OPTION B

## Crops around the World

How do agricultural chemicals affect the stability, fertility, and productivity of the soil in different geographical locations?

OPTION C

## Impacts of Human Activity

What chemical reactions naturally occur in soil ecosystems, how does human agricultural activity alter them, and with what consequences?

## 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
- Consider the role of scientists in innovation? AI
- Present the results of the inquiry using language, conventions, and representations appropriate for a specific purpose and audience? C

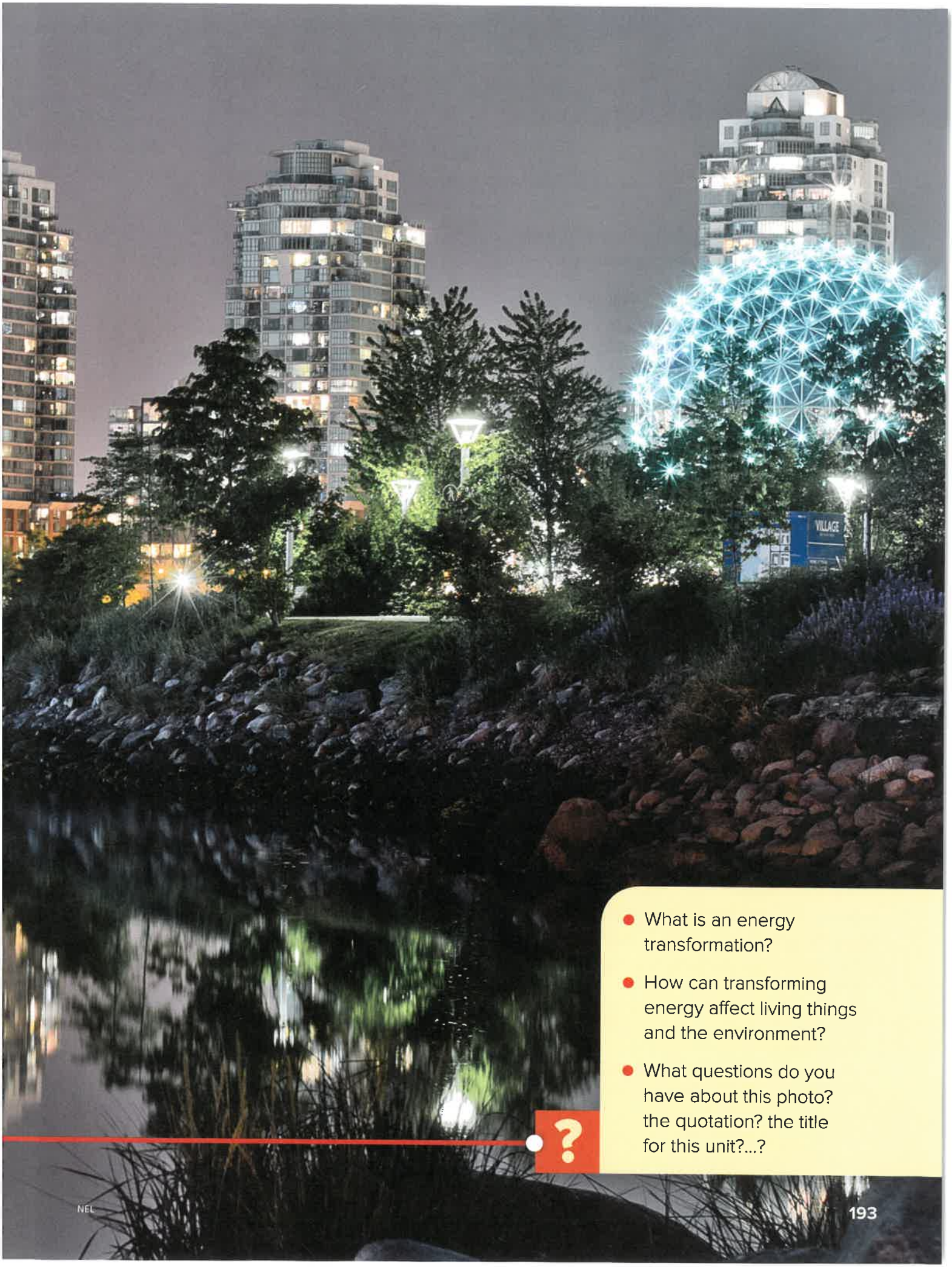
# UNIT 3

# Energy is conserved and its transformation affects living things and the environment.

It takes an enormous amount of electrical energy to light up a city. This energy is transformed from other types of energy—the energy stored in fossil and nuclear fuels, and the energy of the Sun, moving water, and wind. In the future, buildings and the materials used to make them may play a role in transforming energy as well.

**"In the cities of the future, advances such as glass that can harness the sun's power—so skyscrapers could be covered in windows that double as solar panels—have the potential to propel widespread use of solar energy."**

*Dr. James Tansey,*
*executive director of the UBC Sustainability Initiative and the Sauder Centre for Social Innovation and Impact Investing, University of British Columbia*




- What is an energy transformation?
- How can transforming energy affect living things and 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**

- Design and perform investigations to explore the nature and effects of energy transfer and transformation
- Develop and use models and other methods to show connections between different forms of energy
- Develop evidence-based explanations about beneficial and harmful applications of energy transfer and transformation
- Seek patterns and connections to describe, explain, and evaluate local and global impacts of energy transformations

**ESSENTIAL QUESTION**

**How can we investigate and apply our understanding of energy transfer and transformation?**

### TOPIC 3.1:
### What are the properties of energy?

***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:***

- We can investigate energy by observing its effects on other things.
- There are different forms of energy, which can be classified under the categories of kinetic and potential.
- When energy is transferred or transformed, the total amount of energy involved is conserved.

## TOPIC 3.2:
## How is energy transformed?

***Some things you will do:***

- critically analyze the validity of information and evaluate approaches used to solve problems
- generate and introduce new or refined ideas when problem solving

***Some things you will come to know:***

- Energy is transformed in chemical reactions as well as in nuclear reactions.
- Life as we know it could not exist without energy transformations associated with photosynthesis and cellular respiration.
- Nuclear fission and nuclear fusion are the two types of nuclear reactions.

## TOPIC 3.3:
## How does energy transformation affect global systems?

***Some things you will do:***

- use knowledge of scientific concepts to draw conclusions that are consistent with evidence
- demonstrate an awareness of assumptions and bias in your own work and in secondary sources

***Some things you will come to know:***

- The transformation and transfer of energy have local, national, and global effects on weather and climate.
- Negative consequences of energy transformation and transfer must be understood in order to be addressed.

## TOPIC 3.4:
## How does energy transformation affect humans?

***Some things you will do:***

- contribute to finding solutions to problems at a local and/or global level through inquiry
- consider changes in knowledge over time as tools and technologies have developed

***Some things you will come to know:***

- We depend on First Peoples and other ways of knowing to help us revise, extend, and complement ideas of Western science.
- We have responsibilities as individuals, members of local communities, and members of the global community to think and act responsibly with regard to energy-related knowledge and technologies.

# UNIT 3

## Connect To What You Already Know

This feature helps you reflect on what you know about some foundational ideas that you have learned in previous grades. Work alone or quietly in small groups to answer the questions. Reach out to your classmates to ask about things that you are unsure about or to offer assistance. Your teacher also can provide additional reinforcement materials to help you prepare for this unit.

1. Compare and contrast the wave model of light and the particle model of light.
2. Use **Figure 1** on the next page to create a table comparing types of electromagnetic radiation in terms of wavelength, frequency, uses, and any other properties you can think of.
3. Describe three examples of how you interacted with different types of electromagnetic radiation today.
4. Different observations and experiments have led to an understanding of the various properties of electromagnetic radiation. Describe at least three of these properties.
5. Electromagnetic radiation is released by the unstable nuclei of certain atoms.
   a) What are atoms with unstable nuclei called?
   b) What type or types of electromagnetic radiation do these nuclei release?
   c) Is this electromagnetic radiation harmful to living things? Explain your answer.
6. The incredible amount of energy generated on and emitted by the Sun supports life on Earth. Use a labelled sketch to explain the relationships among nuclear fusion, solar energy, and electromagnetic radiation.
7. Use **Figure 2** on the next page to help you describe the role of greenhouse gases in maintaining Earth's average global temperature.
8. Use a Venn diagram to compare and contrast global warming and global climate change.
9. Copy and complete the following table.

| Greenhouse Gas | Natural Sources | Human Sources |
|---|---|---|
| carbon dioxide | | |
| methane | | |
| nitrous oxide | | |
| water vapour | | |

10. Describe three ways that Earth's systems may be affected by an increase in greenhouse gases.
11. Agree or disagree with the following statements. Give reasons for your views.
    a) Global climate change is a consequence of increased levels of greenhouse gases in the atmosphere.
    b) Global climate change will affect Earth's temperature, but not precipitation amounts, wind patterns, or storm severity.
12. Think about what you know about the carbon cycle. Use a flowchart to show
    a) how carbon moves between the biosphere, geosphere, hydrosphere, and atmosphere when fossil fuels (coal, oil, and natural gas) are formed, extracted, and burned
    b) how solar energy travels through and interacts with Earth's spheres

13. Create a comic strip or infographic that shows three ways that humans could act to reduce the amount of greenhouse gases that we contribute to the atmosphere.

14. You have answered questions about several different topics. Use a graphic organizer to identify these topics and outline your understanding of them.

**Figure 1** The electromagnetic spectrum is a model that shows the range (spectrum) of electromagnetic radiation in terms of wavelength.

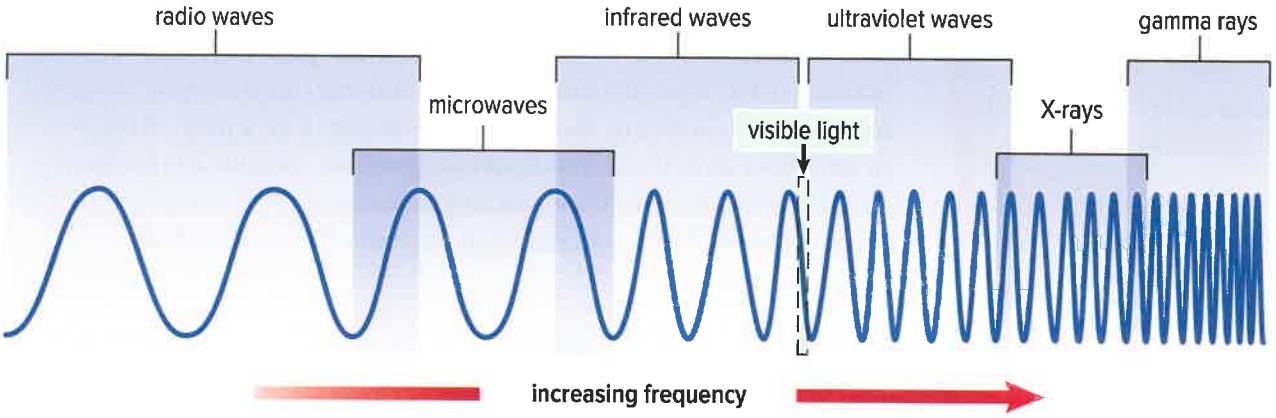
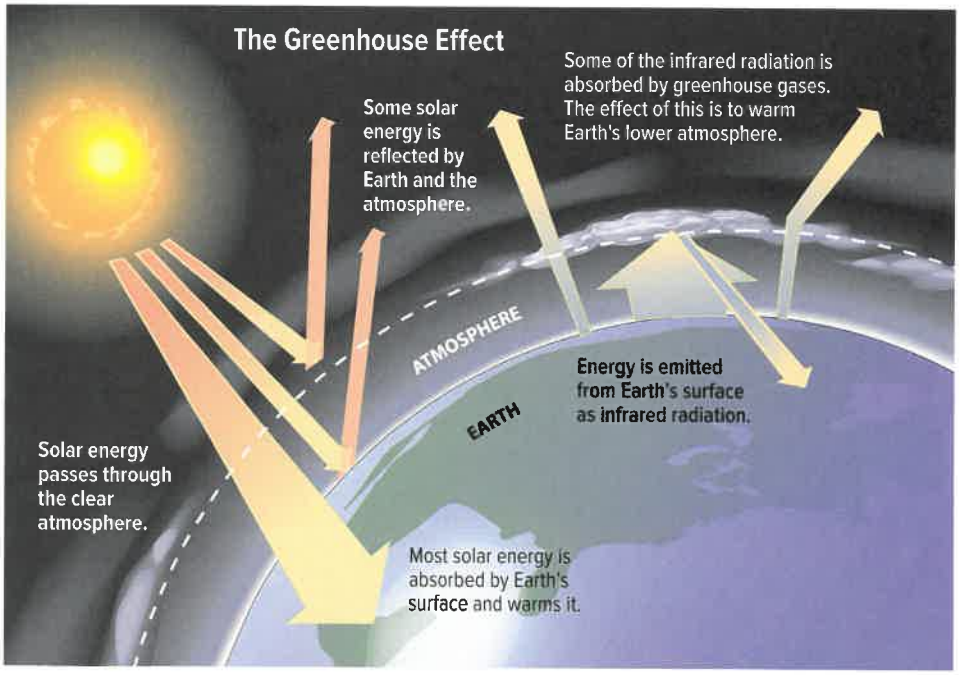



**Figure 2** Most of the solar energy that enters Earth's atmosphere is absorbed by land and water at the surface. Some is reflected by the surface and the atmosphere and passes back into space. Some of the absorbed energy is re-emitted as infrared radiation and absorbed by gases in the atmosphere. The gases that absorb this energy are called greenhouse gases.



TOPIC 3.1

# What are the properties of energy?

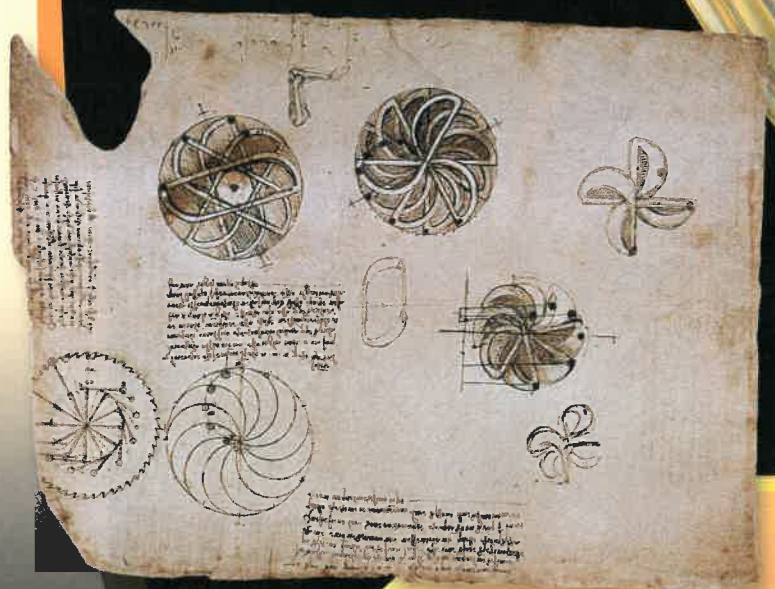
## Key Concepts

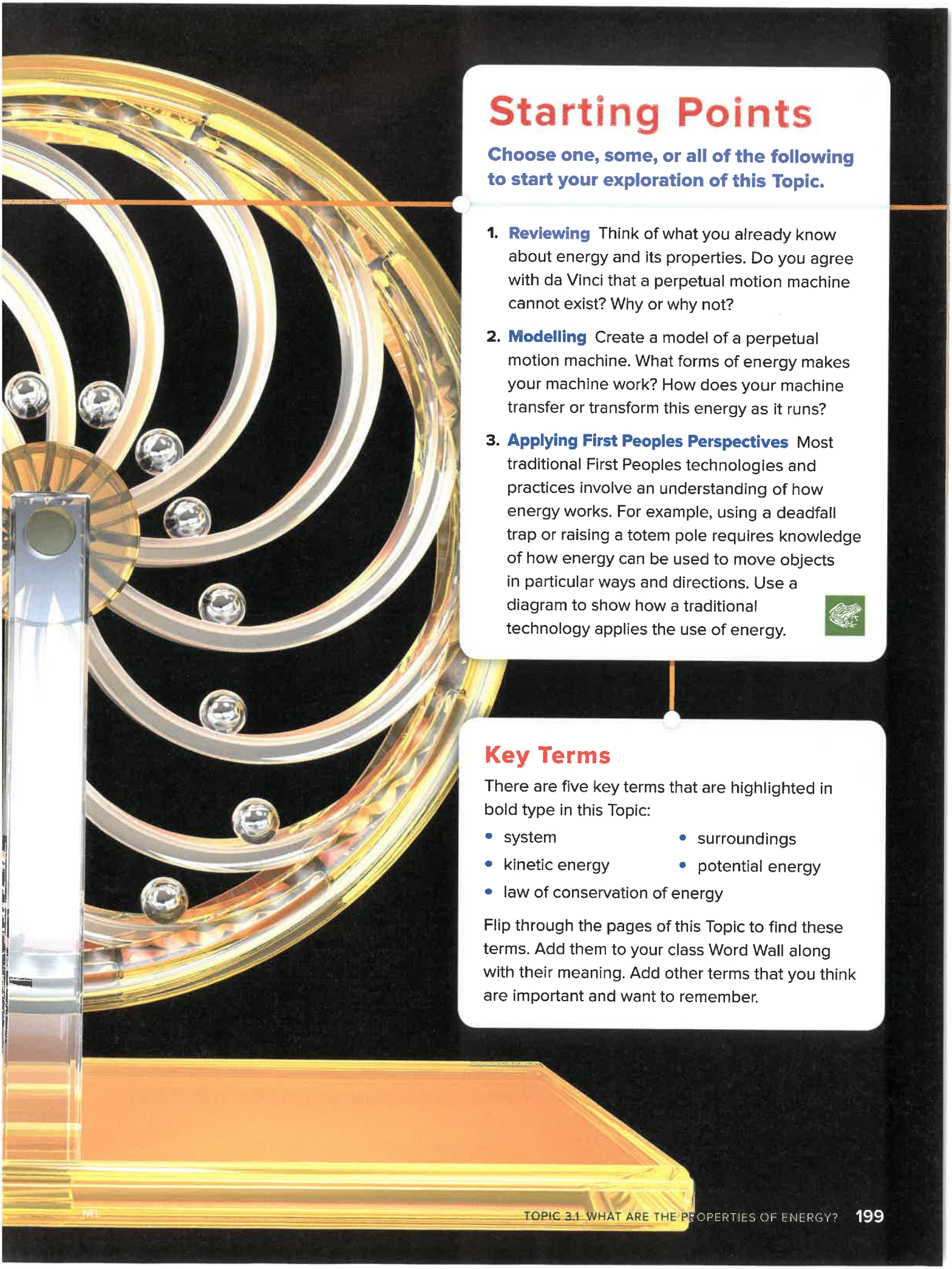
- Energy can produce change in a system.
- There are different forms of energy.
- Energy can be transferred or transformed.
- Physical quantities contribute to different forms of energy.

## Curricular Competencies

- Make observations aimed at identifying your own questions about the natural world.
- Use scientific knowledge to draw conclusions consistent with evidence.
- Generate and introduce new or refined ideas.

A perpetual motion machine is a machine that runs forever. For hundreds of years, it's been the dream of visionaries and gadget lovers alike. The famous Italian artist and thinker, Leonardo da Vinci, drew designs for several perpetual motion machines (inset photo). A modern reproduction of one of da Vinci's machines is shown in the main photo. A perpetual motion machine, were it to actually work, transfers and transforms energy, but energy is never lost. Once it is running, the machine does not need a push, fuel, or any other additional source of energy—ever. Despite his designs, da Vinci believed perpetual motion machines wouldn't, and couldn't, work. But that hasn't stopped countless people from trying to create one.





# Starting Points

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

1. **Reviewing** Think of what you already know about energy and its properties. Do you agree with da Vinci that a perpetual motion machine cannot exist? Why or why not?
2. **Modelling** Create a model of a perpetual motion machine. What forms of energy makes your machine work? How does your machine transfer or transform this energy as it runs?
3. **Applying First Peoples Perspectives** Most traditional First Peoples technologies and practices involve an understanding of how energy works. For example, using a deadfall trap or raising a totem pole requires knowledge of how energy can be used to move objects in particular ways and directions. Use a diagram to show how a traditional technology applies the use of energy.

## Key Terms

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

- system
- surroundings
- kinetic energy
- potential energy
- law of conservation of energy

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

# Energy can produce change in a system.

## Activity

### How Do *You* Describe Energy?

1. Think of an activity you are passionate about or interested in. What roles do energy play in it? For example, what forms does it take? What changes does it bring about? How does energy itself change? Record your ideas.
2. Discuss your ideas in small groups. Work together to come up with a description of what you think energy is.
3. Share and discuss your group's description with the class. Your teacher may add descriptions of energy from other sources as well.

What is **energy**? What does it do? How does it behave? Scientists have asked questions like these about energy for hundreds of years. Defining energy presents a problem, because it cannot be observed directly. Consider a scene like the one in Figure 3. 1. Energy is present in many forms. It's in the air, a walk down the street, and even in a conversation. But it cannot be seen.

Figure 3.1 Energy is all around you. **Analyzing: How is energy present in this image?**

Despite this limitation, scientists can investigate energy indirectly. They do so by observing the effects it has on other things. Over time, by inquiring about such effects, scientists began to develop an understanding of the properties of energy. They found that

- energy can cause change in a system.
- there are different forms of energy, with different characteristics.
- these forms of energy can be transferred or transformed.
- different physical quantities contribute to different forms of energy.

## Energy and Systems

Anything that is under observation can be referred to as a **system**. For example, the person and the bungee cord in Figure 3.2 could be considered a system. Everything that is not part of this system—that is, everything else in the entire universe—is considered the **surroundings**. This idea can be expressed as an equation:

$$\text{universe} = \text{system} + \text{surroundings}$$

**system** anything that is under observation

**surroundings** anything that is not part of a system

Notice that a system is something that we define. One person might define the system in Figure 3.2 as the person jumping and the bungee cord. Someone else might define it as the person, the bungee cord, and the bridge that the cord is attached to. We define a system to help us study the system itself, as well as the parts of the surroundings that interact with it.

Energy produces change in a system. In the case of the person and the cord, the system is moving from a greater height to a lesser height. Energy may be added to the system from its surroundings or released from the system to its surroundings. For example, energy would be added to the system from its surroundings if wind pushed the person and the cord off the bridge. Similarly, energy is being released from the system to its surroundings as air resistance provides friction that slows the jumper down.

**Figure 3.2** This person and cord above the Nanaimo River on Vancouver Island can be considered a system. **Inferring: What are the surroundings of this system?**

## Activity

### Dropper Popper Dilemma

A dropper popper is a special kind of half-ball. You will invert and release it from head height, waist height, and knee height.

1. Write a hypothesis to predict what you think will happen for each drop.
2. Test your hypothesis. How did it compare with your observations?
3. For each drop, identify the system you observed and its surroundings.
4. Discuss your observations and the following questions with your partner, and then with the class.
   - **a)** What change(s) did you observe in the system?
   - **b)** How was energy exchanged between the system and its surroundings?
   - **c)** What other information about energy and its properties could help you explain your observations?

## Before you leave this page . . .

1. **a)** Why can it be a challenge to observe energy directly?
   **b)** How can this challenge be overcome?
2. **a)** Describe a system that could be applied to your classroom.
   **b)** What makes up the surroundings of the system you defined?

CONCEPT 2

# There are different forms of energy.

**kinetic energy** the energy of motion

**potential energy** the stored energy of an object as a result of its condition or its position

At the simplest level, energy may be classified into two main types: kinetic energy and potential energy. **Kinetic energy** is the energy of motion. Anything that is moving has kinetic energy. **Potential energy** is the stored energy an object has as a result of its condition or position. For example, the energy stored in the bonds of a chemical compound is a type of potential energy. So is the energy objects have due to their location relative to a reference point, such as the ground. The mountain bike and its rider in Figure 3.3 have kinetic energy because they are moving and potential energy because they are above the ground. The examples on the next page show different forms of kinetic energy. Examples of the forms of potential energy appear on the pages that follow.

**Figure 3.3** This mountain bike and its rider have both kinetic energy due to their motion and potential energy due to their position. **Inferring:** When will the mountain bike and its rider have the most kinetic energy? When will they have the most potential energy?

## Kinetic Energy


**Mechanical Kinetic Energy**
This is the energy of motion of objects that are larger than atoms and molecules. Any object that is moving has mechanical kinetic energy, from the smallest bacteria to the largest galaxies.

**Radiant Energy**
Radiant energy is the energy of electromagnetic waves that travel or "radiate" from an energy source. For example, light bulbs radiate ultraviolet radiation, visible light, and infrared radiation, which are transformed into thermal energy when they are absorbed by matter. The Sun radiates the entire electromagnetic spectrum. The energy of these waves is often called solar energy. Visible light is often called light energy.

**Thermal Energy**
This is the energy of the random motion of the particles that make up a substance. Particles of matter are always moving. However, the particles of warmer objects are moving faster than those of cooler objects. In common language, we use the word heat to mean the same thing as thermal energy. In science, however, heat and thermal energy are different. *Heat* is defined as thermal energy that is transferred from one object to another.

**Electrical Kinetic Energy**
This is the energy of electrons moving along a wire or other conductor. A load (any electrical appliance) changes the electrical kinetic energy into another form, such as radiant energy. Lightning is also a form of electrical kinetic energy, where the air acts as the conductor.

