SEPUP
Issue-Oriented Science

ISSUES AND
EARTH SCIENCE

Earth's Resources

THIRD EDITION

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THIRD EDITION

THE LAWRENCE HALL OF SCIENCE
UNIVERSITY OF CALIFORNIA, BERKELEY

LAB-AIDS®

This book is part of SEPUP's *Issues and Science* 17-unit multi-year course. The units are designed to allow for custom sequencing to meet local needs. For more information about these units, see the SEPUP and Lab-Aids websites listed at the bottom of this page.

- Land, Water, and Human Interactions
- Geological Processes
- Earth's Resources
- Weather and Climate
- Solar System and Beyond
- Ecology
- Body Systems
- From Cells to Organisms
- Reproduction
- Evolution
- Biomedical Engineering
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- Chemistry of Materials
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FIELD TEST CENTERS

The classroom is SEPUP's laboratory for development. We are extremely appreciative of the following center directors and teachers who taught the program during the 2003–04 and 2004–05 school years. These teachers and their students contributed significantly to improving the first edition of the course. Since then, *Issues and Earth Science* has been used in thousands of classrooms across the United States. This third edition is based on what we have learned from teachers and students in those classrooms. It also includes new data and information, so the issues included in the course remain fresh and up-to-date.

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A Letter to *Issues and Science* Students

As you look through this book, you may wonder, "Why does this book look different from other science textbooks I've seen?" The reason is simple: It is a complete science program, and only some of what you will learn can be seen by leafing through these pages! SEPUP is an *active learning* program. Through hands-on laboratories, investigations, readings, simulations, scientific debates, role plays, and design projects, you will develop your thinking about science and engineering and how they relate to many important issues facing our society today.

In this program, you will think scientifically about natural phenomena or observable events. For example, you might investigate why most people look unique but also look more like their biological relatives than they look like most other people. Or perhaps you will model how a river can change its path due to natural processes, which can then change the landscape and impact human-made structures.

The activities in this course provide many opportunities for you to figure out *why* or *how* something happens. Like a scientist, you'll begin by asking questions and analyzing evidence to help you create explanations and models. Like an engineer, you will solve specific problems by designing a solution—for example, designing a model of an artificial heart valve for a person with advanced heart disease.

This program will ask you to think about issues at the intersection of science and society. You may consider how to create a mechanical system to help drivers maintain a safe distance behind other cars, or debate the trade-offs of using different materials (aluminum, glass, or plastic) to make a water bottle. You'll improve your decision-making skills by using evidence and analysis to make the best decision about what should be done for a community, such as deciding where to mine for valuable resources like copper while minimizing environmental impact. You'll consider the influence of science, engineering, and technology on societal issues, and what role scientists, engineers, and citizens play in the decision-making process.

How do we know that this is a good way for you to learn? Because most research on science education supports it. Many activities in this book were tested by hundreds of students and their teachers. Their feedback, and what we've learned about how people develop an understanding of science, has informed the SEPUP approach. We believe the SEPUP program will show you that learning about science and engineering is important, enjoyable, and relevant to your life.

SEPUP Staff

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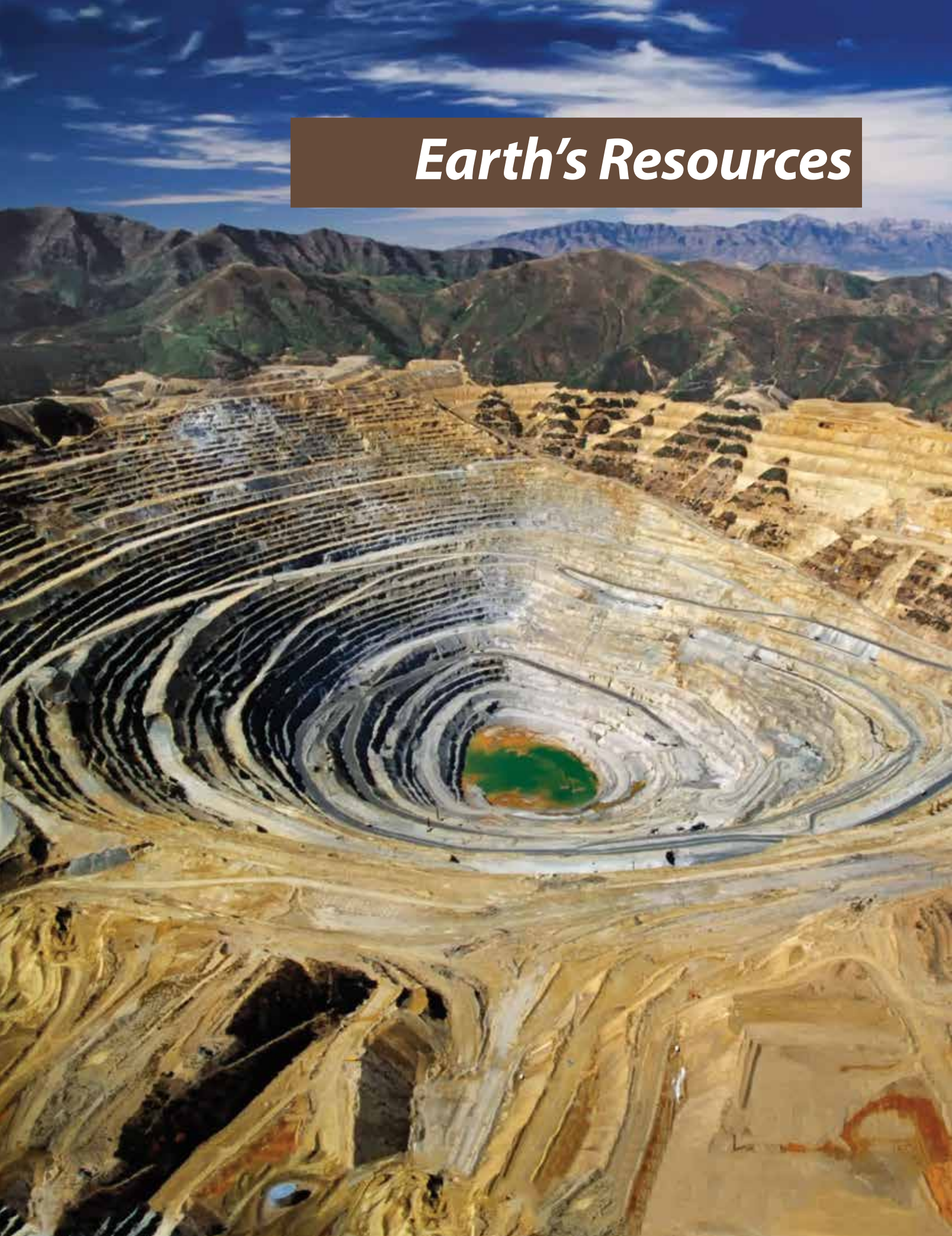
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Earth's Resources

Otto and his older sister, Anna, were doing one of their Saturday morning chores—sorting the trash.

"Where does all this stuff come from?" wondered Otto, as he gathered cans into the recycling bin.

"The earth," said Anna. "Metal is a natural resource."

"What's a natural resource?" Otto asked.

