connected to a battery and an open switch in series.
3. Draw a circuit diagram for the following circuit.



Measuring Current and Electrical Potential Difference

The meters you will use to measure current and electrical potential difference will be either analogue or digital. Digital meters display values as numbers on a screen. Analogue meters have a needle that points to a value on a dial. The methods you use to measure current and electrical potential difference are the same with both types of meter.

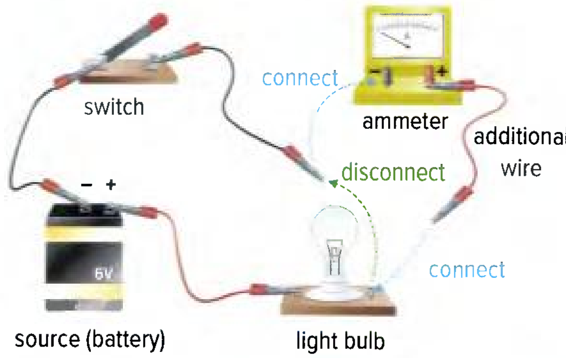
You may use separate meters to measure current and electrical potential difference or a multimeter. An ammeter measures current only, while a voltmeter just measures electrical potential difference. A multimeter can be set to measure either current or electrical potential difference. The methods used to make measurements are the same for all types of meters. However, because the details of setup may vary slightly, be sure to read the directions for the specific meter that you use.

The Terminals of a Meter

All meters have two terminals that you connect to the circuit. The negative terminal (−) is black, and the positive (+) is red. To avoid damaging the meter, the positive (red) terminal must be connected to the positive side of the source. You should be able to trace from the positive terminal on the meter, along the conductor, to the positive terminal of the source. The negative (black) terminal of the meter will then be connected to the negative side of the source.

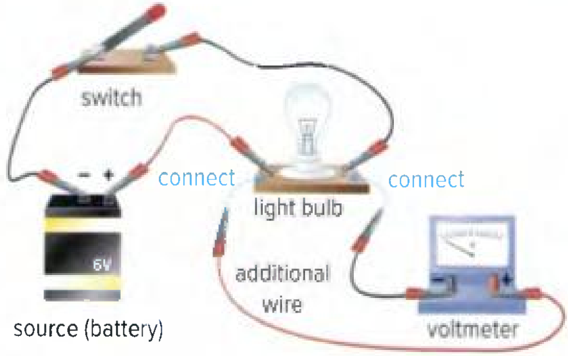
Connecting an Ammeter

When you want to measure the current passing through a circuit component such as a light bulb, that current must pass through the ammeter. To do this, disconnect the conductor from one end of the component, and connect it to one side of the ammeter. Then connect the other side of the ammeter to where you just disconnected the conductor from the component. This is shown in the diagram below. You can see that the same current that passes through the light bulb will pass through the ammeter.



Connecting a Voltmeter

There is an electrical potential difference between two points in a circuit such as across a battery, light bulb, or other circuit component. When you connect a voltmeter to a circuit, do not disconnect any points in the circuit. Instead, connect the two terminals of the voltmeter to the two points between which you want to measure the electrical potential difference. For example, if you want to measure the electrical potential difference across a light bulb, connect the two terminals of the voltmeter to the two sides of the light bulb, as shown below.



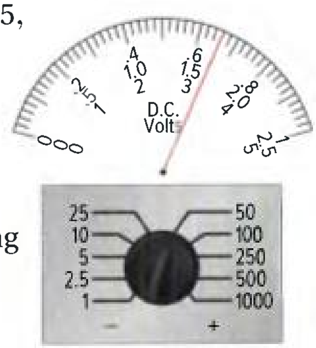
Connecting a Multimeter

When using a multimeter, position the dial on the meter to the application—current or electrical potential difference—that you want to measure. As well, the connecting wires must be inserted into the correct terminals on the meter. Each terminal will be labelled for a specific application. Then connect the multimeter to the circuit in the same way that you would with an ammeter or voltmeter.

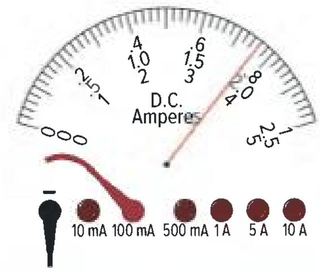
Reading a Meter

A digital meter is easy to read, because the measured value is displayed directly as numbers. However, to get the most accurate reading, you need to set the meter to the appropriate scale. For example, if the dial is set to the 2 V setting, the meter will measure voltages between 0 V and 2 V. If you move the dial to the 200 V setting, the meter will measure between 0 V and 200 V, but the reading will be less accurate. The best approach is to set the meter to the largest scale to get an approximate value. Then lower the scale until you have the highest possible reading without going off scale.

This approach is the same for analogue meters. Some analogue meters have a dial that is used to change the scale. Once the scale is selected, you obtain your reading from the most appropriate display on the meter. For example, in the diagram below, the voltmeter is set to 50 V. To determine the electrical potential difference, look for the number at the top of the scale with the same first digit as 50. The bottom scale has a maximum value of 5, so the 5 represents 50 V. To read the scale, multiply the number the needle is pointing to by 10. The needle is pointing to 3.3. When you multiply by 10, the result is 33 V.

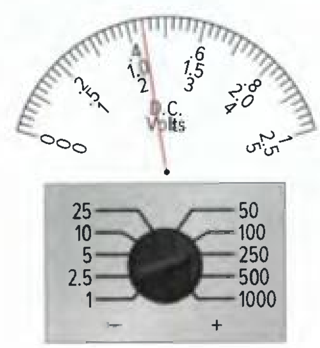


In other analogue meters, the scale is determined by how the wires are connected to the terminals. For example, in the diagram at the top right, the positive connection is in the terminal labelled 100 mA. (An mA is a milliampere or 0.001 A.) To determine the current, look for the number at the top of the scale with the same first digit as 100. The uppermost scale has a maximum value of 1, so the 1 represents 100 mA. To read the scale, multiply the number the needle is pointing to by 100. The needle is pointing to 0.76. When you multiply by 100, the result is 76 mA.

