CHAPTER 9

Plate movements cause both sudden and gradual changes to Earth's crust.

KEY IDEAS

- Moving plates interact at divergent, convergent, and transform fault boundaries.
- Earthquakes are caused by the sudden movement of plates at plate boundaries.
- Volcanoes can erupt at plate boundaries or at hot spots.

As you have learned, Earth's surface is constantly changing. Even though we may be unaware of it, mountains, valleys, and new islands are being formed. Some of the changes are sudden. Earthquakes can happen with little warning. Other changes are very gradual. The movement of the plates can create different kinds of mountains. Some changes, such as a volcanic eruption, are noticeable and newsworthy. Other changes, such as the formation of a ridge under the surface of the ocean, are seldom noticed or commented on. Even the slowest and least noticeable of these changes can have an enormous effect on the surface of Earth over a long period of time.

In this chapter, you will learn about both the sudden and gradual changes that alter the landscape of Earth. As you study this chapter, keep asking yourself what these changes have to do with the movement of the plates of Earth's crust.

Plates on the Move

9.1

Some of Earth's plates are being pulled apart, some are colliding, some are being pulled under others, and some are sliding past each other. The areas where plates meet are called plate boundaries. There are three types of plate boundaries:

1. divergent boundaries, where plates are being pulled apart
2. convergent boundaries, where plates are being pushed together
3. transform fault boundaries, where plates are sliding past each other

LEARNING TIP

Preview this section and look at the headings. There are three main headings, one for each type of plate movement. Under one of the headings are three subheadings. Use this structure for taking point-form notes as you read the section. Your notes should always answer two questions:

- What is happening at this type of boundary?
- Where in the world is an example of this type of boundary?

Divergent Boundaries

The boundaries between plates that are moving apart are called **divergent boundaries.** As plates separate, hot molten magma rises to Earth's surface to form new crust. On the ocean floor this separation of plates and production of new crust is called sea-floor spreading (**Figure 1**).

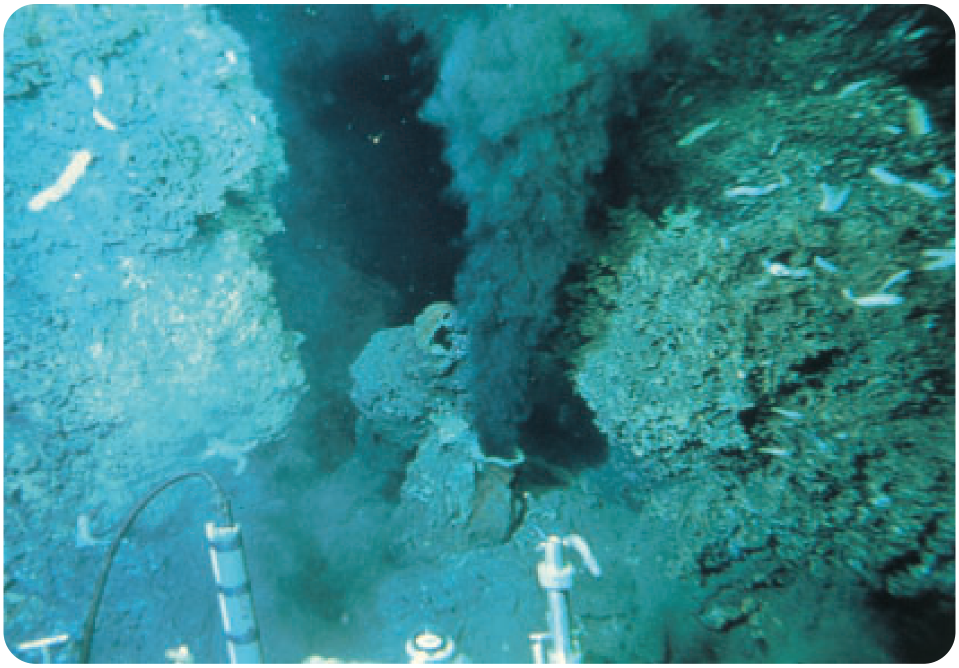


Figure 1

This photo of the sea floor was taken by the deep-sea submersible seen at the bottom of the photograph. As plates move apart and create a crack in the crust, seawater seeps into the crack and becomes heated by the magma that is being pushed up from below.

The magma cools and hardens, forming ridges of new rock. These ridges can rise a kilometre above the ocean floor. The entire length of the Atlantic Ocean has a ridge in the middle where the North American and Eurasian plates are separating. This is known as the Mid-Atlantic Ridge (**Figure 2**). The rate of sea-floor spreading along the Mid-Atlantic Ridge is about 2.5 cm per year. Although this seems slow, it is gradually widening the Atlantic Ocean.

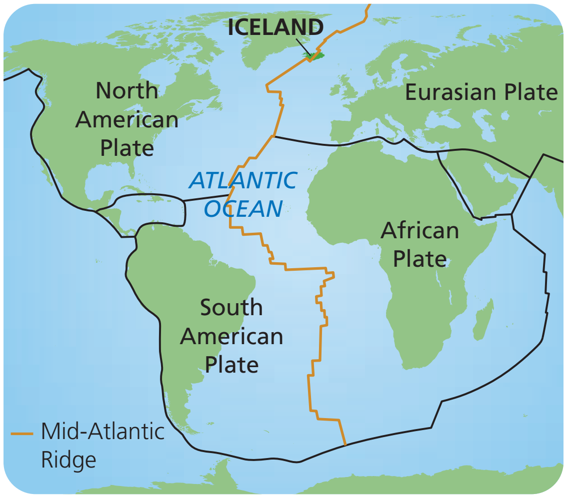


Figure 2
The Mid-Atlantic Ridge marks where the North American and Eurasian plates are separating.

On land, divergent boundaries create valleys called rifts. In Iceland, the divergent boundary between the North American Plate and the Eurasian Plate is visible on land (**Figure 3**).

Figure 3
A divergent boundary between separating plates is clearly visible as a rift near Thingvellir, Iceland.

Another divergent boundary is found in East Africa. Here the spreading between the African Plate and the Arabian Plate has already separated Saudi Arabia from the rest of the African continent and formed the Red Sea (**Figure 4**). It has also created the East African Rift system on land.

Figure 4
The divergent boundaries between plates in East Africa

Convergent Boundaries

Since there is no evidence that the size of Earth has changed significantly, old crust must be destroyed, or recycled, at the same rate that new crust is being formed at divergent boundaries. The recycling of old crust takes place at boundaries where plates move toward each other. These boundaries are called **convergent boundaries.**

The collisions that occur when plates come together are very slow and can last millions of years. When plates come together, one plate sinks below the other. The place where this occurs is called a **subduction zone** [sub-DUC-shun]. You can think of subduction as nature's way of recycling Earth's crust.

The landforms created at a convergent boundary depend on whether an oceanic plate is converging with a continental plate, two oceanic plates are converging, or two continental plates are converging.

Oceanic Plate Converging with Continental Plate

When an oceanic plate collides with a continental plate, the oceanic plate is subducted under the continental plate (**Figure 5**). This creates deep ocean trenches along the edge of a continent. Along the coast of British Columbia, this happens where the Juan de Fuca Plate is being subducted under the North American Plate.

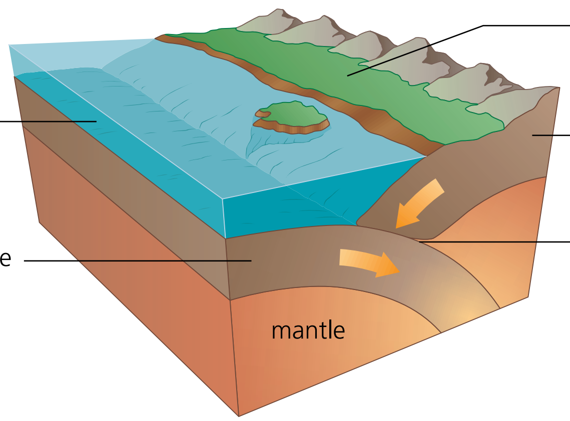


Figure 5
The Juan de Fuca Plate is being subducted under the North American Plate, which is moving west.

Off the coast of South America, the oceanic Nazca Plate is being subducted under the continental South American Plate. The South American Plate is being pushed up, creating the Andes Mountains. A **mountain** is any landmass that rises significantly from the surrounding level of Earth's surface. This type of mountain building is common where an oceanic plate is converging with a continental plate.

Oceanic Plate Converging with Oceanic Plate

When two oceanic plates converge, one plate sinks below the other. As with the convergence of oceanic and continental plates, trenches are formed at the subduction zone. Challenger Deep, the deepest part of the oceans, is part of the Mariana Trench in the subduction zone between the Pacific and Philippine Plates (**Figure 6**). Challenger Deep is so deep that even Mount Everest could not fill it in (**Figure 7**)!

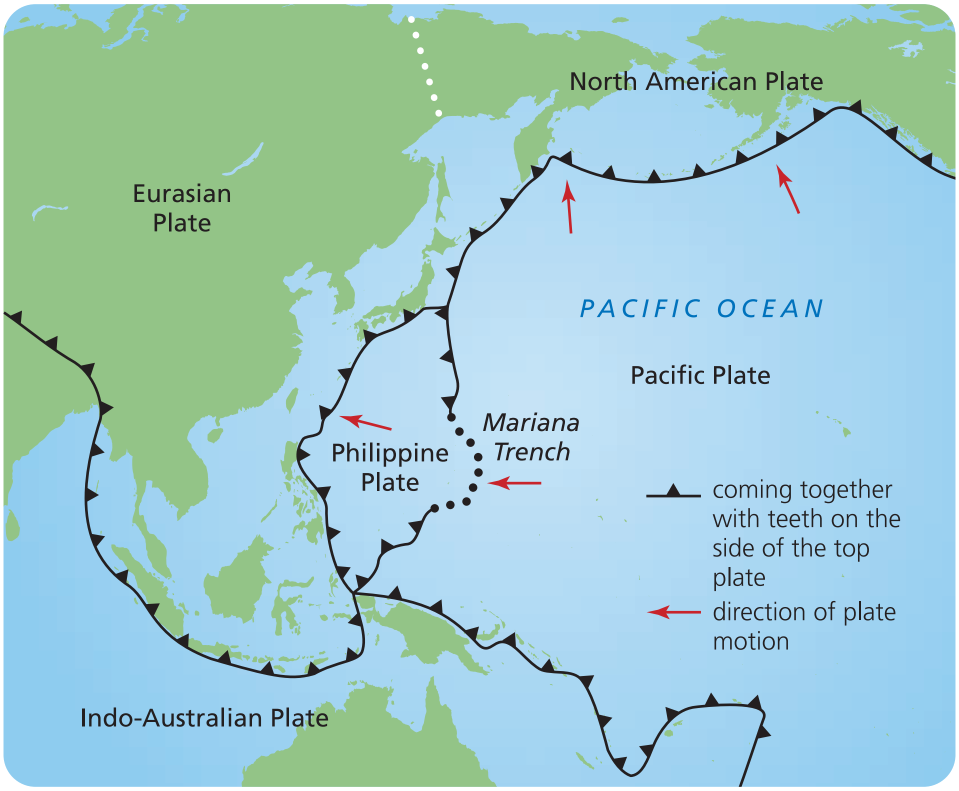


Figure 6
The Mariana Trench is being formed at a subduction zone.

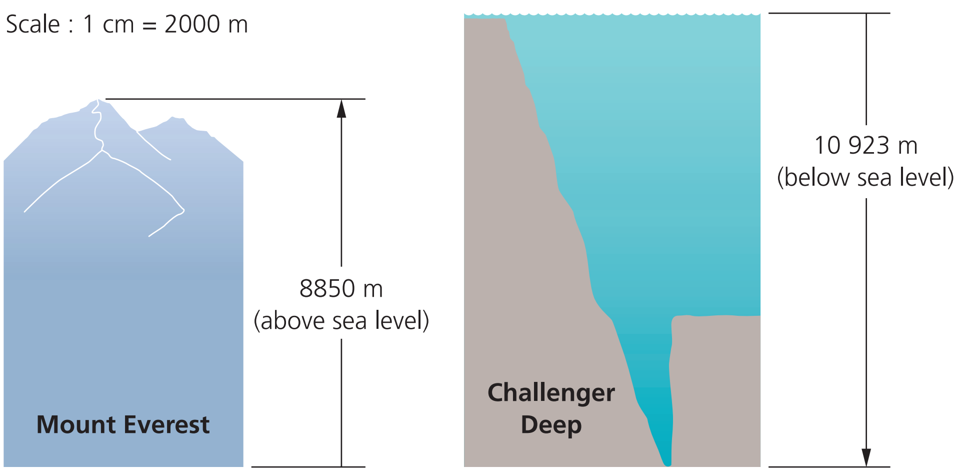


Figure 7
If you put Mount Everest into Challenger Deep, there would still be more than two kilometres of water over the top of Mount Everest!