"Something found in nature that we can gather and use to make other things," she answered.

"Imagine how large a hole you'd have to dig to gather enough metal to make all the cans in a grocery store . . ." said Otto, trying to picture it.

Anna quickly responded, "It would have to be huge! I read that there's a mine in Utah that's over 1 kilometer [0.75 miles] deep and 4 kilometers [2.5 miles] wide."

• • •

In this unit, you will:

- *Explore phenomena* related to how humans affect the availability of natural resources, such as metals, fossil fuels, and freshwater
- *Model* the technologies and discuss the trade-offs involved with obtaining these resources
- *Construct explanations* about how earth processes form natural resources over geological time
- *Analyze* resource distribution and consumption patterns to determine what makes one resource more valuable than another
- *Investigate* the issue of how the use of natural resources by humans can affect the availability of these resources and how these resources vary in their distribution around the world

1 Observing Earth's Resources

INVESTIGATION

HUMANS USE A lot of materials found on Earth. These include metals such as copper and woods such as pine. Materials that are found on Earth naturally and used by people are known as **natural resources**. Some of these resources are **renewable**, meaning that they can be replaced or replenished faster than they are used up by human populations. For example, wood is a renewable resource since more trees can be planted to replace those that are cut down. **Nonrenewable** resources cannot be replaced faster than they are used up by human populations. Oil, which takes millions of years to form, is a nonrenewable resource.

GUIDING QUESTION

What are natural resources?



Natural resources such as rocks are mined in rock quarries (KWOR-eez) like this one.

MATERIALS

For each group of four students

- 1 copper strip
- 1 rock containing fossils
- 1 sample of oil shale
- 1 vial of freshwater
- 1 sample of wood

For each pair of students

- 1 magnifying lens
- 1 metric ruler

For each student

- 1 Student Sheet 1.1, "Resource Observations"

PROCEDURE

1. Using the magnifying lens and ruler, work with your partner to carefully examine one of the natural resource samples.



2. Record your observations about the sample in the table on Student Sheet 1.1, "Resource Observations."
3. Share the natural resource samples with the other pair of students in your group. Repeat Steps 1 and 2 until you have examined all five samples.
4. Discuss with your group how valuable you think each sample is and what you think makes it more or less valuable. Remember to listen to and consider the ideas of other members of your group. If you disagree with others in your group, explain why you disagree.

5. In your table, rank each of the five natural resources from 1 to 5, where 1 = most valuable and 5 = least valuable. You do not need to agree with the other members of your group.
6. In your table, write down why you decided to rank the samples as you did. Be sure to list at least one reason for each sample. Then identify each sample as a renewable or nonrenewable resource.
7. Discuss your responses with the other members of your group. Explain why you ranked each sample as you did and why you identified a resource as renewable or nonrenewable.
8. Share your responses with your class.

ANALYSIS

1. Think about the natural resources you examined.
   a. What was the most valuable natural resource, according to the class?
   b. What was the least valuable natural resource, according to the class?
   c. What reasons did other students have for identifying a natural resource as more or less valuable?
2. What else would you like to know about these natural resources to help you determine their value? What other questions do you have about these natural resources?
3. Which resource(s) did you identify as renewable? Explain your thinking.
4. Copy the list of words shown below:

   oil
   natural resource
   salt
   air
   plastic

   a. Look for a relationship among the words. Cross out the word or phrase that does not belong.
   b. Circle the word or phrase that includes the others.
   c. Explain how the word or phrase you circled is related to the other words on the list.
5. **Reflection**: What do you think makes a natural resource valuable?

EXTENSION

Do you want to see more natural resources? Bring in any natural resources you may have collected to share with your class, or go the *SEPUP Third Edition Earth's Resources* page of the SEPUP website at **www.sepuplhs.org/middle/third-edition** to link to sites with photos of more natural resources.

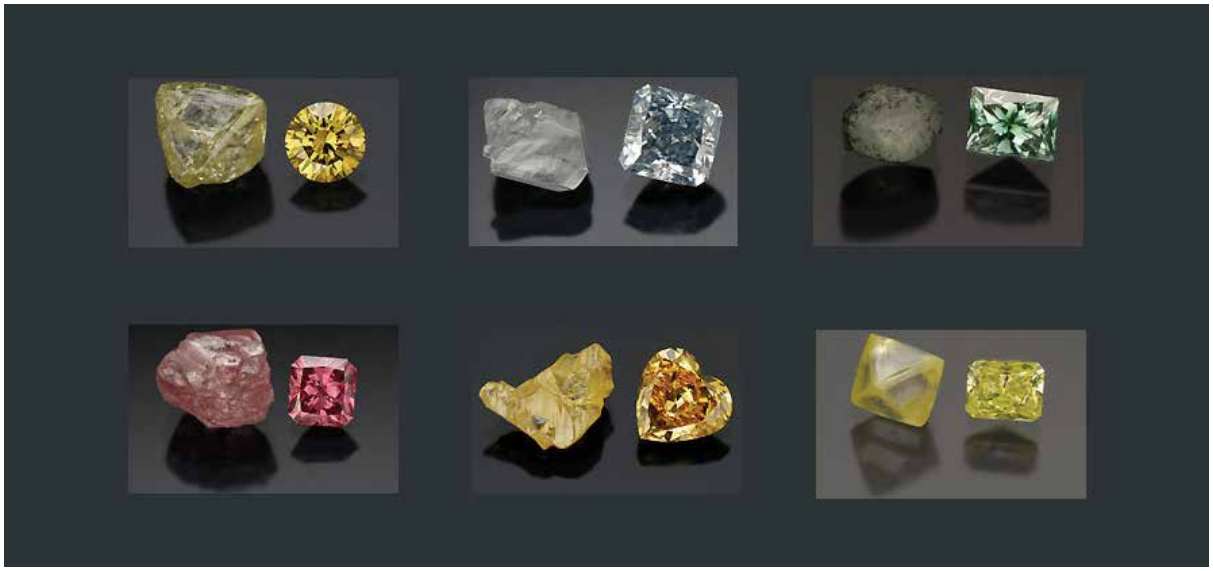
2 World Resource Consumption

READING

In the past, people treasured natural resources that are not very valuable today. For example, salt was once so valuable that Roman soldiers were paid with it instead of money! Many valuable natural resources were formed in the earth over millions of years and are nonrenewable. Because people have been using resources for thousands of years, most of the easy-to-find, valuable natural resources have been collected already.

GUIDING QUESTION

How has an increase in human population affected resource consumption?



Gemstones come out of the ground looking a lot like other rocks. Each pair of gemstones shows the rough stone (left) and the cut and polished stone (right).

MATERIALS

For each student

1 Student Sheet 2.1, "My Ideas About Resource Use"

1 Student Sheet 2.2, "Three-Level Reading Guide: Population and Consumption"

READING

Use Student Sheet 2.1, "My Ideas About Resource Use," to prepare you for the following reading. Then use Student Sheet 2.2, "Three-Level Reading Guide: Population and Consumption," to guide you as you complete the reading..

You may have heard the word *consume* being used for things that people buy, like televisions or phones. **Consumption** is the purchase or use of things, including natural resources. This activity explores how people consume three valuable resources—copper, petroleum, and freshwater—and how human population growth has affected their consumption.