**Sound Energy**
Sound is the energy of vibrations or disturbances of the particles that make up matter. It travels through substances as a pressure wave. As the wave passes through a substance, its particles vibrate back and forth, colliding with nearby particles. In this way, sound energy travels away from its source.

# Potential Energy

**Chemical Potential Energy**
This energy is stored in chemical bonds. Much of human society relies on the chemical potential energy stored in fossil fuels. Some animals, like the firefly shown here, transform chemical potential energy to produce light.

**Elastic Potential Energy**
This energy is stored in a stretched or compressed object. Elastic potential energy does not just apply to an elastic band or a spring. It applies to any object, like the soles of your shoes when you walk, or the tennis ball and racquet shown here.

**Gravitational Potential Energy**
This energy is due to the position of an object relative to a reference point, such as the ground. A roller coaster at the top of a large hill has more gravitational potential energy than it does at the bottom. This change results in a hair-raising ride.

**Nuclear Energy**
This energy is stored within the nucleus of an atom. Nuclear processes can release an enormous amount of energy. Topic 3.2 explores nuclear energy further.

**Electrical Potential Energy**
This energy is stored by a separation of positive and negative charges, as it is in a cell or battery.


**Magnetic Potential Energy**
A compass needle moves because it's magnetic and is attracted by Earth's magnetic field. If you prevent the needle from moving, it has magnetic potential energy, as it now has the potential to move.

## Activity

### Energy Stations

Visit the different energy stations set up around the room, as per your teacher's instructions. At each station, follow the instructions provided. Then identify the type(s) of energy demonstrated at each station.

## Before you leave this page . . .

1. Use a Venn diagram to compare kinetic and potential energy.
2. Give one example of each of the following:
   a) a form of kinetic energy
   b) a form of potential energy
   c) a form of energy that has both kinetic and potential energy

CONCEPT 3

# Energy can be transferred or transformed.

**law of conservation of energy** law stating that energy is neither created nor destroyed, but is transformed from one form of energy to another or transferred from one object to another

Scientists have conducted thousands of experiments to investigate the properties of energy. The results of these experiments are consistent. The total amount of energy present before energy is transferred or transformed is always exactly equal to the total amount of energy present afterwards. In other words, energy is neither created nor destroyed. Instead, it is transformed from one form of energy to another, or transferred from one object to another. This concept is called the **law of conservation of energy** (Figure 3.4).

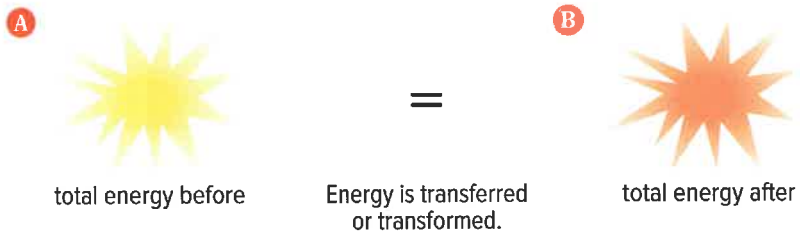



**Figure 3.4** According to the law of conservation of energy, energy present before energy transfer or transformation A is equal to energy present afterward B. The form of energy may change (the shapes differ in colour), but the amount of energy remains equal (the size of the shape is the same).

The transfer and transformation of energy often enables useful tasks to be carried out. For example, observe the system in Figure 3.5. Chemical potential energy is transformed into electrical potential energy in the battery. When a light bulb is placed in a closed circuit, electrical potential energy is transformed into electrical kinetic energy, and current flows. As the current flows through the light bulb, the energy is transformed into radiant energy—visible light, with some infrared and ultraviolet radiation—and thermal energy. Because the light energy lets you see, a useful task is carried out.

## Energy Transformation, Energy Transfer, and Systems

Connect to Investigation 3-A on page 216

No energy transformation is 100 percent efficient. Each time that energy changes form, some of it becomes unusable. For example, the system in Figure 3.5 is designed to transform chemical potential energy into light energy. The thermal energy is an unusable byproduct of this energy transformation. In fact, all energy transformations result in some amount of unusable energy. This idea, and how it is linked to the law of conservation of energy, is shown in Figure 3.6.

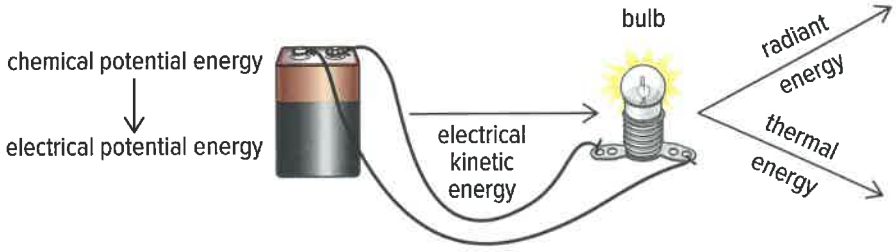



**Figure 3.5** Energy is both transformed and transferred in this image, but it is never destroyed. The result is that a useful task is carried out.

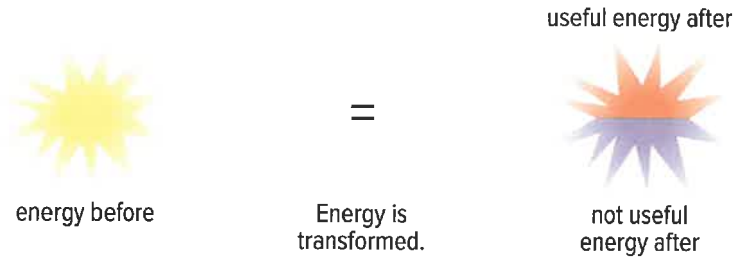



**Figure 3.6** When energy is transformed, some of that energy becomes energy that is not useful to carry out a task. However, total energy is still conserved.

## Types of Systems

Sometimes, non-useful energy is described as "lost." However, whether this energy actually leaves the system depends on which type of system it is—open, closed, or isolated. Each type of system is described in terms of the transformation of energy and the transfer of both energy and matter.

- An open system can exchange both energy and matter with its surroundings.
- A closed system can exchange energy, but not matter, with its surroundings.
- An isolated system cannot exchange energy or matter with its surroundings.

Connect to Unit 2 on page 125

**Figure 3.7** illustrates the three types of systems.

**Open System**

An uncovered pot of potatoes boiling on the stove is an open system. Thermal energy is transferred from the stove burner to the pot and its contents, as well as to the surrounding cooler air. As the water boils, thermal energy is also transformed into the mechanical kinetic energy of rising steam. As the steam leaves the pot, the system loses both matter and energy to the surroundings.

**Closed System**

A pressure cooker with potatoes boiling represents a closed system, because the tightly sealed lid prevents loss of matter and energy to the surroundings in steam. Thermal energy can be transferred into the system from contact between the pot and the stove. It also can be transferred out of the system where the pot contacts the surrounding cooler air and through transformation into radiant energy.

**Isolated System**

The pot of potatoes inside an insulated container represents an isolated system. In theory, the insulation prevents the exchange of any energy or matter between the system and its surroundings. In reality, energy exchange is significantly reduced, but not eliminated entirely. This is because it is hard to completely isolate a system.

**Figure 3.7** An open system, a closed system, and an isolated system are shown. **Applying: Why is it impossible to cook potatoes in an isolated system in real life?**

Connect to Investigation 3-B on page 217

## Comparing Energy Transfer and Transformation

Whenever a system releases energy, the surroundings absorb it. In the same way, when a system absorbs energy, the surroundings release it. These processes can involve either energy transfer, energy transformation, or both. When energy is *transferred*, it stays in the same form. However, when energy is *transformed*, the form of energy always changes. For example, when one pool ball strikes another in Figure 3.8, mechanical kinetic energy is transferred from one ball to the other, but it is also transformed into sound and thermal energy, which are absorbed by the surroundings. We cannot feel the resulting small change in the thermal energy of the surroundings. But, we do hear the vibrating air molecules as sound when it reaches our ears.

**Figure 3.8** In pool, mechanical kinetic energy is transferred from one ball to another, but it is also transformed into sound and thermal energy.

## Activity

### Modelling Energy Transfer and Transformation

1. Build a catapult with the materials provided by your teacher.
2. Experiment with the design of your catapult to determine changes that affect its performance.
3. Record all the ways that energy is transformed and transferred as your catapult operates.
4. Using your observations, try to determine what variables affected energy transformation in the catapult. To answer this question, consider how changes to your design affected a certain function. For instance, if you used an elastic band in your design, did the length or thickness of the band affect the distance the catapult was able to throw an object? What type of energy might have been affected by this variable?

### Before you leave this page . . .

1. Describe the law of conservation of energy.
2. How do energy transfer and transformation differ? How are they similar?
3. Use an example from your everyday life to show how you could change an open system to **a)** a closed system and **b)** an isolated system.

CONCEPT 4

# Physical quantities contribute to different forms of energy.

## Activity

### Energy Thought Experiments

Thought experiments are experiments done in your mind. Complete the ones below to determine the physical quantities that contribute to mechanical kinetic energy and gravitational potential energy. Justify your answers.

**Experiment 1: Mechanical Kinetic Energy**

1. A bowling ball and a table tennis ball are rolling toward your foot with the same speed. Which would you try hardest to avoid?
2. Two identical golf balls are rolling toward your foot. One is coming at you slowly, and the other is coming toward you very quickly. Which would you try hardest to avoid?
3. Based on your answers to questions 1 and 2, what physical quantities do you think affect mechanical kinetic energy?

**Experiment 2: Gravitational Potential Energy**

1. A bowling ball and a tennis ball are dropped from a height of 10 m. Which one would hit the ground harder?
2. If one bowling ball is dropped from a height of 10 cm and another is dropped from a height of 10 m, which one would hit the ground harder?
3. Which golf ball would hit the surface with the greatest impact: a ball dropped from 1 m above Earth's surface or a ball dropped from 1 m above the Moon's surface? (Refer to Appendix C.)
4. What physical quantities do you think affect gravitational potential energy?

Experience tells you that different physical quantities contribute to different forms of energy. For example, you know that if you throw different balls at a target, as in Figure 3.9, the mass and speed of each ball affect whether it can knock over the target. This means that both mass and speed contribute to the mechanical kinetic energy of a system.

On the other hand, observing the impact of falling objects, as in Figure 3.10, tells you that mass and the height from which they begin their fall contribute to an object's gravitational potential energy. You also know that Earth exerts a gravitational pull on objects. Any object that is thrown up comes down again. This helps you understand that the force of gravity affects gravitational potential energy as well.

Figure 3.9 A faster ball with greater mass would be more likely to knock over the target in this game.

Figure 3.10 Gravity, the mass of these rocks, and the height from which they begin their fall contribute to their gravitational potential energy.

## Visualizing Physical Quantities That Affect Kinetic and Potential Energy

Figure 3.11 shows how different physical quantities affect the mechanical kinetic and gravitational potential energy of a person and a sled. In the figure, gravitational potential energy (GPE) is being transformed into mechanical kinetic energy (KE) and back again as the sled travels down one hill and up another. Note that the gravitational potential energy of an object is always compared to a reference position. This can be any position you choose, but it is often the surface toward which the object is falling or might fall. In Figure 3.11, the reference position is the ground at the base of each hill.


**Figure 3.11**
Gravitational potential energy (GPE) is transformed into mechanical kinetic energy (KE) and back again in this sled run. After the sled stops on the second hill, it will slide backward down the hill as the remaining GPE is once again transformed into mechanical KE. **Analyzing: Which physical quantity is not changing in this scenario for KE? for GPE?**

**Why doesn't the sled make it up the second hill?**

Gravitational potential energy isn't just transformed into mechanical kinetic energy as the sled travels. It's also transformed into unusable thermal energy and sound energy. This unusable energy is the product of *friction*. When two surfaces touch, attractive forces form between the atoms that are in contact with each other. When the sled travels over the snow, these forces are continually broken and reformed, producing thermal energy and sound energy. The farther the sled travels, the more energy leaves the system (person and sled) in this way. When it reaches the second hill, it doesn't have enough energy to go all the way up.

The sled stops when it is almost at the top of the second hill. It does not have enough mechanical kinetic energy to keep going.

- The sled is not moving, so it has no KE.
- Height above the reference point is less than it was at the top of the highest hill, so GPE is less than it was at the beginning of the sled run.

The sled is partway up the second hill.

- The sled is decreasing in speed. KE is decreasing.
- Height above the reference point is increasing, so GPE is increasing.

Connect to Investigation 3-C on page 218

## Energy Equations

Many forms of energy can be described mathematically. The equations describing mechanical kinetic energy and gravitational potential energy are given below. Your teacher may choose to assign the two activities that follow, which introduce you to approaches for how to solve problems that involve these forms of energy.

### Mechanical Kinetic Energy (KE)

The formula shown here is the mathematical relationship between an object's mechanical kinetic energy and its mass and velocity. The term *velocity* refers to the speed that something is moving in a specific direction.

$$E_k = \frac{1}{2}mv^2$$

| Quantity | Symbol | SI unit |
|---|---|---|
| mechanical kinetic energy | $E_k$ | J (joule) |
| mass | $m$ | kg (kilogram) |
| velocity* | $v$ | $\frac{\text{m}}{\text{s}}$ (metres per second) |

** Velocity is squared in the calculations for mechanical kinetic energy.*

### Gravitational Potential Energy (GPE)

The formula shown here is the mathematical relationship between an object's gravitational potential energy and its mass, the acceleration due to gravity (9.8 $\text{m/s}^2$), and the change in height. Acceleration due to gravity is the rate at which an object's velocity increases when it falls toward Earth and there is no friction to slow it down.

$$E_g = mg\Delta h$$

| Quantity | Symbol | SI unit |
|---|---|---|
| gravitational potential energy | $E_g$ | J (joule) |
| mass | $m$ | kg (kilogram) |
| acceleration due to gravity | $g$ | $\frac{\text{m}}{\text{s}^2}$ (metres per second squared) |
| change in height (from reference position) | $\Delta h$ | m (metre) |

Note: The SI unit for energy is the joule (J), which is equivalent to a $\text{kg} \cdot \frac{\text{m}^2}{\text{s}^2}$. One joule is needed to lift one large kiwi fruit (about 100 g) a distance of 1 m. Since the energy represented by a joule is very small, it is often expressed in kilojoules (1 kJ = 1000 J).

## Activity

### Energy Equation Thought Problems

Use the equations on the previous page to determine how mechanical kinetic and gravitational potential energy are affected in the following problems. Explain your answer in each case.

1. Two cars are driving at the same velocity, but one has twice the mass of the other. Is the mechanical kinetic energy of the larger car two times, three times, or four times that of the smaller car?
2. You are skateboarding to school and realize that you are late. If you double your pace, by what factor would your mechanical kinetic energy increase?
3. Two rock climbers of the same mass are climbing a cliff.
   a) One stops to rest at a position that is 50 m above the ground. The other climber stops at a height of 25 m above the ground. Which one has greater gravitational potential energy?
   b) Would the climbers have more or less gravitational potential energy if they were climbing a cliff on the Moon?

## Activity

### Energy Equation Calculation Problems

Study the following sample problem to understand how to use the two energy equations you just learned. Then solve the practice problems.

### Sample Problem

A 45 kg boulder is sitting on a cliff that is 125 m high.

a) How much gravitational potential energy does the boulder have with respect to the bottom of the cliff?

b) If the boulder rolls off the cliff and falls to the ground, at what velocity will it be falling just before it hits the ground? Ignore friction with the air.

#### Solution

a) Substitute the known values into the gravitational potential energy equation.

$$\begin{aligned} E_g &= mg\Delta h \\ &= 45 \text{ kg} \times 9.8 \frac{\text{m}}{\text{s}^2} \times 125 \text{ m} \\ &= 55\,125 \frac{\text{kg} \cdot \text{m}^2}{\text{s}^2} \\ &\cong 5.5 \times 10^4 \text{ J} \end{aligned}$$

The answer has two significant digits because two is the fewest number of significant digits in the data. The answer has been converted into scientific notation.

**b)** Rearrange the mechanical kinetic energy equation to determine the velocity ($v$). To do this, divide both sides of the equation by $m$ and multiply both sides by 2. Then take the square root of both sides of the equation.

$$E_k = \frac{1}{2}mv^2$$

$$\frac{E_k}{m} = \frac{\frac{1}{2}mv^2}{m}$$

$$\frac{E_k}{m} = \frac{1}{2}v^2$$

$$\frac{E_k}{m} \times 2 = \frac{1}{2}v^2 \times 2$$

$$\frac{E_k}{m} \times 2 = v^2$$

$$v = \sqrt{\frac{E_k \times 2}{m}}$$

Now substitute the known values into the mechanical kinetic energy equation. Because energy is conserved, all the potential energy the boulder had at the top of the cliff is transformed into mechanical kinetic energy at the bottom. Thus, the total mechanical kinetic energy of the boulder at the instant before it hits the ground is 55 125 J, the unrounded answer from part a). When you use one answer in a calculation for another part of a question, always use the unrounded number. Again, the answer has two significant digits because two is the fewest number of significant digits in the data.

$$v = \sqrt{\frac{55\,125\ \frac{\text{kg} \cdot \text{m}^2}{\text{s}^2} \times 2}{45\ \text{kg}}}$$

$$v = \sqrt{2450\ \frac{\text{m}^2}{\text{s}^2}}$$

$$v = 49.497\ \frac{\text{m}}{\text{s}}$$

$$v \cong 49\ \frac{\text{m}}{\text{s}}$$

## Practice Problems

1. A 54 kg skier, including equipment, stands at the top of a black diamond ski run. The vertical distance to the bottom of the run is 420 m. What is the gravitational potential energy of the skier relative to the bottom of the ski run?
2. A satellite has a mass of 689 kg and travels at a speed of 27 000 km/h (7500 m/s). How much mechanical kinetic energy does the satellite have?
3. A bowling ball is rolling down the lane at 2.8 m/s. If it has a mechanical kinetic energy of 25.5 J, what is its mass?
4. A person who has a mass of 65 kg goes on the Sky Tower ride at an amusement park. The ride is simply a free fall from the top of a tower into a net below. If the person reaches a final velocity of 24.6 m/s just before hitting the net, from what height did the rider drop? Ignore friction with the air.

## Before you leave this page . . .

1. What physical quantities affect **a)** mechanical kinetic energy and **b)** gravitational potential energy?
2. Why might it appear that the law of conservation of energy does not apply to the sled in Figure 3.11?

# 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. Use the photo to answer the following questions. PA

   a) Identify four types of energy in the photo.
   b) Classify each type of energy as either kinetic or potential. Explain your answer in each case.

2. Explain why thermal energy is a form of kinetic energy. PA

3. a) Identify an energy transformation that occurs in your daily life.
   b) Identify an energy transfer you experience every day.
   c) Explain how the energy transformation you described differs from the energy transfer. PA AI

4. Why is no process of energy transformation 100 percent efficient? PA

5. Draw a sketch and write a caption that relates the properties of an open mug, a travel mug covered by a lid, and a closed, insulated thermos to the three types of systems. Your answer should explain the differences among the three types of systems. PA C

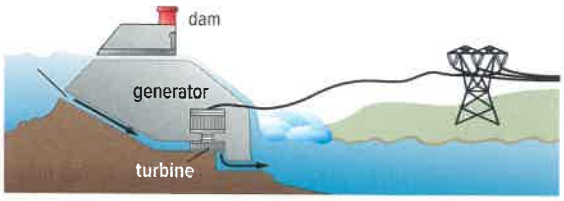
6. Imagine that a referee tosses a basketball straight up and it falls to the floor.
   a) At what point in its journey would the ball's gravitational potential energy be at a maximum?
   b) At what point would the ball have no gravitational potential energy?
   c) At what point would the ball's mechanical kinetic energy be at a maximum?
   d) At what points would the ball have no mechanical kinetic energy? (Hint: This occurs at more than one point.) QP PA AI

## Connecting Ideas

7. a) Identify a system and surroundings in the photo.
   b) Describe how energy enters the system.
   c) Draw a diagram to show how energy is being transformed within the system.
   d) Describe how energy leaves the system.
   e) Explain how the law of conservation of energy applies to the system. PA AI C

## Making New Connections

8. Explain why the amount of electrical energy generated by a hydro dam depends on both the mechanical kinetic energy and the gravitational potential energy of the water shown in the diagram. PA AI



INVESTIGATION
# 3-A

GUIDED INQUIRY

## Build a Rube Goldberg Machine

### Skills and Strategies

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

### What You Need

- materials your team's design requires

Rube Goldberg was a prize-wining cartoonist famous for his drawings of fun machines that perform simple tasks in the most complicated way imaginable. Rube Goldberg machines usually employ a lot of different energy transfers and transformations to get the job done.

### Question

How can you design and build a machine that uses many different energy transformations and transfers to perform a simple task?

### Procedure

1. With your group, choose a task you want to carry out.
2. Design your machine. Sketch your design, complete a list of materials that you will need, and record any safety precautions.
3. Have your teacher approve your sketch, materials list, and safety precautions. Collect the materials you need and build your machine.
4. Test your machine, making any required modifications to improve its performance.

### Process and Analyze

1. Identify each different energy transfer and/or transformation that occurs when you run your machine.

### Evaluate and Communicate

2. a) Did your machine perform its task as planned? Explain.
   b) How might you change your design to improve its performance?

INVESTIGATION
# 3-B

GUIDED/OPEN INQUIRY

## Investigating Energy Transformation and Transfer

In this investigation, you will design and carry out a controlled experiment to answer a question about energy transformation and/or transfer.

### Skills and Strategies

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

### What You Need

**Suggested Materials**

**Question A**

- sand
- empty plastic containers with lids
- laboratory balance
- measuring tape
- scoop
- tray

**Question B**

- toy car track
- marbles of different sizes
- measuring tape
- clamps and supports

**Question C**

- water
- ice
- thermometers
- plastic containers or cups
- variety of insulative materials
- tape

### Questions

**A.** Does the mechanical kinetic energy of a falling object increase if its mass increases?

**B.** When an object rolls down a U-shaped ramp and back up the other side, can it reach the height from which it was released?

**C.** Can you construct an isolated system?

**D.** What question of your own can you investigate?

### Procedure

1. Choose one of the above questions, and develop a hypothesis for it.
2. Design a procedure to test your hypothesis. Decide on the independent and dependent variables. Determine how you will keep other factors constant.
3. Create a data table to record your observations. Plan how you will analyze your data to determine if they support your hypothesis.
4. Have your teacher approve your procedure. Then carry it out.
5. Summarize your results using a method assigned by your teacher.

### Process and Analyze

1. How well do your data support your hypothesis?
2. Describe the energy transformation or transfer in your experiment.

### Evaluate and Communicate

3. Exchange procedures with another group that answered the same question. After reading their procedure, suggest one way that you might improve your own.

INVESTIGATION
# 3-C

STRUCTURED AND GUIDED INQUIRY

## Skills and Strategies

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

## Safety

- Use caution if handling scissors or other sharp utensils.

## What You Need

- materials your team's design requires

# Roller Coaster Physics

## PART A: Roller Coaster Simulation

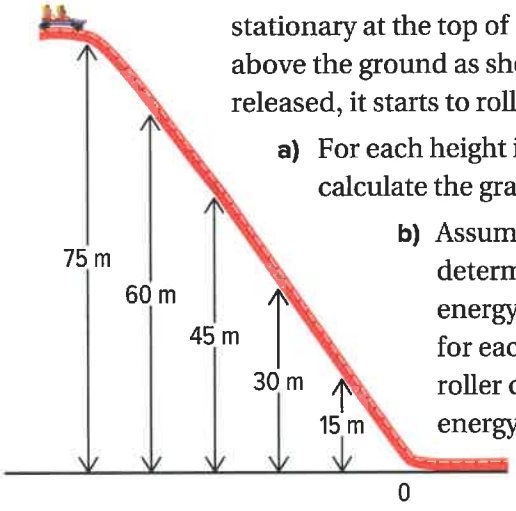
### Question

How are the gravitational potential energy and the mechanical kinetic energy of a roller coaster related?

### Procedure

1. Make a table to record answers to the Step 2 questions. Include columns for height (m), total energy (J), gravitational potential energy (J), mechanical kinetic energy (J), and velocity (m/s).

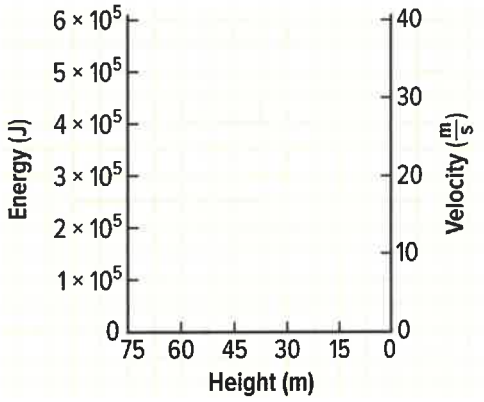
2. A roller coaster with a mass of 800 kg sits stationary at the top of a section of track, 75 m above the ground as shown. When the brake is released, it starts to roll down the track.




   a) For each height indicated in the diagram, calculate the gravitational potential energy.

   b) Assuming that there is no friction, determine the mechanical kinetic energy and calculate the velocity for each of the heights of the roller coaster. (Hint: Recall that energy is conserved.)

   c) Use your answers to graph how gravitational potential energy, mechanical kinetic energy, and velocity change as the roller coaster changes height. Use different colours for the graphs.