LEARNING TIP

Visualize turning Mount Everest upside down into Challenger Deep.

Continental Plate Converging with Continental Plate

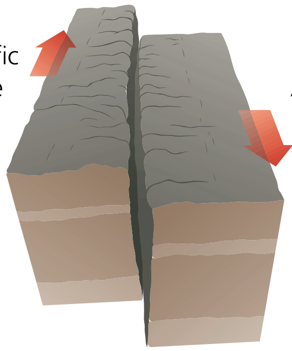
When two continental plates meet, neither is subducted. Instead, the crust buckles and crumbles, pushing up mountains or areas of high level ground called **plateaus.** When the Indian Plate converged with the Eurasian Plate 50 million years ago, the slow uplift over millions of years pushed up the highest continental mountains in the world, the Himalayas (**Figure 8**). It also pushed up the Tibetan Plateau. Although the Tibetan Plateau is fairly flat, it is higher than the Alps mountain range in Europe.

Figure 8
The Himalayas

Transform Fault Boundaries

J. Tuzo Wilson, a Canadian geophysicist, made models of plate boundaries with paper and scissors. He discovered a new kind of plate boundary, which he called a fault. A fault is an area where rocks are being broken by movement in the crust. Wilson also discovered that divergent and convergent plate boundaries could end abruptly and "transform" into faults. He therefore called the zone between plates that are slipping past each other **transform fault boundaries.**

Most transform fault boundaries are found on the ocean floor. The most famous of the few on land is the San Andreas Fault (**Figure 9**) in California. At the San Andreas Fault, the Pacific Plate, which carries part of California, is moving north past the North American Plate, which carries the rest of California. Shallow earthquakes are very common along transform fault boundaries, such as the San Andreas Fault.



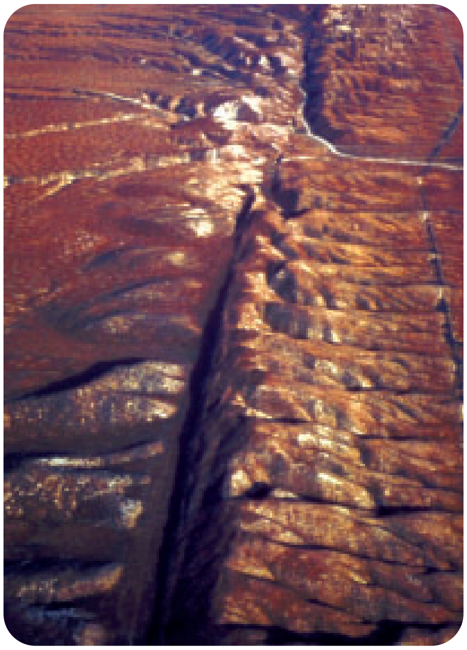


Figure 9
The San Andreas Fault is a transform fault boundary. Major earthquakes have often occurred along this fault.

CHECK YOUR UNDERSTANDING

1. Copy and complete **Table 1**.

1. Table 1 Types of Plate Boundaries

Type of plate boundary	Description of plate movement	Places on Earth where this type of plate boundary is found

2. Where would you expect to find the newest rocks on the ocean floor? Where would you expect to find the oldest rocks?

9.2 Conduct an Investigation

SKILLS MENU

○ Questioning	● Observing
○ Predicting	○ Measuring
○ Hypothesizing	● Classifying
○ Designing Experiments	○ Inferring
○ Controlling Variables	○ Interpreting Data
● Creating Models	● Communicating

Creating Models of Plate Movements

The movement of plates and the changes to Earth's surface that result from this movement are too slow for you to observe directly. In this investigation, it will take you only a few minutes to use models to demonstrate the different ways that plates move over millions and millions of years.

Question

How can you demonstrate plate movement at the three types of plate boundaries?

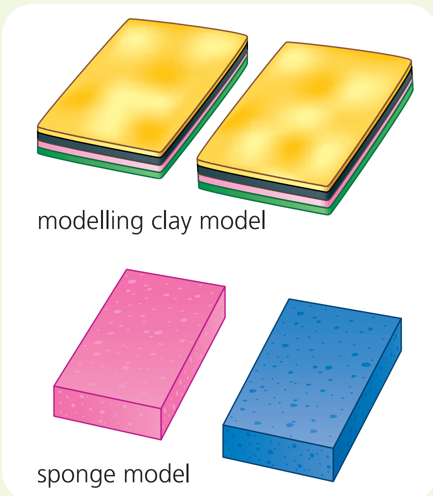
Materials

- modelling clay in 4 different colours
- rolling pin
- dinner knife
- 2 sponges of different colours

Handle the knife carefully. Always cut away from yourself and others when using a knife.

Procedure

1 Use the rolling pin to flatten each colour of modelling clay to about 1 cm thick. Stack the four layers on top of each other and press down. Cut straight across the slab so that you have two equal pieces. These pieces will be one of your models for plates. The two sponges will be your other model.



2 Using the sponge model, demonstrate plate movement for each type of plate boundary:

- divergent
- convergent
- transform fault

Record your demonstration for each boundary with sketches.

3 Repeat step 2 using your modelling-clay model.

4 Use whichever model seems to work best for each of the following demonstrations:

- Demonstrate how movement at the boundary between the African Plate and the Arabian Plate separated Saudi Arabia from the rest of Africa. What type of boundary is this?
- Demonstrate how the Juan de Fuca plate is being subducted under the North American Plate. What type of boundary is this? Identify the type(s) of plates (oceanic and/or continental) involved.
- Demonstrate the formation of an ocean trench.
- Demonstrate how the Andes Mountains were formed. What type of boundary is this? Identify the type(s) of plates (oceanic and/or continental) involved.
- Demonstrate how the Himalayas were formed. What type of boundary is this? Identify the type(s) of plates (oceanic and/or continental) involved.
- Demonstrate how a landform (hill or stream) can be separated by plates sliding past each other along a transform fault boundary.

Analyze and Evaluate

1. Which model worked best for each demonstration? What were the limitations of the other model?
2. Were you able to create mountains in more than one way with colliding plates?

Apply and Extend

3. What were the limitations of your models in demonstrating the formation of a rift valley? How could you modify or add to one of your models to improve the demonstration?
4. What other materials could you use to model plate movement?

CHECK YOUR UNDERSTANDING

1. What are the advantages and disadvantages of using models to show plate movement?

9.3 Earthquakes

LEARNING TIP

Preview the headings on these two pages. What can you say about where earthquakes occur?

As the plates that make up Earth's crust move, the rough edges lock together. Over time, pressure builds up until one or both of the plates suddenly move, releasing the energy stored in rocks. The sudden release of energy causes vibrations of Earth's crust called **earthquakes.**

Earthquakes can occur at all three types of plate boundaries:

1. divergent
2. convergent
3. transform fault.

Earthquakes at Divergent Boundaries

Earthquakes can occur where two plates are being pushed apart. Hot magma rising below the crust pushes upward toward an opening in the crust (**Figure 1**). Pressure builds up where the plates are joined. Then suddenly, the pressure is enough to push the plates apart, and the crust shakes. This produces a small local earthquake. There are constant small earthquakes along the Mid-Atlantic Ridge.

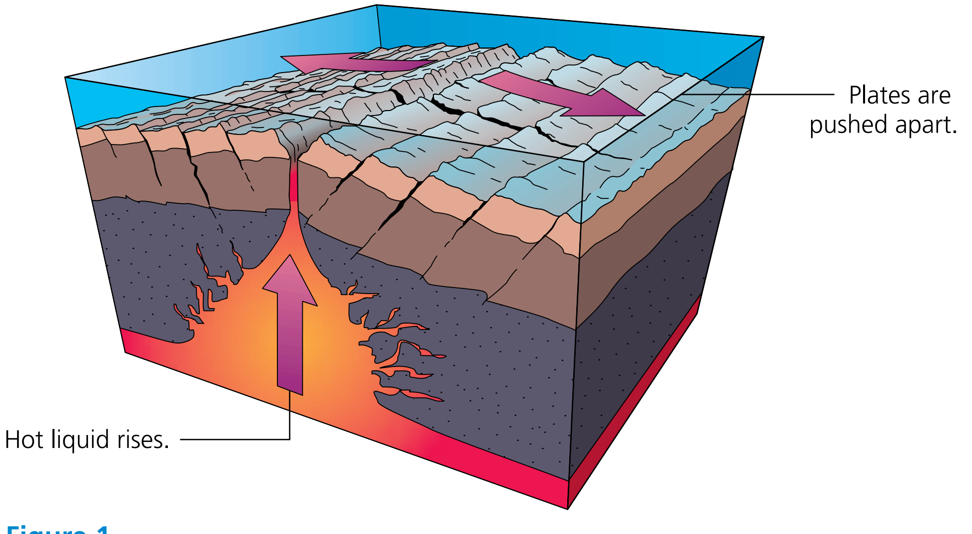


Figure 1
Some earthquakes occur as two plates are pushed apart.

Earthquakes at Convergent Boundaries

When an oceanic plate is subducted under another oceanic plate or a continental plate, it may get stuck against the top plate (**Figure 2**). The force builds up until the top plate suddenly moves. This sudden movement can cause a large earthquake. The longer a plate is stuck, the stronger the earthquake is when the plate breaks free. Southern British Columbia experiences almost 200 earthquakes a year as the Juan de Fuca Plate is subducted under the North American Plate.

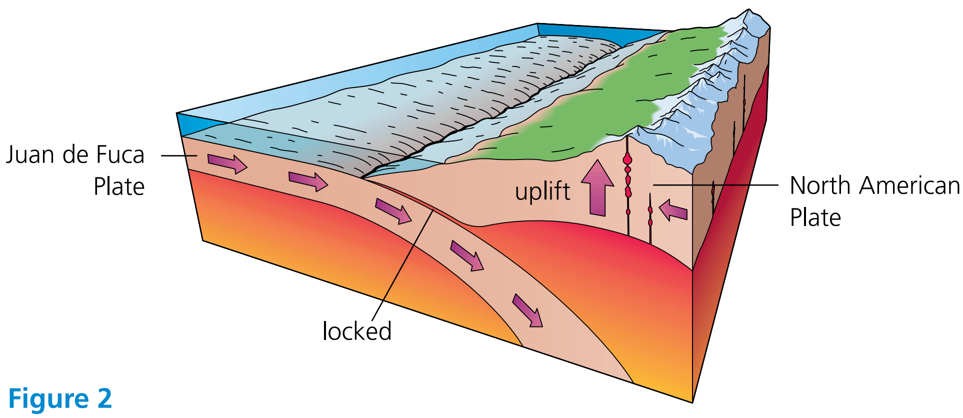


Figure 2
Some earthquakes occur in subduction zones.

Earthquakes at Transform Fault Boundaries

When two plates are moving past each other in opposite directions along a transform fault boundary, they sometimes get stuck (**Figure 3**). The force builds up until one plate suddenly moves, causing an earthquake. The longer the time before the plates slip, the stronger the earthquake is. There have been many powerful earthquakes of this type along the San Andreas Fault in California.

LEARNING TIP

Check your understanding of why earthquakes occur at plate boundaries by explaining **Figures 1**, **2**, and **3** to a partner.