Consumption of Copper

In the "Observing Earth's Resources" activity, you observed and described samples of natural resources. What did they look like? How did they feel? The characteristics that can be used to identify a resource are called **properties**. Metals, and in particular copper, are good conductors of electricity and heat. This makes them very useful for products that conduct electricity. Natural resources such as copper are typically consumed in the form of a product or parts in a product. Copper is often made into copper wire and copper tubing. These are then used in household appliances, home construction, and electronics, such as cell phones and televisions.

Native copper (left) and copper wire (right)





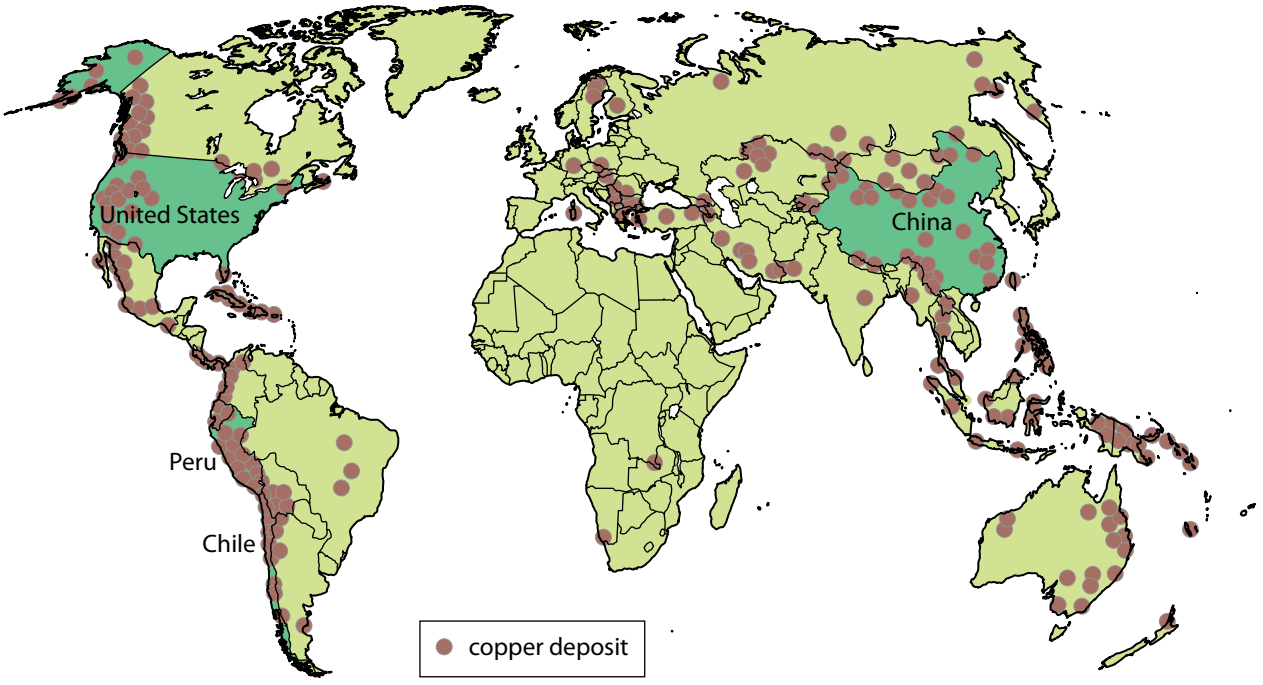
Copper is a nonrenewable resource that is extracted from the earth through mining. It is also one of the most recycled metals; approximately one-third of the copper consumed is from recycled copper. To gather new copper, people usually have to dig into the surface of the earth. In some cases, they remove large pieces of rock and break them into smaller pieces. This process is known as **mining**. Until the year 2000, the United States was the world's largest copper producer. The Bingham Canyon copper mine in Utah has produced more than 12 million tons of copper. This open-pit mine is more than 4 kilometers (2.5 miles) across at the top and 800 meters (0.5 mile) deep, and is visible from space.



Utah's Bingham Canyon copper mine

Today, the largest producer of copper is Chile, followed by Peru, China and the United States. Not every country produces copper because copper is not distributed evenly around the world. You can see copper **deposits**—areas containing significant amounts of a resource—in the map below.

Global Copper Deposits



Consumption of Petroleum

Another important use of natural resources is for energy. Energy from natural resources is used to produce electricity, fuel cars, heat homes, and run factories. Natural resources used for energy can be renewable or nonrenewable. Renewable energy sources include sunlight, wind, and biofuels, such as ethanol made from corn. Nonrenewable energy sources include petroleum, coal, and natural gas. Together, these nonrenewable energy sources are known as **fossil fuels**, because they formed from the remains of marine plants and animals over millions of years.



Solar cells (left) and wind turbines (right) use renewable energy sources to create electricity.

Petroleum, also known as oil or crude oil, is a liquid found underground. It is extracted by drilling oil wells. The first oil wells were relatively shallow, but over time, people have had to go deeper. Modern oil wells are almost 2 kilometers (over 1 mile) below the surface. Almost 80% of petroleum is refined into gasoline, jet fuel, and other fuels used to power transportation and heat buildings.

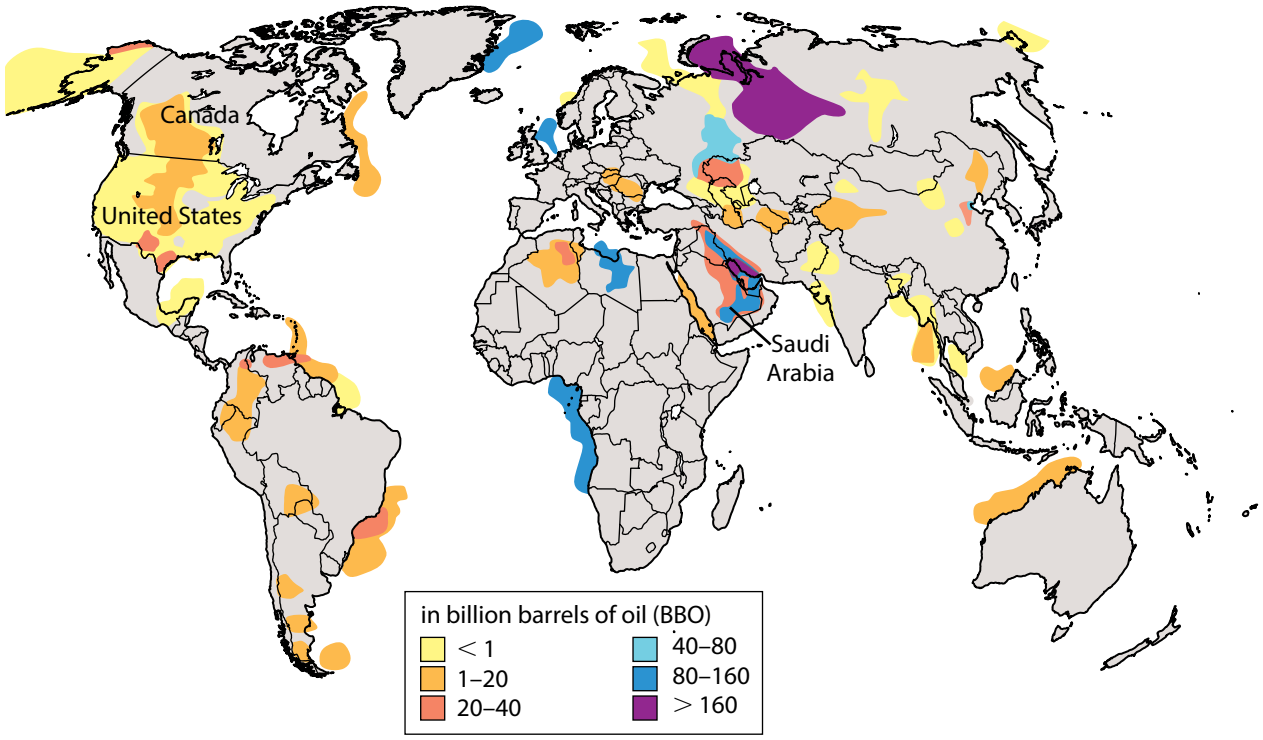
While the Middle East is the top oil-producing region of the world, Saudi Arabia, the United States, Russia, and China are the countries that produce the most oil. These countries are not extracting only petroleum. Oil shale, the rock that you examined in the previous activity, can be processed to make an oil known as shale oil. The United States has large deposits of oil shale and oil sands (also known as tar sands), which are just beginning to be extracted. It is more difficult and expensive to extract these resources than petroleum. But