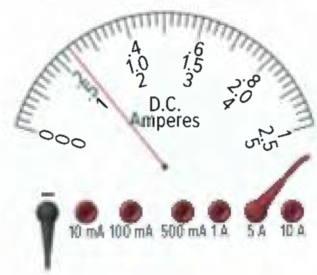


Instant Practice

1. Explain how you would use a multimeter to measure the electrical potential difference across a load.
2. Describe the procedure you would use to build a circuit that has a battery, a switch, an electric buzzer, an ammeter, and several red and black wires with alligator clips on the ends.
3. If the current or voltage you are measuring is much higher than the maximum value to which the meter is set, it can damage the meter. Explain how you would choose the scale that would give the most accurate result without damaging the meter.
4. Determine the value of the electrical potential difference for the analogue meter shown below.



5. Determine the value of the current for the analogue meter shown below.



Using Ohm's Law

Ohm's law is the mathematical relationship among electrical potential difference (V), current (I), and resistance (R). It can be stated in words as, "The electrical potential difference between two points in a circuit is equal to the current times the resistance between those two points." The mathematical equation is $V = IR$.

Rearranging the Ohm's Law Equation

If you know the value of any two of the variables, you can find the value of the third variable by substituting the values into the equation. If you know the current and the resistance, you can substitute the values into $V = IR$ and calculate the electrical potential difference. However, if the unknown variable is current (I) or resistance (R), you have to rearrange the formula to solve for the unknown variable.

If current is the unknown variable, divide both sides of the equation by R.

$$\frac{V}{R} = \frac{I\cancel{R}}{\cancel{R}}$$

$$I = \frac{V}{R}$$

If resistance is the unknown variable, divide both sides of the equation by I.

$$\frac{V}{I} = \frac{\cancel{I}R}{\cancel{I}}$$

$$R = \frac{V}{I}$$

The three forms of Ohm's law are

$V = IR$, $I = \frac{V}{R}$, and $R = \frac{V}{I}$.

Examples

1. A technician measures the resistance of a load that will be used in a circuit and finds that it is 48 Ω. If the potential difference of the source is 120 V, what current will be passing through that load?

Solution

Because you want to determine the current, you will use the formula, $I = \frac{V}{R}$.

Substitute the values into the formula.

$$I = \frac{120\ \Omega}{48\ \Omega}$$

$$I = 2.5\ \text{A}$$

A current of 2.5 A will be flowing through the load.

2. Starting a car requires a very large current. If a car needs a current of 150 A and the total resistance of the circuit is 0.08 Ω, what must be the electrical potential provided by the battery?

Solution

Because you want to determine the electrical potential difference, you will use the formula, $V = IR$.

Substitute the values into the formula.

$$V = (150\ \text{A})(0.08\ \Omega)$$

$$V = 12\ \text{V}$$

The car battery must provide an electrical potential difference of 12 V.

Instant Practice

1. A toaster uses a current of 10.4 A when it is plugged into an 110 V outlet. What is the resistance of the heating coils of the toaster?
2. A circuit breaker is a safety device that acts like a switch if the current gets too high. In a home, a circuit breaker will open a circuit if the current rises above 15 A. An electric heater is plugged into a 120 V outlet. Some broken wires touch each other, which causes the resistance to drop to 6.0 Ω. Will this faulty electric heater cause the circuit breaker to open the circuit?

Reading Effectively

Identifying the Main Idea and Details

The main idea of a text is the *most important* idea. Here are some strategies for identifying the main idea of a topic or paragraph.

- Pay attention to titles, headings, and subheadings. Note how print size and colour help you identify each of these.
- Look at the images on the page to get a general idea of the content.
- Note any terms that appear in bold or italic print. Bold print is used to identify key terms. Italics are used to add emphasis to other important words.

Details in the text *support and explain* the main idea. Details might be facts or examples. These phrases are clues that details will follow:

- For instance
- For example
- … such as

Instant Practice

1. Examine the pages below and explain how the headings communicate the main idea.

CONCEPT 1

Matter and its interactions make up our world.

Activity

Describe It, Separate It

Your teacher will provide your group with a mixture. You will have access to equipment such as magnets, filters, and sieves. Before starting, examine Figure 2.1 below.

1. Is your mixture heterogeneous or homogeneous (a solution)? How do you know?
2. Can you separate your mixture into parts? Try to do so.
3. Are the parts of your sample mixtures or pure substances? Explain.
4. What further tests would you like to conduct to gather more information about the components of your sample?

You are surrounded by **matter**, and chemistry is the science of matter and its interactions. By studying chemistry, we can better understand the properties and behaviour of matter on Earth and beyond. Matter can be classified as either a **pure substance** or a **mixture**. Pure substances are made up of one type of particle. Mixtures are made up of two or more pure substances, and therefore two or more types of particles. Figure 2.1 summarizes the classification of matter.

matter anything that has mass and takes up space

pure substance matter that has a definite composition and cannot be separated by physical means

mixture a blend of two or more pure substances in which each substance retains its individual properties; can be separated by physical means

Figure 2.1 Matter is either a mixture or a pure substance. A mixture can be homogeneous or heterogeneous. A pure substance can be an element or a compound. Give one example of each of these: a solution, an element, and a compound.

88 MHE UNIT 2

Figure 2.2 This pair of railway bridges, called the Cisco bridges, is found at Siska, B.C. **Make a table to list the mixtures, compounds, and elements mentioned. Add one example not mentioned.**

Mixtures, Compounds, and Elements

Most of the materials we interact with each day are mixtures. Figure 2.2 shows and describes some examples of solid, liquid, and gas mixtures. Some—such as air and steel—are homogeneous mixtures, or *solutions*. They are mixed uniformly throughout, and you cannot see their components, even with a microscope. Others, such as rock, have different parts that you can see. These are *heterogeneous mixtures*. But all are made up of two or more different pure substances.

Pure substances can be elements or compounds. **Elements** are made up of just one type of atom and cannot be broken down into simpler substances by chemical means. **Compounds** are made up of atoms of two or more elements.

element a pure substance that cannot be broken down into simpler substances by physical or chemical means

compound a pure substance made up of two or more elements; can be broken down into elements by chemical means

Properties of Matter

The steel of the railway tracks in Figure 2.2 is a strong, hard, shiny solid. Rock is also a hard solid, but it is brittle. Air is a clear, colourless gas. These descriptions all use *physical properties*. These are characteristics of matter that can be observed or measured without changing its chemical identity. In contrast, *chemical properties* describe the ability of matter to react with another substance to form one or more different substances. Table 2.1 gives further examples.