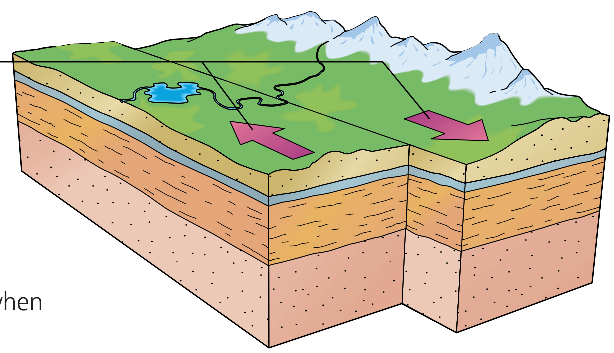


Figure 3
Some earthquakes are caused when plates move past each other.

The Effects of Earthquakes

News reports and newspaper articles about earthquakes usually include large, dramatic photos of the damage that earthquakes cause (**Figure 4**). How does this damage occur?

Figure 4
Earthquake damage in Mexico City in 1985.

The exact location within Earth at which an earthquake starts is called the focus (**Figure 5**). The focus is often deep within Earth's crust. The point on the surface of Earth directly above the focus is called the epicentre of the earthquake. The shock waves that are sent out when an earthquake occurs are called **seismic waves.** Smaller tremors can occur at any time for months after an earthquake as the pressure within Earth's crust is gradually released. These tremors are called **aftershocks.**

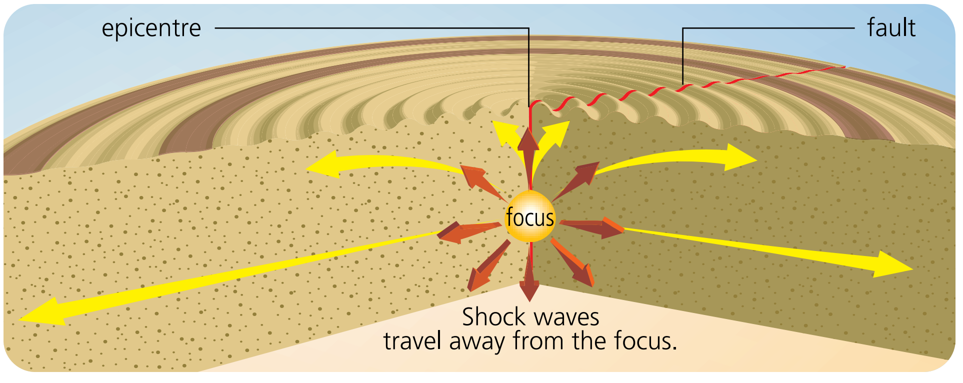


Figure 5
Comparing the focus and epicentre of an earthquake.

The energy that is released from the focus travels outward in all directions. The strength of the earthquake depends on the amount of energy that is released from the plate movement. There are two main types of seismic waves: primary (P) waves and secondary (S) waves. These waves and their effects are compared graphically in the Venn diagram in **Figure 6**.

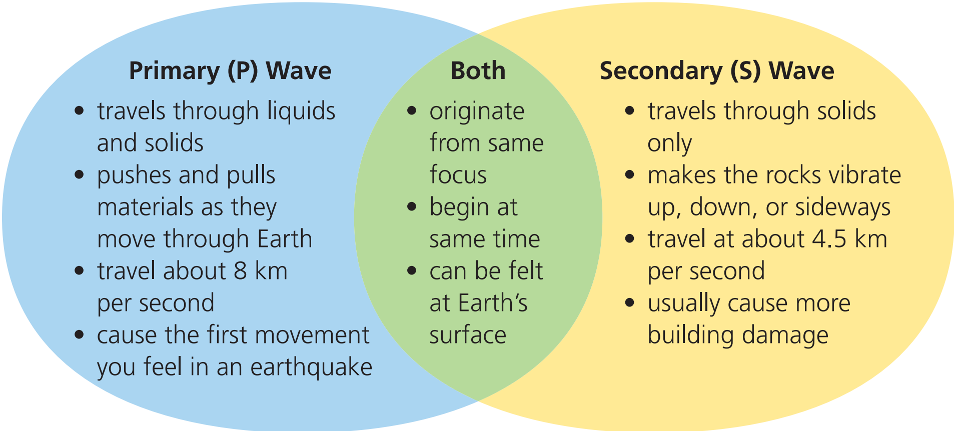


Figure 6
The two types of seismic waves that are produced by an earthquake cause different effects.

Geologists cannot observe Earth's mantle and core directly. They use indirect evidence from seismic waves to infer the characteristics of the interior of Earth (**Figure 7**).

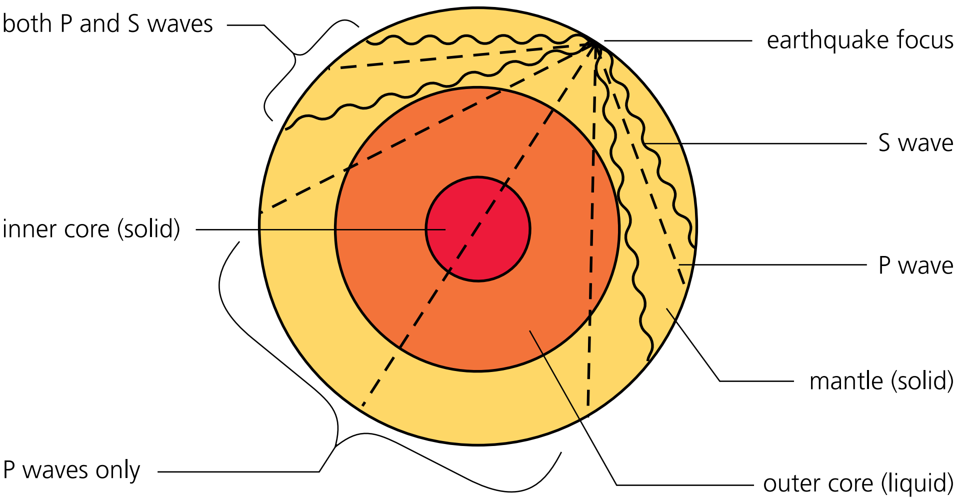


Figure 7
When an earthquake starts at the focus, the P waves can be detected anywhere. The S waves can be detected only at the locations shown. Since S waves cannot travel in liquid, scientists assume that part of Earth's interior must be liquid. This liquid part is called the outer core.

LEARNING TIP

Look at the overall diagram of earthquake waves travelling though Earth. Then look closely at each type of wave (P or S) separately and follow its path. If you are not sure why their paths are not the same, re-read the caption.

When an earthquake begins, the ground starts to shake, causing buildings to sway back and forth. If this happens in a rural area, only a few people may be in danger. If this happens in a city or town, many people may be affected. In addition to damaging buildings and roads, earthquakes can cause tunnels and overpasses to collapse. Fires can start when fuel tanks and gas lines break (**Figure 8**). Water lines can also break, leaving people without drinking water or water to fight fires.

Figure 8
In 1995, an earthquake caused massive damage when it hit the city of Kobe, Japan. Over 300 fires were started as a result.

LEARNING TIP

The name "tsunami" comes from the Japanese words for harbour (津 or *tsu*) and wave (波 or *nami*). Why is this name a good choice?

If a large earthquake causes a section of the sea floor to move, a series of ocean waves is created. Ocean waves that are caused by an earthquake or an underwater volcano are called **tsunamis** [tsu-NAH-mees].

In the open ocean, tsunamis are small and pass almost unnoticed, except that they travel much faster than normal ocean swells. Tsunamis can travel at speeds of more than 800 km/h, as fast as a commercial jetliner, in deep water. When they approach shallower waters, their speed is reduced but they grow to surprising heights. In narrow inlets or shallow harbours, their height can increase to 30 m or more. Tsunamis can cause massive destruction and flooding in coastal areas.

Tsunamis from the Anchorage, Alaska, earthquake of 1964 hit the coast of British Columbia. The Hesquiaht [HESH-dwit] village at the head of Hot Spring Cove was completely wiped out (**Figure 9**). As well, there was considerable damage to Port Alberni because the narrow Alberni Inlet pushed the waves to greater heights.

Figure 9
In 1964, tsunamis moved nearly every house in this Hesquiaht village at Hot Spring Cove off its foundation, forcing the people to rebuild elsewhere.

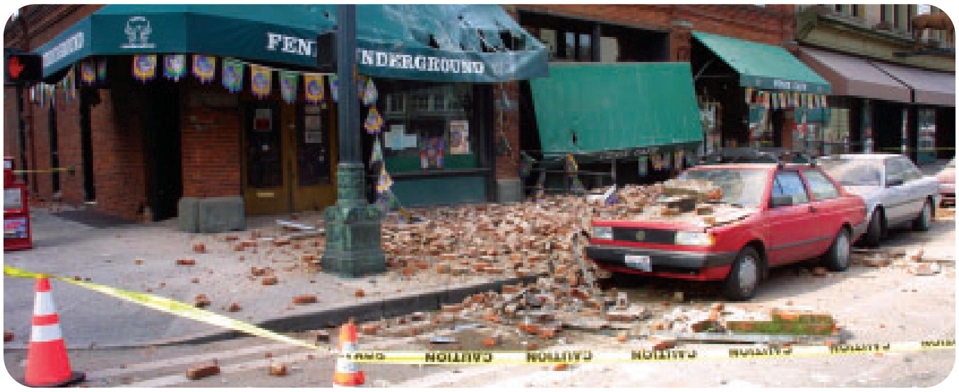
CHECK YOUR UNDERSTANDING

1. What is the main cause of earthquakes?
2. List the three types of plate boundaries. Explain why earthquakes can occur at each type of boundary. Use sketches and diagrams in your explanation.
3. Which two types of plate movement produce the biggest earthquakes? Why do you think the other type of plate movement produces smaller earthquakes?
4. Why do seismologists (scientists who study earthquakes) worry if a plate stops moving?
5. What are aftershocks? Why do aftershocks present a special danger?
6. What are tsunamis? Describe how tsunamis are produced.

9.4 Solve a Problem

▶ **LEARNING TIP**

To review the steps in solving a problem or researching see the Skills Handbook sections "Solving a Problem" and "Researching."



Preparing for an Earthquake

Problem

Are you prepared for the big one? Since many parts of British Columbia are in an earthquake zone, it is only a matter of time before a major earthquake occurs. You need to be prepared for a major earthquake, both at school and at home. What can you do before, during, and after an earthquake to keep yourself as safe as possible?

Task

Create two Earthquake Preparedness Checklists—one for school and one for home.

Criteria

To be successful, your checklists must

- provide details about the dangers during and after an earthquake
- describe precautions that you can take before, during, and after an earthquake
- be thorough and accurate
- be clear and easy to understand

Plan and Test

1. Research dangers that you might expect during a major earthquake. What can you do now to prepare for these dangers? What can you do during an earthquake to keep yourself as safe as possible from these dangers? Are the dangers at home different from those at school? Take notes as you do your research.

2. Now research dangers that you might expect after an earthquake. What can you do now to prepare for these dangers? What can you do during and after an earthquake to keep yourself as safe as possible from these dangers? Are the dangers at home different from those at school? Take notes as you work.

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3. Use your notes to draft school and home Earthquake Preparedness Checklists. Use the following headings: Before an earthquake, During an earthquake, After an earthquake.

Evaluate

4. Compare your draft school and home checklists with those of other students. Is there anything that you think you should add?
5. Compare your school checklist with the school's earthquake preparedness plan, if there is one. Is there anything that you think you should add to your checklist?
6. Show your home checklist to your parents. Is there anything that they think you should add or change?

Communicate

7. Make final copies of your school and home checklists. You may want to illustrate your checklists to emphasize important points.
8. Use your school checklist to teach a group of younger students about how to be prepared for an earthquake.
9. Is there anything on your checklist, or your classmates' checklists, that you think should be added to your school's plan? If so, get advice from your teacher about how to communicate this to your principal.
10. Is there anything on your checklist that your family has not done? Talk to your family about why it is important to do everything on your checklist.

CHECK YOUR UNDERSTANDING

1. What resources did you use to create your checklists?
2. Are there organizations in your community that could provide you with additional information? Compare your checklists with any information that these organizations provide.

Indigenous Knowledge Sheds Light on British Columbia's Geological Past

Native carver Tim Paul depicts the earthquake god as a fearsome relative of humanity. While humanity's other 10 relatives, such as Moon and stars, nurture us, the earthquake god humbles us.