Modern oil rigs, like this one in the Gulf of Mexico, can drill for nonrenewable resources under land or water.

as demand for oil increases, it becomes more cost-effective to gather oil from these sources.

Estimated Global Petroleum Deposits

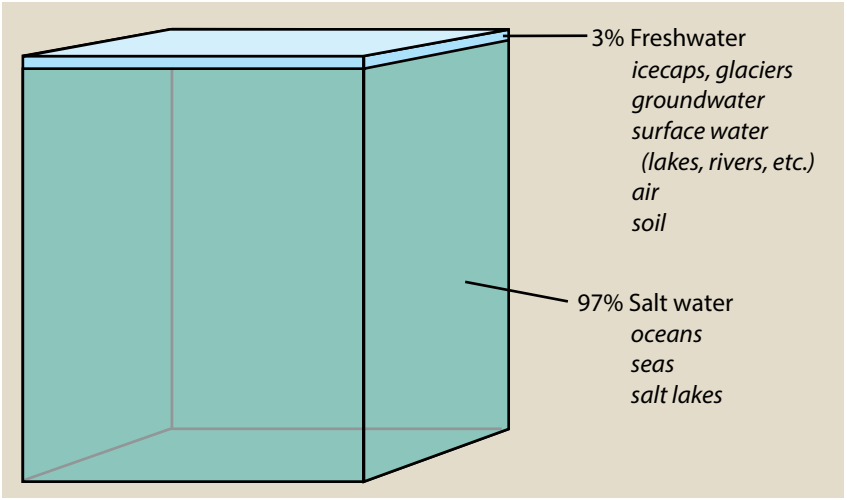


Consumption of Freshwater

Natural resources like water may seem plentiful because they are all around us. However, providing all of the world's population with freshwater is not as simple as it may seem. If you took all the water from Earth's surface and poured it into a container, about 97% of it would be salt water from oceans, seas, and salt lakes. The other 3% would be all of Earth's freshwater, including water in ice sheets, icebergs, groundwater, and water vapor in the air. The surface water in lakes, rivers, and streams makes up only 0.03%. This makes the freshwater that people use for drinking, bathing, and washing an important natural resource.

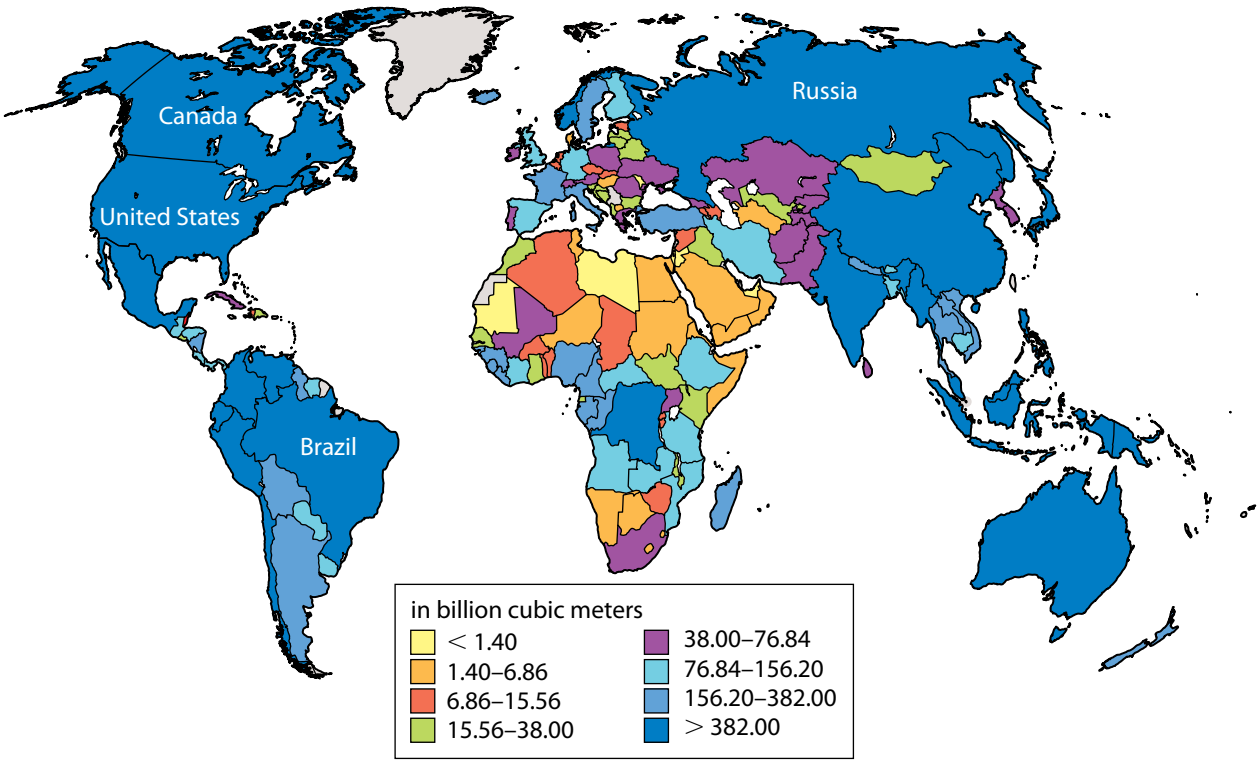
Freshwater is essential to producing food. In most of the world, over 70% of freshwater is used for agriculture. Some of the irrigated crops are for human consumption; other crops are used to feed livestock, such as cows. Freshwater is also used to make products like clothing. On average, it takes 2,700 liters (713 gallons) of freshwater to make one cotton shirt and 9,800 L (2,600 gallons) to make one pair of blue jeans. Most of that water is used to grow cotton on farms; a smaller amount is used in the factories that make the clothes.