## Process and Analyze

1. a) Describe the relationship between the gravitational potential energy and the mechanical kinetic energy of the roller coaster on your graph.
   b) Describe the shape of the three lines in the graph. Explain why the shape is different.
2. At what point does the roller coaster have a maximum value of the following? Justify your responses.
   a) gravitational potential energy
   b) mechanical kinetic energy
   c) velocity
3. In your calculations, you assumed that the roller coaster was frictionless. All real roller coasters encounter friction. Describe how the actual values of the variables would differ, or not differ, from your calculated values for a real roller coaster.

## PART B: Designing and Testing a Model Roller Coaster

You are part of a team that is working to design the world's fastest roller coaster, *The Vortex*. Your responsibility on the team is to design, build, and test the initial model for the roller coaster.

## Question

How can you increase the velocity of a roller coaster?

## Procedure

Engineers who design roller coasters and other vehicles build scale models to test their ideas. With a partner or group, you will design, build, and test a model roller coaster.

1. With your partner or group, discuss the following questions.
   - What physical quantities would affect the velocity of a roller coaster?
   - What will you use to model the roller coaster?
   - What will you use to make a track?
   - How will you be sure that your roller coaster will stay on its track?
   - How will you support your track?
   - How will you ensure that your roller coaster will have enough energy to reach the end of the track?
   - How could you reduce friction experienced by the roller coaster?
2. Design your roller coaster model. Sketch your design, complete a list of materials that you will need, and record any safety precautions.
3. Have your teacher approve your sketch, materials list, and safety precautions. Collect the materials you need and build your model.
4. Test your model, making any required modifications to improve its performance.

## Process and Analyze

1. a) Calculate the gravitational potential energy of your roller coaster at each high point on your track.
   b) Determine the mechanical kinetic energy and velocity of the roller coaster at points where you expect it to be moving at near maximum velocity. Assume no friction.

## Evaluate and Communicate

2. Compare your model with others in the class. Based on your observations, decide if and how you could improve your model. Modify and retest your model if time allows.
3. How would you promote your roller coaster design based on scientific evidence? Use a medium of your choice to create an evidence-based promotion of your rollercoaster.

TOPIC 3.2

# How is energy transformed?

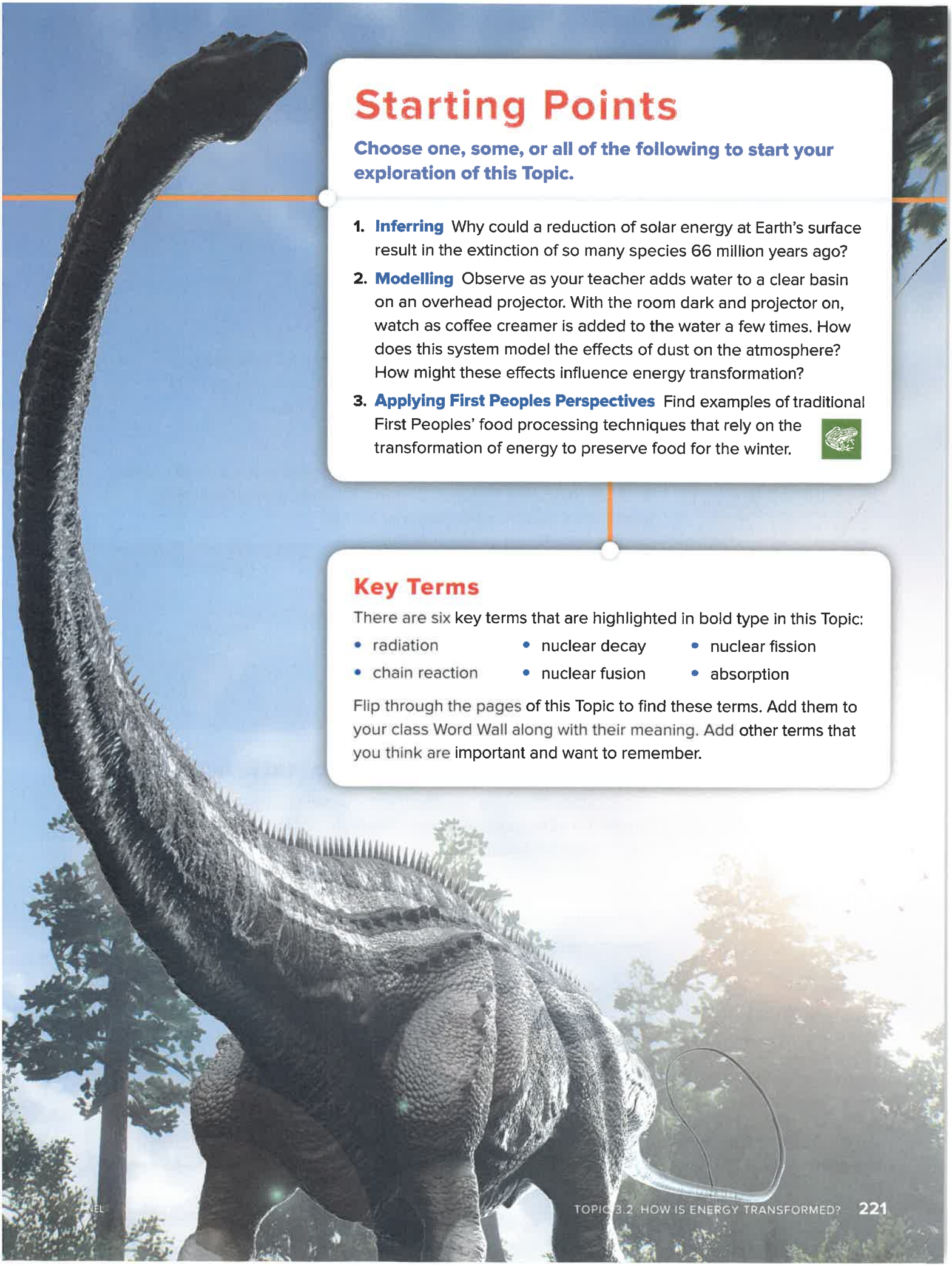
### Key Concepts

- Energy is transformed in chemical reactions.
- Energy is transformed in nuclear reactions.
- Energy is transformed when light energy interacts with matter.

### Curricular Competencies

- Collaboratively and individually plan, select, and use appropriate investigative methods.
- Evaluate your methods and experimental conditions.
- Transfer and apply learning to new situations.
- Formulate physical or mental theoretical models to describe a phenomenon.

About 66 million years ago, a meteor hurtled through space, plunged through Earth's atmosphere, and struck what is now the Yucatan Peninsula in Mexico. The impact sent vast amounts of dust and debris into the atmosphere as the mechanical kinetic energy of the meteorite was transferred to Earth. About 150 000 000 km away in the Sun, nuclear energy continued to be transformed into solar energy as it had been for billions of years. Now, however, the particles in Earth's atmosphere kept some of that energy from reaching the surface. Many scientists believe that this contributed to the extinction of the dinosaurs and many other species at the time. In doing so, it may have given a competitive edge to another group of animals—the mammals.



# Starting Points

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

1. **Inferring** Why could a reduction of solar energy at Earth's surface result in the extinction of so many species 66 million years ago?
2. **Modelling** Observe as your teacher adds water to a clear basin on an overhead projector. With the room dark and projector on, watch as coffee creamer is added to the water a few times. How does this system model the effects of dust on the atmosphere? How might these effects influence energy transformation?
3. **Applying First Peoples Perspectives** Find examples of traditional First Peoples' food processing techniques that rely on the transformation of energy to preserve food for the winter.

## Key Terms

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

- radiation
- chain reaction
- nuclear decay
- nuclear fusion
- nuclear fission
- absorption

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

# Energy is transformed in chemical reactions.

## Activity

### That's How It Glows

**Materials**

| | | |
|---|---|---|
| 2 glow sticks | 2 beakers | 2 pairs of tongs |
| 2 thermometers | ice water | hot water |

Design a procedure that uses the above materials to determine how energy transfer and/or transformation can be affected by adding or removing thermal energy from a system. Get your teacher's approval to carry it out.

Connect to Unit 2, Topic 2.3

How is chemical potential energy transformed to run a car or contract a muscle, as in Figure 3.12? How can other forms of energy be transformed into chemical potential energy?


**Figure 3.12** Chemical potential energy is transformed to contract a muscle (A) or run a race car (B).

## Energy Transformation in Chemical Reactions

Chemical reactions can transform some of the energy stored in chemical bonds into other forms of energy. The materials involved in a chemical reaction can be thought of as a system. In all chemical reactions, energy is released to the surroundings or absorbed from the surroundings. This energy tends to be thermal energy, but other forms, such as sound and light, can be released as well (Figure 3.13).

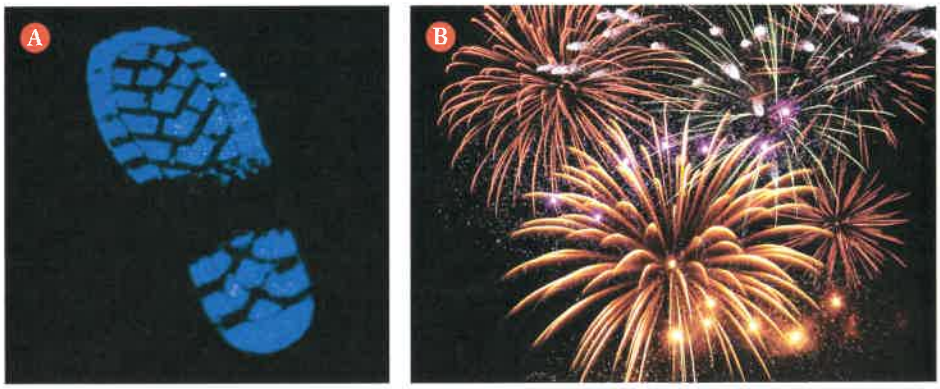



**Figure 3.13** (A) Luminol undergoes a chemical reaction at crime scenes, releasing light energy that makes blood visible to investigators. (B) Fireworks undergo chemical reactions to release both light and sound.

The amount of energy transformed in a chemical reaction is determined by the nature of the chemical bonds in the reactants and products. The amount of energy stored in the bonds of some compounds is more, or less, than in others.

- Some compounds would release little energy if formed from elements. Their bonds give these compounds high chemical potential energy. The compounds have the *potential* of releasing more energy by undergoing chemical reactions and forming different compounds.
- Some compounds would release a lot of energy if formed from elements. Their bonds give these compounds low chemical potential energy. Their *potential* for releasing more energy by undergoing chemical reactions and forming different compounds is low.

Whether a chemical reaction releases or absorbs energy is determined as follows.

- If the reactants are higher in chemical potential energy than the products, energy is released by the system during the reaction. The reaction is *exothermic*.
- If the reactants are lower in chemical potential energy than the products, energy is absorbed from the surroundings during the reaction. The reaction is *endothermic*.

**Figure 3.14** reviews how this works with the combustion of methane—a common reaction in gas stoves, furnaces, and Bunsen burners.

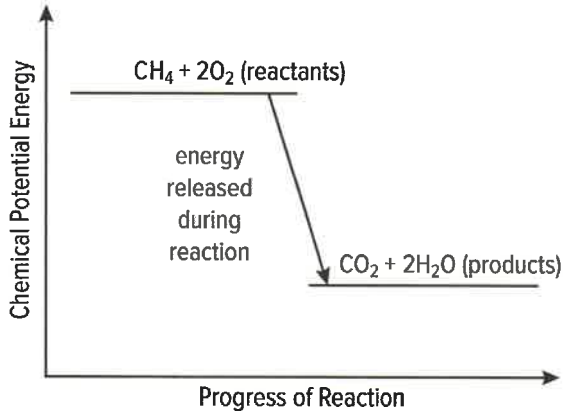



**Figure 3.14** When compounds that are higher in chemical potential energy react to form compounds that are lower in chemical potential energy, energy is released in the reaction.

$$CH_4(g) + 2O_2(g) \longrightarrow CO_2(g) + 2H_2O(g) + \text{energy}$$

The reactants, methane and oxygen, are higher in chemical potential energy; the products, carbon dioxide and water, are lower in chemical potential energy. Thus, when methane reacts with oxygen to form carbon dioxide and water, a large amount of energy is released.

# Chemical Reactions in Animals and Plants

## Cellular Respiration

All living things, including us, transform chemical potential energy to carry out life processes. This generally occurs through *cellular respiration*—a series of chemical reactions in which glucose, $C_6H_{12}O_6$, and oxygen react to form carbon dioxide and water (Figure 3.15). The amount of energy released is similar to the amount released when methane reacts with oxygen. Your body does not combust or burn, however, because the overall reaction takes place in small, controlled steps.

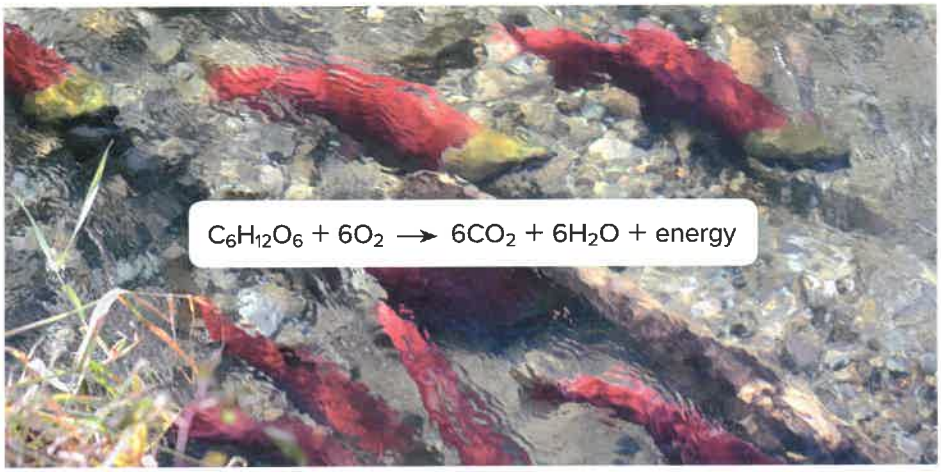



**Figure 3.15** This equation for cellular respiration summarizes a series of reactions.

During cellular respiration (Figure 3.16), some of the chemical potential energy in the glucose bonds is used to make bonds in a molecule called adenosine triphosphate (ATP). ATP is then used in nearly all reactions that require energy in living tissues. For instance, some of the energy is transformed into mechanical kinetic energy when muscles contract, some is transformed into more chemical potential energy when new molecules are created, and some is transformed into electrical potential energy, which can then be used to send signals along nerve cells.

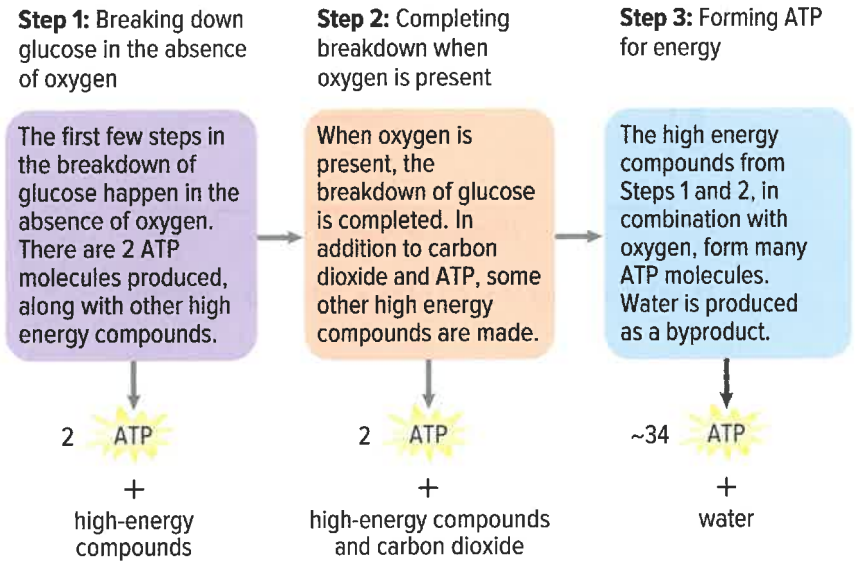



**Figure 3.16** Living things get energy through a series of chemical reactions in cellular respiration. In total, up to 38 ATP molecules are produced in three main steps. **Applying: How is energy lost to the surroundings during cellular respiration?**

## Photosynthesis

If glucose is constantly undergoing chemical reactions in living things, where does this glucose come from? The answer is from other chemical reactions. In *photosynthesis*, carbon dioxide and water combine, with the addition of light energy, in a series of reactions to produce glucose and oxygen (Figure 3.17). Photosynthesis occurs mainly in plants, although it also occurs in algae and some other microscopic organisms.

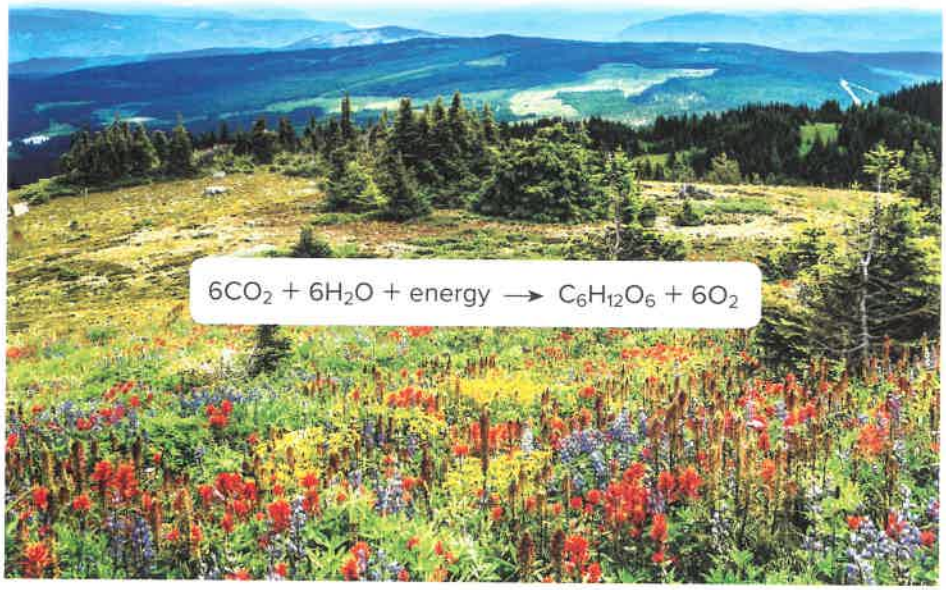



**Figure 3.17** This equation for photosynthesis summarizes a series of reactions.

In plants, photosynthesis occurs in structures called chloroplasts through a series of reactions (Figure 3.18). In these reactions, light energy is transformed into the chemical potential energy stored in the bonds of glucose molecules.

**Figure 3.18** Plants transform light energy to chemical potential energy through photosynthesis. Two sets of reactions occur—ones that need light energy and ones that don't.

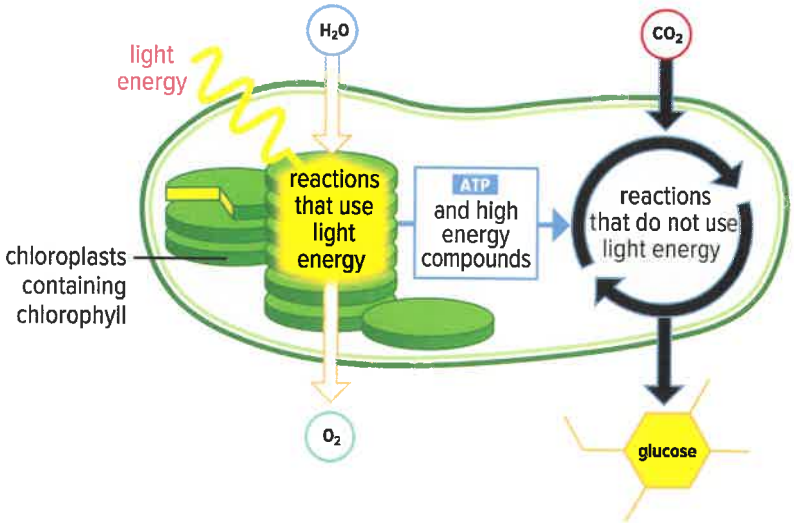
A green molecule in the chloroplasts, called chlorophyll, absorbs incoming light energy.

↓

The chlorophyll molecules become excited and pass the energy to special compounds, which use it to make ATP and other high energy compounds. Water is also used in these reactions, and oxygen is produced.

↓

Another set of reactions can occur without light. These reactions use carbon dioxide, ATP, and the other high energy compounds to make glucose.



# Energy Transformation and Fuels

## Fossil Fuels

*Fossil fuels* contain large amounts of chemical potential energy that was transformed from solar energy by ancient plants. **Figure 3.19** shows how they became buried under the right conditions to form these fuels. Certain bacterial decay processes and long periods of time under high pressure eventually produced deposits of coal, oil, and natural gas.

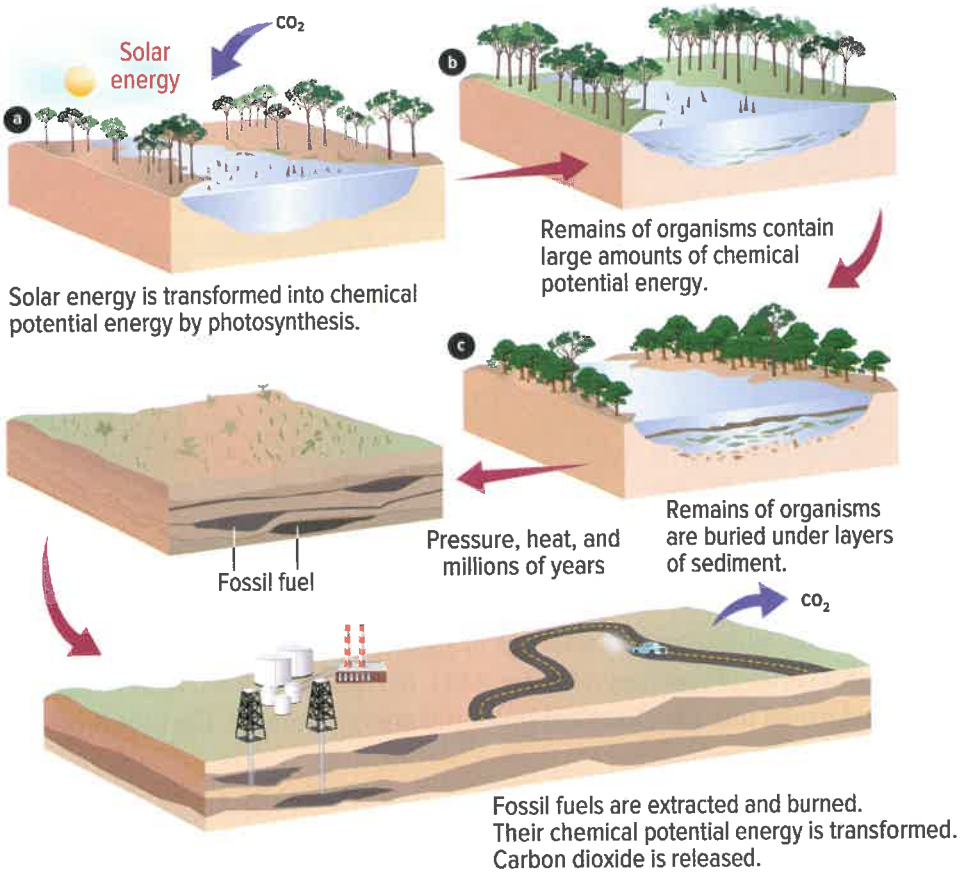



**Figure 3.19** Solar energy is transformed into chemical potential energy in living things, which ultimately provides the energy in fossil fuels. **Analyzing: How is the transformation of chemical potential energy from fossil fuels by humans helpful? How is it harmful?**

## Fossil Fuel Combustion

It took millions of years for fossil fuels to accumulate on Earth. Today, we are extracting these energy resources very rapidly. As we burn and process fossil fuels, tonnes of carbon dioxide are released into the air. This gas plays a major role in atmospheric warming, and changes in its concentration contribute to both natural and human-induced climate change.

When fossil fuels are "burned" to run motor vehicles or machinery, they undergo a combustion reaction, where the fuel reacts with oxygen to release energy. The example below shows the combustion of oil. Oil contains a variety of hydrocarbons. The equation for the combustion of octane, a hydrocarbon with eight carbon atoms, is shown here.

**Connect** to Unit 2, pages 165 to 167

$$2C_8H_{18}(\ell) + 25O_2(g) \rightarrow 16CO_2(g) + 18H_2O(g) + \text{energy}$$

Note the production of carbon dioxide in the reaction. Fossil fuels also contain contaminants such as sulfur and nitrogen that pollute the environment.

## Fuel Cells

Other forms of energy transformation emit fewer pollutants. In fuel cells, chemical potential energy is transformed into electrical energy when oxygen reacts with hydrogen. If the fuel cell is 100% efficient, the only product is water, as shown below.

$$2H_2(g) + O_2(g) \rightarrow 2H_2O(g) + \text{energy}$$

**Figure 3.20** shows how one type of fuel cell, called a proton exchange membrane fuel cell, works. Hydrogen in tanks and oxygen in air provide a supply of reactants. An electrolyte membrane lets only hydrogen ions pass to the cathode. Electrons from the gas stay on the anode. Hydrogen ions that reach the cathode react with electrons and oxygen to form water. The electrons are drawn from the anode, through an external circuit, to the cathode. This current powers a load.