On a still midwinter night, long before Europeans first landed on Vancouver Island, native legend tells of a great disaster. The sea rose in a heaving wave, and landslides buried a sleeping village.

"They had practically no way or time to save themselves. They simply had no time to get hold of canoes, no time to get awake," the late Nuu-chah-nulth Chief Louie Clamhouse told Alan McMillan, an anthropologist at Simon Fraser University. "I think a big wave slammed into the beach. The Pachena Bay people were lost."

Over time, storytellers began to speak of dwarfs in the mountains, mythic creatures who would dance around their great wooden drum, causing Earth to shake and the waters to rise.

In 2003, government research proved that an earthquake, the most intense Canada has ever seen, hit the sea floor off the British Columbia coast at 9:00 P.M. on January 26, 1700. Earthquakes of that intensity cause tsunamis, and Japanese written history tells of a massive tsunami striking fishing villages the next day along the coast of Honshu, killing hundreds. Coupled with geological evidence of the level 9 quake, the connection was clear.

Tim Paul, a Nuu-chah-nulth carver and silkscreen artist, has recorded these earthquake legends in his art. In one celebrated mask, he casts the earthquake god Ta-gil as a terrifying, cave-dwelling "relative" of humanity. The other 10 relatives—Sun, stars, Moon, and so on—nurture us, but Ta-gil "puts us in our place" and with his destruction, he "reminds us that we are the smallest part of nature," Mr. Paul says.

In Mr. Paul's silkscreens, Ta-gil is depicted with an enlarged foot, the "earthquake foot," that enables him to shake the ground. The Juan de Fuca tectonic plate, whose motion is responsible for all these myths, is the smallest tectonic plate on Earth and thus the easiest to study.

Volcanoes

9.5

One of the most spectacular shows in nature occurs when a volcano erupts (**Figure 1**). Any opening in Earth's crust through which molten rock and other materials erupt is called a **volcano.**

Volcanoes and earthquakes are proof that, deep within our planet, there are tremendous forces at work. Like earthquakes, most volcanoes are located along the edges of Earth's plates. Only a few volcanoes are found away from the edges of plates.

Some volcanoes erupt frequently and relatively quietly. You can actually watch the lava flow out of these volcanoes from a safe distance. Other volcanoes only erupt once every few hundred years, but with massive explosions. Many volcanoes go unnoticed at the bottom of oceans.

LEARNING TIP

Make a three column K-W-L chart. Record what you already know about volcanoes in the first column. Record what you wonder about them in the second column. After you finish reading this section, write what you have learned in the third column.

Figure 1
Molten lava flows from a Hawaiian volcano into the ocean.

Volcanoes at Divergent Boundaries

When you hear the word "volcano," you probably think of a volcano on land. However, about three-quarters of all lava produced on Earth comes from eruptions at divergent boundaries on the ocean floor. Magma pushes to the surface where plates are moving apart (**Figure 2**). The lava erupts and cools to form a ridge on each side of the crack on the ocean floor. Some of these ridges may rise high enough to reach the surface, creating islands. Iceland was formed, and continues to be formed, in this way.

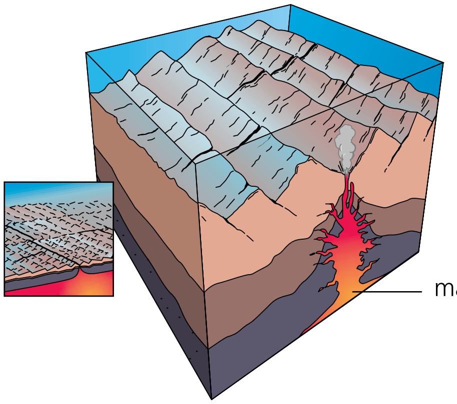


Figure 2
The Mid-Atlantic Ridge was formed by magma pushing two plates apart.

In 1963, plumes of smoke billowed out of the ocean near Iceland (**Figure 3**). Soon a new island appeared, as large amounts of magma flowed out of the ocean rift between the Eurasian and North American Plates. Eventually, the island grew to 150 m above sea level.

Mount Edziza, Hoodoo Mountain, Lava Fork, and Crow Lagoon are volcanoes on a divergent boundary in the northwestern corner of British Columbia, near the border of Alaska. These are the youngest volcanoes in the province. It has been 150 years since one erupted.

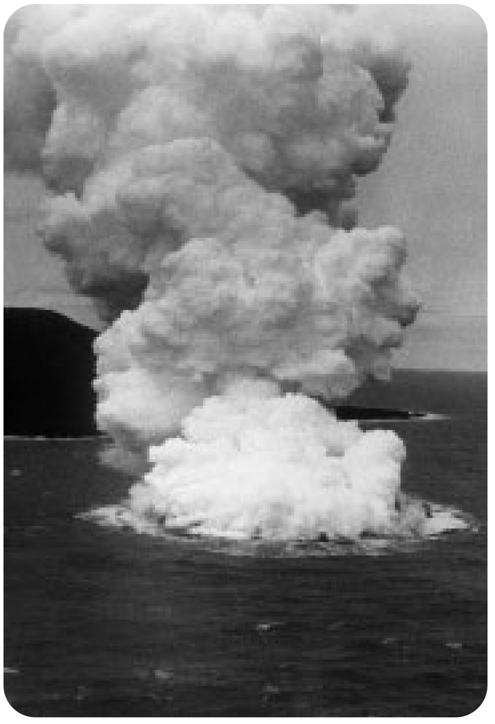


Figure 3
The new island formed off the coast of Iceland was named Surtsey, after Surt, the lord of the land of fire giants in Norse mythology.

Volcanoes at Convergent Boundaries

Most of the volcanoes on land are located near convergent plate boundaries. Some of the most powerful volcanic eruptions occur where one plate is being subducted under another plate. The magma that is formed in a subduction zone is thick and sticky. Since the magma is too still to allow steam and volcanic gases to escape, tremendous pressure builds up. This type of volcano erupts explosively as the pressure is released. As the lava reaches the surface, the high-pressure steam escapes, carrying the lava and ash with it (**Figure 4**).

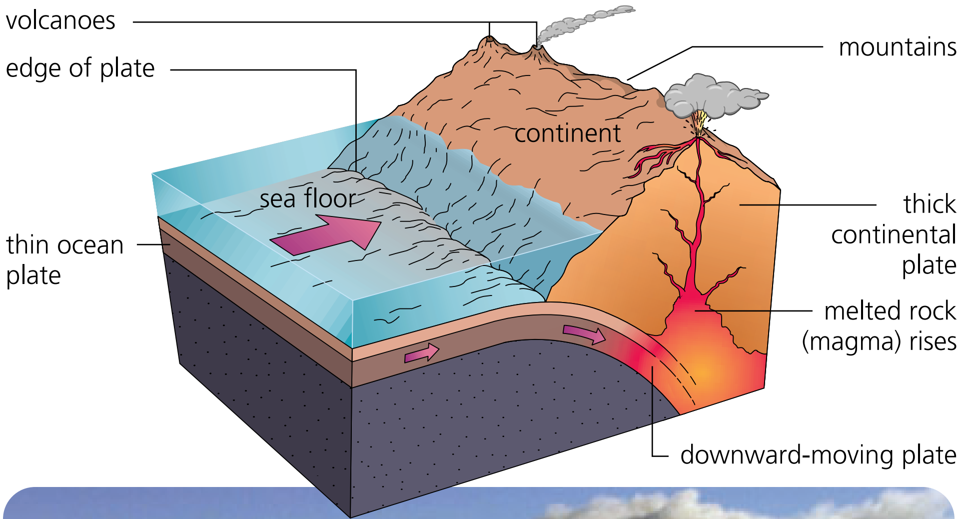


Figure 4
In 2004, Mount St. Helens, in the state of Washington, erupted. Mount St. Helens is near the convergent plate boundary where the Juan de Fuca Plate is being pulled under the North American Plate.

There has not been an explosive volcanic eruption in British Columbia since Mount Meager, near present-day Whistler, erupted over 2000 years ago. Mount Silverthrone, Mount Cayley, and Mount Garibaldi are other volcanoes on the convergent boundary where the Juan de Fuca plate is being subducted under the North American plate.

Volcanoes That Form at Hot Spots

Although most of Earth's volcanoes occur near plate boundaries, there are some exceptions. The Hawaiian Islands formed from volcanoes in the middle of the Pacific Ocean, over 3000 km from the nearest plate boundary. This puzzled scientists until J. Tuzo Wilson discovered evidence of hot spots. **Hot spots** are parts of the mantle where the temperature is much higher than normal.

At a hot spot, magma collects in enormous pools. The hot magma eventually melts a hole in the rock above it and pours out of the hole onto Earth's surface as lava (**Figure 5**). The lava that is produced at a hot spot tends to be runny and so fluid that the volcano does not erupt explosively. The lava simply pours out of the volcano like a river and hardens.

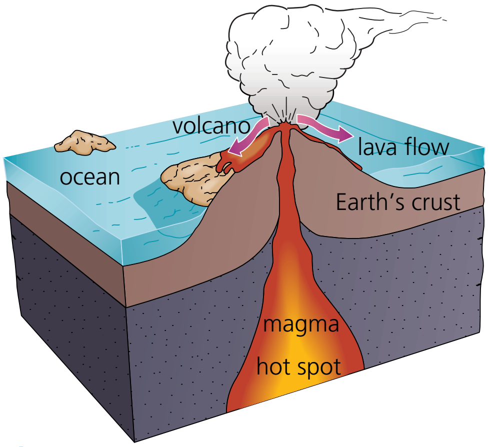


Figure 5
Volcanoes can form at a hot spot, where a huge pool of hot magma has risen through the mantle and melted a hole through the solid rock of Earth's crust.

If this type of volcano forms on the ocean floor, the lava hardens more quickly than it would on land. The hardened lava forms a cone-shaped mountain that may eventually rise above sea level as an island. This is how the Hawaiian Islands were formed (**Figure 6**).

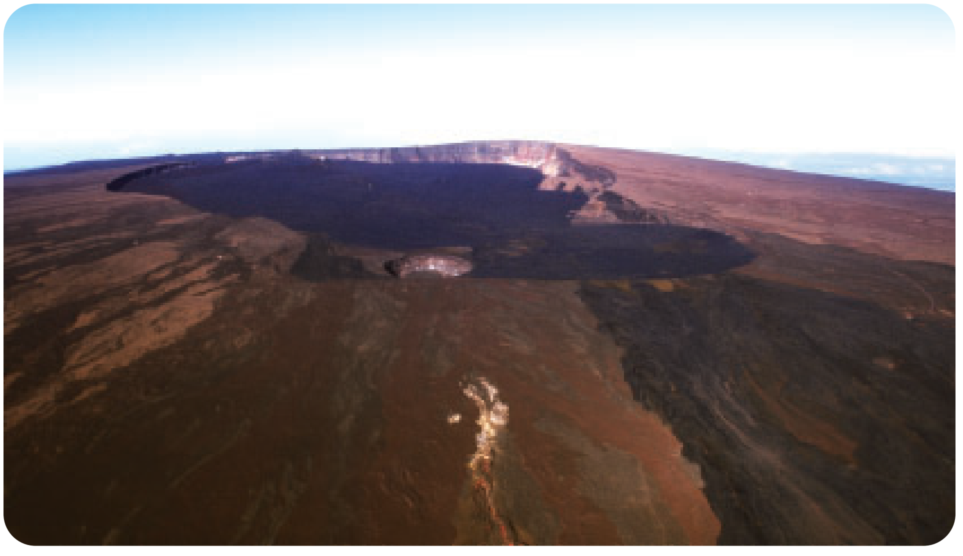


Figure 6
Mauna Loa, on the island of Hawaii, is a volcano that formed at a hot spot. From its base at the bottom of the Pacific Ocean to its summit, it rises 9750 m. This makes it taller than Mount Everest!

Recently, an underwater volcanic peak rising above the ocean floor was discovered close to the southern coast of the island of Hawaii. Scientists call it Loihi. It is over 3000 m above the floor of the ocean, but it is not expected to become an island officially for another 45 000 years.

British Columbia has a small hot spot area called the Anahim Volcanic Belt. This area stretches from the coast to Quesnel. **Figure 7** summarizes the locations where all three types of volcanoes are found in British Columbia.