World's Freshwater



Brazil, Russia, the United States, and Canada are countries with a lot of freshwater resources. Although water is a renewable resource, it is not distributed evenly over Earth's surface. Some areas have large reservoirs of freshwater, such as the Great Lakes in the United States. Other areas, like Brazil, receive high levels of precipitation in the form of rain or snow. Parts of the world that have large populations but do not have these freshwater resources often face severe water shortages.

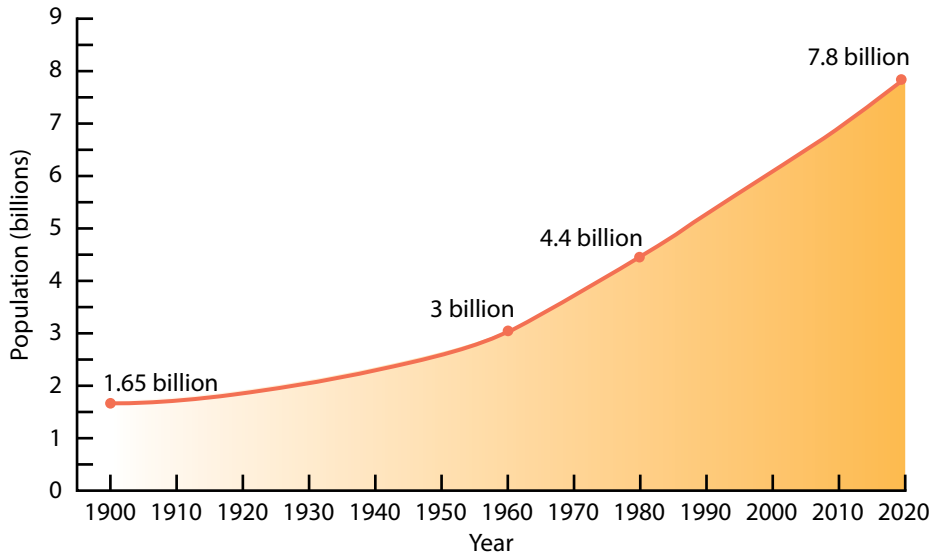
Global Freshwater Resources



Consumption and World Population Growth

The consumption of natural resources is increasing as the world's population increases. In 1800, the world's population was approximately 1 billion people. By 1900, it had almost doubled to 1.9 billion people. The population of the world today is close to 8 billion people, almost four times what it was over 100 years ago. The United Nations estimates the world population will be over 11 billion people by the year 2100. You can observe this growth in the graph below.

World Population Growth Over Time

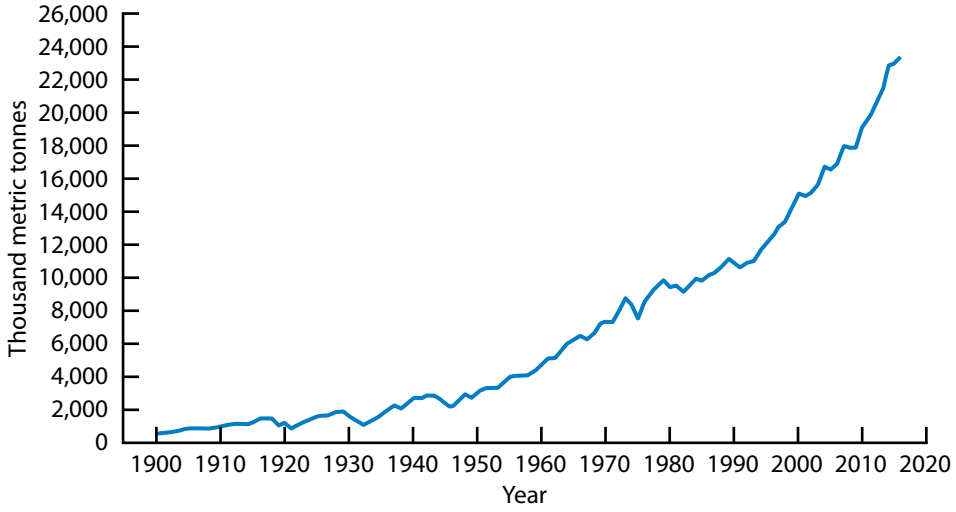


Natural resource extraction—mostly of nonrenewable materials, such as metals and fossil fuels—more than tripled from 1970 to 2010, from 22 billion tons to 70 billion tons. This is in part because the availability of food, clothing, shelter, and recreation has improved for growing numbers of people. There has been a rise in the consumption of goods such as cars, with a resulting increase in the burning of fossil fuels. You can see these trends in the consumption of copper, petroleum, and freshwater in the graphs on the next page.

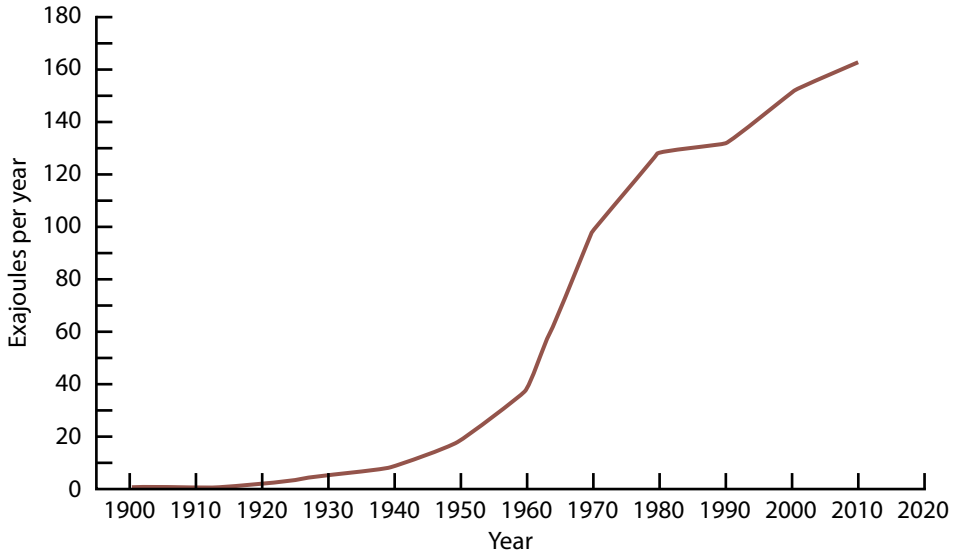
This increase in consumption has resulted in both intended and unintended environmental effects. Examples include the damming of rivers, enlarging of croplands, increased soil erosion, loss of forested land, and an increase in some gases, such as carbon dioxide. Population growth and increasing natural resource consumption contribute to these changes. As the number of people continues to grow, there will likely be further effects on Earth's air, land, and water.