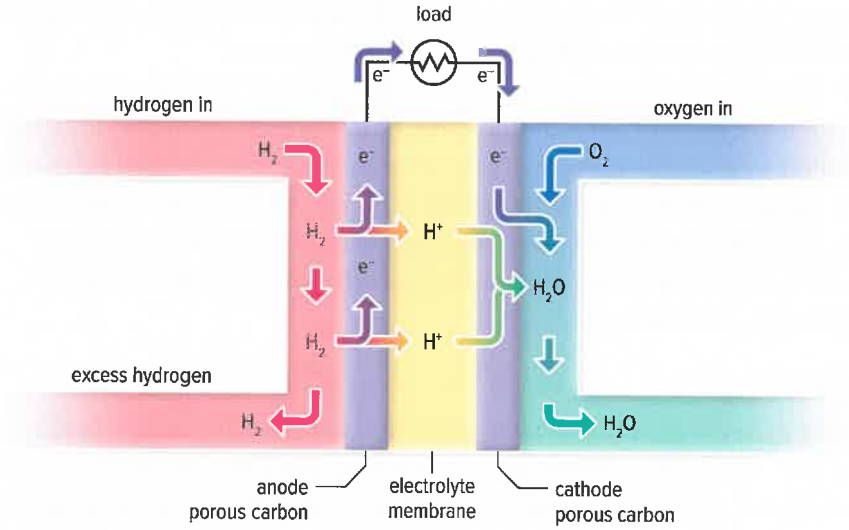



**Figure 3.20** The electron flow generated by this proton exchange membrane fuel cell can run a load, such as a vehicle motor.

### Extending the Connections

#### The Future of Fuel Cells

Use the resources available to you (information provided by your teacher, digital or print resources) to find out more about how fuel cells may be used in the future. What is currently restricting the development of future technologies?

### Before you leave this page . . .

1. Where is chemical potential energy in molecules stored?
2. How is chemical potential energy transformed by living things?

CONCEPT 2

# Energy is transformed in nuclear reactions.

Nuclear reactions are reactions in which changes occur in the nuclei of atoms. In many cases, the atoms are transformed into other elements. As in chemical reactions, energy is transformed in nuclear reactions. However, the amount of energy transformed is much greater.

## Types of Nuclear Reactions

Recall that atoms are conserved when energy is transformed in a chemical reaction. The atoms stay the same, but they are rearranged to form new substances. In a nuclear reaction, the atoms of one element are usually changed into atoms of a different element. Often, the atoms involved are isotopes. *Isotopes* are two or more forms of the same element with the same number of protons but a different number of neutrons.

If isotopes have too many neutrons compared to protons, they have too much energy and are, therefore, unstable. Isotopes that are unstable are called *radioactive isotopes*. To become more stable, they get rid of their extra energy by emitting particles from their nuclei. These emissions are often accompanied by radiation. **Radiation** is a mechanism of energy transfer in which atoms or molecules give off energy in the form of electromagnetic waves.

**radiation** a mechanism of energy transfer in which atoms or molecules give off energy in the form of electromagnetic waves

**nuclear decay** the change to an atom due to the emission of particles or radiation

### Alpha Decay

**Nuclear decay** is the change to an atom due to the emission of particles or radiation. The nuclei of some radioactive isotopes decay by emitting alpha ($\alpha$) particles, which are the same as helium nuclei. This process is called *alpha decay*. When a nucleus emits an $\alpha$ particle, the resulting nucleus has two fewer protons and two fewer neutrons. Therefore, its mass number is reduced by 4 and its atomic number is reduced by 2. Recall that mass number is the number of protons plus neutrons in an atomic nucleus. Atomic number is the number of protons alone. In a nuclear equation, this information is written as shown in Figure 3.21, where an $\alpha$ particle is written as a helium nucleus (He). The mass number is written to the left, above the atomic number.

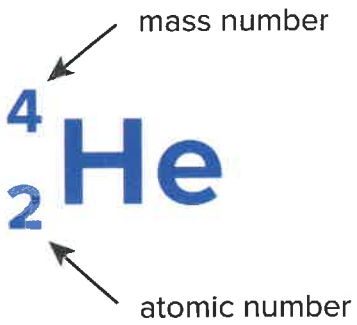



**Figure 3.21** In a nuclear equation, mass number (upper left) and atomic number (lower left) are written with the chemical symbol, as they are for this helium nucleus.

Figure 3.22 shows the alpha decay of the isotope radium-226. Notice that when radium-226 emits an α particle, it becomes a radon-222 atom. The alpha particle is ejected at high speed and has a lot of energy.

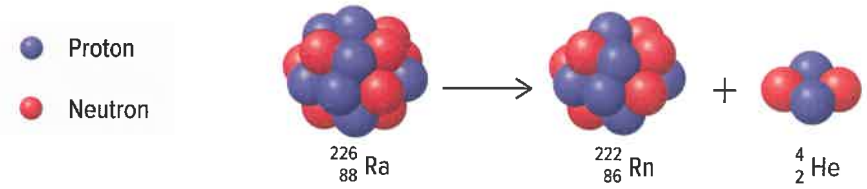



Figure 3.22 Alpha decay of radium-226

$$^{226}_{88}\mathrm{Ra} \longrightarrow {}^{222}_{86}\mathrm{Rn} + {}^{4}_{2}\mathrm{He} + \mathrm{energy}$$

$^{4}_{2}\mathrm{He} = {}^{4}_{2}\alpha$, where 4 is the mass number and 2 is the atomic number

## Beta Decay

Some radioactive isotopes emit a beta (β) particle, which is a fast-moving electron (e). In this process of beta decay, a neutron in the nucleus decays into a proton and an electron. The electron is emitted as a beta particle; the proton stays in the nucleus. The new nucleus has one less neutron and one more proton. Figure 3.23 shows the beta decay of lithium-8.

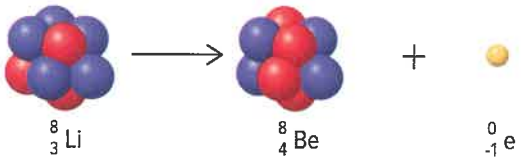



Figure 3.23 Beta decay of lithium-8 **Analyzing: What are the products of this nuclear reaction?**

$$^{8}_{3}\mathrm{Li} \longrightarrow {}^{8}_{4}\mathrm{Be} + {}^{0}_{-1}\mathrm{e} + \mathrm{energy}$$

$^{0}_{-1}\mathrm{e} = {}^{0}_{-1}\beta$, where 0 is the mass number and −1 is the atomic number

## Gamma Decay

After alpha or beta decay, a nucleus is often left in an excited state, so it is unstable. To become stable, the nucleus gives off a high energy photon called a gamma (γ) ray (Figure 3.24). Since a photon is electromagnetic energy, thorium-234 does not become a different atom. The * indicates an excited state.

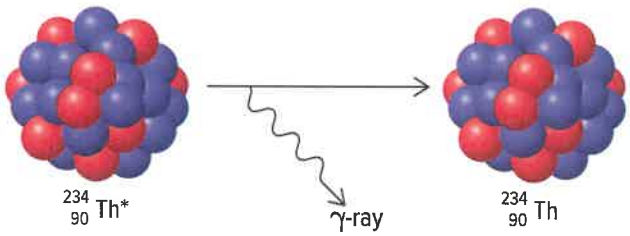



Figure 3.24 Gamma decay of thorium-234

$$^{234}_{90}\mathrm{Th} \longrightarrow {}^{234}_{90}\mathrm{Th} + {}^{0}_{0}\gamma$$

For $^{0}_{0}\gamma$, 0 is the mass number and 0 is the atomic number

## Nuclear Fission

**nuclear fission** a process in which a heavier nucleus is split into smaller, lighter nuclei with the release of energy

In **nuclear fission**, a heavier nucleus is split into smaller, lighter nuclei with the release of energy. For example, when uranium-235 is bombarded with neutrons, some of the nuclei absorb a neutron (n). This causes them to split into two smaller nuclei, releasing energy in the process. The two nuclei can vary among many combinations of elements, depending on how the atom splits. One example is shown in Figure 3.25.

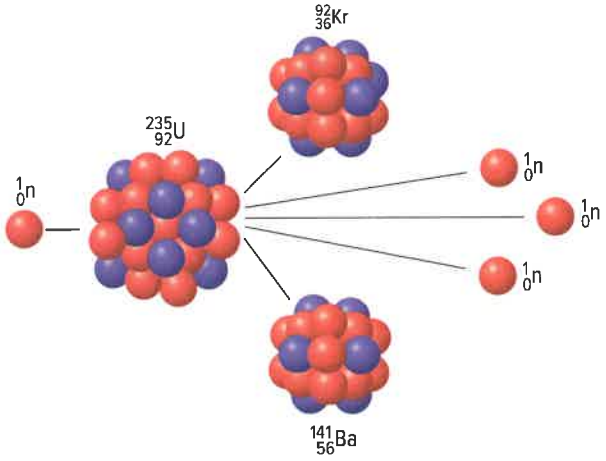



Figure 3.25 When a uranium-235 nucleus absorbs a neutron, it undergoes fission to produce a krypton-92 nucleus, a barium-141 nucleus, and three free neutrons. The krypton and barium isotopes are radioactive. **Analyzing: Do krypton-92 and barium-141 have more or less energy than uranium-235? Explain your reasoning.**

$$^{1}_{0}n + {}^{235}_{92}U \longrightarrow {}^{141}_{56}Ba + {}^{92}_{36}Kr + 3\,{}^{1}_{0}n + \text{energy}$$

For $^{1}_{0}n$, 1 is the mass number and 0 is the atomic number

## Fission Chain Reactions

Notice that three neutrons are produced in the reaction in Figure 3.25. Each neutron can split a neighbouring uranium-235 nucleus, and each of these produces three more neutrons. In this **chain reaction**, a single reaction causes many further reactions. For nuclear fission, a chain reaction results in the fission of many uranium-235 nuclei. This dramatically increases the amount of energy transformed. An example of a chain reaction is shown in Figure 3.26. The products are all radioactive isotopes, so they give off alpha or beta particles and sometimes gamma rays.

**chain reaction** a process in which one reaction leads to a series of further reactions

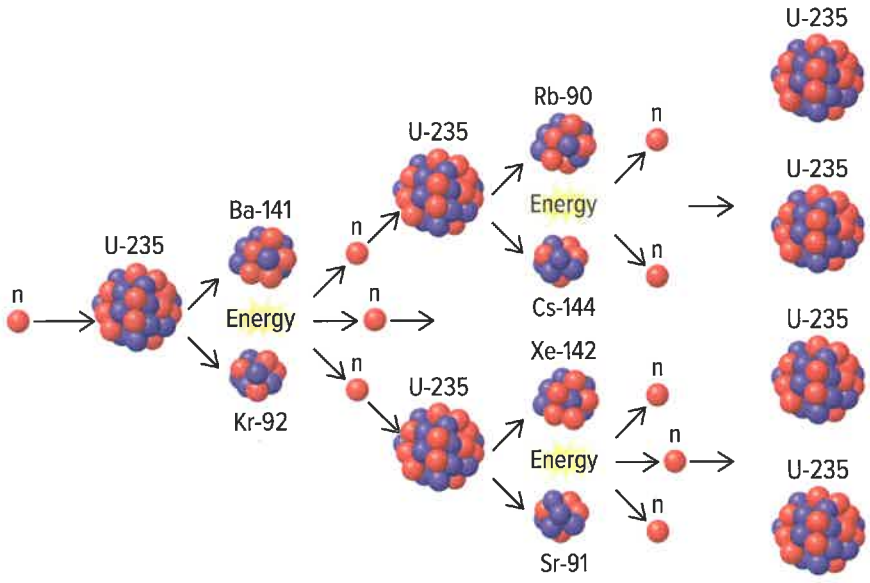


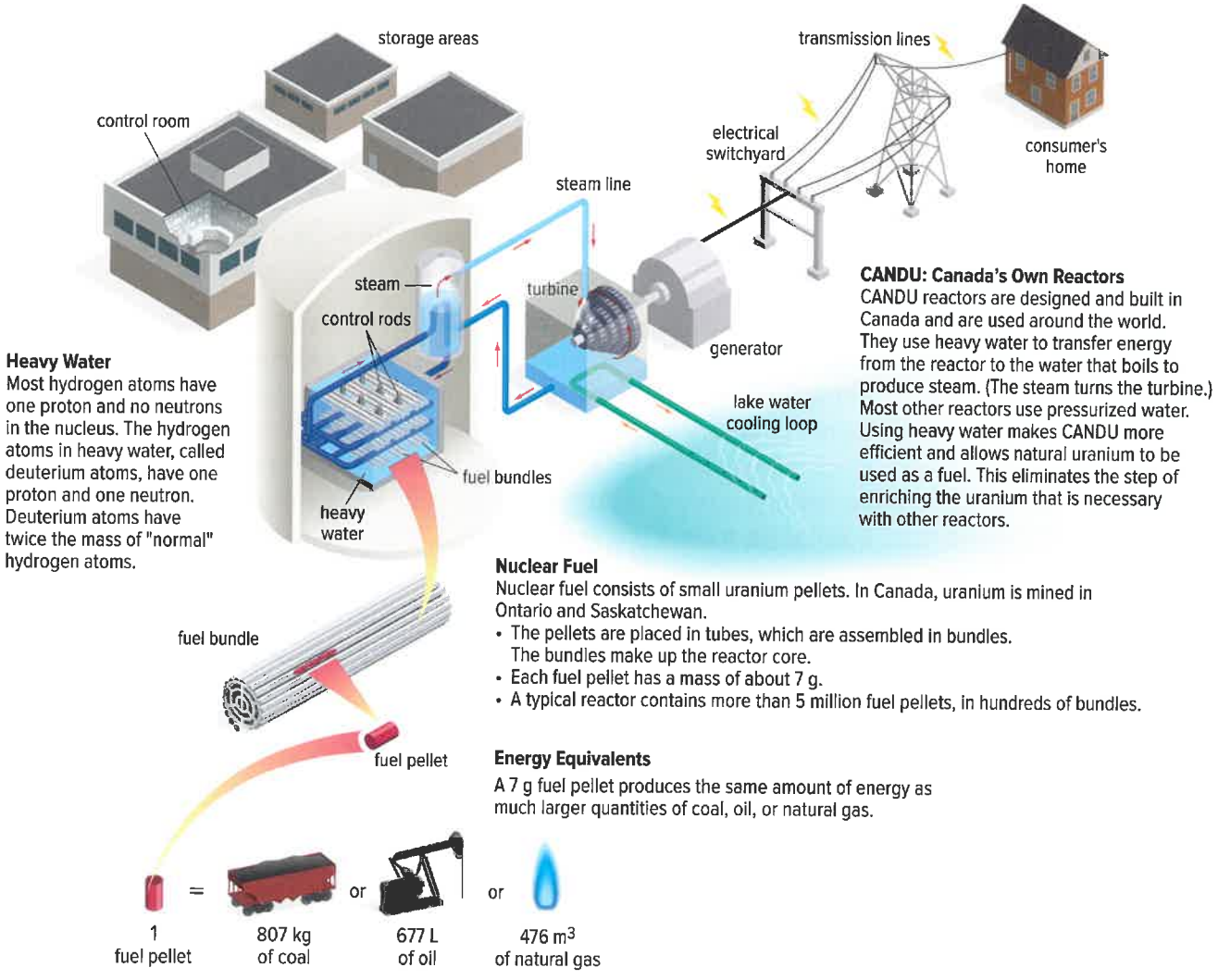

Figure 3.26 Two or more neutrons are produced as one uranium-235 nucleus undergoes fission. These neutrons split apart neighbouring uranium nuclei to form other radioactive isotopes and more nuclei. This results in a chain reaction and the fission of more uranium nuclei. **Modelling: How can you design a model to demonstrate a fission chain reaction?**

## Nuclear Reactors

Nuclear reactors transform the thermal energy produced in nuclear fission reactions into electrical energy. These reactors generally use uranium. Natural uranium consists mostly of the isotope uranium-238. Only about 0.7% is uranium-235, which is the isotope that fuels nuclear reactors. Inside a nuclear reactor, uranium-235 atoms undergo fission. If enough of this uranium is present, the neutrons emitted in the fission of one uranium nucleus can be absorbed by other uranium nuclei. This sets off a chain reaction that releases an enormous amount of energy.

A nuclear reactor contains and controls fission reactions and the energy they release. A liquid coolant flows through pipes close to the fuel and carries thermal energy away from the reactor. The liquid carries the thermal energy to another set of water-filled pipes, which the heat converts into steam. The steam turns turbines that generate electrical energy. The Canadian CANDU reactor in **Figure 3.27** uses natural uranium. This differs from other reactors, which use fuel enriched with uranium-235.

**Figure 3.27** At this time, there are 18 CANDU reactors operating in Canada and about 20 in other countries.




**Heavy Water**
Most hydrogen atoms have one proton and no neutrons in the nucleus. The hydrogen atoms in heavy water, called deuterium atoms, have one proton and one neutron. Deuterium atoms have twice the mass of "normal" hydrogen atoms.

**CANDU: Canada's Own Reactors**
CANDU reactors are designed and built in Canada and are used around the world. They use heavy water to transfer energy from the reactor to the water that boils to produce steam. (The steam turns the turbine.) Most other reactors use pressurized water. Using heavy water makes CANDU more efficient and allows natural uranium to be used as a fuel. This eliminates the step of enriching the uranium that is necessary with other reactors.

**Nuclear Fuel**
Nuclear fuel consists of small uranium pellets. In Canada, uranium is mined in Ontario and Saskatchewan.

- The pellets are placed in tubes, which are assembled in bundles. The bundles make up the reactor core.
- Each fuel pellet has a mass of about 7 g.
- A typical reactor contains more than 5 million fuel pellets, in hundreds of bundles.

**Energy Equivalents**
A 7 g fuel pellet produces the same amount of energy as much larger quantities of coal, oil, or natural gas.

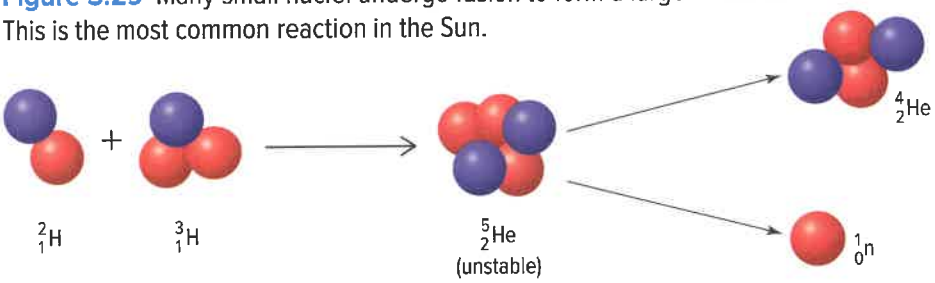
## Nuclear Fusion

**nuclear fusion** a process in which two very small nuclei combine, or fuse, to form a slightly larger nucleus

In **nuclear fusion**, two very small nuclei combine, or fuse, to form a slightly larger nucleus. For nuclei to fuse, they must collide with a tremendous amount of force. Thus, fusion requires very fast-moving particles to begin. This means it needs to occur at extremely high temperatures. However, once the nuclei fuse, they themselves generate the energy needed for fusion reactions to continue. Scientists have been trying to find a way to control fusion to produce energy, but they haven't been successful. However, fusion reactions occur in the Sun and other stars, like those in Figure 3.28. The reaction that occurs most frequently in the Sun is the fusion of two isotopes of hydrogen. These are called deuterium, $^{2}_{1}\mathbf{H}$, and tritium, $^{3}_{1}\mathbf{H}$. This fusion reaction forms the very unstable isotope, helium-5. Helium-5 immediately breaks down into helium-4 and a neutron. The reaction is shown in Figure 3.29. The helium-4 that is produced is stable. Thus, fusion does not produce radioactive materials.

Figure 3.28 Nuclear fusion occurs in all stars.

Figure 3.29 Many small nuclei undergo fusion to form a larger nucleus. This is the most common reaction in the Sun.




$$^{2}_{1}\mathbf{H} + {}^{3}_{1}\mathbf{H} \longrightarrow {}^{5}_{2}\mathbf{He} \longrightarrow {}^{4}_{2}\mathbf{He} + {}^{1}_{0}\mathbf{n} + \mathbf{energy}$$

Connect to Investigation 3-D on page 240

The amount of energy released in a fusion reaction is about 10 times less than the amount transformed by the fission of uranium-235. However, the sum of the masses of deuterium and tritium is about 47 times smaller than the mass of uranium-235. Therefore, the energy released per unit mass is much larger for nuclear fusion than for nuclear fission. As well, the products produced by fusion are not radioactive isotopes, so no radioactive nuclear waste products result.

### Before you leave this page . . .

1. Compare chemical reactions and nuclear reactions in terms of how much energy they transform.
2. a) What is a radioactive isotope?
   b) How do these isotopes get rid of their extra energy?
3. How is alpha decay different from beta decay?
4. Why does gamma decay occur?
5. How are nuclear fission and fusion similar? How do they differ?
6. At a glance, it appears like the law of conservation of energy does not apply to nuclear reactions. Explain why it does.

# AT ISSUE

# Effects of Radiation on Living Tissues

## What's the Issue?

Radiation that is harmful to living things is called *ionizing radiation*. When this radiation interacts with matter, including living tissue, it ionizes atoms. When an atom is ionized, it loses electrons, which often breaks chemical bonds. New bonds may then form, creating different compounds. When this happens in living tissue, molecules, cells, tissues, and even entire organs can no longer perform their normal functions. Alpha, beta, and gamma decay can all ionize atoms.

Alpha particles have about 8000 times the mass and twice the charge of beta particles. Their large size and charge cause alpha particles to deposit all their energy on the surface of the matter with which they collide. If that matter is the skin of living tissue, the energy is often deposited on dead cells, so it does no harm. However, if radioactive isotopes that emit alpha particles are ingested or inhaled, they can damage tissue significantly.

Beta particles can penetrate the surface of matter. If skin is exposed to beta radiation, it penetrates into living tissue and causes serious burns. However, it does not go beyond the skin into other organs unless it is inhaled or ingested.

Gamma radiation has no mass or charge, so it can pass through very dense matter, including lead and concrete, without interacting with it. This means it can ionize atoms and molecules anywhere in the body. When a gamma ray photon does interact with matter, it deposits all of its energy in one interaction, so it is much more dangerous than alpha or beta radiation.

## Dig Deeper

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

1. How do people who work in facilities where they are exposed to ionizing radiation protect themselves?
2. Radiopharmaceuticals are medicines used to treat cancer and other diseases. They contain radioactive isotopes. Radioactive isotopes emit ionizing radiation. How can these harmful isotopes be used to heal the body?

CONCEPT 3

# Energy is transformed when light energy interacts with matter.

**absorption** a process in which energy is taken up by matter without being reflected or transmitted

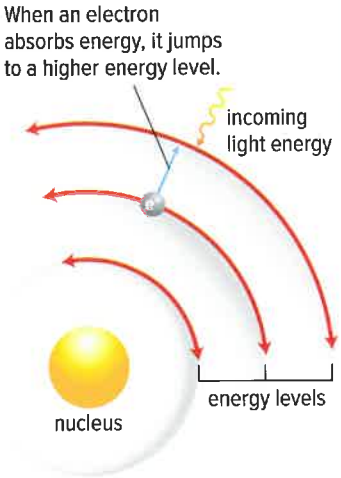



**Figure 3.30** When a chlorophyll molecule absorbs light energy, an electron receives this energy and jumps to a higher energy level. As a result, the molecule becomes excited.

Connect to Investigation 3-E on page 241

Chlorophyll in plants absorbs light energy. In **absorption**, energy is taken up by matter without being reflected or transmitted. When light energy is absorbed, an electron in a chlorophyll molecule receives this energy and becomes excited (Figure 3.30). In chlorophyll, the energy is used to make high energy bonds. However, in different applications, it is often transformed into other forms of energy. How the energy is used in an excited molecule depends on the properties of the molecule and where it is located. The following examples explore the transformation of light energy in a photovoltaic cell and the human eye.

## Photovoltaic Cells

Photovoltaic cells transform light energy directly into electrical kinetic energy (Figure 3.31). To make a cell, thin slices of a semiconductor such as silicon are treated with different materials and then sandwiched together. When two types of silicon come into contact in a photovoltaic cell, some of the electrons in one type of silicon jump into the holes in the other. This creates a separation of charge that attracts the remaining electrons to one side and repels them from the other. However, these electrons are held tightly by their atoms. When they absorb light energy, they are freed, move across the cell, and cause a current to flow. The current flows through metal conductors to an electric circuit.