LEARNING TIP

It is easier to remember information if you personalize it. How might a volcano affect your life?

Figure 7
Volcano locations in British Columbia.

TRY THIS: CLASSIFY VOLCANOES

Skills Focus: inferring, classifying

Go back to the map you labelled in Investigation 8.5. Beside each volcano you labelled, indicate whether it is occurring near a

- divergent boundary
- convergent boundary
- hot spot

Design your own symbols to use on your map.

The Effects of Volcanoes

Earthquakes can be very destructive, killing people and destroying property. People have been killed by clouds of hot ash and poisonous gases, and buried by volcanic mudslides. People have died of starvation because their crops, livestock, or other sources of food were destroyed. Whole villages and even cities have been destroyed by volcanoes. About 250 years ago, a lava flow in northern British Columbia destroyed two villages and killed about 2500 people (**Figure 8**). Scientists believe they were killed by carbon dioxide gas.

LEARNING TIP

Ask yourself, "How could community planners make use of this information on the effects of volcanoes?"

Figure 8

Lava beds at Anhluut'ukwsim Laxmihl Angwinga'asanskwhl Nisga'a: This is the first provincial park in British Columbia that has been established to combine the interpretation of geological features and Aboriginal culture.

Not all the effects of a volcano are felt right away or only close to the volcano. Ash from the 1980 eruption of Mount St. Helens fell on Vancouver. Large, explosive eruptions can send ash and gases high into the atmosphere. Volcanic clouds from the eruptions of Tambora (Indonesia) in 1815 and Mount Pinatubo (Philippines) in 1991 drifted around Earth, blocking the Sun and cooling temperatures for years.

Volcanoes have positive effects, as well. Volcanic ash improves soil and creates rich farmland. Volcanic rocks contain many useful minerals and gems. Some of the largest diamonds in the world are found in volcanic rocks. People have been using volcanic rocks for thousand of years. The Tahltan [TALL-tan] First Nation was mining obsidian several thousand years ago because the sharp edges and points of this volcanic rock could be made into useful tools (**Figure 9**). Some Aboriginal peoples used obsidian scalpels for surgery. This indigenous knowledge is important today—obsidian scalpels are still used for eye surgery.

Figure 9
Aboriginal people in many areas used the volcanic rock obsidian to make tools.

CHECK YOUR UNDERSTANDING

1. Copy and complete **Table 1** to summarize what you have learned about the three main types of volcanoes.

Table 1 Types of Volcanoes

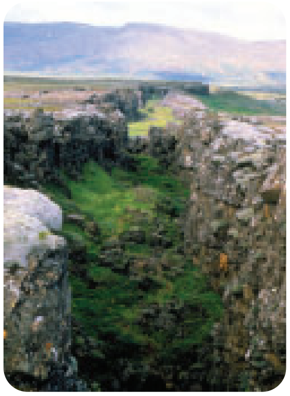
Location	Characteristics	Examples

2. People were killed when Mount St. Helens erupted, but tourists can watch volcanic eruptions in Hawaii. Why are some volcanoes more explosive than others?
3. The ancient Roman city of Pompeii was destroyed by an earthquake in 63 C.E. Pompeii was rebuilt, only to be destroyed again in 79 C.E. when a nearby volcano, Vesuvius, erupted and buried the city in ash. Why are many volcanoes found in the same areas that earthquakes occur?
4. All the volcanoes in Canada are located in British Columbia and the Yukon Territory. Explain why.

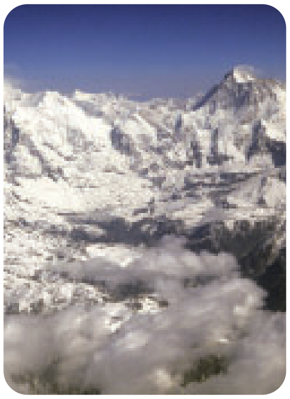
9 Chapter Review

Plate movements cause both sudden and gradual changes to Earth's crust.

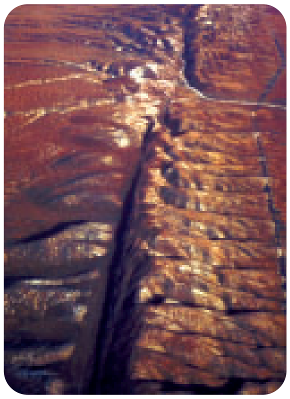
Key Idea: **Moving plates interact at three types of boundaries:**



Divergent boundary



Convergent boundary

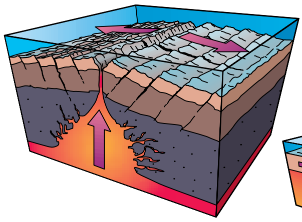


Transform fault boundary

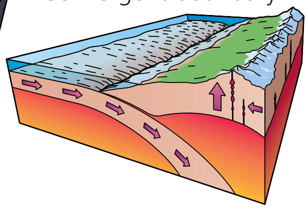
Vocabulary

divergent boundaries p. 237
convergent boundaries p. 240
subduction zone p. 240
mountain p. 240
plateaus p. 242
transform fault boundaries p. 243

Key Idea: **Earthquakes are caused by the sudden movement of plates at plate boundaries.**



Divergent boundary



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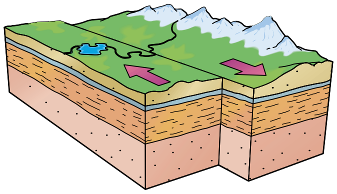
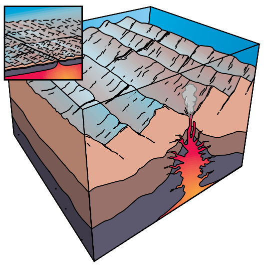


Transform fault boundary

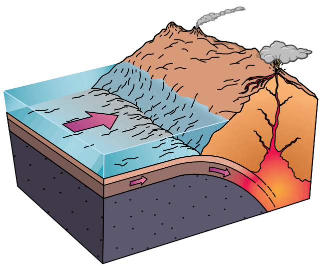
Vocabulary

earthquakes p. 246
seismic waves p. 248
aftershocks p. 248
tsunamis p. 250

Key Idea: **Volcanoes can erupt at plate boundaries or at hot spots.**



Divergent boundary



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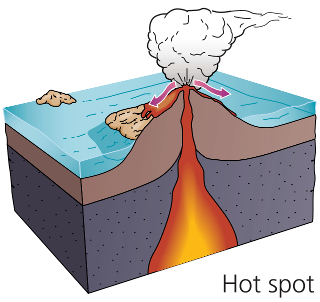

Hot spot

Vocabulary

volcano p. 255
hot spots p. 258

Review Key Ideas and Vocabulary

When answering the questions, remember to use vocabulary from the chapter.

1. What are the three types of plate boundaries? Sketch a diagram to explain plate movement at each.
2. What causes earthquakes? Where do earthquakes usually occur?
3. Where are volcanoes likely to be found? What type of volcano is found in each area, and why?
4. Why are earthquakes and volcanoes often found in the same areas?

Use What You've Learned

5. Many scientists believe that the Great Rift Valley of Africa will be the location of the next ocean as eastern Africa breaks away from the rest of the continent. Research what is known and predicted about the movement of plates in this area.

www.science.nelson.com GO

6. Why might frequent, smaller earthquakes be desirable along a transform fault boundary?
7. If a small earthquake occurs in Ontario, should people be worried that it is a sign of a bigger earthquake to come? Is this a reasonable worry?
8. What is a seismograph? What do scientists use seismographs for? Research seismographs and their use. Can you make a simple seismograph from everyday materials?

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9. In Iceland, where hot magma is close to Earth's surface, many people use its heat to warm their homes. This form of energy is called geothermal energy. Research geothermal energy. Would geothermal energy be practical to use in your community? Prepare a report.

www.science.nelson.com GO

10. Research and prepare a report on a volcanic eruption. You might consider Thera in 2600 B.C.E., Mount Vesuvius in 79 C.E., Krakatoa in 1883, Mount Pelee in 1902, Mount St. Helens in 1980 or 2004, or the Nisga'a lava beds. Is there a volcano erupting now somewhere in the world that you could research?

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Think Critically

11. Imagine that you had to live and work in one of the following areas: an area where earthquakes are common or an area where volcanic eruptions are common. Which area would you choose? Give reasons for your choice.
12. Describe some of the social problems that could result if scientists predicted an earthquake near a city. What could be done in advance to minimize these problems?

Reflect on Your Learning

13. Which hands-on activity in this chapter was most helpful to your learning? How did it help you learn?
14. How have your ideas about Earth changed since learning about plate movements? Will you look at the world differently since studying plate tectonics?

UNIT C

Making Connections

Writing the Life Story of a Rock

Looking Back

In this unit, you studied examples of both sudden and gradual changes to Earth's crust. You learned about rock and how rock from one family can change into rock from another family. You also learned that Earth's crust is made up of moving plates.

Throughout the unit, you explored, created, and used models to help you learn about processes that were too large or dangerous, or happened too slowly, for classroom observations.

In this activity, you will work with a partner to develop a detailed presentation about a single rock.

Demonstrate Your Learning

Part 1: Investigate the present.

Select a rock from the samples provided by your teacher. If you are interested in using a rock you found, check with your teacher. Use physical properties to identify your rock. Make notes for your presentation as you work. Consider the following questions about your rock.

- What rock family does your rock belong to?
- Where is it usually found?
- Are there ways in which people use this type of rock?
- Is there anything especially interesting or unusual about this type of rock?

You might do Internet research to help you find out more about your rock.

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Part 2: Describe a realistic past

Take notes as you discuss your ideas about a realistic past for your rock. Consider the following questions when describing your rock's past.

- How and where do you think your rock was formed?
- Could it once have been a different type of rock?
- How could it have been changed since it was formed?
- How could it have been moved from where it was formed?
- What type of land feature could it have been part of?

Remember that your rock's past may cover several million years. Create a model to explain your rock's past to your classmates.

Part 3: Describe a realistic future

Take notes as you brainstorm the possibilities for the future of your rock. Consider the following questions when describing your rock's future.

- What realistic predictions could you make about what will happen to your rock over the next several million years?
- Could it travel far from where it is now?
- Could it be dramatically changed?

Create a model to demonstrate your rock's possible future.

Part 4: Develop your presentation

Use your notes to develop a presentation. Your presentation could be oral or written. It could be a book, a Web site, a skit, a comic strip, or anything else you choose. Use your creativity to develop a presentation that will be informative and interesting for your classmates. Use simple materials to make models that will help you explain some of the processes you describe.

ASSESSMENT

Check to make sure that your work provides evidence that you are able to

- identify and classify your rock
- describe how your rock was formed
- describe the possible effects of weathering, erosion, and plate movement on your rock
- create models to help you explain processes that could have, or might in the future, affect your rock
- use appropriate scientific language to describe these processes

THINKING AS A SCIENTIST

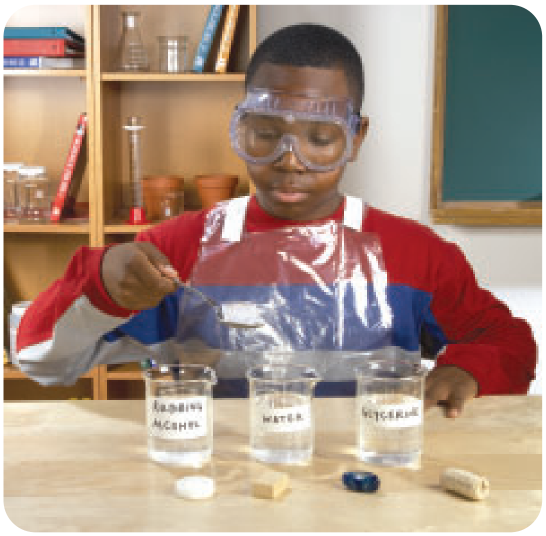
You may not think you're a scientist, but you are! You investigate the world around you, just like scientists do. When you investigate, you are looking for answers. Imagine that you are planning to buy a mountain bike. You want to find out which model is the best buy. First, you write a list of questions. Then you visit stores, check print and Internet sources, and talk to your friends to find the answers. You are conducting an investigation.