Natural Resource Use Over Time

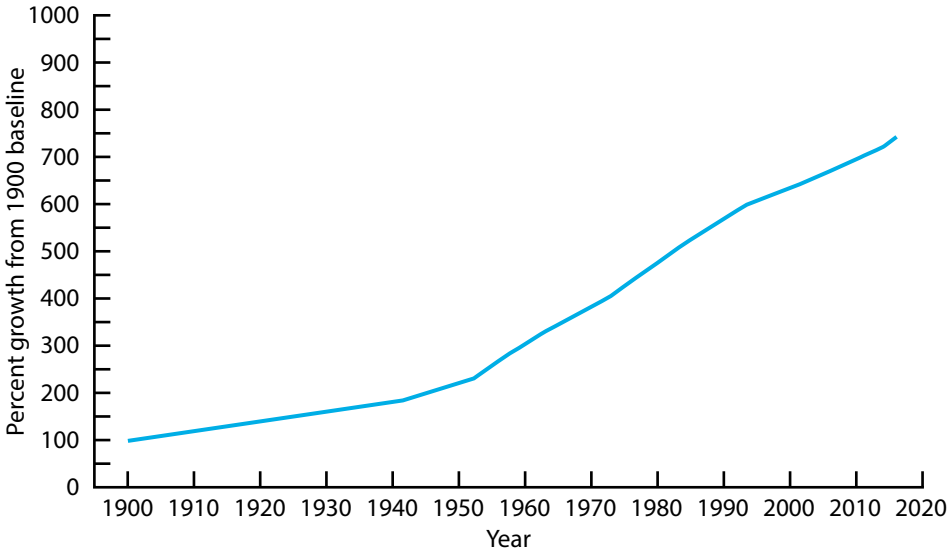
Global Copper Consumption, 1900–2016



Global Oil Consumption, 1900–2016



Global Freshwater Consumption, 1900–2016



ANALYSIS

1. Create a concept map in your science notebook.
   a. Use the following 10 words:

water	deposits
mining	renewable
petroleum	consumption/consume
copper	nonrenewable
people	natural resources

   b. Add at least five more words related to natural resources to your concept map. Choose words that show what you now know about natural resources.

2. As a class, brainstorm a list of natural resources. Copy the list in your science notebook.
   a. Which three resources do you think are the most valuable? Explain your answer.
   b. What properties make a natural resource valuable? Explain your reasoning.

3. Examine the graphs of world population growth, global copper consumption, global petroleum consumption, and global freshwater consumption on pages 13–15.

   a. Based on the trend in the graphs, what do you predict will happen to the consumption of each of the following resources in the future?

      - metal ores such as copper
      - energy resources such as petroleum
      - freshwater

   b. Support your answer with evidence from this activity. **Evidence** is information that supports or refutes a claim.

4. **Revisit the issue:** Think about how people gather and use natural resources.

   a. What impact does resource consumption have on the planet?
   b. What actions could people take to reduce these impacts?
   c. What additional questions do you have about human resource consumption?

5. Examine the maps showing the global distribution of copper, petroleum, and freshwater. What do you predict each map will look like in 100 years? Explain your thinking.

3 Properties of Natural Resources

LABORATORY

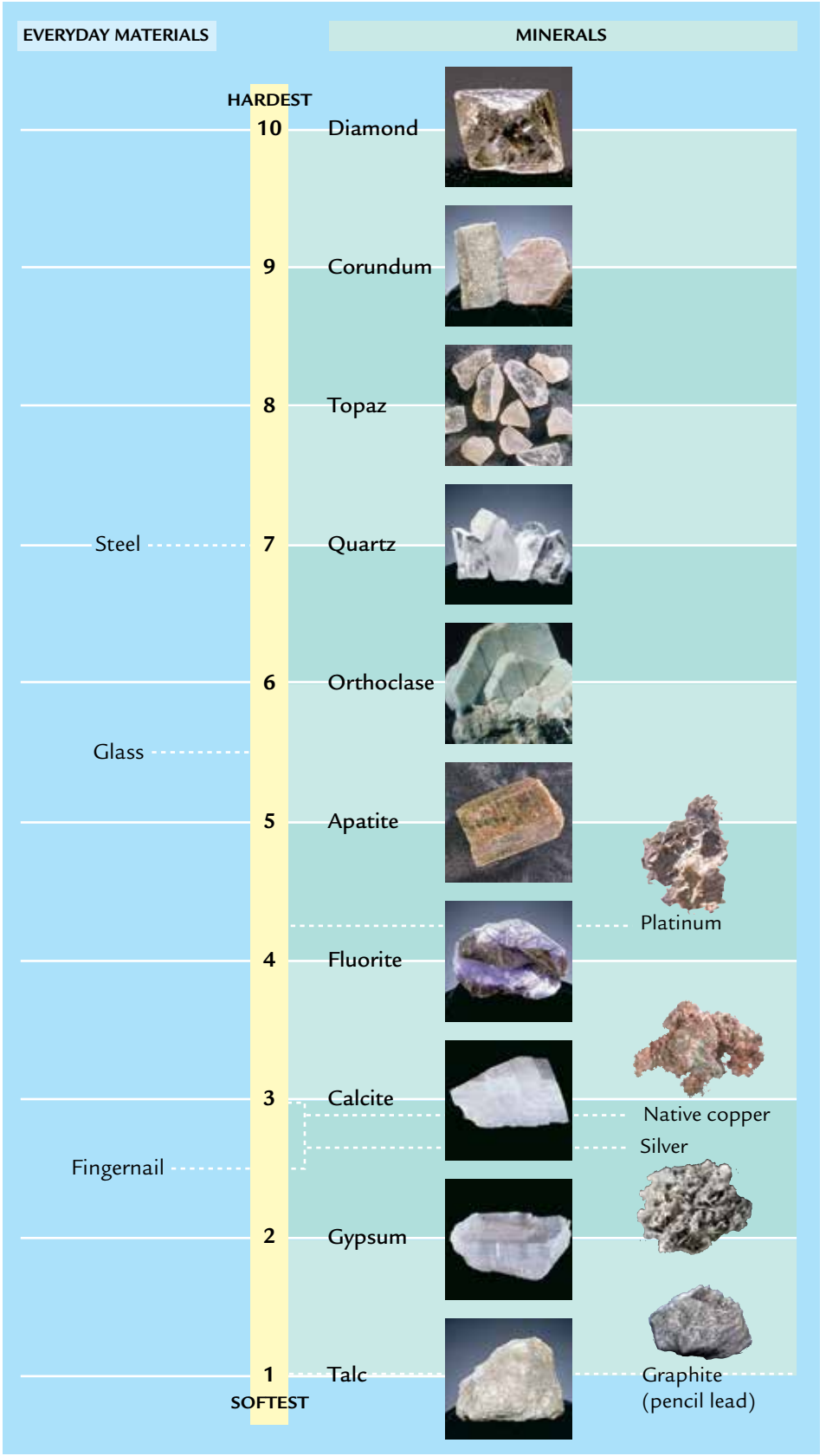
Geologists are people who study rocks and other nonliving parts of the earth. Geologists group some natural resources into a category called **minerals**. Minerals are nonliving materials that are found naturally on Earth. Many metals, such as copper and gold, are minerals. Each mineral has a unique set of properties. Geologists use these properties to tell when a yellow stone is a diamond and not another yellow mineral, like topaz.