Table 2.1 **Physical and Chemical Properties**

Physical Properties		Chemical Properties
• colo	• state of matter	• combustibility
• malleability	• melting point	• eactivity with acids
• texture	• boiling point	• reactivity with oxygen
• v scos ty	• hardness	• lack of reactivity
• ability to conduct heat and electricity	• solubility	

TOP C 2 HOW AND WHY DO WE STUDY MATTER? MHE 89

Skim, Scan, or Study

Not all parts of a textbook should be read at the same speed. In general, how fast you should read a chunk of text depends on your purpose for reading. The table below shows three reading speeds, each suiting a different purpose for reading.

Purposes of Reading Speeds

Purpose	Reading Approach (Skim, Scan, or Study)
Preview text to get a general sense of what it contains	Read quickly (skim).
Locate specific information	Read somewhat quickly (scan)
Learn a new concept	Read slowly (study)

Sometimes the features of the text can help you decide how fast you should read. For example, if you see a page that contains several bold, highlighted key terms, you should read the text slowly and carefully. Text in a chapter opener can be read more quickly, since it is only an introduction to the topic.

Asking Questions

As you are reading, stop every now and then to ask yourself questions starting with who, what, where, why, when, and how.

Read the following paragraph and then answer the questions below it.

> Until a few hundred years ago, people actually had no way to measure temperature. This problem became central to the discussion of a group of scientists in Venice, Italy, in the 1500s. The puzzle of how to measure temperature was eventually solved by one of these scientists, Galileo Galilei. Galileo invented the first device that could measure variations in temperature in 1593.

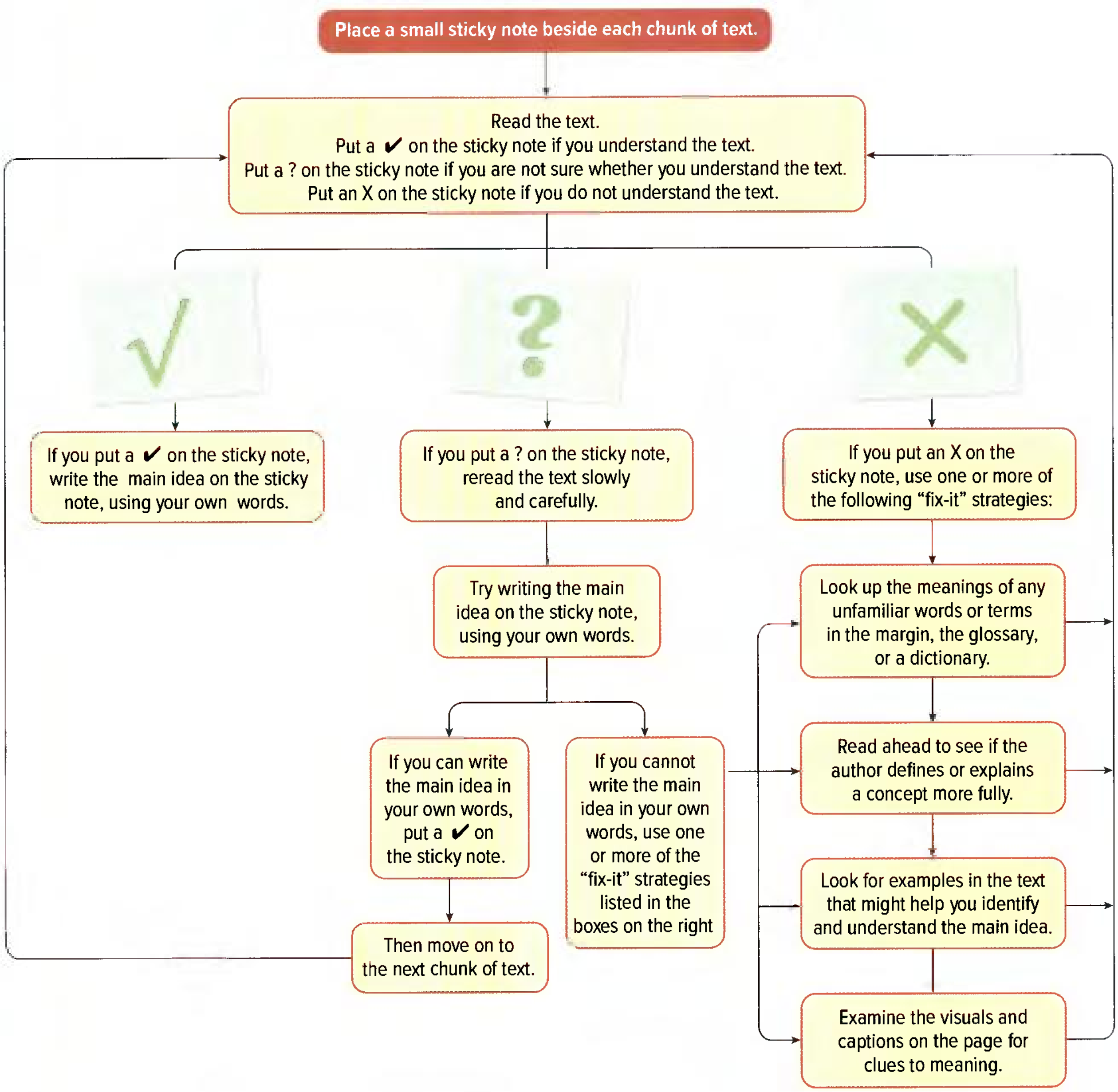
Who solved the problem discussed in this paragraph?
What was the problem?
Where was the group of scientists who were focussed on this problem?
Why was this problem important?
When did he solve this problem?
How was the problem solved?

If you can't answer these questions about the text you've just read, you might need to go back and read more carefully.

You can also use these questions to predict what you will read next. Then continue reading to see if your questions are answered by the text. If they are not, write them down. You can discuss them with a partner, ask your teacher, or do some research to find out more.

Checking Your Understanding

When you are reading text that contains new ideas and new key terms, stop after each chunk of text to make sure that you understand what you have just read. You can use the steps in the following flowchart to do this.



Instant Practice

1. Make a list of steps you could follow if you were not sure that you had understood a section of text. Number your steps.
2. Make a bulleted list of the four "fix-it" strategies, using your own words.