Scientists conduct investigations for different purposes:

- *Scientists investigate the natural world in order to describe it.* For example, scientists study rocks to find out what their properties are, how they were formed, and how they are still changing today.

- *Scientists investigate how objects and organisms can be classified.* For example, scientists examine substances and classify them as pure substances or mixtures.

- *Scientists investigate to test their ideas about the natural world.* Scientists ask cause-and-effect questions about what they observe. They propose hypotheses to answer their questions. Then they design experiments to test their hypotheses.



CONDUCTING AN INVESTIGATION

When you conduct an investigation or design an experiment, you will use a variety of skills. Refer to this section when you have questions about how to use any of the following investigation skills and processes.

- Questioning
- Predicting
- Hypothesizing
- Controlling Variables
- Observing
- Measuring
- Classifying
- Inferring
- Interpreting Data
- Communicating
- Creating Models

Questioning

Scientific investigations start with good questions. To write a good question, you must first decide what you want to know. This will help you think of, or formulate, a question that will lead you to the information you want.

You must think carefully about what you want to know in order to develop a good question. The question should include the information you want to find out.

Sometimes an investigation starts with a special type of question, called a cause-and-effect question. A cause-and-effect question asks whether something is causing something else. It might start in one of the following ways:
What causes ...?
How does ... affect ...?
What would happen if ...?

When an investigation starts with a cause-and-effect question, it also has a hypothesis. Read "Hypothesizing" on page 270 to find out more about hypotheses.

PRACTICE

Think of some everyday examples of cause and effect, and write statements about them. Here's one example: "When I stay up too late, I'm tired the next day." Then turn your statements into cause-and-effect questions: for example, "What would happen if I stayed up late?"

Predicting

A prediction states what is likely to happen based on what is already known. Scientists base their predictions on their observations. They look for patterns in the data they gather to help them see what might happen next or in a similar situation. This is how meteorologists come up with weather forecasts.

Remember that predictions are not guesses. They are based on solid evidence and careful observations. You must be able to give reasons for your predictions. You must also be able to test them by doing experiments.

Hypothesizing

Figure 1
This student is conducting an investigation to test this hypothesis: if the number of times the balloon is rubbed against hair increases, then the length of time it will stick to the wall will increase.

To test your questions and predictions scientifically, you need to conduct an investigation. Use a question or prediction to create a cause-and-effect statement that can be tested. This kind of statement is called a **hypothesis**.

An easy way to make sure that your hypothesis is a cause-and-effect statement is to use the form "If … then …." If the independent variable (cause) is changed, then the dependent variable (effect) will change in a specific way (**Figure 1**). For example, "If the number of times a balloon is rubbed against hair (the cause or independent variable) is increased, then the length of time it sticks to a wall (the effect or dependent variable) increases." Read "Controlling Variables" below to find out more about independent and dependent variables.

Questions, predictions, and hypotheses go hand in hand. For example, your question might be "Does a balloon stick better if you rub it more times on your hair?" Your prediction might be "A balloon will stick to a wall longer the more times it is rubbed on your hair." Your hypothesis might be "If the number of times you rub a balloon on your hair is increased, then the length of time it sticks to a wall will increase." If you prove that your hypothesis is correct, then you have confirmed your prediction.

You can create more than one hypothesis from the same question or prediction. Another student might test the hypothesis "If the number of times you rub a balloon on your hair is increased, then the length of time it sticks to a wall will be unchanged."

Of course, both of you cannot be correct. When you conduct an investigation, you do not always prove that your hypothesis is correct. Sometimes you prove that your hypothesis is incorrect. An investigation that proves your hypothesis to be incorrect is not a bad investigation or a waste of time. It has contributed to your scientific knowledge. You can re-evaluate your hypothesis and design a new experiment.

PRACTICE

Write hypotheses for questions or predictions about rubbing a balloon on your hair and sticking it to a wall. Start with the questions above, and then write your own questions. For example, if your question is "Does the balloon stick better if you rub it more times?", then your hypothesis might be "If the number of times you rub the balloon on your hair is increased, then the length of time it sticks to the wall is increased."

Controlling Variables

When you are planning an investigation, you need to make sure that your results will be reliable by conducting a fair test. To make sure that an investigation is a fair test, scientists identify all the variables that might affect their results. Then they make sure that they change only one variable at a time. This way they know that their results are caused by the variable they changed and not by any other variables (Figure 2).

- The variable that is changed in an investigation is called the **independent variable**.
- The variable that is affected by a change is called the **dependent variable**. This is the variable you measure to see how it was affected by the independent variable.
- All the other conditions that remain unchanged in an experiment, so that you know they did not have any effect on the outcome, are called **controlled variables**.

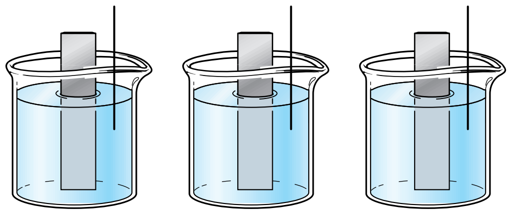


Figure 2

This investigation was designed to find out if the amount of salt in a solution has an effect on the rusting of metal.

- The amount of salt in each solution is the independent variable.
- The amount of rust on the pieces of metal is the dependent variable.
- The amount of water in each beaker and the amount of time the metal strip stays in the water are two of the controlled variables.

PRACTICE

Suppose that you have noticed mould growing on an orange. You want to know what is causing the mould. What variables will you have to consider in order to design a fair test? Which variable will you try changing in your test? What is this variable called? What will your dependent variable be? What will your controlled variables be?

Observing

When you observe something, you use your senses to learn about the world around you. You can also use tools, such as a balance, metre stick, and microscope.

Some observations are measurable. They can be expressed in numbers. Observations of time, temperature, volume, and distance can all be measured. These types of observations are called **quantitative observations**.

Other observations describe qualities that cannot be measured. The smell of a fungus, the shape of a flower petal, or the texture of soil are all examples of qualities that cannot be put in numbers. These types of observations are called **qualitative observations**. Qualitative observations also include colour, taste, clarity, and state of matter.

The colour and shape of this box are qualitative observations. The measurements of its height, depth, and width are quantitative observations.

PRACTICE

Make a table with two columns, one for quantitative observations and the other for qualitative observations. Find a rock that you think is interesting. See if you can make 10 observations about the rock. Record your observations in your table.

Measuring

Measuring is an important part of observation. When you measure an object, you can describe it precisely and keep track of any changes. To learn about using measuring tools, turn to "Measurement and Measuring Tools" on page 285.

Measuring accurately requires care.

Classifying

You classify things when you sort them into groups based on their similarities and differences. When you sort clothes, sporting equipment, or books, you are using a classification system. To be helpful to other people, a classification system must make sense to them. If, for example, your local supermarket sorted all the products in alphabetical order, so that soap, soup, and soy sauce were all on the same shelf, no one would be able to find anything!

Classification is an important skill in science. Scientists try to group objects, organisms, and events in order to understand the nature of life (**Figure 3**).

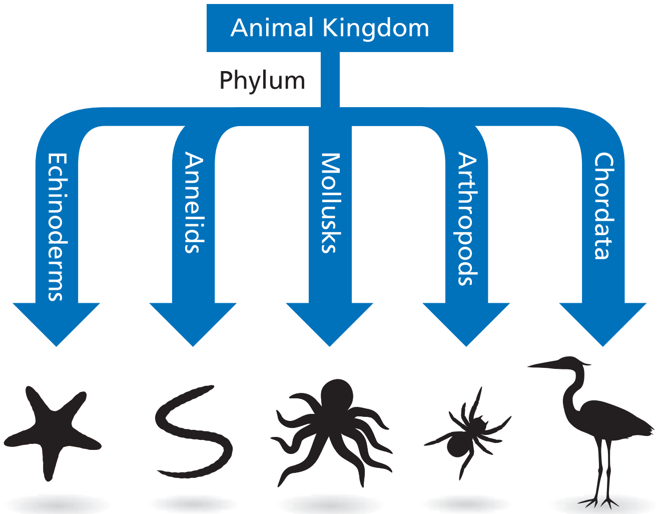


Figure 3
To help classify animals, scientists divide the animal kingdom into five smaller groups called *phyla* (singular *phylum*).

PRACTICE

Gather photos of 15 to 20 different insects, seashells, or flowers. Try to include as much variety as possible. How are all your samples alike? How are they different? How could you classify them?

Inferring

An inference is a possible explanation of something you observe. It is an educated guess based on your experience, knowledge, and observations. You can test your inferences by doing experiments.

It is important to remember that an inference is only an educated guess. There is always some uncertainty. For example, if you hear a dog barking but do not see the dog, you may infer that it is your neighbour's dog. It may, however, be some other dog that sounds the same. An observation, on the other hand, is based on what you discover with your senses and measuring tools. If you say that you heard a dog barking, you are making an observation.

PRACTICE

Decide whether each of these statements is an observation or an inference.

a) You see a bottle filled with clear liquid. You conclude that the liquid is water.

b) You notice that your head is stuffed up and you feel hot. You decide that you must have a cold.

c) You tell a friend that three new houses are being built in your neighbourhood.

d) You see a wasp crawling on the ground instead of flying. You conclude that it must be sick.

e) You notice that you are thirsty after playing sports.

Interpreting Data

When you interpret data from an investigation, you make sense of it. You examine and compare the measurements you have made. You look for patterns and relationships that will help you explain your results and give you new information about the question you are investigating. Once you have interpreted your data, you can tell whether your predictions or hypothesis are correct. You may even come up with a new hypothesis that can be tested in a new experiment.

Often, making tables or graphs of your data will help you see patterns and relationships more easily (**Figure 4**). Turn to "Communicating in Science" on page 297 to learn more about creating data tables and graphing your results.

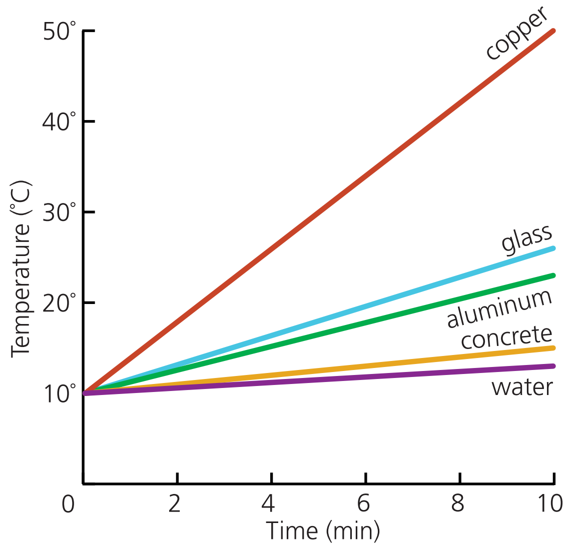


Figure 4

This graph shows data from an investigation about the heating rates of different materials. What patterns and relationships can you see from this data?

Communicating

Scientists learn from one another by sharing their observations and conclusions. They present their data in charts, tables, or graphs and in written reports. In this student text, each investigation or activity tells you how to prepare and present your results. To learn more about communicating in a written report, turn to "Writing a Lab Report" on page 300.

Creating Models

Have you ever seen a model of the solar system? Many teachers use a small model of the solar system when teaching about space because it shows how the nine planets orbit the Sun. The concept of how planets orbit the Sun is very difficult to imagine without being able to see it.

A scientific model is an idea, illustration, or object that represents something in the natural world (**Figure 5** on page 274). Models allow you to examine and investigate things that are very large, very small, very complicated, very dangerous, or hidden from view. They also allow you to investigate processes that happen too slowly to be observed directly. You can model, in a few minutes, processes that take months or even millions of years to occur.