One property used to identify minerals is hardness. In 1822, German scientist Friedrich Mohs created a scale to rank the hardness of a mineral from 1 to 10. He scratched one mineral with another. The mineral that was scratched was softer than the other. On the Mohs Hardness Scale, minerals with higher numbers can scratch minerals with lower numbers. Diamonds can be used to scratch any other mineral, but no other mineral—except another diamond—can scratch a diamond. (This doesn't mean that a diamond cannot break. If hit hard enough, a diamond will break into smaller pieces.) You can see the Mohs Hardness Scale on the next page. Today, scientists have created other hardness scales, but the Mohs Scale is still the easiest to use.

In this activity, you will receive an unidentified mineral sample. You will test various properties of the sample to determine whether it is calcite or quartz.



Each of these minerals is used to make jewelry. Some of these minerals are more valuable than others. How can you tell which mineral is which?



Compare the hardness of the minerals to some everyday materials. What material(s) could scratch fluorite? What material(s) could scratch corundum?

GUIDING QUESTION

What makes one mineral resource different from another?

MATERIALS

For the class

- copper strips
- glass scratch plates
- white ceramic streak plates
- bottles of dilute hydrochloric acid
- cups of water
- droppers
- SEPUP trays
- magnifying lenses

For each pair of students

- 1 mineral
- 1 paper clip
- paper towels

For each student

- 1 pair of chemical splash goggles

SAFETY

The hydrochloric acid solution can cause skin irritation and damage clothing. Always handle acids carefully and wear chemical splash goggles. Wash your hands after completing the activity.



The hardness of metals is often determined using the Rockwell test. A diamond or steel ball is pressed into the metal at a set pressure. The depth of the indentation in the metal is then measured.

PROCEDURE

1. Learn how to test mineral properties by examining the table "Conducting Tests."

Conducting Tests

PROPERTY	TEST
Color	Observe the color of the mineral.
Transparency	Place the mineral on a printed page and try to read the letters through the mineral. • It is *opaque* if you cannot see through it. • It is *translucent* if you can see through it but letters are blurry. • It is *transparent* if you can see through it clearly.
Luster	Try to reflect light off of your sample. • It is *brilliant* if it reflects lots of light and is very shiny. • It is *glassy* if it reflects some light and is somewhat shiny. • It is *dull* if it does not reflect any light and is not shiny.
Hardness (Mohs Scale)	Try to scratch copper and glass with the mineral. Use your results to decide if the hardness of the mineral is: • less than 3 (hardness of copper) • between 3 and 5.5 • more than 5.5 (hardness of glass) *Hint:* You may want to use the Mohs Hardness Scale on page 18.
Streak color	Use the mineral to draw a line on a white ceramic streak plate and observe the color of the streak.
Reaction with acid	If the mineral surface is shiny, scratch it slightly with the end of a paper clip. Place the mineral in Cup A of a SEPUP tray and add 1 drop of hydrochloric acid to the surface of the mineral. Observe if small bubbles form or if you hear a fizzing sound when you put your ear close to the mineral sample. After completing the test, use the dropper to rinse the mineral with water and then pat dry the mineral.
Light refraction	Place the mineral on a printed page and look at a word through the mineral. Record whether you see one or two images of the word.

2. The unidentified mineral is either calcite or quartz. Examine the "Mineral Properties" table, and discuss with your partner which properties will be the most useful in identifying the unknown mineral.

   Hint: Think about whether properties that are similar or different are more useful in identifying a material.

Mineral Properties

PROPERTY	CALCITE	QUARTZ
Color	Colorless, white, pink, red, green, blue, brown, yellow	Colorless, white, pink, purple, blue, yellow
Transparency	Translucent or transparent	Translucent or transparent
Luster	Dull or glassy	Glassy
Hardness (Mohs Scale)	3	7
Streak color	White	White
Reaction with acid	Small bubbles, fizzing	No reaction
Light refraction	Sometimes shows two images	Always shows a single image

3. Select five properties to observe or test. Remember to select properties that are most useful in distinguishing one mineral from the other.
4. Design an investigation to identify the unknown mineral. Think about the following questions:
   - What is the purpose of your investigation?
   - What properties will you observe or test? (Test only five properties.)
   - Why did you choose these five properties?
   - What materials will you need in order to to investigate these five properties?
   - How will you record your data?
   - How will you use the data to make a conclusion?
5. Record your planned investigation in your science notebook.
6. Make a data table that has space for all the data you need to record. You will fill it in during your investigation.
7. Obtain your teacher's approval of your investigation.
8. Conduct your investigation, and record your results.

EXTENSION

Some minerals have another property called *fluorescence* (flor-ESS-ens). This means that the mineral will glow under ultraviolet (UV) light. Look at mineral samples under UV light. Which minerals are fluorescent? How could you use this property to help identify a mineral?

ANALYSIS

1. Think about the investigation you carried out.
   a. What is the unknown mineral: calcite or quartz?
   b. Support your identification with at least four pieces of evidence from your investigation. Be sure to compare your laboratory results to the properties of both calcite and quartz.
2. Copper, iron, and tin are all metals that are also minerals.
   a. What properties make metal minerals useful to people?
   b. Would you expect these properties to change over time? Explain.
3. Think about what you now know about the distribution of resources on Earth. Would you expect diamonds to be distributed evenly over Earth's surface? Explain your reasoning.
4. **Revisit the issue:** Today, not all minerals are mined from the earth. Some can now be created in laboratories and are called synthetic (sin-THET-ik). Even though synthetic mineral substitutes are made by humans, they are not fake. They have the same structure and other properties as the natural mineral. But synthetics are not defined as minerals since they are not found naturally on Earth. They are less expensive because they are created in a laboratory rather than mined.

   Imagine that you've decided to buy a diamond.
   a. Which type of diamond—synthetic or mined—would you buy?
   b. Provide two or more pieces of evidence that support your decision.
   c. A **trade-off** is a desirable outcome given up to gain another desirable outcome. What are the trade-offs of your decision?



5. **Reflection**: Do you think the cost of a natural resource reflects its true value? Why or why not?

4 Per Capita Consumption

TALKING IT OVER

CONSUMPTION OF NATURAL resources is increasing with the growing world population. Scientists study the consumption patterns of people, businesses, and even entire countries. A **pattern** is something that happens in a repeated and predictable way. Studying consumption patterns of countries can provide information about what is happening in the present and what may happen in the future to Earth's natural resources. Patterns can be used to identify possible cause-and-effect relationships.

GUIDING QUESTION

How are natural resources used globally?