Interpreting Graphic Text

Reading Diagrams

A diagram is a kind of visual that includes labels to help communicate information about the visual and how to interpret it.

To read a diagram

1. **Read the title or caption to understand the main idea of the diagram.**
   For example, the caption of Figure 3.23 tells you that a water circuit is being compared with an electrical circuit.
2. **Consider how each part illustrates the main idea.**
   The diagram shows important features of the two circuits.
3. **Look closely at the labels and reread the caption, if you need to, to understand the details of the diagram.**
   The labels help to describe specific features of each circuit.
4. **Find the reference to the diagram in the text to find out additional information, and to understand how the diagram relates to the main idea in the text.**
   In the main text, near the figure reference, you find the following information: "To gain a better understanding of how the components of an electric circuit work together, compare the electrical circuit with the water circuit in Figure 3.23." Each step in what happens is then described in detail within the main text.

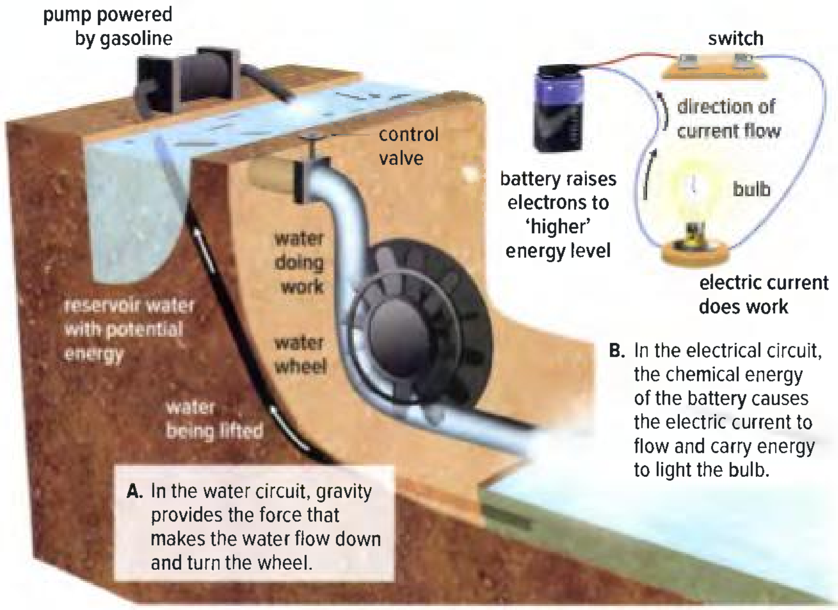


Figure 3.23 A comparison of a water circuit and an electrical circuit.

Instant Practice

Examine a figure within a Topic. Follow the steps above to read the diagram.

1. Explain the main idea of the diagram.
2. How did the caption, labels, and information in the main text help you to understand the diagram?

Reading Tables

A table contains cells that are organized in rows and columns. Each cell contains data. Each column has a heading to help you understand the information in each cell. Sometimes each row also has a heading.

To read a table or to find patterns in a table

1. **Read the title of the table.**
   Based on the title, you should be able to predict what kind of information you will see in the cells
2. **Read the column and row headings carefully.**
3. **Move your eyes left and right across the rows, and up and down along the columns.**
4. **When you look at a cell, look again at the headings.**
   What is the heading of the column containing this cell? What is the heading of this row?
5. **Look for units.** If measurements are included in the table, the column headings should tell you what units are being used to report the measurements.
6. **Look for patterns as you move from left to right across a row, or from top to bottom down a column.**
   If the column contains numbers, do the numbers increase steadily as you move down the column? Do they decrease steadily?
7. **Look for breaks in patterns.**
   Is there one cell that doesn't fit the pattern in the rest of its column? Think about why this might be the case.
8. **Look for relationships between columns or rows.**
   Do the numbers in one column increase as the numbers in another column decrease?
   Do numbers increase from top to bottom in every column? What does this tell you?

Instance Practice

Follow the steps listed above for the table shown here

Average Monthly Snowfall in Winter

Snow (cm)	Month
21	December
67	January
138	February
97	March

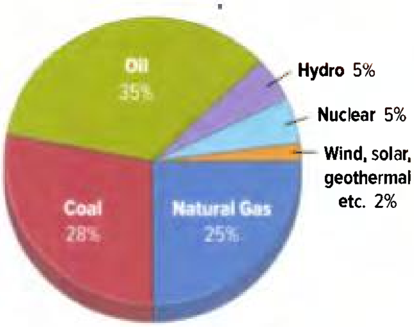
Reading Graphs

First read the graph's title.
Predict what relationship the graph will display based on the title.

Read the labels on each of the sections (pieces of pie) in a pie graph.
What is being compared? In a pie graph, each section represents a percentage of the whole circle. Think about what the whole circle represents.

Look for the percentages on each section of a pie graph.
If two sections are similar in size, it can be difficult to compare the size of the sections visually. It helps to compare the percentage of the whole that each section takes up.

Compare the sections of a pie graph.
Which section takes up most of the circle? Which section takes up the least? Is the circle evenly divided into sections?



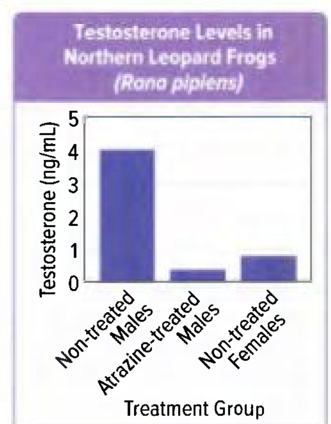
World's Energy Consumption
(Approximation)

Read the labels on the *x*-axis and the *y*-axis of line graphs and bar graphs.
What relationship will the graph display, based on the axes labels?