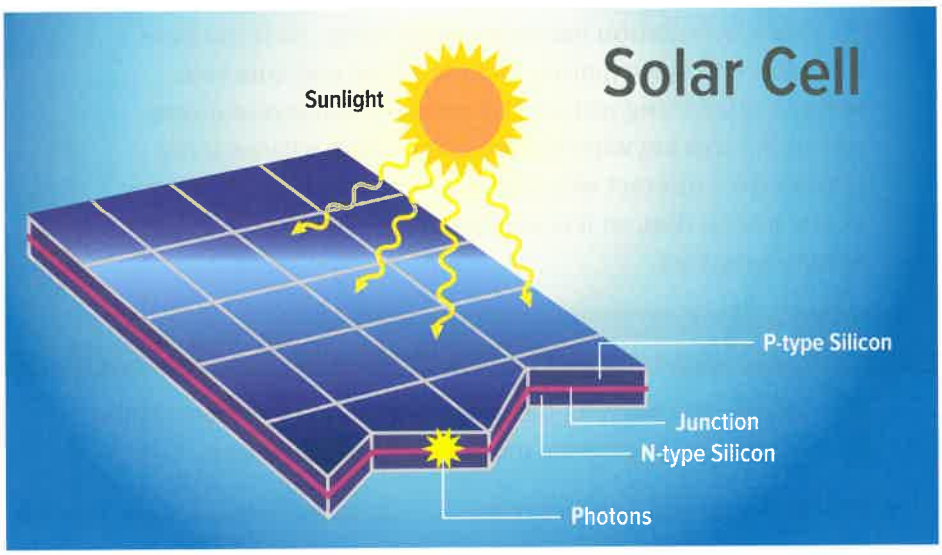



**Figure 3.31** Two types of silicon come into contact in a photovoltaic cell. Some electrons in the N-type jump into holes in the P-type. A separation of charge then attracts the other electrons. When these electrons absorb light energy, they are free to move across the cell, and a current flows through conductors into a circuit.

## Vision

Vision also involves the transformation of light energy (Figure 3.32). After light energy enters the eye, it is absorbed by rod and cone cells in the retina. These cells contain light-absorbing molecules called rhodopsin. When rhodopsin absorbs light energy, an electron in the molecule becomes excited, causing one part of the rhodopsin molecule to separate from the other. This starts a chain of events that causes a nerve cell to send out an electrical signal. After interacting with other nerve cells in the eye, the signal carries the information to the brain. The brain interprets the information, and you perceive an image.

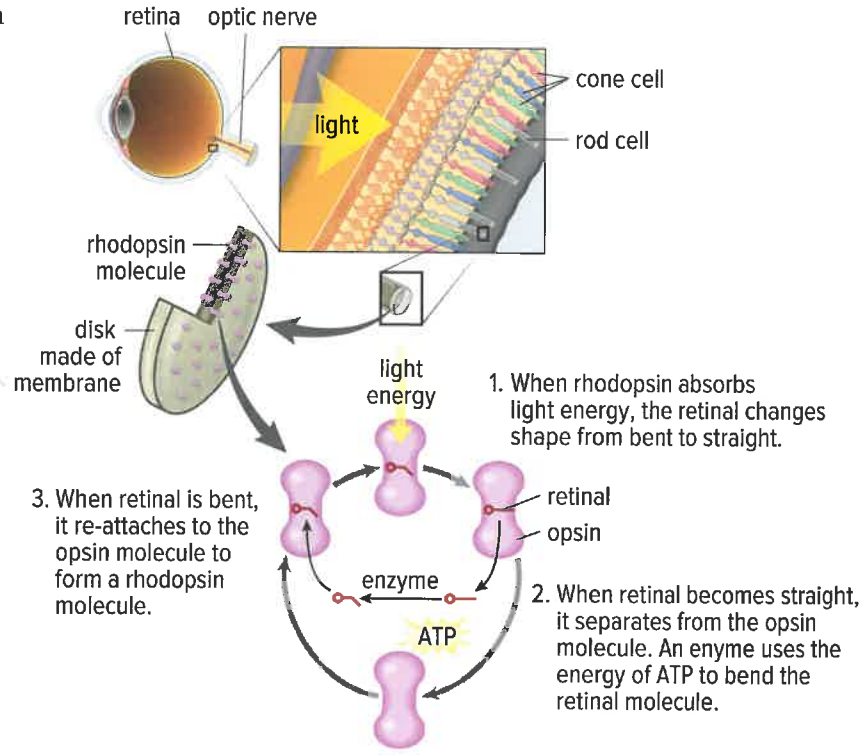



**Figure 3.32** Rhodopsin molecules are made up of a protein called opsin and a small molecule called retinal. When the rhodopsin absorbs light energy, an electron in the retinal molecule becomes excited, and the retinal separates from the opsin. This sends a signal to the brain.

## Activity

### Transforming Light Energy

1. With your group, brainstorm how you could apply the transformation of light energy to achieve a goal or carry out a task of your choice.
2. Create a plan to complete your task and share it with your class. Incorporate any feedback from your class to improve your design.
3. With your teacher's approval, build your design (or create a model if it is not possible to build it).
4. Once you are finished, demonstrate how the task is completed.

### Before you leave this page . . .

1. What role do electrons play in transforming light energy?
2. Compare human vision to a photovoltaic cell in terms of energy transformation.

# SCIENCE AT WORK

## Focus on Physics

Radiation Protection Technician

Biomedical Engineer

Materials Designer

What kinds of jobs are there that involve transformation of energy?

Oceanographer

Environmental Educator

### Audiologist

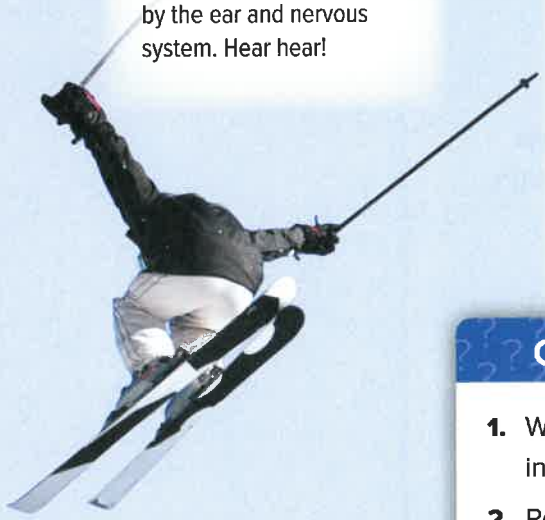
An audiologist needs to understand how sound energy is transformed into mechanical kinetic energy and electrical energy by the ear and nervous system. Hear hear!

### Archeologist

Ground-penetrating radar, magnetometers, radiocarbon dating, electrical resistivity—these are some of the tools and techniques related to energy that help archeologists investigate the past.

### Meteorologist

A meteorologist can tell you whether there will be a thunderstorm tomorrow, as well as how thermal energy, mechanical kinetic energy, and electrical potential energy are all transformed to produce that storm.



### Questions

1. What other jobs and careers do you know or can you think of that involve energy transformation?
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?

TAKE Action

# Make a Difference

## Transforming Solar Energy to Make a Difference in Remote Areas

More than 1.2 billion people lack access to electrical energy. Many do not have a reliable source of clean drinking water or access to basic disaster relief supplies. It is especially difficult to supply these resources in poorer, rural areas. However, several Canadian inventors and entrepreneurs are working to meet these needs with some innovative technologies.

**The Energy Hub** This device uses solar energy to charge portable battery packs for rural communities in sub-Saharan Africa. When the battery packs are drained, they are easily recharged. One Energy Hub can provide electrical energy for up to 100 homes.

**The SunSaluter** This innovation provides both electrical energy and clean water. It uses Earth's gravity and three bottles of water to move a solar panel. The water drips through a filter that cleans it during the day. As the bottle gets lighter, the panel moves to follow the Sun. The inventor, Eden Full, was a keynote speaker at UBC's Changemaker event, which celebrates making a difference in people's lives.

**Solarships** These Canadian hybrid aircraft deliver supplies to remote areas. Built to suit their specific missions, their compact design lets them take off and land in the space of a soccer field. They are partially lifted by a buoyant gas and have a large surface area to expose solar panels to maximum sunlight. Solarships can use either solar energy or fossil fuels but emphasis is on the sustainability offered by solar energy.

### Apply and Innovate

1. Imagine that you are volunteering with one of these projects. Communicate with a friend back home about your experience.
2. Do you think any of these projects could be useful in Canada? Explain your reasoning.
3. What kind of energy-related action can you take—for example, coming up with an innovative idea, designing a prototype, developing a public information campaign—that can make a difference in the lives of people locally, nationally, or globally?


A solarship being built at the company's assembly and testing facility

# AT ISSUE

# Storing Energy in Salt

## What's the Issue?

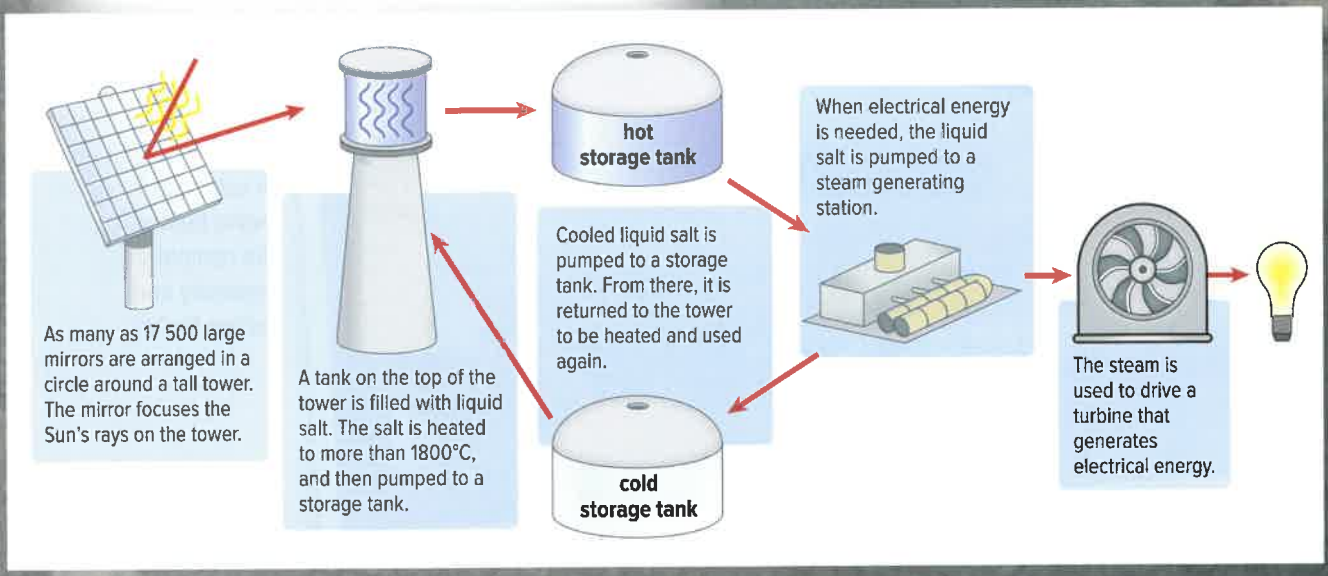
Transformation of solar energy to electrical energy can't occur at night, and it is decreased on cloudy days. This reduces how effectively solar energy can supply electrical energy on a large scale. We can't change when and how much sunlight reaches Earth, but there is a solution to this problem. It relies on salt.

The photo shows an array of thousands of mirrors that are programmed to move with the Sun at Gemasolar in Spain. The mirrors reflect sunlight onto a central molten salt tower. Molten salt is pumped through a coil in the tower. Solar energy is transformed into thermal energy, causing the molten salt to become extremely hot (about 565°C). The salt is then pumped to a power plant, where its thermal energy boils water into steam that drives a turbine to generate electrical energy. Some of the molten salt is also pumped to a storage tank, where it is stored for use at night. This allows the plant to run 24 hours a day.

### Dig Deeper

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

1. The molten salt used at Gemasolar is not table salt. Use resources available to you, including those provided by your teacher, to find out what kind of salt is used, and why.
2. In the opening pages of this unit, you read that skyscrapers might one day be built of glass that can generate electrical energy. What benefits and problems might be associated with this technology?



# 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. What factor determines the amount of energy transformed in a chemical reaction? PA

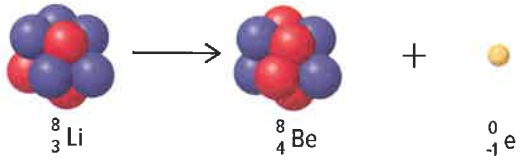
2. Indicate whether the following statements are true or false. Correct any statements that are false. PA
   a) More chemical potential energy is stored in the bonds of some compounds than in others.
   b) In all chemical reactions, energy is absorbed from the surroundings when chemical bonds form.
   c) Energy released in a chemical reaction is always thermal energy.
   d) If the reactants are higher in chemical potential energy than the products, energy is absorbed from the surroundings during the reaction.
   e) If the reactants are lower in chemical potential energy than the products, the reaction is endothermic.

3. The amount of energy released in cellular respiration is similar to the amount released when methane reacts with oxygen. Why does your body not burn? PA AI

4. Compare energy transformation in fossil fuel combustion and fuel cells. PA AI
   a) How are these processes similar?
   b) How do they differ?

5. a) What is a radioactive isotope?
   b) What role do radioactive isotopes play in nuclear reactions? Use a diagram to support your answer. PA C

6. Examine the diagram below. PA AI




   a) What process is occurring here?
   b) What are the products of the process?
   c) How does this process differ from a chemical reaction?

## Connecting Ideas

7. Describe how the processes of cellular respiration and photosynthesis are connected. PA AI C

8. Explain why a chain reaction is necessary for using nuclear fission to generate electrical energy. PA AI

9. Describe how the process carried out in a photovoltaic cell is similar to what occurs in human vision. PA AI C

## Making New Connections

10. Nuclear fission generates about 15% of the electrical energy used in Canada. QP PA E AI C
    a) Describe why nuclear fission is currently used for this purpose rather than nuclear fusion.
    b) What are two benefits of using nuclear fusion to generate electrical energy rather than fission?
    c) Predict whether fission or fusion will be used to generate electrical energy by the end of the century. Explain your reasoning.

11. "We are all nuclear powered." Evaluate whether this statement is true. Justify your response. PA E AI

INVESTIGATION

# 3-D

OPEN INQUIRY

## Solar Cooker Challenge

"It's so hot outside you could fry an egg on the pavement!" You've probably heard this saying before, but is it actually possible for solar energy to cook something? In this Investigation, you will see if you can use solar energy to boil water.

### Skills and Strategies

- Questioning and Predicting
- Planning and Conducting
- Processing and Analyzing
- Evaluating

### Safety

- Use care in cutting materials.
- Setups and/or materials in this Investigation will generate heat. Work very carefully and conscientiously to protect yourself and your surroundings.

### What You Need

- timer
- materials your team's design requires

### Question

How can you design an apparatus that uses solar energy to boil water? Formulate a hypothesis that you can investigate and evaluate.

### Procedure

1. With your group, design an apparatus that solves the problem posed in the question.
2. Brainstorm the materials that you will use, and determine how you will construct your cooker. In your design, consider the following questions.
   - What will you use to reflect sunlight?
   - What shape will direct the most sunlight onto the water?
   - How will you use materials to create the shape?
   - How will you contain the water and keep it in the correct position?
   - How will you orient your cooker to capture the most sunlight?
3. Sketch the design of your cooker. Create a materials list and record any safety precautions. Have your teacher approve these before you continue.
4. Assemble your materials and build your cooker.
5. On a sunny day, attempt to boil water with your cooker. Time how long it takes your cooker to boil the water.

### Evaluate

1. How was energy transformed and/or transferred in this investigation?
2. Compare your results as a class.
   a) Which solar cooker boiled the water in the least amount of time?
   b) How might you change the design of your cooker to improve its function? If the cooker in part a) was not your own, you might try to apply some of its properties to your own design.

INVESTIGATION
# 3-E

STRUCTURED INQUIRY

## Fission versus Fusion

### Skills and Strategies

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

### What You Need

- access to information resources (for example: online, print, interviews)

You are volunteering at a B.C. company that is trying to find a way to control fusion to produce electrical energy. Part of your job is to create educational materials that compare fission and fusion. These materials are used in presentations to the public, possible funding sources, and other stakeholders.

Fusion Reactor at General Fusion, a Burnaby company involved in fusion research

### Question

How can you create and present educational materials that compare fission and fusion?

### Procedure

1. With your team, create a summary table that compares fission and fusion. Use the questions below to help.
   - How do the reactions in nuclear fission and fusion differ?
   - What conditions are required for fission and fusion to occur?
   - How are these processes currently being used on Earth?
   - Why is your company choosing fusion over fission? (Consider by-products, energy released, and so forth.)
2. Your teacher will assign you a stakeholder as your audience. Use your table to create your presentation promoting fusion. Be sure to keep your audience in mind when creating the presentation.
3. Give your presentation to a panel of students that represent your stakeholder.

### Evaluate

1. Use the feedback provided by the panel to write a paragraph explaining how you could improve your presentation.

### Extension

2. Use resources available to you, including those provided by your teacher, to find out more about the current state of fusion research in B.C. and around the world.

TOPIC 3.3

# How does energy transformation affect global systems?

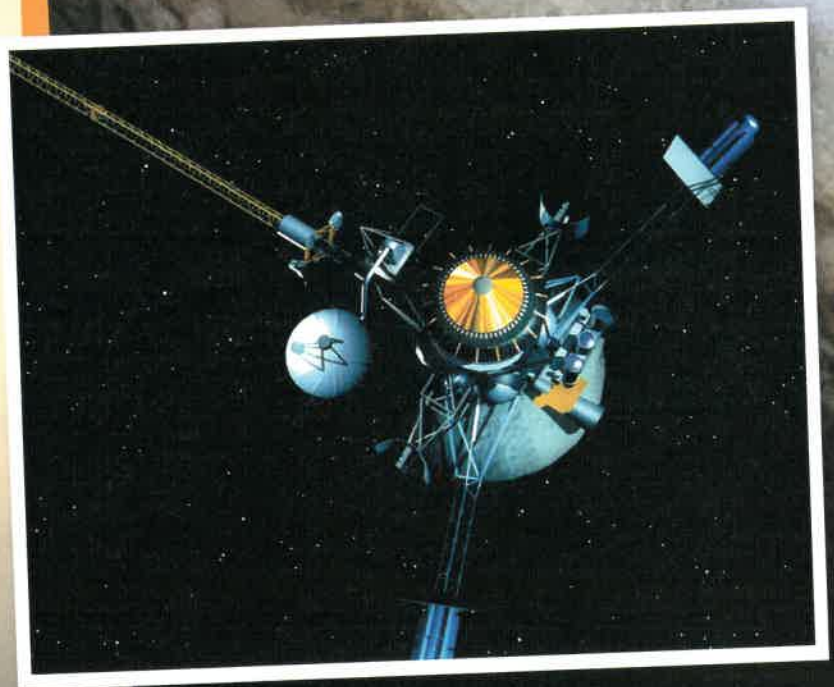
## Key Concepts

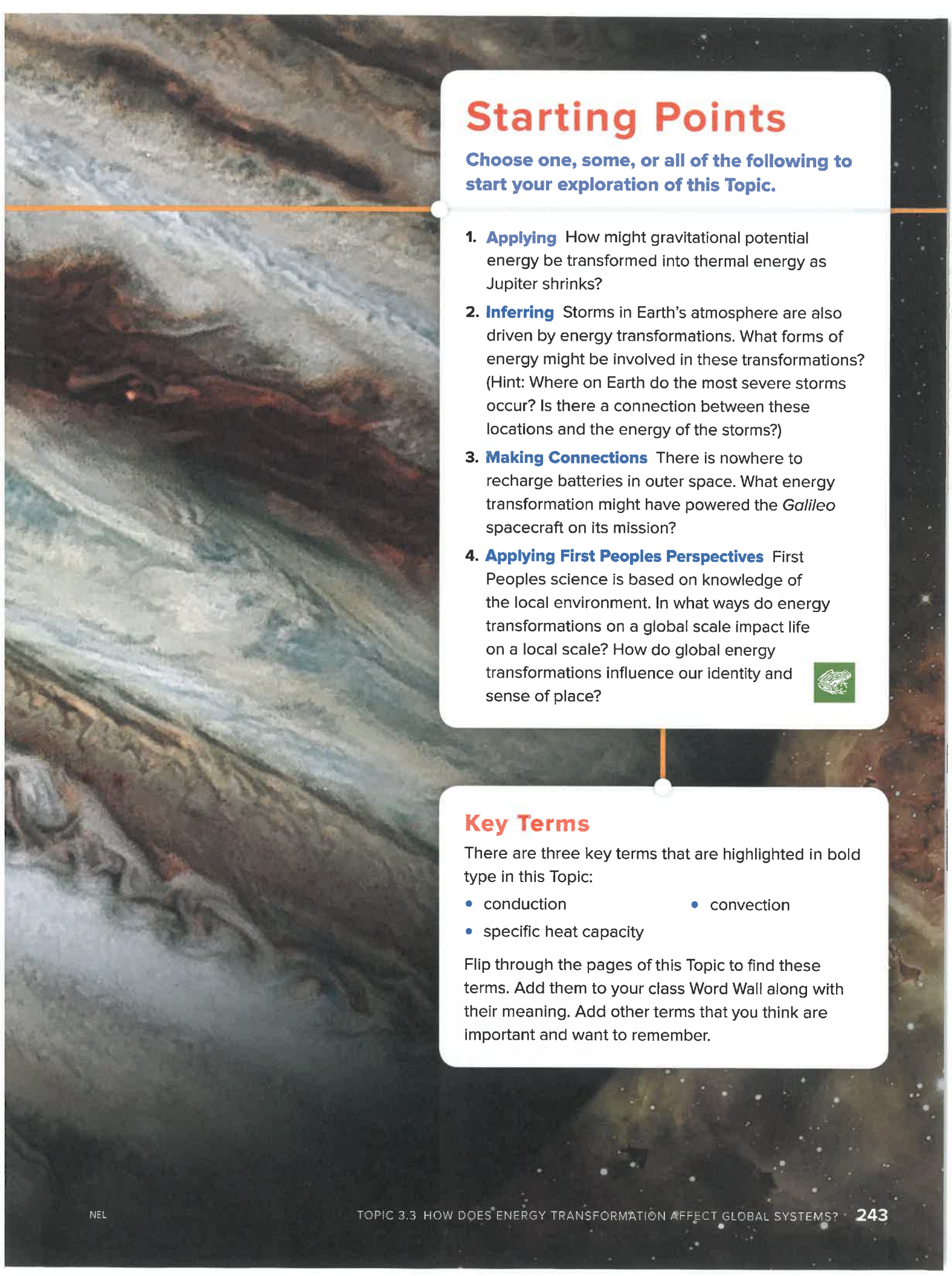
- Earth is a system in which energy is transformed.
- Earth's atmosphere is heated by the transformation and transfer of solar energy and thermal energy.
- Energy transfer and energy transformation moderate Earth's temperature.
- Energy transformation and transfer can harm aquatic and terrestrial ecosystems.

## Curricular Competencies

- Construct, analyze, and interpret graphs, models, and diagrams.
- Transfer and apply learning to new situations.
- Contribute to finding solutions to problems at the local and/or global level.

Knowing how energy is transformed helps us understand the processes that shape the unique environments of different planets. In 2003, NASA sent the space craft *Galileo* into the swirling, gaseous depths of Jupiter's atmosphere. The data collected by the spacecraft supported the theory that the gas giant's own gravitational potential energy is causing it to shrink. In the process, gravitational potential energy is being transformed into thermal energy. This thermal energy is the driving force behind intense storms in Jupiter's atmosphere, including a giant storm known as the "Great Red Spot." The diameter of several Earths put together, this super storm has been raging for nearly 200 years, perhaps longer.





# Starting Points

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

1. **Applying** How might gravitational potential energy be transformed into thermal energy as Jupiter shrinks?
2. **Inferring** Storms in Earth's atmosphere are also driven by energy transformations. What forms of energy might be involved in these transformations? (Hint: Where on Earth do the most severe storms occur? Is there a connection between these locations and the energy of the storms?)
3. **Making Connections** There is nowhere to recharge batteries in outer space. What energy transformation might have powered the *Galileo* spacecraft on its mission?
4. **Applying First Peoples Perspectives** First Peoples science is based on knowledge of the local environment. In what ways do energy transformations on a global scale impact life on a local scale? How do global energy transformations influence our identity and sense of place?

## Key Terms

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

- conduction
- convection
- specific heat capacity

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

# Earth is a system in which energy is transformed.

## Activity

### Energy and Earth's Systems

1 "How do Earth's systems rely on energy transformation?" In this activity, you will work with a partner to answer this question.

2. With your partner, brainstorm how living and nonliving processes on Earth involve energy transformations. Have one student act as recorder. The following questions can help you complete this task.

   What energy transformations occur when

   - a plant carries out photosynthesis?
   - you eat a sandwich?
   - you sweat?
   - it rains?
   - a volcano erupts?
   - the wind blows?
   - the tide goes in and out?

3. Discuss the question from step 1 with your partner. Use your answers from step 2 to guide your discussion.

4. When you are done, share your ideas with another pair of partners, or with the class.

Consider the different processes that occur on Earth. These include Earth's wind and weather, tides and currents, volcanic and mountain building processes, and the processes that take place in living things. None of these would occur without the transformation of energy. Topic 3.1 introduced the idea of a system. Recall that a system is anything that is being observed. This means that Earth, shown in **Figure 3.33**, can be considered a system, and often is. Three main types of energy play a role in this system: solar energy, gravitational potential energy, and nuclear energy.

**Figure 3.33** Earth can be considered a system. All of Earth's processes rely on energy transformation. **Inferring: What energy transformation drives the hurricane shown in the Atlantic Ocean in this figure?**

**Solar energy:** The transformation of solar energy drives movement of water in the atmosphere and hydrosphere, as well as through and over land. It also provides the energy that sustains most life on Earth. All three of these effects are represented here in the South Okanagan Valley at Naramata.