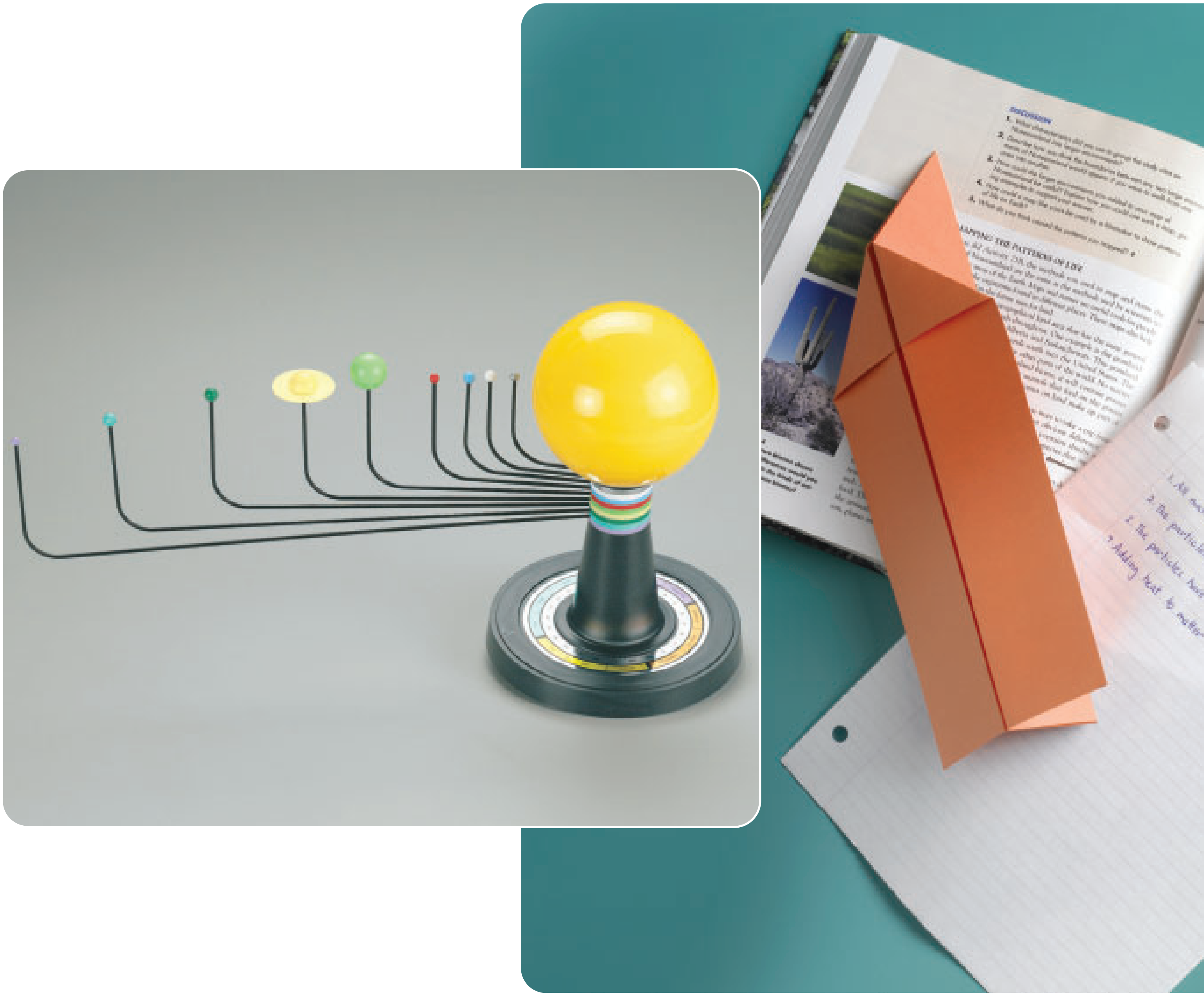
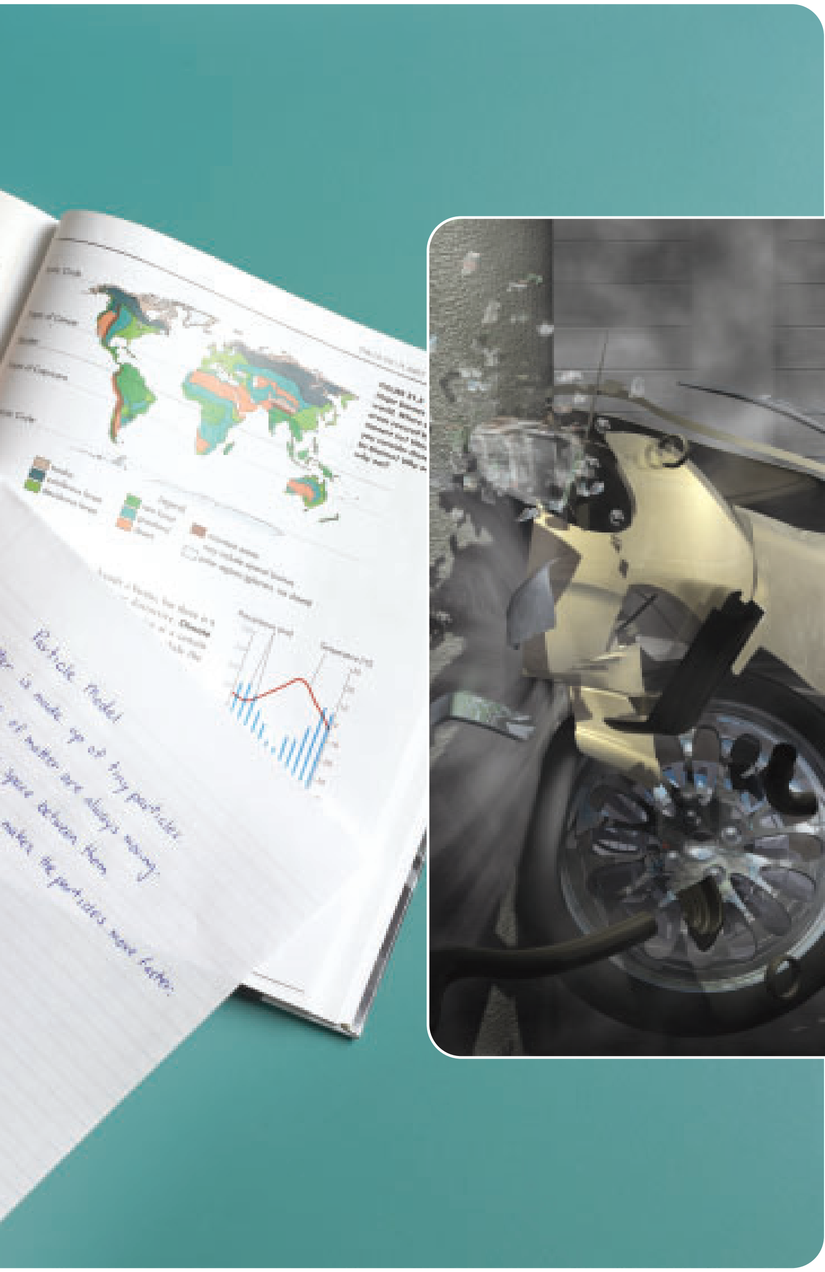


Figure 5
Why do we use these models? How are they different from what they represent? Are there any limitations or disadvantages to using them? Think of another model you could make to represent each of these things.

A model of the solar system is an example of a physical model. You can create physical models from very simple materials. Have you ever thrown a paper airplane? If so, you were actually testing a model of a real airplane. You could use paper airplane models to test different airplane designs.

Illustrations are also models. A map of Earth, showing all the biomes, is a model. So is a drawing of a particle of water. Models can be created from ideas and words, as well. Some Aboriginal stories communicate models of interconnected ecosystems and the appropriate place of humans in nature. The particle model explains, in words, what matter



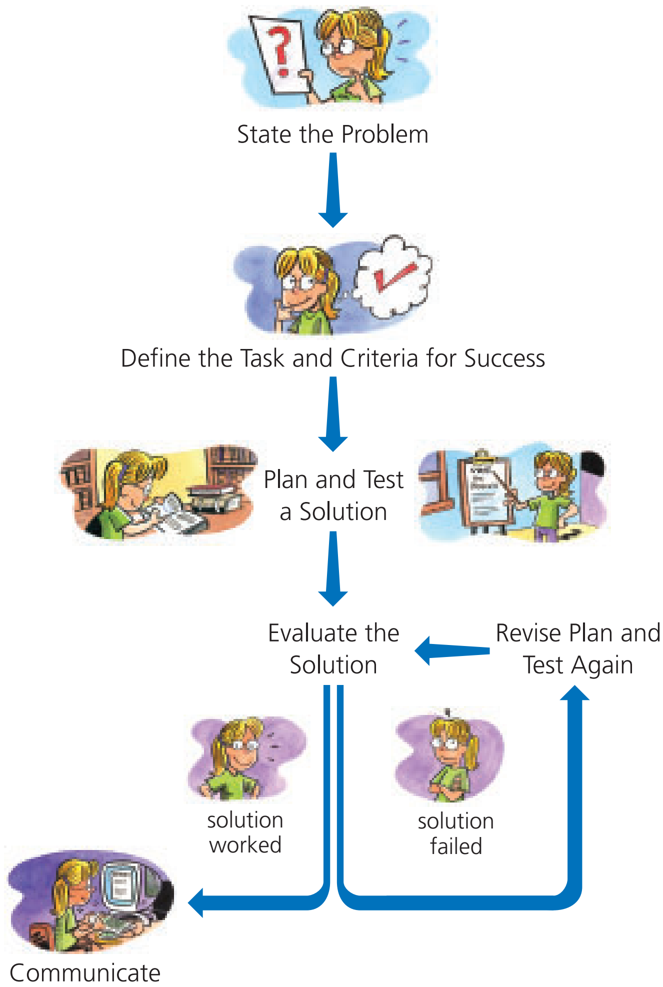
is made from and why different substances behave as they do.

Although models have many advantages, they also have some disadvantages. They are usually more simple than what they represent.

Models change over time as scientists make new observations. For example, models of Earth have changed. Long ago, European people thought that Earth was flat. They thought that if they sailed far enough out to sea, they would fall off the edge. Central American people thought that Earth was held up by a turtle. When the turtle moved, Earth rumbled. As scientists made more and more observations over time, they revised their model of Earth.

SOLVING A PROBLEM

Refer to this section when you are doing a "Solve a Problem" activity.



State the Problem

The first step in solving a problem is to state what the problem is. Imagine, for example, that you are part of a group that is investigating how to reduce the risk of people getting the West Nile Virus. People can become very sick from this virus.

When you are trying to understand a problem, ask yourself these questions:

- What is the problem? How can I state it as a problem?
- What do I already know about the problem?
- What do I need to know to solve the problem?

Define the Task and the Criteria for Success

Once you understand the problem, you can define the task. The task is what you need to do to find a solution. For the West Nile Virus problem, you may need to find a way to reduce the number of mosquitoes in your community because they could be carrying the West Nile Virus.

Before you start to consider possible solutions, you need to know what you want your solution to achieve. One of the criteria for success is fewer mosquitoes. Not every solution that would help you achieve success will be acceptable, however. For example, some chemical solutions may kill other, valuable insects or may be poisonous to birds and pets. The solution should not be worse than the problem it is meant to solve. As well, there are limits on your choices. These limits may include the cost of the solution, the availability of materials, and safety.

Use the following questions to help you define your task and your criteria for success:

- What do I want my solution to achieve?
- What criteria should my solution meet?
- What are the limits on my solution?

Plan and Test a Solution

The planning stage is when you look at possible solutions and decide which solution is most likely to work. This stage usually starts with brainstorming possible solutions. When you are looking for solutions, let your imagination go. Keep a record of your ideas. Include sketches, word webs, and other graphic organizers to help you.

As you examine the possible solutions, you may find new questions that need to be researched. You may want to do library and Internet research, interview experts, and talk to people in your community about the problem.

Choose one solution to try. For the West Nile Virus problem, you may decide to inspect your community for wet areas where mosquitoes breed, and try to eliminate as many of these wet areas as possible. You have discovered, through your research, that this solution is highly effective for reducing mosquito populations. It also has the advantage of not involving chemicals and costing very little.

Now make a list of the materials and equipment you will need. Develop your plan on paper so that other people can examine it and add suggestions. Make your plan as thorough as possible so that you have a blueprint for how you are going to carry out your solution. Show your plan to your teacher for approval.

Once your teacher has approved your plan, you need to test it. Testing allows you to see how well your plan works and to decide whether it meets your criteria for success. Testing also tells you what you might need to do to improve your solution.