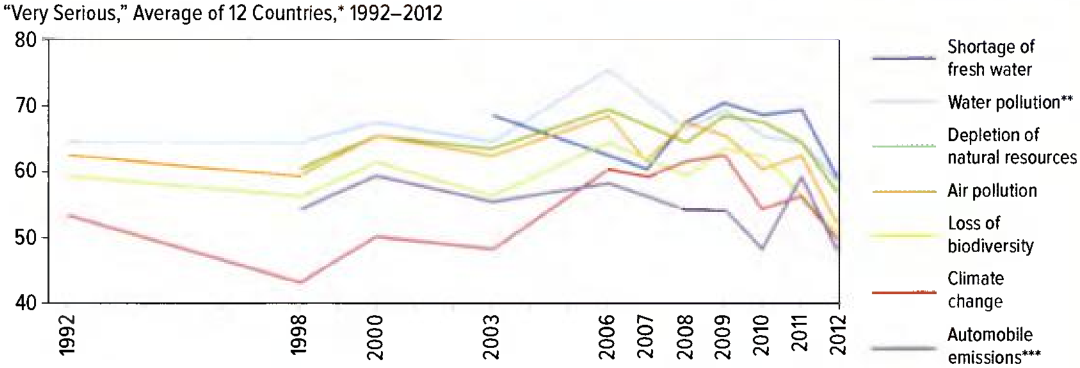
Note the units on the axes and the numbering on the scales of line graphs and bar graphs.
Does the graph use very large units or very small ones?

Look for and describe patterns in the shape of a line graph.
Line graphs show relationships between two sets of numbers. How does an increase in the numbers on the *x*-axis affect the numbers on the *y*-axis? Is the graph a straight line or a curved one? Does it increase or decrease as you look at it from left to right? Does the line zigzag up and down regularly?

Compare the size of the bars in a bar graph.
Describe any pattern you see in how the height of the bar changes between categories.



Relative Seriousness of Issues
"Very Serious," Average of 12 Countries,* 1992–2012



*Average of Brazil, Canada, China, France, Germany, India, Indonesia, Mexico, Nigeria, Turkey, UK, and USA. Not all questions were asked in all countries in all years.
**Not asked in Brazil, Canada, and France
***Not asked in Brazil and Canada

Appendix C: References

Electrostatic Repulsion and Attraction

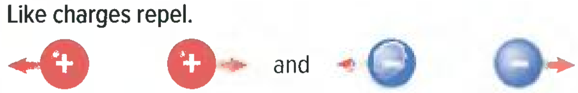
Have you ever noticed that when you rub two different materials against each other, they attract? For example, when you pull off a wool sweater and it rubs against your hair, your hair and the sweater will stick together. Why does this happen? The answer has to do with how electrically charged objects interact.

Opposites Really Do Attract

Electric charge is a physical property of matter, and can be positive or negative. Materials that have an excess of either positive or negative charge are said to be charged, or to carry an electric charge. (Uncharged objects are said to be neutral.) Charged objects attract and repel one another in predictable ways. Their behaviour is summarized by the law of electric charges, shown below.

Laws of Electric Charges

1. Like charges repel.



2. Opposite charges attract.

3. Charged and neutral objects attract each other.

The degree to which two charged objects attract or repel one another depends on the distance between the charges and the amount of charge:

- The greater the distance, the weaker the attraction or repulsion (and vice versa).
- The greater the magnitude of the charges, the stronger the attraction or repulsion (and vice versa).

For example, two positive charges will repel each other strongly when close together, but if you move them apart the repulsion will decrease until it is effectively zero. A positive charge of 4+ will attract a negatively charged object more strongly than a positive charge of 1+ would.

Electrons, Protons, and Electric Charge

Electrons are negatively charged and protons are positively charged. The magnitude of their charge is equal: electrons have a charge of 1– and protons have a charge of 1+. (Neutrons are neutral—they do not have a charge.) Electrons and protons attract one another, but electrons repel other electrons, and protons repel other protons.

So why did the sweater stick to the hair? Before the materials were rubbed together they had the same number of positive and negative charges. They were electrically neutral. But when the materials came in contact, electrons moved from the hair to the wool. The wool gained an overall negative charge, and the hair gained an overall positive charge. They then had opposite charges and attracted one another.

Wool, hair, and other materials become charged through the movement of electrons, not protons. This is due to the structure of the atom. Electrons exist in energy shells surrounding the atom, and can move from atom to atom and from one material to another. Protons, however, are bound in the nucleus of atoms and cannot move from one material to another.

Answers to Unit 2 Practice Problems

Page 79

1. a) $NaBr$
   b) K_2S
   c) ZnI_2
   d) Mg_3N_2
2. a) NaI
   b) ZnO
   c) $MgCl_2$
   d) K_2Se
   e) Ag_2S
   f) AlI_3
   g) AlP
   h) Ba_3P_2
   i) CaS
   j) $RbBr$
3. AgI

Page 81

1. a) cobolt(III) oxide
   b) copper(I) bromide
   c) copper(II) chloride
   d) manganese(IV) sulfide
2. a) iron(II) oxide
   b) copper(I) nitride
   c) tin(IV) sulfide
   d) tin(II) nitride
   e) nickel(III) sulfide
   f) molybdenum(III) chloride
   g) lead(IV) fluoride
   h) titanium(IV) sulfide

Page 83

1. a) $Ba(NO_3)_2$
   b) K_2CO_3
   c) $NiSO_4$
   d) $Mg_3(PO_4)_2$
   e) $Na_2Cr_2O_7$
   f) $FeCrO_4$
   g) $Pb(CH_3CO_2)_4$
   h) $(NH_4)_2SO_4$
2. a) Na_3PO_4; P is not phosphate
   b) $Mg(NO_3)_2$; should be neutral and two nitrate ions needed
   c) K_2SO_3; should be neutral and two potassium ions needed
   d) $NaOH$; brackets not needed
   e) NH_4Cl; incorrect representation of ammonium ion
   f) $NaCH_3COO$; only one acetate ion needed
   g) $K_2Cr_2O_7$; brackets not needed for metal ion

Page 88

1. a) SF_4
   b) S_2F_2
   c) N_2O_3
   d) OF_2
   e) NBr_3
   f) I_2Cl_6
2. a) phosphorus triiodide
   b) sulfur dioxide
   c) sulfur trioxide
   d) disulfur decafluoride
   e) carbon tetrachloride
   f) dinitrogen pentoxide
   g) dinitrogen oxide
   h) nitrogen triiodide
   i) diphosphorus pentoxide
   j) phosphorus pentabromide
   k) diarsenic trisulfide
   l) iodine trichloride

Glossary

How to Use This Glossary

This Glossary provides the definitions of the key terms that are shown in boldface type in the text. Definitions for terms that are italicized within the text are included as well. Each glossary entry also shows the number(s) of the topic(s) where you can find the terms in their original contexts.