**Nuclear energy:** Nuclear energy is transformed into thermal energy by radioactive decay in Earth's crust and mantle. This thermal energy causes volcanic activity, tectonic plate movement, geysers, and hot springs such as those at the village of Radium Hot Springs.

**Gravitational potential energy:** The transformation of this form of energy also helps to move water. Transformation of the Moon's gravitational potential energy causes the tides. Shown here is low tide at Long Beach on Vancouver Island.

Of these three types of energy—solar, gravitational potential, and nuclear—it is transformation of solar energy that has the greatest impact. It adds 5000 times more energy to the Earth system than nuclear decay. In total, about 174 000 terrajoules of energy move through the Earth system at any time. A Boeing 737 airplane would have to cross the Atlantic Ocean 174 000 trillion times to use this much energy. It is also 10 000 times as much energy as we generate on Earth in a given moment.

## Before you leave this page . . .

1. What types of energy contribute to the Earth system?
2. Which type of energy transformation has the greatest impact on Earth?

CONCEPT 2

# Earth's atmosphere is heated by the transformation and transfer of solar energy and thermal energy.

Solar energy is made up of different wavelengths of electromagnetic radiation (Figure 3.34). These waves are transformed into thermal energy when they interact with matter, such as the ground, water, or air. The Sun is constantly radiating solar energy. Yet, Earth's temperature has remained relatively constant. This has provided conditions that are well-suited for life for millions of years. How is this possible? Following the path that energy takes through Earth's atmosphere in Figure 3.35 provides an answer.

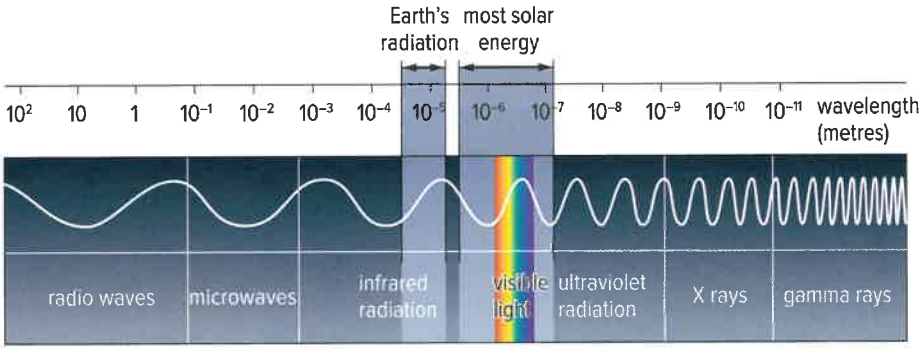



**Figure 3.34** Electromagnetic radiation consists of the seven types shown here, from long-wavelength radio waves to short-wavelength gamma rays.

## Absorption, Reflection, and Radiation of Energy

Most of the solar energy that reaches Earth's surface consists of visible light, infrared radiation, and ultraviolet radiation. Solar energy takes a variety of paths as it travels through Earth's atmosphere, as shown in Figure 3.35.

- About half of the solar energy that enters Earth's atmosphere is absorbed by the land and ocean. Visible light tends to pass through the atmosphere and reach Earth's surface unchanged. When it is absorbed by the surface, it is transformed into thermal energy. This energy is transformed and radiated into its surroundings as infrared radiation. The atmosphere absorbs much of the infrared radiation coming from Earth's surface. It temporarily traps some of this energy as thermal energy in the rapid motion of its molecules. This plays an important role in atmospheric warming, because these molecules constantly re-radiate the energy in all directions.
- Most of the remaining solar energy is absorbed, reflected, and scattered by clouds and particles in the atmosphere. Reflection and scattering involve energy transfer.
- This leaves about 10 percent that is reflected by Earth's surface.

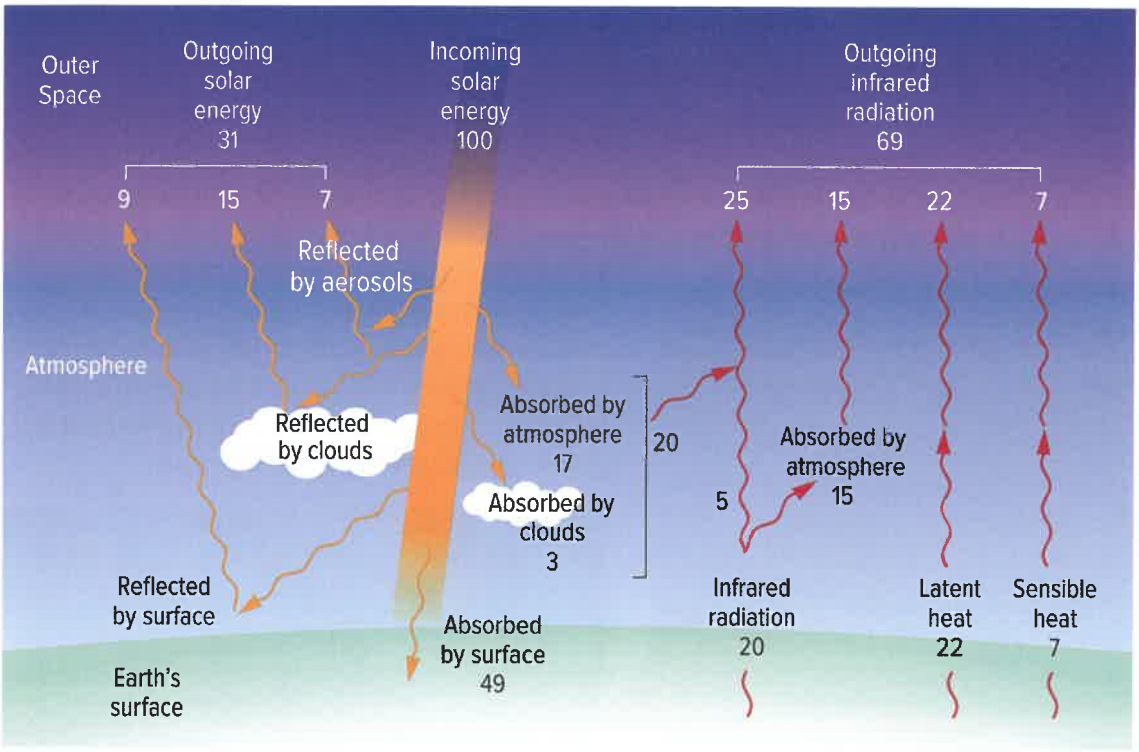



**Figure 3.35** Incoming solar energy interacts with Earth's atmosphere and surface in different ways. This energy diagram is based on 100 units of solar energy entering the atmosphere. It shows the approximate amounts of energy radiated, reflected, and absorbed.

## Activity

### Analyzing Incoming and Outgoing Energy

Use **Figure 3.35** to answer the questions below with your partner or group.

1. What type of energy do the orange arrows represent?
2. What type of energy do the red arrows represent?
3. How can you verify that incoming and outgoing energy balance out?
4. Look up the terms *sensible* and *latent*. Record their meanings. Based on their meanings, what do you think the terms *sensible heat* and *latent heat* refer to in the lower right-hand corner of the figure?
5. **a)** How much solar energy is absorbed by the surface?
   **b)** How much energy is radiated from the surface?
6. What percentage of incoming solar energy leaves Earth again over time?
7. Write a paragraph that describes a possible journey of the energy of a photon of solar energy through Earth's atmosphere.

## The Role of Greenhouse Gases

Greenhouse gases play an important role in warming Earth's atmosphere. Ones that are naturally present, such as carbon dioxide, water vapour, nitrous oxide (dinitrogen monoxide), and methane, are especially good at absorbing infrared radiation. The warming influence of these gases is often called the *greenhouse effect*. The greenhouse effect is the main reason Earth's average temperature is about 14°C, instead of a very chilly −18°C. Earth's moderate average temperature allows life as we know it to thrive (Figure 3.36). In a later Concept, you will learn how human emissions of greenhouse gases has affected global ecosystems.

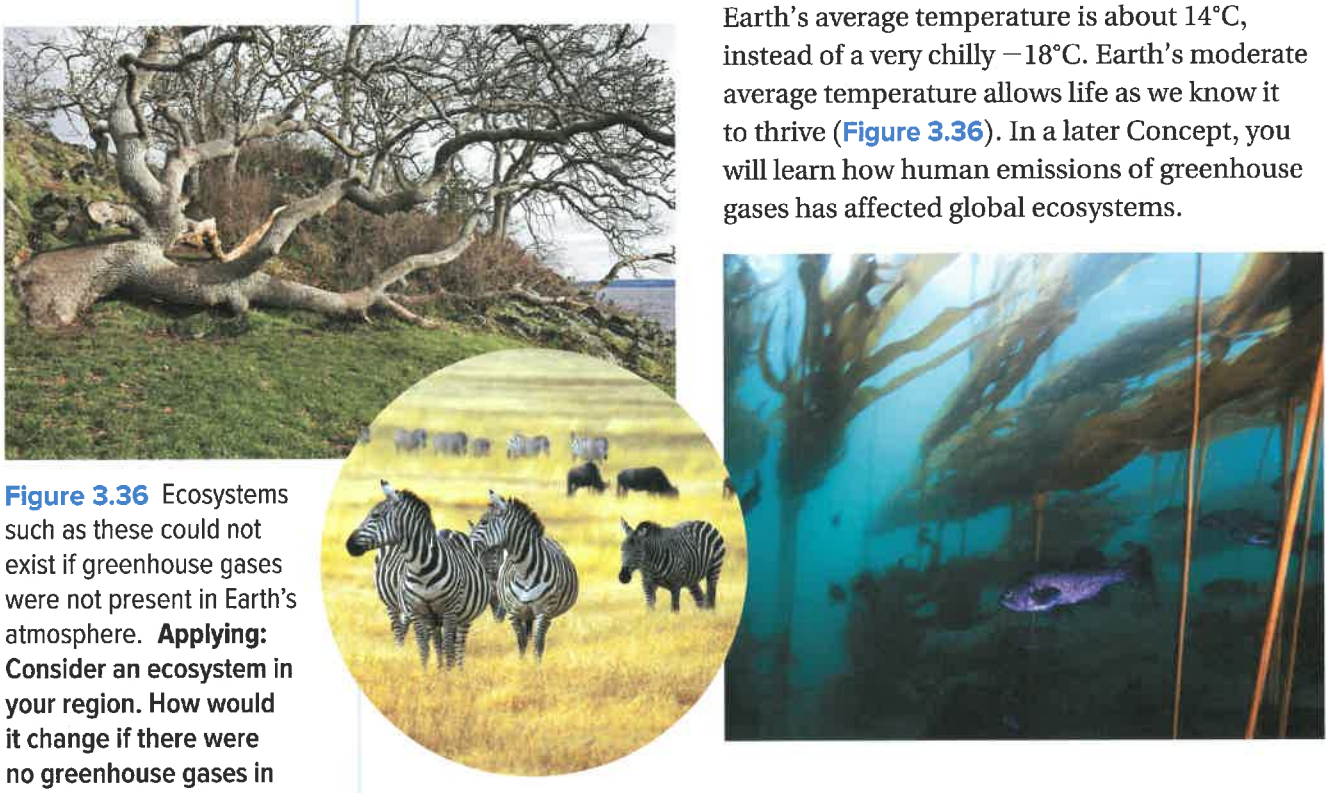


**Figure 3.36** Ecosystems such as these could not exist if greenhouse gases were not present in Earth's atmosphere. **Applying: Consider an ecosystem in your region. How would it change if there were no greenhouse gases in the atmosphere?**

## Conduction and Convection

You just read how solar energy is absorbed by Earth's surface and transformed into thermal energy. This thermal energy can be radiated again as infrared radiation. It can also be transferred to the atmosphere by conduction and convection. These processes are shown in Figure 3.37.

**conduction** the transfer of thermal energy between two substances that are touching

**convection** the transfer of thermal energy by the movement of heated fluids from one place to another

- **Conduction** is the transfer of thermal energy between two substances that are touching. After land and water absorb solar energy, their molecules collide more frequently with air molecules close to the surface. These collisions transfer thermal energy from the warmer surface to the cooler air by conduction. As a result, the temperature of the lower air comes close to the temperature of the land and water beneath it.
- **Convection** is the transfer of thermal energy by the movement of heated fluids (gases and liquids) from one place to another. Convection occurs as air circulates and distributes thermal energy. As the lower layer of the air warms, it expands, becoming less dense. Less-dense fluids rise, and more-dense fluids fall. As the cooler air falls, it takes the place of the rising warmer air.

Despite the important roles of conduction and convection, infrared radiation still plays the largest role in maintaining Earth's average temperature. Not only does radiation help warm the atmosphere, it also keeps it from getting too hot. Regardless of what processes solar energy undergoes once it reaches Earth, it is all eventually radiated back into space. This is shown back on Figure 3.35.

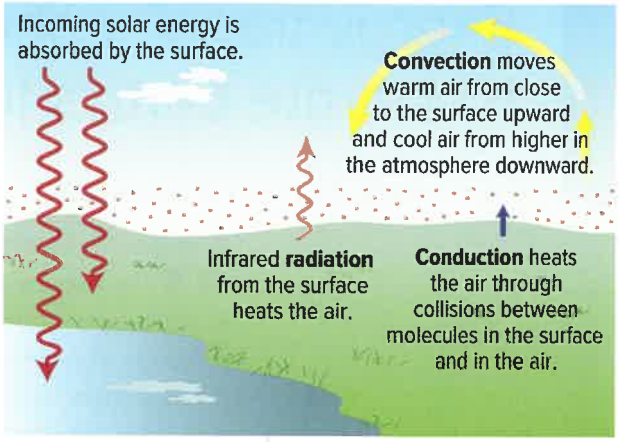



**Figure 3.37** Radiation, conduction, and convection all affect atmospheric temperature.

## Activity

### Modelling Convection

In this activity, you will make a lava lamp to model convection in the atmosphere.

1. Add water to a 1 L clear plastic bottle with a funnel until it is three-quarters full.
2. Using the funnel, add vegetable oil until the bottle is nearly full.
3. Wait for the oil and water to separate. Then add 10 drops of food colouring to the bottle.
4. Add half of an effervescent tablet to the bottle. Observe what happens.
5. Your teacher may dim the lights. Add another half a tablet to the bottle. Then shine a flashlight through the bottom of the bottle to better observe what is happening.
6. **a)** How does this activity model convection in the atmosphere well?
   **b)** What are the shortcomings of this model?
7. A real lava lamp has a heat source at the bottom of the lamp. This warms a waxy substance that expands and rises, carrying heat to the top of the lamp. When the wax rises, it cools again and sinks to the bottom of the lamp.
   **a)** How is this process like convection in the atmosphere?
   **b)** How is it different?

## Before you leave this page . . .

1. Describe the roles played by the following in warming Earth's atmosphere.
   **a)** radiation
   **b)** conduction
   **c)** greenhouse gases
   **d)** convection

CONCEPT 3

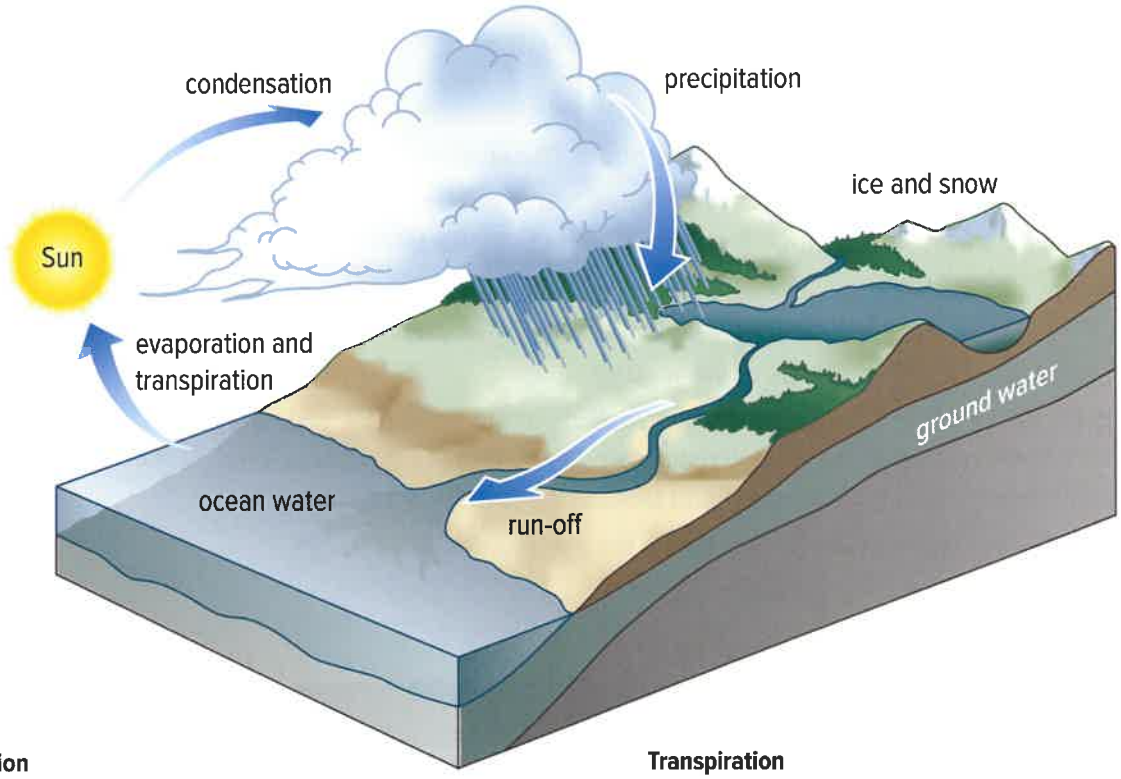
# Energy transfer and energy transformation moderate Earth's temperature.

When scientists search for life on other planets, they often look for the presence of water. Water is the medium in which life processes, at least as we know them, occur. On Earth, water moves between three spheres—the hydrosphere, geosphere, and atmosphere—in the water cycle. It does so through the processes described below. As each of these processes transport water, they also move energy between Earth's different spheres, as shown in Figure 3.38.

**Figure 3.38** The water cycle transports water and energy.

**Condensation**
As water vapour rises in the atmosphere, it gains gravitational potential energy. It also releases thermal energy to air molecules through collisions. It then cools, condenses around particles in the atmosphere, and forms clouds. The condensation process releases more thermal energy to the atmosphere.

**Precipitation**
The water returns to Earth's surface through precipitation when it rains or snows. As the precipitation falls, its gravitational potential energy is transformed into mechanical kinetic energy. This transformation continues as water flows from higher to lower elevations on land. Thermal energy is also transferred to the atmosphere through friction as precipitation falls.




**Evaporation**
When water absorbs the Sun's energy, its molecules begin to move faster as the solar energy is transformed into thermal energy. If enough solar energy is transformed, water evaporates from Earth's surface. It enters the atmosphere as water vapour, bringing its thermal energy with it.

**Transpiration**
In transpiration, plants take up water from the ground, or bodies of water in the case of aquatic plants, and release it into the atmosphere as vapour. Like evaporation, transpiration moves thermal energy into the atmosphere.

## Water Moderates Earth's Temperature

Water absorbs a lot of energy when it evaporates. As a result, evaporation has a cooling effect. You experience this when you sweat on a hot day. Your body temperature decreases as water evaporates from your skin. You notice this effect more if you stand in front of a fan, because the moving air increases the rate of evaporation from your skin. Evaporation cools Earth in a similar way, as it moves thermal energy away from the surface.

Storing energy also affects Earth's temperature. The amount of energy needed to change the temperature of 1 g of a substance by 1°C is called **specific heat capacity**. Water has a very high specific heat capacity, so Earth's vast oceans can store a large amount of thermal energy with very little change in temperature. Oceans also transfer and radiate energy to their cooler surroundings, but this happens slowly. Without this effect, Earth would experience much greater shifts in temperature between day and night. It would also be much colder in winter and warmer in summer.

**specific heat capacity** the amount of energy required to change the temperature of 1 g of a substance by 1°C

The moderating effect of oceans is best seen in coastal regions. Water has a much higher specific heat capacity than land does. Thus, in summer, when land and water absorb the same amount of heat, the temperature of the land increases much more than that of water. In winter, when land and water lose the same amount of heat, land cools much more than water. For coastal regions, water acts like an air conditioner or heater during different seasons. Summers tend to be cooler compared with inland locations, and winters tend to be warmer.

Connect to Investigation 3-F on page 258

## Activity

### Energy Transformation in Other Earth Processes

1. Choose one of the processes below or another of Earth's processes that interests you.
   - life processes (photosynthesis and cellular respiration)
   - geological processes (volcanic activity and the motion of Earth's crusts)
   - tides
   - winds
2. Determine the role energy transformation plays in the process. Use the resources available to you (this textbook, group discussion, online or print resources, and/or resources provided by your teacher) to do so.
3. Share your explanation with the class by creating an info-graphic using either self-produced artwork or technology.

### Before you leave this page . . .

1. Describe the role energy transformation plays in the water cycle.
2. What is specific heat capacity?
3. Why are coastal temperatures more moderate than inland ones?

CONCEPT 4

# Energy transformation and transfer can harm aquatic and terrestrial ecosystems.

Energy transformations that can harm the environment may be part of natural events, such as forest fires or volcanic activity. However, great harm is also, often, the result of human activity. These two pages explore two examples.

**Aquatic Ecosystems and Climate Change**

Aquatic ecosystems are especially harmed by changes in temperature. Earth's average temperature is about 1°C warmer than it was last century due to the human-induced greenhouse effect. Greenhouse gases play a large role in warming Earth's atmosphere. For at least 200 years, humans have been adding significant amounts of these gases to the atmosphere. This has been mainly to generate electrical energy, power vehicles, warm homes, and carry out industrial processes.



Many aquatic organisms thrive at a certain water temperature. As ocean temperature increases, many species move to cooler waters. This affects the animals that rely on them. In B.C., warming ocean water is affecting the tufted puffin. The small fish the puffins eat are moving to cooler waters. Mature puffins follow their food source and abandon their young in the process. Each year, fewer young puffins survive to adulthood.



Warming ocean temperatures are also destroying an important nursery and habitat for ocean life: coral reefs. Corals are animals that live in close association with algae. Through photosynthesis, the algae provide the coral with food. This relationship is threatened by climate change. As oceans warm, the corals expel the algae and die. In the process, they become white, or bleached.

**Connect** to Investigation 3-G on page 261

## Extending the Connections

### Terrestrial Ecosystems and Climate Change

Develop and investigate questions about the effects of climate change on terrestrial ecosystems. How can you use your findings to educate people about the issues involved?

### Terrestrial Ecosystems and Radiation Exposure

Terrestrial ecosystems are much more likely to be harmed by radiation exposure than aquatic ones. This is because radioactive materials accumulate in soil, while they tend to flush through aquatic ecosystems more quickly. Radioactive materials can build up in terrestrial ecosystems due to accidents at nuclear power plants. Although such accidents are infrequent, their effects can be devastating to ecosystems. Improperly stored nuclear wastes can also contaminate terrestrial ecosystems. This issue is explored on the next page.

In March 2011, radioactive materials were released into the environment after the Fukushima Daiichi nuclear plant in Japan was struck by a tsunami. Harmful effects of the radiation were seen within two months of the accident. Scientists found mutations in eye and wing structures of butterflies near the accident site. The butterflies had been overwintering as larvae when the accident occurred. Butterflies studied six months after the accident had even more mutations. This showed that mutations in the butterflies' reproductive cells were being passed to their offspring.

In 1986, a nuclear reactor at the Chernobyl nuclear plant ruptured when it overheated. The accident released part of the radioactive reactor core into the surrounding area. Radioactive materials were still being released 10 days later. Plants and animals within 20–30 km of the reactor were the most affected by radiation from the nuclear decay of the materials. In the nearby Red Forest, all the trees were killed. Over 30 years later, the effects of radiation poisoning are still felt in the area. Trees do not grow as quickly. Birds have smaller brain sizes. Perhaps most important is the loss of fungi, microorganisms, and insects involved in biological decay. This decay frees nutrients in dead matter, so they can be taken up by living things. In the Red Forest, many trees did not decay even 15 to 20 years after they were killed.

## Before you leave this page . . .

1. Explain how climate change is affecting at least one aquatic organism.
2. Why are radioactive materials so harmful to terrestrial ecosystems?

# AT ISSUE

# Storing Nuclear Waste Safely

## What's the Issue?

Nuclear wastes contain radioactive isotopes that release harmful radiation through nuclear decay over time. Eventually they become less radioactive. However, some nuclear waste takes a very long time to reach this state. Because there are no nuclear power plants in British Columbia, the issue of safe storage of nuclear wastes may seem very far from home. However, improper storage of these wastes can harm ecosystems around the world.

Nuclear energy provides about 15% of Canada's electrical energy. The safe management and storage of nuclear wastes is overseen by government organizations and regulatory bodies. Nuclear wastes are classified based on how much containment and isolation they require to be stored safety.

- **Low-level and Intermediate-level Waste** These are stored at the sites where they are produced. Once their radioactivity decays to acceptable levels, they are disposed of by conventional means, such as in landfills.
- **High-level Waste** These include used nuclear fuel and other waste from producing nuclear power. It can take a long time to undergo nuclear decay. The waste also gives off a lot of thermal energy, so it must be handled in two phases. First, used fuel bundles are stored under water in secure, leak-proof pools for 6 to 10 years until they cool. Then the bundles are transferred to concrete containers where they decay further.