Evaluate the Solution

The evaluating stage is when you consider how well your solution worked. Use these questions to help you evaluate your solution:

- What worked well? What did not work well?
- What would I do differently next time?
- What did I learn that I can apply to other problems?

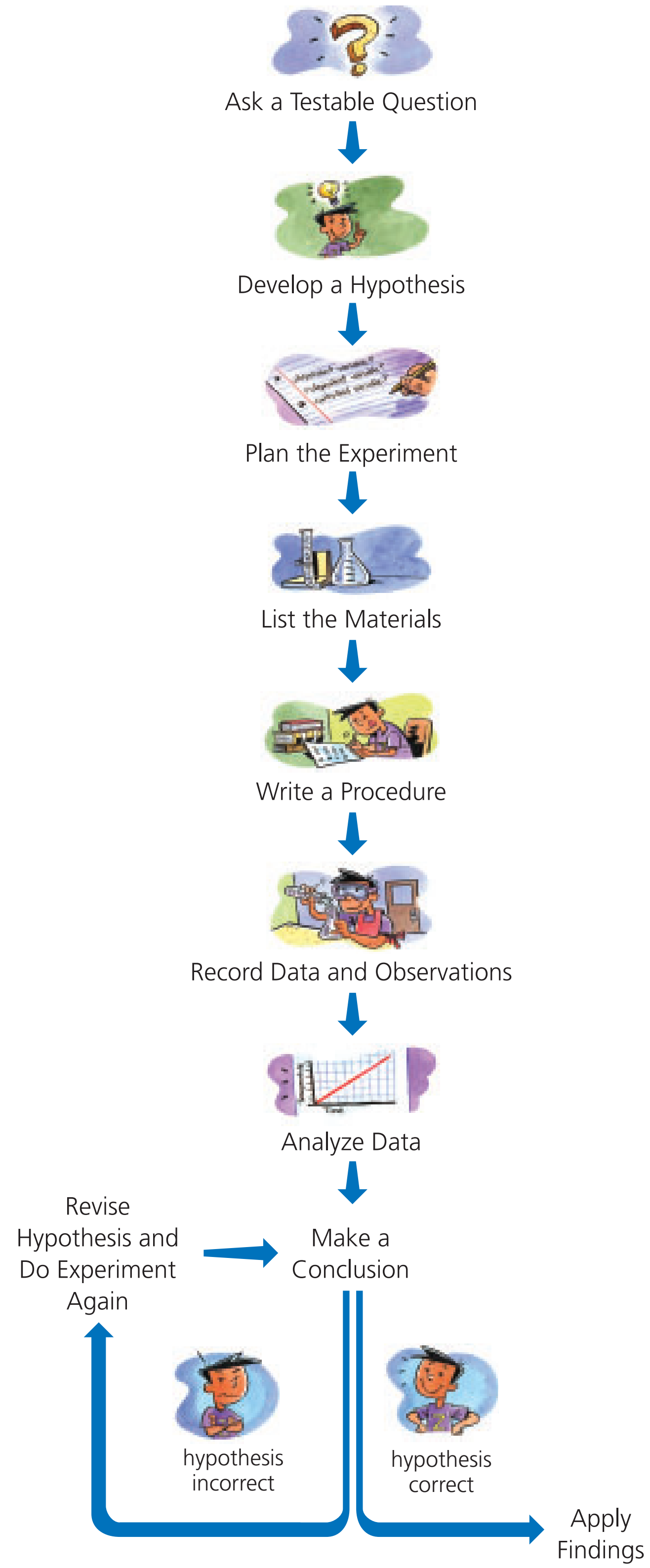
If your solution did not work, go back to your plan and revise it. Then test again.

Communicate

At the end of your problem-solving activity, you should have a recommendation to share with others. To communicate your recommendation, you need to write a report. Think about what information you should include in your report. For example, you may want to include visuals, such as diagrams and tables, to help others understand your results and recommendation.

DESIGNING YOUR OWN EXPERIMENT

Refer to this section when you are designing your own experiment.



After observing the difference between his lunch and Dal's, Simon wondered why his food was not as fresh as Dal's.

Scientists design experiments to test their ideas about the things they observe. They follow the same steps you will follow when you design an experiment.

Ask a Testable Question

The first thing you need is a testable question. A testable question is a question that you can answer by conducting a test. A good, precise question will help you design your experiment. What question do you think Simon, in the picture above, would ask?

A testable question is often a cause-and-effect question. Turn to "Questioning" on page 269 to learn how to formulate a cause-and-effect question.

Develop a Hypothesis

Next, use your past experiences and observations to formulate a hypothesis. Your hypothesis should provide an answer to your question and briefly explain why you think the answer is correct. It should be testable through an experiment. What do you think Simon's hypothesis would be? Turn to "Hypothesizing" on page 270 to learn how to formulate a hypothesis.

Plan the Experiment

Now you need to plan how you will conduct your experiment. Remember that your experiment must be a fair test. Also remember that you must only change one independent variable at a time. You need to know what your dependent variable will be and what variables you will control. What do you think Simon's independent variable would be? What do you think his dependent variable would be? What variables would he need to control? Turn to "Controlling Variables" on page 270 to learn about fair tests and variables.

List the Materials

Make a list of all the materials you will need to conduct your experiment. Your list must include specific quantities and sizes, where needed. As well, you should draw a diagram to show how you will set up the equipment. What materials would Simon need to complete his experiment?

Write a Procedure

The procedure is a step-by-step description of how you will perform your experiment. It must be clear enough for someone else to follow exactly. It must explain how you will deal with each of the variables in your experiment. As well, it must include any safety precautions. Your teacher must approve your procedure and list of materials. What steps and safety precautions should Simon include?

Record Data and Observations

You need to make careful observations, so that you can be sure about the effects of the independent variable. Record your observations, both qualitative and quantitative, in a data table, tally chart, or graph. How would Simon record his observations?

Turn to "Observing" on page 271 to read about qualitative and quantitative observations. Turn to "Creating Data Tables" on page 297 to read about creating data tables.

Analyze Data

If your experiment is a fair test, you can use your observations to determine the effects of the independent variable. You can analyze your observations to find out how the independent and dependent variables are related. Scientists often conduct the same test several times to make sure that their observations are accurate.

Make a Conclusion

When you have analyzed your observations, you can use the results to answer your question and determine if your hypothesis was correct. You can feel confident about your conclusion if your experiment was a fair test and there was little room for error. If you proved that your hypothesis was incorrect, you can revise your hypothesis and perform the experiment again.

Apply Findings

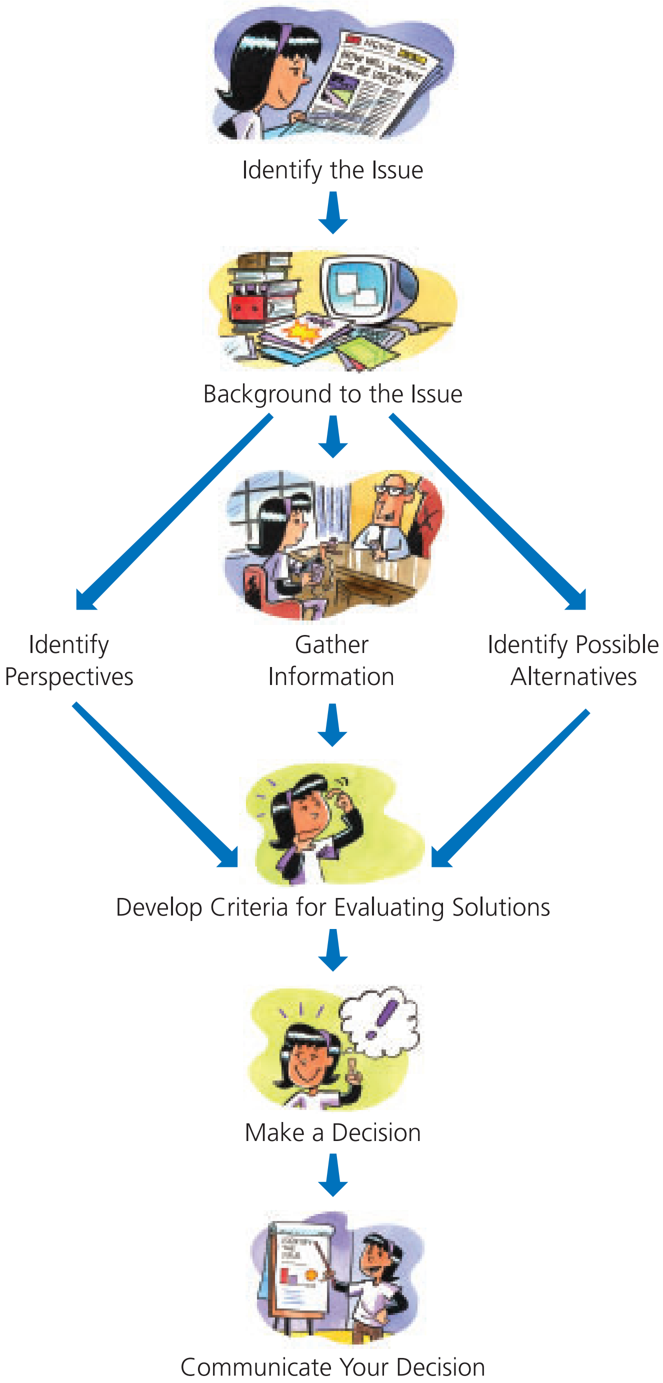
The results of scientific experiments add to our knowledge about the world. For example, the results may be applied to develop new technologies and medicines, which help to improve our lives. How do you think Simon could use what he discovered?

PRACTICE

You are a tennis player. You observe that your tennis ball bounces differently when the court is wet. Design a fair test to investigate your observation. Use the headings in this section.

EXPLORING AN ISSUE

Use this section when you are doing an "Explore an Issue" activity.



An issue is a situation in which several points of view need to be considered in order to make a decision. Often what different people think is the best decision is based on what they think is important or on what they value. Often, it is difficult to come to a decision that everyone agrees with.

When a decision has an impact on many people or on the environment, it is important to explore the issue carefully. This means thinking about all the possible solutions and trying to understand all the different points of view—not just your own point of view. It also means researching and investigating your ideas, and talking to and listening to others.

Identify the Issue

The first step in exploring an issue is to identify what the issue is. An issue has more than one solution, and there are different points of view about which solution is the best. Try stating the issue as a question: "What should ...?

Background to the Issue

The background to the issue is all the information that needs to be gathered and considered before a decision can be made.

- *Identify perspectives.* There are always different points of view on an issue. That's what makes it an issue. For example, suppose that your municipal council is trying to decide how to use some vacant land next to your school. You and other students have asked the council to zone the land as a nature park. Another group is proposing that the land be used to build a seniors' home because there is a shortage of this kind of housing. Some school administrators would like to use the land to build a track for runners and sporting events.
- *Gather information.* The decision you reach must be based on a good understanding of

the issue. You must be in a position to choose the most appropriate solution. To do this, you need to gather factual information that represents all the different points of view. Watch out for biased information, presenting only one side of the issue. Develop good questions and a plan for your research. Your research may include talking to people, reading about the issue, and doing Internet research. For the land-use issue, you may also want to visit the site to make observations.

- *Identify possible alternatives.* After identifying points of view and gathering information, you can now generate a list of possible solutions. You might, for example, come up with the following solutions for the land-use issue:
  - Turn the land into a nature park for the community and the school.
  - Use the land as a playing field and track for the community and the school.
  - Create a combination park and playing field.
  - Use the land to build a seniors' home, with a "nature" garden.

Develop Criteria for Evaluating Solutions

Develop criteria to evaluate each possible solution. For example, should the solution be the one that has the most community support? Should it be the one that protects the environment? You need to decide which criteria you will use to evaluate the solutions so that you can decide which solution is the best.

Make a Decision

This is the stage where everyone gets a chance to share his or her ideas and the information he or she gathered about the issue. Then the group needs to evaluate all the possible solutions and decide on one solution based on the list of criteria.

Communicate Your Decision

Choose a method to communicate your decision. For example, you could choose one of the following methods:

- Write a report.
- Give an oral presentation.
- Design a poster.
- Prepare a slide show.
- Create a video.
- Organize a panel presentation.
- Write a newspaper article.
- Hold a formal debate.