A

abiotic non-living components of an environment (4.1)

algal bloom overgrowth of algae in water that occurs under certain temperature and nutrient conditions (1.4)

alkali metals a group of metals found in Group 1 of the periodic table; are shiny, soft, and highly reactive with many substances (2.2)

alkaline-earth metals a group of metals found in Group 2 of the periodic table; shiny, soft, and highly reactive, but not as much as the alkali metals (2.2)

ampere unit used to measure electrical current (3.3)

artificial vegetative propagation the use of asexual reproductive methods to produce plants with specific qualities or features; used by people such as horticulturalists, gardeners and plant nurseries (1.2)

asexual reproduction reproduction that requires only one parent and produces genetically identical offspring (1.1)

atmosphere the layer of gases above Earth's surface (4.1)

atomic mass the average mass of an atom of an element (2.2)

atomic number the number of protons in an atom's nucleus; used to identify an element and its place in the periodic table (2.2)

atomic radius the distance from the centre of an atom to the boundary of the surrounding area occupied by the electrons; is a measure of the size of an atom (2.3)

B

battery a connection of two or more cells (3.2)

binary covalent compound a compound made up of the atoms of two elements joined by covalent bonds (2.5)

binary fission a type of asexual reproduction in which a cell splits into two daughter cells that have identical genetic information (DNA) (1.2)

binary ionic compound a compound made up of ions of one metal element and ions of one nonmetal element (2.5)

bioaccumulation the process by which pollutants collect in the cells and tissues of organisms (4.4)

biodiversity the variety (diversity) of all species of living things, the genetic information stored in their cells, and the environments in which they live and interact (1.4)

biomagnification the increase in concentration of pollutants in tissues or organisms that are at successively higher levels in a food chain or food web (4.4)

biosphere all the regions of Earth where there is life (4.1)

biotic living components of an environment (4.1)

budding a type of asexual reproduction that involves the formation of an outgrowth, or bud, from a parent cell (1.2)

C

cell cycle a series of events in the life cycle of a cell (1.2)

cellular respiration chemical reactions in the cells of most organisms that releases the energy needed to carry out life processes (4.2)

charging by friction charging a material by rubbing it (3.2)

chemical energy energy stored in chemical bonds (3.1)

chemical property the ability of matter to react with another substance to form one or more new substances with new properties (2.1)

chemical reaction a process in which the atoms of one or more pure substances are rearranged to form a different substance or substances (2.1)

chromosome genetic material that is a condensed form of DNA (1.1)

chromatin a structure that a cell's genetic material forms in the nucleus (1.1)

clone an exact copy of a cell or organism (1.2)

compound a pure substance made up of two or more elements; can be broken down into elements by chemical means (2.1)

conductivity an indication of how easily charges travel through a material (3.3)

conductor a material charges can travel through (3.3)

connections with place the First Peoples idea that knowledge, culture, and identity are intimately connected to the local territories (the places) where they live (xxvi)

consumers living things that consume (eat) producers or other consumers to get the energy they need to live (4.3)

continuity the idea that "like produces like", enabling a species to continue to exist over time from one generation to another (1.1)

covalent bond a strong attraction between atoms that forms when atoms share valence electrons (2.4)

covalent compound a compound made up of molecules (2.4)

current moving charges (3.3)

cytokinesis the stage of the cell cycle, after mitosis, when the cell cytoplasm divides and two independent cells form (1.2, 1.3)

D

daughter cell a new cell that is produced when a cell divides; forms from cell division of a parent cell (1.2, 1.3)

decomposers living things that break down dead organic material, such as dead plant or animal tissue, to obtain the energy they need to live (4.3)

deoxyribonucleic acid stores the genetic information of an organism; represented as DNA (1.1)

diploid a cell with a complete set of chromosomes (1.3)

DNA molecule that stores the genetic information of an organism; short for deoxyribonucleic acid (1.1)

DNA sequence the specific order in which nucleotides are linked together in DNA (1.1)

double bond a covalent bond that results from atoms sharing two pairs of electrons (2.4)

dry cell a cell that contains an electrolyte made of a paste (3.2)

E

ecosystem services the benefits that organisms receive from the environment and its resources (4.1)

electrical circuit at a minimum, a source, a load, and wires that allow current to flow (3.3)

electrical energy the energy of charged particles (3.1)

electrical potential difference the amount of electrical potential energy that a unit of charge can gain when passing through a source (3.3)

electrical power the rate at which electrical energy is used by a load (3.5)

electrochemical cell (cell) a source of energy that produces an electric current by chemical reactions involving two different metals or metal compounds that are separated by a conducting solution (3.2)

electrode one of two metal terminals in a cell or battery (3.2)

electrolyte a solution or paste that conducts charge (3.2)

element a pure substance that cannot be broken down into simpler substances by physical or chemical means (2.1)

embryonic stage in human prenatal (before birth) development, the period during the first eight weeks of pregnancy

EnerGuide label gives details about the amount of energy that an appliance uses in one year of normal use (3.5)

energy pyramid a model that shows the amount of energy available in each level of a food chain (4.3)

ENERGY STAR® identifies a product as meeting or exceeding certain standards for energy efficiency (3.5)

eukaryote an organism composed of one or more cells that consist of a nucleus and other internal structures that are surrounded by membranes (1.2, 1.3)

F

fertilization the combining of male and female reproductive cells (1.3)

fetal stage in human prenatal (before birth) development, the period between the ninth week of pregnancy and birth (1.3)

food chain a model that describes how the stored energy in food is passed on from one living thing to another (4.3)

food web a model of feeding relationships that shows a network of interacting and overlapping food chains (4.3)

formula unit the smallest repeating part of a crystal lattice (2.5)

G

gamete male or female reproductive cell (1.3)

generator device that uses the energy of motion to produce electric current (3.1)

generator system a system that transforms kinetic energy to electrical energy (3.1)

genetic variation variation in the DNA sequences of each individual of a species (1.4)

geosphere the land-forming continental crust above sea level and the oceanic crust at the ocean bottom (4.1)

global climate change a long-term change in Earth's climate (4.4)

global warming an increase in the average temperature of Earth's surface (4.4)

great ocean conveyor belt a massive system of deep-water ocean currents that moves water, nutrients, and thermal energy around Earth (4.2)

greenhouse effect process that absorbs outgoing solar energy in Earth's atmosphere (4.2)

greenhouse gases gases that absorb solar energy in Earth's atmosphere (4.2)

group a vertical column of elements in the periodic table; also called a family (2.2)