## Dig Deeper

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

1. Compare nuclear waste with another harmful form of pollution. Which do you think is a greater threat to ecosystem health? Explain.
2. Use resources available to you, including those provided by your teacher, to find out more about nuclear waste contamination at the Hanford Nuclear Reservation in Washington. What mistakes were made at the site in terms of safe waste storage? Describe any harmful effects to the environment that resulted from these mistakes.

# AT ISSUE

# The Not So Silent Sea

## What's the Issue?

In 2017, 20 marine scientists wrote a letter to the federal government on the behalf of 78 B.C. residents who couldn't write it themselves—the endangered orcas that make their home in southern B.C.'s Salish Sea. The Salish Sea includes the Strait of Georgia, the Strait of Juan de Fuca, and Puget Sound. These waters are busy marine shipping routes. Many tankers and freighters pass through them on their way to the ports of Vancouver, B.C. and Seattle, Washington.

In their letter, the scientists called on the government to commit to reducing underwater noise pollution, such as that produced by marine vessels, in the region. As explained in the letter, noise pollution interferes with the orcas' ability to communicate and find food. It is also a cause of chronic stress. The urgency of the letter is underscored by the fact that the Salish Sea will get louder if proposed oil and coal terminal expansions go ahead in the area.

## Dig Deeper

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

1. Freighters produce much of the underwater noise in the Salish Sea. These ships don't have to make as much noise as they do. Engine and propeller noise can both be reduced. In fact, some naval vessels are designed to be extremely quiet. Despite this, little effort has been made to reduce engine and propeller noise. Why do you think this is the case?
2. Do you think noise pollution should be regulated to protect endangered animals in marine environments? Prepare an argument or participate in a debate in which you argue one side of the issue.
3. What other animals are harmed by noise pollution? How are they affected by the noise? Use the information provided by your teacher, or research an animal of personal interest.

BE Inspired

# Make a Difference

## Marilyn Slett: Advocating for an Indigenous Marine Response Centre

Marilyn Slett is Chief Councillor of the Heiltsuk Nation. She is a vocal advocate for the need for an improved oil-spill response plan in B.C. marine ecosystems. This need was reinforced in October 2016, when a tug boat crashed near Bella Bella in an endangered abalone habitat, running aground onto the shores of an ancient clam garden for the Heiltsuk. The boat released diesel fuel, a harmful marine contaminant, into the water. According to an article the Chief Councillor wrote in 2017, the response to this spill was unsafe and poorly managed. Clearly, there was need for improvement. This improvement has come in the form of the Heiltsuk proposal for an Indigenous Marine Response Centre.

First Peoples are often the first responders to marine emergencies in B.C. Creating a response centre near Bella Bella would allow First Peoples to respond to a spill on the central and north coasts of the province within 5 hours or less. The centre would use both Western and First Peoples knowledge to mount the effective response. According to Marilyn Slett, "The question is how best to develop community capacity to address emergencies in our territories as they arise, and how to deliver the world class protection Canada's oceans and communities need and deserve." This Indigenous Marine Response Centre may provide a much-needed solution.

### Evaluate, Apply, and Communicate

1. What lessons can you learn from Marilyn Slett about preparing for and dealing with emergencies that threaten the health of your community?
2. Mobilize your community to assess emergency response plans or to develop plans if they are lacking.

# 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

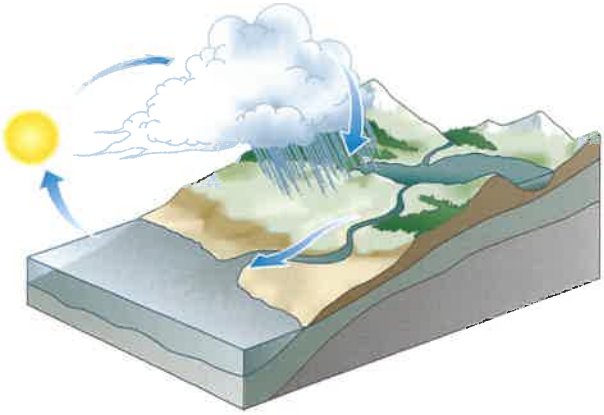
## Understanding Key Ideas

1. Consider the photo below. PA AI

   a) If Earth, including its atmosphere, is defined as the system, what are the surroundings?
   b) How does this system absorb energy from its surroundings?
   c) How does this system release energy to its surroundings?

2. Identify the three main types of energy that play a role in Earth's processes. PA AI

3. Refer to the stages of the water cycle below to describe how energy moves between Earth's surface and atmosphere. PA C



4. a) What is the greenhouse effect?
   b) Why is it important to life on Earth? PA AI

5. Use a graphic organizer to explain the roles that absorption, radiation, conduction, and convection play in warming the atmosphere. PA C

6. Why are terrestrial ecosystems harmed more by nuclear radiation than aquatic ecosystems are? PA AI

## Connecting Ideas

7. Imagine that you move from Vancouver to Kamloops. Predict how and explain why the average temperatures you experience will now be different in winter and in summer. QP PA AI

8. Design the procedure for a controlled experiment that could be used to determine the effects of warming oceans on coral reefs. PC PA AI

## Making New Connections

9. Climate change also affects ocean temperatures. As the temperature of water increases, the space between the water molecules expands. This causes sea level to rise. How do you predict that aquatic and terrestrial ecosystems would be affected by these changes? Explain your reasoning. QP PA AI

10. One molecule of nitrous oxide warms Earth's atmosphere more than one molecule of carbon dioxide. And yet, new reports about global warming and climate change focus substantially on carbon dioxide and rarely mention nitrous oxide or other greenhouse gases that are more potent than carbon dioxide. Why might this be the case? Provide reasons to justify your opinion. E AI C

INVESTIGATION

# 3-F

STRUCTURED INQUIRY

## Specific Heat Capacity

### Skills and Strategies

- Planning and Conducting
- Processing and Analyzing

### Safety

- Use caution when handling the lamps, as the bulbs will become very hot.

### What You Need

- 2 heat lamps
- 2 500 mL beakers
- 4 thermometers
- 125 mL water
- 125 mL soil
- apparatus to support heat lamps
- graph paper
- 2 data table templates

## PART A: Comparing Temperature Changes

In this part, you will compare the ability of water and soil to absorb radiant energy, and its affect on overlying air temperature.

### Question

How can you compare the absorption of radiant energy by water and soil, and its affect on overlying air temperature?

### Procedure

1. Your teacher will set up the apparatus in the photo and provide the mass of the water and soil.
2. Obtain copies of the two data tables from your teacher.
3. Turn on the heat lamps. Record the temperature at each of the four thermometers at one-minute intervals for a total of 10 min.
4. Turn off the heat lamps, and wait a few minutes to let the heat dissipate.
5. With the lamps off, repeat the temperature readings from step 3.
6. Make two graphs using the results from your data tables. Use a different symbol or colour for each variable.

### Analyze

1. What did you notice about the temperature changes in the soil compared to those measured in the water
   **a)** when the lamp was on? **b)** when the lamp was off?
2. What did you notice about the temperature changes above the soil compared to those measured above the water
   **a)** when the lamp was on? **b)** when the lamp was off?

## Conclude and Apply

3. Which has a higher specific heat capacity: soil or water? Explain your choice.
4. Sea breezes are local winds common to coastal areas during daytime hours. They are also called onshore breezes. Land breezes are local winds that occur during nighttime hours. They are also called offshore breezes. Use what you have learned in this Investigation to explain how sea breezes and land breezes form. Include diagrams in your answer.

# PART B: Calculating Energy Transformation

In this part, you will learn how to carry out calculations involving the relationships among energy, mass, and changes in temperature.

## Question

How can you solve problems involving relationships among energy, mass, and changes in temperature?

## Procedure

1. Read the text below about calculating specific heat capacity. Then study the sample problems.

Scientists have used many measurements to determine the values for the specific heat capacity, $c$, of many materials. A few of these values are listed in the table.

**Table of Specific Heat Capacities for Some Common Substances**

| Substance | Specific Heat Capacity (J/g°C) |
|---|---|
| Water (liquid) | 4.18 |
| Dry soil | 0.800 |
| Wet soil | 1.48 |
| Wood (pine) | 1.50 |
| Steel | 0.490 |
| Salt (sodium chloride) | 0.880 |
| Air (dry) | 1.005 |

Scientists have also determined that the mathematical relationship between heat absorbed by a material and its specific heat capacity, mass, and temperature change can be summarized in the following equation.

$Q = mc\Delta T$, where $Q$ represents the amount of heat absorbed or released by a substance of mass, $m$, with a specific heat capacity, $c$, at a change in temperature of $\Delta T$.

## Sample Problems

**A.** Using data from the table, determine the heat that must be added to raise the temperature of a cup (250 g) of water from 20°C to 100°C.

**B.** City engineers want to know the specific heat capacity of a new sample of asphalt. A chemist set up a system that would add $3.0 \times 10^4$ J of thermal energy to 1250 g of the sample. The chemist measured the change in the temperature of the asphalt as 26°C. What was the specific heat capacity?

### Solutions

**A.** The change in temperature is
$\Delta T = 100°C - 20°C = 80°C$.
Use the equation to find the heat needed.

$$Q = mc\Delta T$$
$$= 250\,\cancel{g} \times 4.18\ \frac{J}{\cancel{g}\cancel{°C}} \times 80\cancel{°C}$$
$$= 8.36 \times 10^4\ J$$
$$\cong 8 \times 10^4\ J$$

**B.** Rearrange the equation to solve for $c$. Then substitute the values into the equation.

$$Q = mc\Delta T$$
$$\frac{Q}{m\Delta T} = \frac{\cancel{mc\Delta T}}{\cancel{m\Delta T}}$$
$$c = \frac{Q}{m\Delta T}$$
$$c = \frac{3.0 \times 10^4\ J}{1250\ g \times 26°C}$$
$$c = 0.923\ \frac{J}{g°C}$$
$$c \cong 0.92\ \frac{J}{g°C}$$

**2.** Complete the following practice problems.

**a)** Compare the amount of heat necessary to raise the temperature of one cup (250 g) of water and one bathtub ($3.03 \times 10^5$ g) full of water, from 20°C to 50°C.

**b)** How much would the temperature of 250 g of salt increase if 8.36 J of energy were added to it? How does this compare to the temperature increase of water under the same conditions?

## Process and Analyze

**3.** Use data from Part A to calculate the amount of heat absorbed by the water.

**4.** If the soil absorbed approximately the same amount of heat as the water, calculate the specific heat capacity of the soil.

**5.** Do you think that the soil actually absorbed approximately the same amount of heat as the water absorbed? Explain your reasoning.

**6.** Consult the table for the specific heat capacity of dry soil. Is your calculated value similar to the appropriate value given here? If not, does the specific heat capacity of dry soil in the table indicate that the soil actually absorbed more or less heat than water in the Investigation? Explain.

INVESTIGATION

# 3-G

STRUCTURED INQUIRY

### Skills and Strategies

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

### Safety

- Use caution when handling heat sources such as a lamp, since the light bulb will become very hot.
- Advise your teacher if you are allergic to eggs.

### What You Need

**Part A:**

- materials as per your group's design

**Part B:**

- shells from 3 hard-boiled eggs
- 3 containers with lids
- weak vinegar solution
- strong vinegar solution
- water
- universal pH paper
- scale

# Modelling Changes in Earth's Systems

Scientists often create physical models of systems they are studying, including Earth's systems. In this Investigation, you will create models that will help you understand how human-induced changes can affect these systems.

## PART A: Modelling Changes to Earth's Atmosphere

In Part A, you will model and test the natural greenhouse effect. Then you will adjust your design to model and test the human-induced greenhouse effect.

### Question

How can you model and test the natural and human-induced greenhouse effect?

## Problem

You must design and build a physical model of the natural greenhouse effect. Your model should meet the following criteria:

- allow light or solar energy to enter the system
- absorb the solar or light energy
- transform the solar or light energy into thermal energy
- radiate the thermal energy as infrared radiation
- prevent infrared radiation from leaving the system
- allow you to measure the temperature of your system
- allow you to adjust variables to model the human-induced greenhouse effect

## Procedure

1. With your group, review the problem. Identify the variables in your investigation and how you can control them. Decide how you will compare the temperature inside your model with the temperature outside your model.
2. Brainstorm materials that you could use and how you could use them. Create a materials list. Decide on any safety precautions that are required.
3. Sketch a diagram of your model.
4. Describe your model to another group. Incorporate any appropriate changes they suggest into your design and sketch.
5. Write a plan describing your model and how you will build it. Include your materials list and safety precautions. Have your teacher approve your plan.
6. Build your model. Troubleshoot any problems as they arise.
7. Plan a procedure to test your greenhouse model and compare the results to those measured outside your model. Remember to account for and control all the variables, except the one you are measuring.
8. Create a table to record your data.
9. Carry out your test. Record your data.
10. Adjust variables to model the human-induced greenhouse effect.
11. Repeat steps 8 and 9 for your adjusted model.

## Process, Analyze, and Communicate

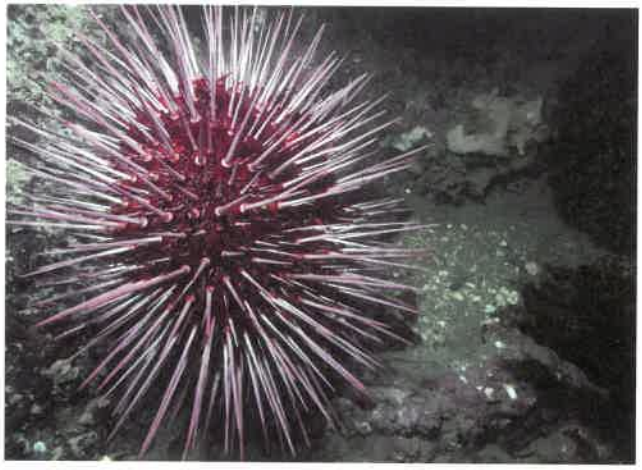
1. Graph your temperature data from inside your model of the natural greenhouse effect, outside your model, and after adjusting variables to model the human-induced greenhouse effect.
2. Compare your graphs. Summarize the results of your comparison. Did you get the results you expected? Explain.
3. Share your model and your summary with the class.

## Evaluate

4. a) In what ways was your model an accurate representation of the natural greenhouse effect? the human-induced greenhouse effect?
   b) In what ways was your model an inaccurate representation of these two effects?
5. Based on the models of other classmates, how could you refine your design to model the greenhouse effect more accurately?

## PART B: Model Ocean Changes

Oceans absorb carbon dioxide from the atmosphere. This helps moderate atmospheric temperature increase due to the human-induced greenhouse effect. However, the more carbon dioxide oceans absorb, the more acidic they become. This is because carbon dioxide reacts with water to form carbonic acid. If ocean water gets too acidic, animals such as corals, clams, and sea urchins cannot build their shells or skeletons very well. In this investigation, you will model and test how shells that contain calcium are affected by different levels of acidity.



### Question

How can you model and test how shells containing calcium are affected by different levels of ocean acidity?

### Procedure

1. In this investigation, egg shells are used to model sea shells. Your group will test what happens when the shells are placed in water with different levels of acidity. Read through all the steps. Make and record predictions about what you will observe.
2. Measure and record the pH of the three liquids.
3. Divide the shells into three piles. Measure and record the mass of each pile.
4. Do the following for each liquid.
   a) Place the shells in a container.
   b) Pour enough liquid to just cover the shells.
   c) Secure the lid, and place the container where it will be left alone for one day.
5. The next day, carefully remove the shells from each container. Record any changes you observe in the shells.
6. Measure and record the mass of the shells from each container.
7. Measure and record the pH of each liquid.

### Process and Analyze

1. Describe the changes you observed in the shells.
2. Which shells changed the most? How did this compare with your predictions?

### Apply

3. Use your results to explain how an animal with a calcium shell might be affected when exposed to ocean water that is too acidic.

TOPIC 3.4

# How does energy transformation affect humans?

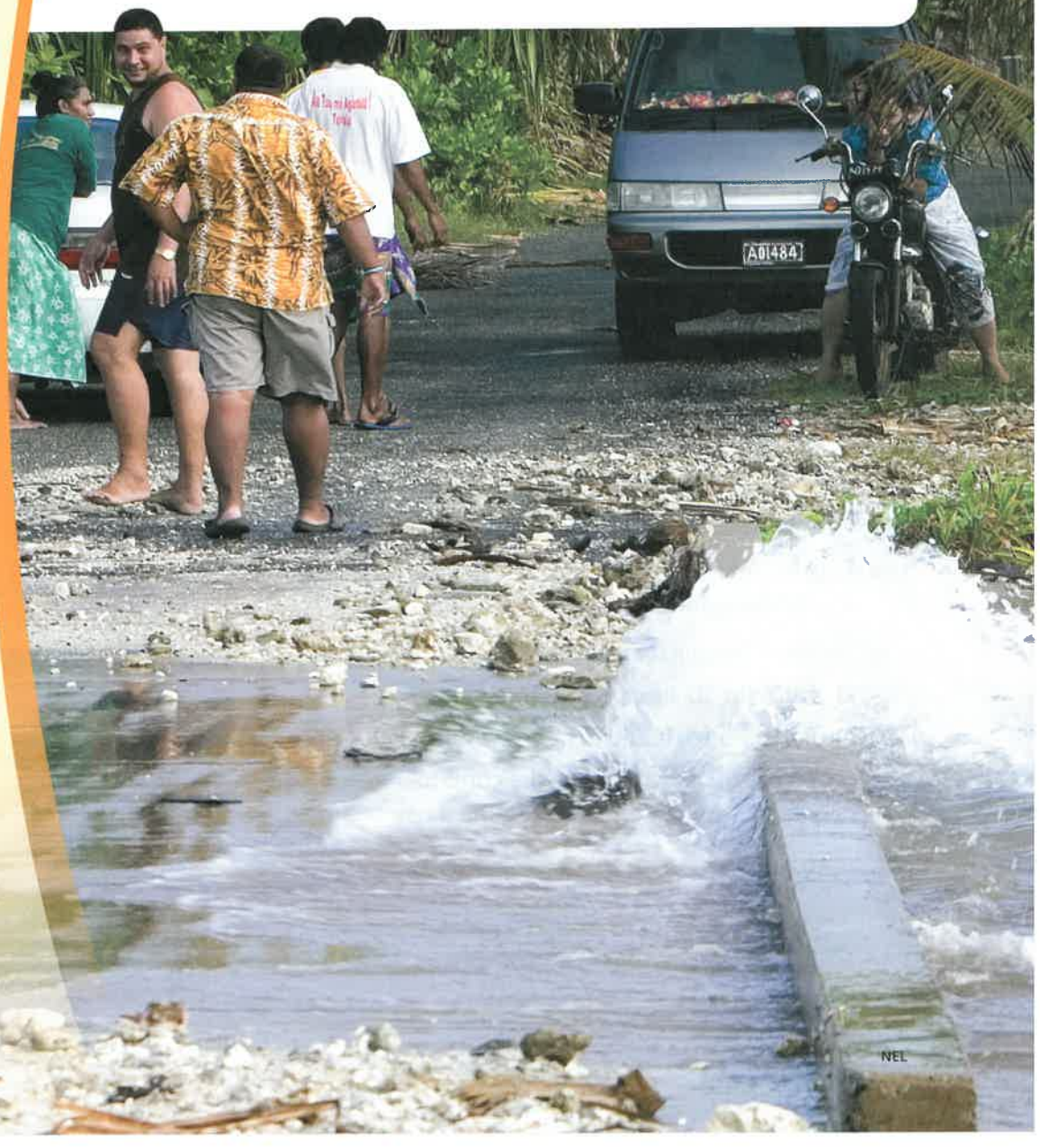
## Key Concepts

- Energy transformations provide benefits, but not without risk of harm.
- We take action and create technology to reduce the harmful impacts of energy transformation.
- We learn from our mistakes and each other to reduce harmful impacts of energy transformation.

## Curricular Competencies

- Demonstrate an awareness of assumptions and bias.
- Consider social, ethical, and environmental implications of findings from investigations.
- Contribute to care for self, others, community, and world through individual or collaborative approaches.

Imagine a world where you find yourself wading across roads, or even your own front yard. It's a reality that the residents of the South Pacific island nation of Tuvalu face at every high tide. Increasing global temperatures are melting polar ice caps and glaciers around the world. Melt water from these processes is already flooding some low-lying coastlines and islands, like Tuvalu. Although not all islands are at risk, some face a future of being lost beneath the waves. Many coastal cities in BC will also be affected by rising sea levels. The Lower Mainland is projected to see a 30 cm increase in sea level by 2050. It won't lead to a Tuvalu-type scenario just yet. However, such an increase may increase flooding of low-lying coastal neighbourhoods and erosion of beaches.



# Starting Points

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

1. **Considering** Why are warmer global temperatures leading to a rise in sea level? (Hint: There is more than one reason.)
2. **Applying** How might a rise in sea level affect you if you live on the coast? What if you do not live on the coast? Discuss your ideas.
3. **Applying First Peoples Perspectives** How can the ideas of renewal and reciprocity be applied to guide the ways that we use energy transformations for human benefit now and for future generations?

CONCEPT 1

# Energy transformations provide benefits, but not without risk of harm.

Connect to Investigation 3-H on page 274

All living things rely on energy transformations, and we are no exception. Locally and globally, human societies develop technologies and understandings that enable us to use and benefit from energy transformations. These benefits, however, rarely come without the risk of negative effects. The time line below provides highlights of our use of energy transformations.

**1 500 000 B.C.E.**
Early humans relied on plants' abilities to transform solar energy into chemical potential energy through photosynthesis. Through cellular respiration, they transformed this energy into various other forms of energy to carry out life functions.

**200 B.C.E–200 C.E.**
Wood was now burned on a large scale. For example, the ancient Roman Empire and the Chinese Han dynasty burned great amounts of wood to form metal for weapons and to heat their homes and baths. However, this also caused the first environmental health problems in recorded history.

**1698–1900 C.E.**
Combustion of coal in steam engines transformed chemical potential energy to thermal energy to mechanical kinetic energy. The kinetic energy was transferred to the vehicle or machinery run by the steam engine. However, burning coal also increased air pollution. This was especially harmful in London, England. Several times in history, coal smoke mingled with fog, covering the city in a deadly blanket. Many lives were lost to bronchitis, pneumonia, and even heart failure.

1 500 000 B.C.E. | 1 000 000 | 500 000 | 0 C.E. | 1600 | 1700

**1 000 000–500 000 B.C.E.**
Fire-starting technology let early humans transform chemical potential energy in firewood into thermal and radiant energy. Food could be cooked, and the night could now be lit up. Also, people could survive in much colder climates.

**125 C.E.**
Cement was used by Romans to build architectural wonders, such as the roof of the Pantheon shown here. Today we produce more than 4.2 trillion tonnes of cement each year. The chemical reaction that produces cement transforms chemical potential energy to thermal energy. It also adds 5% of global carbon dioxide emissions to the atmosphere.

**1800 C.E.**
The first working battery was invented by Italian physicist Alessandro Volta. Batteries involve the transformation of chemical potential energy to electrical potential energy. Modern batteries have become a landfill problem. Also, those that are not recycled properly leach toxic chemicals that harm human health.

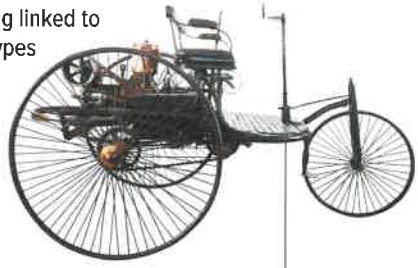
## Activity

### Snapshots of History

1. Through discussion, research, or materials provided by your teacher, find three ways we use energy transformations that are not on the time line.
2. For each example, record the dates it occurred. Then, write a short summary that captures a snapshot of that moment in history. Note any benefits or harm caused by the energy transformation.
3. Use a camera to take a photographic snapshot of an object or scene that visually represents your historical snapshot.
4. Add your snapshots, written and photographic, to your own class time line of human energy transformation. Your teacher may ask you to present your snapshots to the class.

**1859 C.E.**

The first continuously operating gas engine was built by French engineer Étienne Lenoir. This transformation of chemical potential to mechanical kinetic energy paved the way for the automobile. However, by the 1950s, cars and other gas-powered vehicles were already being linked to smog and other types of air pollution.



**1945 C.E.**

The Canadian ZEEP nuclear reactor was one of the world's first nuclear reactors. The reactor transformed nuclear energy into thermal energy, which was used to make steam. The energy of the steam was transferred to a generator, which transformed it into electrical energy. Additionally, radioactive isotopes created in nuclear reactors are used to treat and diagnose a variety of medical conditions. Despite these benefits, the fact remains that nuclear radiation is harmful to all life, including humans.

1800 1900 2000

**1882 C.E.**

The first hydroelectric dam was built to transform gravitational potential and mechanical kinetic energy into electrical energy. However, dam construction can flood vast areas of land. This releases large amounts of the greenhouse gas methane into the atmosphere as plants decay. Also, flooding may displace human populations, often First Peoples, living in the area.

**1959 C.E.**

Harry Ihrig designed the first fuel cell to run a vehicle. A few years later, the technology was used to provide electrical power to the Gemini and Apollo spacecraft. However, producing the hydrogen used in fuel cells adds carbon dioxide to the atmosphere.

### Before you leave this page . . .

1. What do you think is the greatest impact, positive or negative, of our application of energy transformations. Justify your response.