H

halogens non-metal elements found in Group 17 of the periodic table, which are highly reactive (2.2)

haploid A cell with half the number of chromosomes as the parent cell (1.3)

heterogeneous mixture a mixture in which particles are not uniformly scattered (2.1)

homogeneous mixture a mixture in which particles are uniformly scattered; also called a solution (2.1)

hydrosphere the water on or near Earth's surface (4.1)

I

inner transition metals found in the two rows of metals shown at the bottom of the periodic table (2.2)

insulator a material charges cannot travel through (3.3)

ion an atom with a positive or negative charge (2.3)

ionic bond a strong attraction that forms between oppositely charged ions (2.4)

ionic compound a compound made of oppositely charged ions (2.4)

interconnectedness the First Peoples idea that everything in the universe is connected and interdependent (xxv)

interphase the growth and development stage of the cell cycle

K

kinetic energy energy of movement (3.1)

L

lattice regular repeating pattern formed by positive and negative ions in ionic compounds (2.4)

law of electric charge scientific law stating that opposite charges attract each other, and like charges repel each other (3.2)

load device that converts electrical energy into another form of energy (3.3)

M

main-group elements/representative elements elements of Groups 1, 2, and 13 to 18 of the periodic table (2.2)

matter anything that has mass and takes up space (2.1)

mechanical energy the sum of kinetic energy and potential energy (3.1)

meiosis the process of cell division that produces haploid sex cells (reproductive cells with half the genetic material as parent cells) (1.3)

metal typically, an element that is hard, shiny, malleable, ductile, and that conducts electricity and heat; found to the left of the zigzag line on the periodic table (2.2)

metalloids elements that have physical and chemical properties of both metals and nonmetals; also called semi-metals (2.2)

mitosis the stage of the cell cycle when the cell's nucleus and genetic material divide (1.2)

mixture a blend of two or more pure substances in which each substance retains its individual properties; can be separated by physical means (2.1)

molecule a particle made up of two or more atoms bonded by covalent bonds (2.4)

mould a type of fungus that grows in the form of long, thread-like eukaryotic cells; has a fuzzy or hairy appearance (1.2)

multivalent metal a metal element that can form two or more types of ions with different charges (2.5)

N

negative charges the charges of electrons (3.2)

network solid consists of non-metal elements containing covalent bonds that connect their atoms in one large network; essentially consist of one giant molecule (2.4)

noble gases non-metal elements found in Group 18 of the periodic table, which are very unreactive (2.2)

non-metal typically, an element that is not shiny, malleable, or ductile, and is a poor conductor of electricity and heat; found to the right of the zigzag line on the periodic table (2.2)

nonrenewable energy sources an energy source that is non-replaceable in a human lifetime (3.5)

nuclear energy energy generated in the forming of new atoms (3.1)

nucleotide chemical building block that DNA is composed of (1.1)

O

organic compound compounds containing hydrogen and carbon (2.5)

P

parallel circuit a circuit that has at least one branch point where the current splits into two or more pathways (3.4)

parent cell a cell that undergoes cell division to produce new cells; divides to produce daughter cells (1.2, 1.3)

period a horizontal row of elements in the periodic table (2.2)

periodic trend a regular variation in the properties of elements based on their atomic structure (2.3)

phantom load electrical energy a device uses when it is turned off (3.5)

photosynthesis chemical reactions in the cells of green plants and plant-like organisms that convert the Sun's light energy into energy that organisms can use for their life processes (4.2)

physical property a characteristic of matter that can be observed or measured without changing its identity (2.1)

pollen a component of flowering plants that contains the male gametes for reproduction (1.3)

polyatomic ion a charged molecule

positive charges the charges of protons (3.2)

potential energy stored energy that a system has due to its position or condition (3.1)

producers living things that produce (make) their own food to get the energy they need to live (4.3)

prokaryote single-celled organism that lacks a nucleus and internal structures are not surrounded by membranes (1.2)

pure substance matter that has a definite composition and cannot be separated by physical means; substance has the same meaning (2.1)

R

renewable energy sources an energy source that is available on a continuous basis (3.5)

renewal the First Peoples idea that change is cyclical—it recurs in a regular pattern (xxvi)

resistance describes the amount that current is hindered by a load (3.3)

S

semi-metal an element that shares some properties with metals and some properties with non-metals (2.2)

series circuit a circuit in which current can only flow along one path (3 4)

sexual reproduction reproduction that requires two parents and produces genetically different offspring (1.1)

shaft rod that connects a turbine to a generator; as the turbine spins, the shaft spins (3.1)

short circuit a circuit with a resistance that is too low, making the current so high that it is dangerous (3.3)

smart growth strategy focused on concentrating growth in the centre of a city, rather than in outlying areas (4.5)

smart meters electrical energy meters that measure how energy use changes in a building over the course of the day (3.5)

solar energy energy carried by electromagnetic radiation given off by the Sun (3.1)

solution a homogeneous mixture of two or more pure substances (2.1)

source anything that supplies electrical energy (3.3)

spore a structure that produces a new organism by asexual reproduction (1.2)

sustainability the ability of the environment and the organisms that it supports to endure into the future (1.1; 4.1)

sustainable energy system a sustainable way of perceiving, producing, and using energy (3.5)

T

thermal energy energy due to the motion of the particles that make up an object; detected as heat (3.1)

Traditional Ecological Knowledge (TEK) the detailed local knowledge that First Peoples have as a result of their relationships with the particular places where they live (xxii)

transformation the First Peoples idea that things change or move from one form or state to another (xxv)

transition elements elements of Groups 3 to 12 of the periodic table (2.2)

transpiration process by which water is absorbed by the roots of plants, carried through the plant, and lost as water vapour through small pores in the leaves (4.4)

triple bond a covalent bond that results from atoms sharing three pairs of electrons (2.4)

turbine spinning device used in an electric generator to create motion that produces electrical current (3.1)

V

valence electrons the electrons in the outermost occupied electron shell of an atom (2.3)

valence shell the outermost occupied electron shell of an atom (2.3)

vegetative propagation asexual reproduction of a plant from a part of its roots, stems, or leaves (1.2)

W

water pollution any physical, biological, or chemical change in water quality that has an adverse effect on organisms or that makes water unsuitable for desired uses (4.4)

wet cell a cell that contains a liquid electrolyte (3.2)

Z

zygote the cell produced when the nuclei of two gametes fuse together; the fertilized egg in sexual reproduction (1.3)

Index

F

G

R

S

Credits

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Periodic Table of the Elements

(light blue box)	metal
(thick-bordered box)	semi-metal
(yellow box)	non-metal
O	natural
Db	synthetic

Atomic Number	22
Symbol	Ti
Name	Titanium
Atomic Mass	47.9
Ion charge(s)	4+ 3+

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	1 1+ H Hydrogen 1.0																	2 0 He Helium 4.0
2	3 1+ Li Lithium 6.9	4 2+ Be Beryllium 9.0											5 B Boron 10.8	6 C Carbon 12.0	7 3− N Nitrogen 14.0	8 2− O Oxygen 16.0	9 1− F Fluorine 19.0	10 0 Ne Neon 20.2
3	11 1+ Na Sodium 23.0	12 2+ Mg Magnesium 24.3											13 3+ Al Aluminum 27.0	14 Si Silicon 28.1	15 3− P Phosphorus 31.0	16 2− S Sulfur 32.1	17 1− Cl Chlorine 35.5	18 0 Ar Argon 39.9
4	19 1+ K Potassium 39.1	20 2+ Ca Calcium 40.1	21 3+ Sc Scandium 45.0	22 4+ 3+ Ti Titanium 47.9	23 5+ 4+ V Vanadium 50.9	24 3+ 2+ Cr Chromium 52.0	25 2+ 3+ 4+ Mn Manganese 54.9	26 3+ 2+ Fe Iron 55.8	27 2+ 3+ Co Cobalt 58.9	28 2+ 3+ Ni Nickel 58.7	29 2+ 1+ Cu Copper 63.5	30 2+ Zn Zinc 65.4	31 3+ Ga Gallium 69.7	32 4+ Ge Germanium 72.6	33 3− As Arsenic 74.9	34 2− Se Selenium 79.0	35 1− Br Bromine 79.9	36 0 Kr Krypton 83.8
5	37 1+ Rb Rubidium 85.5	38 2+ Sr Strontium 87.6	39 3+ Y Yttrium 88.9	40 4+ Zr Zirconium 91.2	41 3+ 5+ Nb Niobium 92.9	42 2+ 3+ Mo Molybdenum 95.9	43 7+ Tc Technetium (98)	44 3+ 4+ Ru Ruthenium 101.1	45 3+ 4+ Rh Rhodium 102.9	46 2+ 4+ Pd Palladium 106.4	47 1+ Ag Silver 107.9	48 2+ Cd Cadmium 112.4	49 3+ In Indium 114.8	50 4+ 2+ Sn Tin 118.7	51 3+ 5+ Sb Antimony 121.8	52 2− Te Tellurium 127.6	53 1− I Iodine 126.9	54 0 Xe Xenon 131.3
6	55 1+ Cs Cesium 132.9	56 2+ Ba Barium 137.3	57 3+ La Lanthanum 138.9	72 4+ Hf Hafnium 178.5	73 5+ Ta Tantalum 180.9	74 6+ W Tungsten 183.8	75 4+ 7+ Re Rhenium 186.2	76 3+ 4+ Os Osmium 190.2	77 3+ 4+ Ir Iridium 192.2	78 4+ 2+ Pt Platinum 195.1	79 3+ 1+ Au Gold 197.0	80 2+ 1+ Hg Mercury 200.6	81 1+ 3+ Tl Thallium 204.4	82 2+ 4+ Pb Lead 207.2	83 3+ 5+ Bi Bismuth 209.0	84 2+ 4+ Po Polonium (209)	85 1− At Astatine (210)	86 0 Rn Radon (222)
7	87 1+ Fr Francium (223)	88 2+ Ra Radium (226)	89 3+ Ac Actinium (227)	104 Rf Rutherfordium (265)	105 Db Dubnium (268)	106 Sg Seaborgium (269)	107 Bh Bohrium (270)	108 Hs Hassium (269)	109 Mt Meitnerium (278)	110 Ds Darmstadtium (281)	111 Rg Roentgenium (280)	112 Cn Copernicium (285)	113 Nh Nihonium (286)	114 Fl Flerovium (289)	115 Mc Moscovium (289)	116 Lv Livermorium (293)	117 Ts Tennessine (294)	118 Og Oganesson (294)

58 3+ 4+ Ce Cerium 140.1	59 3+ 4+ Pr Praseodymium 140.9	60 3+ Nd Neodymium 144.2	61 3+ Pm Promethium (145)	62 3+ 4+ Sm Samarium 150.4	63 3+ 2+ Eu Europium 152.0	64 3+ Gd Gadolinium 157.3	65 3+ 4+ Tb Terbium 158.9	66 3+ Dy Dysprosium 162.5	67 3+ Ho Holmium 164.9	68 3+ Er Erbium 167.3	69 3+ 2+ Tm Thulium 168.9	70 3+ 2+ Yb Ytterbium 173.0	71 3+ Lu Lutetium 175.0
90 4+ Th Thorium 232.0	91 5+ 4+ Pa Protactinium 231.0	92 6+ 4+ 5+ U Uranium 238.0	93 5+ 3+ 4+ 6+ Np Neptunium (237)	94 4+ 6+ 3+ 5+ Pu Plutonium (244)	95 3+ 4+ 5+ 6+ Am Americium (243)	96 3+ Cm Curium (247)	97 3+ 4+ Bk Berkelium (247)	98 3+ Cf Californium (251)	99 3+ Es Einsteinium (252)	100 3+ Fm Fermium (257)	101 2+ 3+ Md Mendelevium (258)	102 2+ 3+ No Nobelium (259)	103 3+ Lr Lawrencium (262)

Based on mass of C-12 at 12.00.

Any value in parentheses is the mass of the most stable or best known isotope for elements that do not occur naturally.

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ISBN-10: 1-25-965069-3
ISBN-13: 978-1-25-965069-7

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