CONCEPT 2

# We take action and create technology to reduce the harmful impacts of energy transformation.

Reducing the impacts of technology-related energy transformation requires personal and national action. This often involves making choices, such as reducing energy use and choosing sustainable technologies to lessen harmful impacts. However, taking action requires commitment and sometimes making sacrifices in comfort and convenience. Despite these challenges, we can and are taking action to reduce these harmful effects. **Figure 3.39** shows some of the ways students like you are making a difference.

**Figure 3.39** Student initiatives that reduce energy use and support sustainable energy-transformation technologies can bring about change. **Applying: What initiative could you get involved in?**

Urban farm programs like the one at Victoria High School on Vancouver Island help reduce pollution caused by transporting food over long distances.

Many students cycle to school rather than travel by car. This also reduces combustion-related pollution.

Through participating in recycling programs, students in northern BC and Yukon have kept thousands of phonebooks out of landfills. This has helped reduce harmful impacts of manufacturing-related energy transformation.

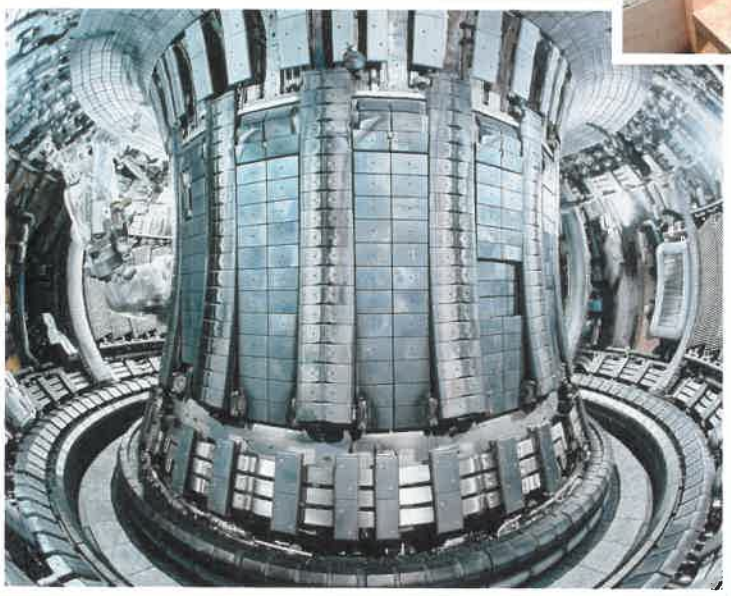
The text and visuals below explore emerging technologies that can help address problems such as air pollution and climate change. Some people believe that such technologies will be a cure-all for the harmful effects of energy transformation. Yet, technology is rarely problem free. For instance, electric vehicles are emission free. However, generating the electrical energy they use may not be. As well, their batteries contain toxic metals that can leach into the landfill if not recycled properly.

**Methane Cracking**

Hydrogen fuel cells are a good example of a type of "clean" energy with hidden harmful impacts. The fuel cells emit no pollutants. But the process that is normally used to produce hydrogen, called steam methane reforming, still releases about half the carbon dioxide of a gas-powered vehicle. An emerging technology known as *methane cracking* can now produce hydrogen from methane without releasing carbon dioxide. Some carbon dioxide is still released, but emissions are very low compared to steam methane reforming.


**Cement Production**

The chemical reaction used to create lime for cement production releases carbon dioxide. Since 2008, work has been underway to develop a way of making cement that produces about 70 percent fewer carbon dioxide emissions. Considering how much cement is made worldwide, this invention could significantly reduce greenhouse gas emissions. Also, researchers are trying to create cement that actually absorbs carbon dioxide as it hardens.



**Nuclear Fusion**

For more than 50 years, scientists have been searching for a way to control nuclear fusion to generate electrical energy. A very high temperature is needed to start a fusion reaction. But scientists have already created temperatures hotter than the Sun. The real challenges are to sustain these temperatures and to contain the super-heated reaction. No known material can withstand such scorching temperatures. Yet a solution may be in the works. A promising technology, called a tokamak reactor, uses powerful magnetic fields to contain the reaction, and keep it away from the reactor walls. In 2017, a tokamak reactor in China was able to contain fusion at a temperature nearly three times that of the Sun. It contained it for 100 seconds--a new record!

## Before you leave this page . . .

1. Describe one way in which people or technology are helping to reduce the harmful impacts of energy transformation.

CONCEPT 3

# We learn from our mistakes and each other to reduce harmful impacts of energy transformation.

As humans, we make mistakes. However, we can also learn from those mistakes. Often, we do this by changing how we look at things. Our perspectives shift because we have more experience or knowledge. We can look back and consider our actions from a different viewpoint. On the other hand, we may have the benefit of seeing an issue through another's eyes, and now see things differently as a result. In either case, we gain insight into what we might do differently. This is the first step in fixing what went wrong. This applies to reducing harmful impacts of technology-related energy transformation, just as it does to any other problem.

## Reducing Harmful Effects by Learning from Past Mistakes

In 2011, a powerful earthquake struck the coast of Japan. Soon after, a 15 m tsunami flooded the Fukushima Daiichi nuclear power plant. A power outage occurred, but the backup generators needed to run the reactors' cooling mechanisms were also disabled by the flooding. The cores of the three operating reactors melted, and several explosions occurred. The fuel tubes melted and burned. Radioactive materials escaped into the atmosphere and water. Almost 20 000 people were exposed to radiation during cleanup efforts (Figure 3.40).

How can we learn from accidents such as the one at Fukushima to prevent them from happening again? After the accident, Japan stopped any plans to expand its nuclear program and launched detailed safety inspections of all its existing nuclear reactors. The reactors involved in the accident were older models with one important design flaw: they still required emergency power to cool during a power failure. Some nations, such as Germany and Italy, have turned away from nuclear power since the accident. In terms of learning from the past, these nations have taken steps to ensure that such an accident does not occur in their country. Other nations, including Japan, still support the transformation of nuclear to electrical energy. However, they are focusing on developing safer technology.

**Figure 3.40** The accident at the Fukushima Daiichi nuclear power plant gives us a chance to learn from the past. **Investigating: Find out how the meltdown at the Fukushima Daiichi nuclear plant was handled and what lessons have been learned since.**

## Activity

### Share Your Knowledge

Create a documentary about how society can learn from a harmful impact of an energy transformation that interests or concerns you. What information you include is up to you. The following questions can help you plan your documentary.

- What is the energy transformation?
- How does society benefit from this transformation?
- How is society harmed by this transformation?
- How can we learn from the harmful impact(s)?

## Managing Canada's Used Nuclear Fuel

At this time, there are four nuclear power plants in Canada—three in Ontario and one in Nova Scotia—with 18 reactors in operation. Local communities, and Canada as a whole, face the issue of how to safely manage and store nuclear wastes. The Nuclear Waste Management Organization (NWMO) is responsible for dealing with nuclear wastes in accordance with Canadian laws. This includes finding and making decisions about an appropriate location to bury the material so that it cannot harm life or the land.

The work of the NWMO is an example of collaboration between Indigenous knowledge and Western science. To ensure Indigenous perspectives are included in the selection of a safe storage site, the NWMO established an Indigenous Knowledge Policy. This policy was developed through a Council of Elders and Youth, including First Nations, Inuit, and Métis representatives. The program for identifying a site is ongoing, with a decision expected in 2023 or later.

## Extending the Connections

### First Peoples Perspectives on Nuclear Waste Management

Indigenous peoples have a variety of opinions about the presence of nuclear waste in their territories. Some support working with industry to find the safest storage method. Others believe no nuclear material should ever enter their lands. Investigate the issue by finding out the NWMO's progress in reaching a solution, how involved Indigenous advisors are in the process, and arguments by people for and against the plan.

## Before you leave this page . . .

1. Is it possible to reduce harmful effects of energy transformation by learning from past mistakes? Justify your response using examples from this Concept.

TAKE a Stand

# Make a Difference

## Should we use nuclear power?

Two main concerns influence public opinion about nuclear power: danger of nuclear accidents and risks related to nuclear wastes. In 2010, the Organization for Economic Co-operation and Development (OECD) conducted a study of international public opinion. Results showed that even though previous nuclear accidents had a negative impact on public opinion about safety, support for nuclear energy had been rising strongly over the past 10 to 20 years in the United States, Western Europe, and Japan. Despite concerns about its waste, nuclear energy was viewed as a dependable energy source. It also reduced a country's dependence on energy imports and contributed less to climate change.

The 2011 accident at Fukushima, Japan, changed things. A study of 23 countries was completed a year after the accident. It showed that attitudes varied by country and were strongly tied to culture and emotions. For example, core support remained strong in the U.S. and Britain. However, Germany and Italy shifted to an anti-nuclear stance. More consistent was the public's perception. The public now thought that the release of information about major nuclear accidents was too slow and contradictory. As well, there was little trust that institutions can prevent or manage accidents. Even so, the public still views nuclear power as more dependable than renewable sources, such as solar and wind.

### Evaluate and Communicate

1. Choose a position for or against the use of nuclear power. Work in a group to prepare for a debate. Consider issues such as safety, costs, waste, reliability, and climate change. If there is time, carry out the debate.
2. What role should public opinion, including your own, play in determining whether nuclear power is part of Canada's energy plan? Write a short (250-word) opinion paper expressing your view.

# 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. Use a graphic organizer to outline three positive effects and three negative effects that energy transformation have had on humans. PA AI C

2. The photo shows smog over the Fraser Valley.

   a) How is the generation of smog linked to energy transformation by humans?
   b) How is smog harmful to human health? PA AI

3. Draw a comic strip that shows one way that you personally could reduce a negative impact of technology-related energy transformation. PA AI C

4. Why is learning from the past important to our energy future? PA AI E

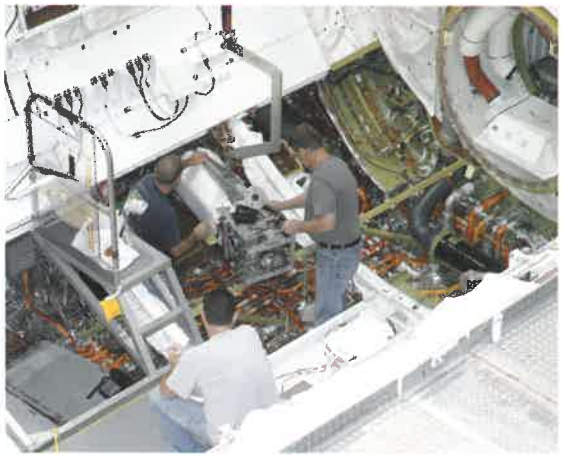
5. a) Describe how cement and fuel cell technology can both reduce the effects of climate change.
   b) Which technology do you think will have a greater effect on the atmospheric concentration of carbon dioxide? Why? PA AI E C

## Connecting Ideas

6. Consider the tokamak fusion reactor.
   a) Describe the energy transformation that takes place in the reactor.
   b) Describe the system that is involved in this energy transformation.
   c) Describe the surroundings of the system.
   d) How does the reactor allow fusion to occur in a controlled way?
   e) Identify the different forms of energy that play role in your answer to part **d)**. PA AI

## Making New Connections

7. During NASA's space shuttle missions, fuel cells were used to provide electrical energy for the shuttles. The photo shows one of the three fuel cells onboard a shuttle being removed. Use your knowledge of fuel cells to evaluate why a fuel cell was a good choice for this application. PA AI E



INVESTIGATION
# 3-H

GUIDED INQUIRY

## Energy Transformation Debate

Do technology-based energy transformations benefit us more than they harm us? Or is the reverse true? The answer to this question is "It's debatable." In this investigation, you will join the debate yourself.

### Skills and Strategies

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

### What You Need

- access to information resources (for example: online, print, interviews)

### Question

Do technology-based energy transformations benefit us more than they harm us? Or is the reverse true?

### Procedure

1. Your teacher will assign you to a debate team. With your team, develop a research plan to find support for your position. Consider the following.
   - What energy transformations will you research? For example, in addition to those that involve fuel combustion in vehicles and generating electrical energy, you might consider those involved in agriculture and food industries, product manufacturing, medicine, crime detection, etc. As well, you might consider the benefits and drawbacks of using radioactive isotopes to diagnose and treat diseases, or the risks and costs to food producers and consumers of food irradiation.
   - What questions do you want to answer?
   - What resources will you use?
   - What role will each group member play in completing the research?
   - How will you record your findings and cite your resources?
2. As part of your research plan, you will need to assess your resources for bias and reliability.

   For each resource you use, consider the following questions.
   - What political positions are represented? Are they obvious or hidden?
   - What special interests might be involved in the issue? Who stands to gain from presenting a particular viewpoint? Who is paying for the message?
   - What sources are used as evidence in the communication? How reliable are they?

- Are facts and statistics cited in the presentation? Are they reliable? Are citations provided so you can check the sources?
- Is the story one-sided, or are alternate views presented?
- Are arguments based on facts and logic, or are they emotional appeals? Does it matter?

3. Complete your research and use your findings to prepare your argument for the debate.
4. Carry out your debate.

## Evaluate

1. As a class, decide which team won the debate and why. Do you agree with the class assessment? Justify your response.
2. Why was it important that you assessed your resources for bias and reliability in this Investigation? Explain your answer, making reference to specific resources you used as part of your research.

# UNIT 3

# Summary

**ESSENTIAL QUESTION**

**How can we investigate and apply our understanding of energy transfer and transformation?**

## TOPIC 3.1:
## What are the properties of energy?

- Energy can produce change in a system.
- There are different forms of energy.
- Energy can be transferred or transformed.
- Physical quantities contribute to different forms of energy.

**Key Terms**

system
surroundings
kinetic energy
potential energy
law of conservation of energy

## TOPIC 3.2:
## How is energy transformed?

- Energy is transformed in chemical reactions.
- Energy is transformed in nuclear reactions.
- Energy is transformed when light energy interacts with matter.

**Key Terms**

radiation
nuclear fission
nuclear fusion
nuclear decay
chain reaction
absorption

## TOPIC 3.3:
## How does energy transformation affect global systems?

- Earth is a system in which energy is transformed.
- Earth's atmosphere is heated by the transformation and transfer of solar energy and thermal energy.
- Energy transfer and energy transformation moderate Earth's temperature.
- Energy transformation and transfer can harm aquatic and terrestrial ecosystems.

**Key Terms**

conduction

convection

specific heat capacity

## TOPIC 3.4:
## How does energy transformation affect humans?

- Energy transformations provide benefits, but not without risk of harm.
- We take action and create technology to reduce the harmful impacts of energy transformation.
- We learn from our mistakes and each other to reduce harmful impacts of energy transformation.

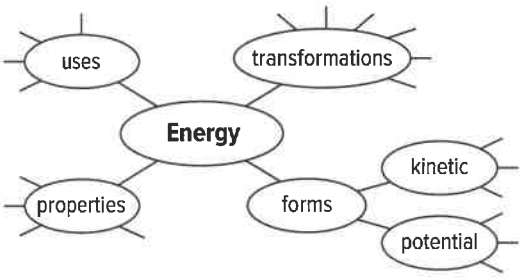
# UNIT 3

# Review

## What Do You Know?
Connecting to Concepts

### Visualizing Ideas

1. Expand the following map about energy. Add as many extensions to the map as you can.




2. Create a Venn diagram that compares kinetic energy with potential energy.

### Using Key Terms

3. Use the list of key terms below to create three or four categories into which the terms can be divided. Write the names of the categories and list the key terms that fit into each. Explain why the terms fit into each category.
   - chain reaction
   - conduction
   - convection
   - kinetic energy
   - law of conservation of energy
   - nuclear decay
   - nuclear fission
   - nuclear fusion
   - potential energy
   - radiation
   - specific heat capacity
   - surroundings
   - system

### Communicating Concepts

4. List three forms of potential energy that we transform into electrical energy.
5. Describe two ways you can indirectly observe energy.
6. The photo shows a scene at the Capilano Suspension Bridge Park in Vancouver. Identify as many forms of energy as you can that are present in or that could be inferred from the photo. Identify each form as kinetic or potential.

7. In living things, glucose reacts with oxygen to produce energy, according to the reaction below.

   $C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O + \text{energy}$

   If energy is released in this reaction, how can photosynthetic organisms carry out the reverse of this reaction and combine carbon dioxide and water to make glucose?
8. ATP is often involved when energy transformations occur in living things.
   a) What is ATP?
   b) Identify two processes that involve ATP.
   c) For each example you listed in part **b)**, explain the role of ATP.

9. Use the following nuclear equation to answer the questions below.

$$^{210}_{85}\text{At} \longrightarrow {}^{206}_{83}\text{Bi} + {}^{4}_{2}\text{He} + \text{energy}$$

   a) What type of nuclear reaction is occurring in the equation?

   b) What is represented by $^{4}_{2}\text{He}$?

10. a) Explain how the mass number of an atom can remain the same if its atomic number changes in a nuclear reaction.

    b) In what type of reaction(s) does this happen?

11. Use the following nuclear equation to answer the questions below.

$$^{235}_{92}\text{U} + {}^{1}_{0}\text{n} \longrightarrow {}^{90}_{38}\text{Sr} + {}^{143}_{54}\text{Xe} + 3\,{}^{1}_{0}\text{n} + \text{energy}$$

    a) What type of reaction does this equation represent?

    b) Where would you expect to find this type of reaction occurring?

    c) Describe one characteristic of the products of this reaction.

12. Compare chemical reactions and nuclear reactions in terms of how much energy they transform.

13. a) Identify two different atmospheric greenhouse gases.

    b) Describe one positive effect of these gases.

    c) Describe one negative effect of the gases.

14. a) What is methane cracking?

    b) What is steam methane reforming?

    c) Which of the above processes is more harmful to the environment? Explain why this is the case.

15. Over history, we have developed technologies that have helped us benefit from energy transformations, but these technologies have also had negative effects. Use two examples to support this statement.

# What Do You Know? Connecting to Competencies

## Developing Skills

16. a) Write the equation that describes gravitational potential energy.

    b) Use this equation to create a graph that shows how gravitational potential energy of an object changes as height measured from a reference point increases.

17. Use a sketch or diagram to explain how energy is transformed and transferred to bring a pot of water to a boil on a stove.

18. Figure 3.32 shows how cells in the retina of the eye transform light energy to enable vision. Use an analogy to help explain this process to a grade 7 student.

19. Use a diagram or write a description to show the relationships among evaporation, gravitational potential energy, transpiration, solar energy, precipitation, thermal energy, and condensation in terms of energy transformation.

## Thinking Critically and Creatively

20. It has been said, "The only truly isolated system is the universe itself." What does that statement mean? Explain whether you believe that it is accurate, and why.

21. In a battery, chemical reactions transform chemical potential energy into electrical potential energy. When attached to a circuit, the electrical potential energy is transformed into electrical kinetic energy in an electric current. A load can transform this electrical kinetic energy to other forms of energy. Explain how fuel cells are similar to batteries, and how they are different.

**22.** **a)** Use an analogy to explain the concept of specific heat capacity to a student who is not taking this course.

**b)** Describe an observation you might make that would tell you that the specific heat capacity of water is higher than the specific heat capacity of land. Justify your response.

**23.** You give your friend a push on a swing. A short time later, your friend and the swing come to a halt.

**a)** Identify a system and its surroundings in this example.

**b)** Explain why the law of conservation of energy can still be applied to this example. Refer to the system and surroundings you identified in part **a)** in your response.

**24.** Photovoltaic cells are made of two thin slices of silicon treated with different materials. They are then sandwiched together. Why could a single slice of silicon not be used instead?

**25.** Hydrogen, helium, and traces of lithium were produced as part of the early history of the universe, before stars formed. Atoms of all other elements were produced by fusion reactions that happened in stars or in supernova explosions. Scientists of First Peoples, Western traditions, and other ways of knowing commonly describe humanity as being made of "star stuff." What does this description mean?

**26.** Uncontrolled fission reactions can result in a reactor meltdown at a nuclear power plant. Control rods in a nuclear reactor control the rate at which fission reactions occur. They are lifted from and lowered into the reactor as needed. The control rods contain cadmium, which absorbs neutrons. How do you think control rods control the rate at which fission reactions occur?

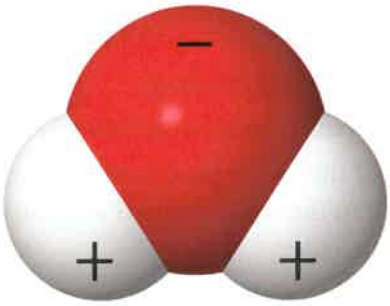
**27.** Photovoltaic cells and vision are two means through which energy is transformed when light interacts with matter. Describe another example in which matter absorbs light and energy is transformed.

**28.** All solar energy that reaches Earth's surface is re-radiated back into space, mostly as infrared radiation. However, solar energy maintains life on Earth. Explain how both these things are possible.

## Understanding Big Ideas
## Making New Connections

### Applying Your Understanding

**29.** Water has unique properties that make it important to living organisms. One of these properties is a large specific heat capacity relative to many other substances. Study the image of a water molecule. Notice that one end is negatively charged and the other end is positively charged. Think about how water molecules interact with each other. Now, use the concepts you are thinking about to suggest why water has such a large specific heat capacity.




**30.** Why do scientists find it so difficult to develop a way to control nuclear fusion so it can be used to generate electrical energy?

## Thinking Critically and Creatively

**31.** Most take-out pizza boxes are made of cardboard.

- **a)** Use the terms open system, closed system, and isolated system to explain why pizza boxes do not keep a pizza very warm.
- **b)** Use your knowledge of these different systems to suggest a design for an improved pizza box.

**32.** Identify three things you did today that used energy. For each example, describe how energy was transferred or transformed.

**33.** A scientist has developed a building material that reduces the damage caused by earthquakes. Use the concepts of energy transfer and/or transformation to suggest how this material might work.

**34.** Active solar-collector systems are often used to provide thermal energy for water heaters, pools, and homes. A simple active solar collector consists of a solar collector, a pump, a heat storage system, and a system of pipes to move the heat from one place to another. Solar energy heats water that circulates through pipes. The hot water is pumped to the location that is to be heated, such as a pool. The cold water is pumped back through the pipes so it passes through the solar collectors, once again being heated by energy from the Sun.

- **a)** Describe how energy is transferred and transformed by an active solar collector.
- **b)** Active solar collectors have few negative effects on the environment. Do you think this technology would be a good way to heat your school? Explain your reasoning.

## Connecting Self and Society

**35.** Only as much as 10% of the electrical kinetic energy that is used by a halogen light bulb is transformed into light energy.

- **a)** What happened to the remaining 90% of the energy?
- **b)** LED bulbs are more efficient than halogen bulbs, but they are expensive to buy. Would you choose to buy LED bulbs? Explain why or why not.
- **c)** Do you think most of society would answer part **b)** in the same way you did? Explain.

**36.** Could society survive without energy transformations? Explain your reasoning.

**37.** **a)** When an accident happens at a nuclear power plant, the local environment can take a long time to recover from the damage. Explain why.

- **b)** When a fossil-fuel-burning power plant is operating normally, it contributes pollutants to the atmosphere. Explain how this can affect living things.
- **c)** Compare the above negative effects as well as any others you know of related to the generation of electrical energy from nuclear reactions and fossil fuels. Which one do you think has the greatest negative effect on society overall? Explain your reasoning.

**38.** Review the five themes that are the foundation of First Peoples perspectives of science. How do these themes relate to Western science perspectives on energy transformation, energy transfer, and the law of conservation of energy? Write, record, or narrate your ideas, along with reasons in support of them.

# Unit Assessment

## How do sustainable vehicles compare to conventional vehicles?


A current push toward the development and use of sustainable vehicles around the world is helping to reduce emissions of greenhouse gases and other pollutants. These vehicles typically do not rely on the combustion of fossil fuels. Instead, scientists and engineers have turned to other energy transfers and transformations—for instance, the transfer of the mechanical kinetic energy of the wind, and the transformation of solar energy and chemical potential energy of non-fossil fuel sources. Some sustainable vehicles do use fossil fuels, but in a way that reduces the impact of their combustion. Sustainable vehicles are not problem-free, however. Issues to resolve include factors such as a speed, cost, availability, public acceptance, and potential effects on living things and the environment.

Work as part of a group to do the following.

**STEP 1** ► Reflect on the three options, their photos, and the questions asked in their captions.

**STEP 2** ► Brainstorm at least three more options and questions of your own about sustainable versus conventional vehicles.

**STEP 3** ► Decide on one of the six 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**

## Solar in the Sky

How can a model help you demonstrate that solar aircraft are, or are not, a practical alternative to conventional aircraft?


**OPTION B**

## Electric Vehicles

UBC is actively engaged in using, as well as further developing, electric cars. How do electric cars compare to gas-powered ones?

**OPTION C**

## Fuel-cell Safety

How do fuel-cell vehicles compare to conventional ones in terms of safety for their human passengers?


## 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
- Compare at least one type of sustainable vehicle with a conventional vehicle? AI
- Present the results of the inquiry using language, conventions, and representations appropriate for a specific purpose and audience? C

# UNIT 4

# The formation of the universe can be explained by the big bang theory.

Have you ever shone a flashlight into the vastness of a twilight or night sky? Many people have done so, especially in their youth. Perhaps they wondered if someone might, somehow, from somewhere, glimpse the dim beam. Maybe it helped them feel more connected to a universe that might otherwise seem impersonal. Could it have been a way of calling out to say "Hey, I'm here. I see you. Do you see me?"

> **"There's as many atoms in a single molecule of your DNA as there are stars in the typical galaxy. We are, each of us, a little universe."**
>
> *Neil deGrasse Tyson, astrophysicist, cosmologist, science communicator*