MATERIALS

For each group of four students

1 set of 8 Natural Resource Consumption Cards

For each pair of students

1 calculator

For each student

1 Student Sheet 4.1, "Analyzing Country Data"

1 Student Sheet 4.2, "Analyzing Per Capita Consumption"

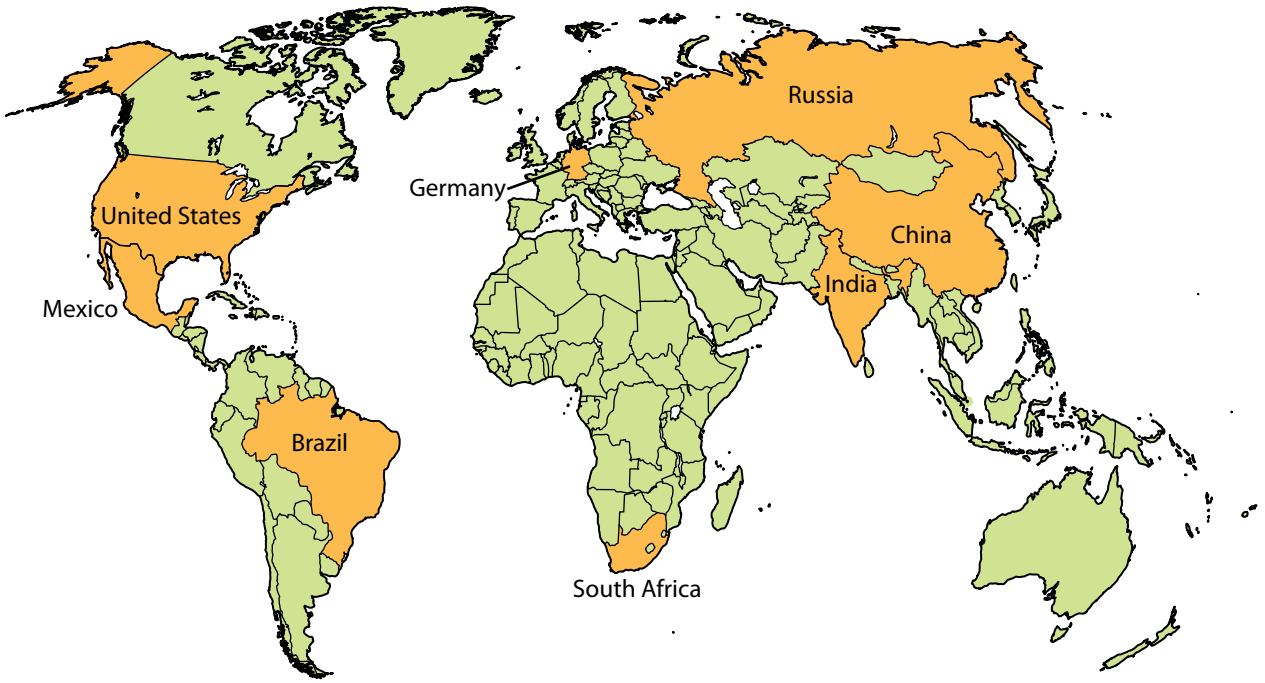


Freshwater is a global natural resource.

PROCEDURE

Part A: Total Consumption

1. Spread out the eight Natural Resource Consumption Cards on a table. You can see the location of each country on the map below.



2. With your group of four, read the information on the cards and discuss the following questions. Remember to listen to and consider the explanations and ideas of other members of your group. If you disagree with a group member, explain why you disagree.

   - Which country or countries are using the most natural resources? Support your response with evidence from the cards.
   - *How has each country's resource consumption changed over a 10-year period?* Sort the countries into three piles: those that have seen an increase in consumption of natural resources, those that have stayed about the same, and those that have seen a decrease in consumption.

3. Complete the first two columns of each table on Student Sheet 4.1, "Analyzing Country Data." Do this by ranking the countries according to their use of each natural resource. Place the country using the most of a resource as number 1 and the country using the least as number 8.

4. With your group of four, discuss the following questions. Remember to listen to and consider the explanations and ideas of other members of your group. If you disagree with a group member, explain why you disagree.
   - What patterns do you see in the use of natural resources over time?
   - Which countries are using more resources than in the past? What could explain this change in resource use?
   - Which countries are using fewer resources than in the past? What could explain this change in resource use?
   - The cards show data over a 10-year period ending in 2011. What do you predict the current consumption of each natural resource is by each country? Explain your reasoning.

Part B: Per Capita Consumption

5. Compare the populations shown in the following table. You will use 2011 data to correspond to the data on the cards. Record the 2011 population of each country in the two tables on Student Sheet 4.2, "Analyzing Per Capita Consumption."

Population of Various Countries

COUNTRY	2011 POPULATION (ROUNDED)	2017 POPULATION (ROUNDED)
China	1,350,000,000	1,410,000,000
India	1,240,000,000	1,340,000,000
United States	310,000,000	325,000,000
Brazil	200,000,000	209,000,000
Russia	143,000,000	144,000,000
Mexico	115,000,000	129,000,000
Germany	82,000,000	82,000,000
South Africa	51,000,000	57,000,000

6. Student Sheet 4.2 includes data about the amount of freshwater used in each country *per person*. The average amount of resources used per person is known as **per capita consumption**.

$$\text{per capita consumption} = \frac{\text{natural resource consumption}}{\text{population}}$$

a. Using your calculator, complete the "Per Capita Use of Copper" table by doing the following:

   (1) Record a country's total consumption of copper in 2011.

   (2) Add 3 zeroes to that number to convert it to kilograms (kg).

   (3) Divide that number by a country's 2011 population.

   Record your answer on Student Sheet 4.2.

b. Using your calculator, complete the "Per Capita Use of Petroleum" table by doing the following:

   (1) Record a country's total consumption of petroleum in 2011.

   (2) Divide the amount of petroleum consumed by the 2011 population of that country.

   Record your answer on Student Sheet 4.2.

7. Rank countries by per capita use on Student Sheet 4.1 using the information from Student Sheet 4.2.

8. Discuss the following questions with your group:

   - Look at the three countries with the highest populations. How does their natural resource consumption compare to their per capita consumption? Describe the similarities and differences.
   - Select a country, and compare the total consumption of a resource to the per capita consumption of the same resource. Why is per capita consumption an important indicator?
   - How can you use per capita consumption to better predict the future of natural resource use in a country?
   - With your group, brainstorm ideas for reducing the global consumption of natural resources.

Part C: Environmental Impact

9. Look at the photos on pages 30–32, which show the use of natural resources in eight different countries.

10. Discuss the following questions with your group:
    - What natural resource is the focus of each photo?
    - How do you think the use of this resource affects the appearance, composition, and/or structure of Earth? (What effects of natural resource use do you observe on the land, air, and water?)
    - What do you think can be done to address these changes?

EXTENSION

What is the most recent data on human population and natural resource consumption? Find links on the *SEPUP Third Edition Earth's Resources* page of the SEPUP website at **www.sepuplhs.org/middle/third-edition**.

ANALYSIS

1. You observed patterns in natural resource consumption by different countries. Based on these patterns, which country do you predict will consume the most of each of the following resources in the future? Explain your reasoning.
    a. copper
    b. freshwater
    c. petroleum
2. Think about your responses to Analysis item 1. Do you think these countries will also consume the most resources per capita? Why or why not?
3. **Revisit the issue:** What do you predict the effect will be on each of the following as the world's population continues to grow?
    a. the availability of nonrenewable natural resources
    b. the environment
4. How has an increase in human population and natural resource consumption affected Earth? Support your answer with evidence from the activity.

    Hint: Think about how the appearance, composition, and/or structure of Earth may have changed.



Like petroleum, coal is a fossil fuel. It is extracted through mining. Germany gets almost half of its energy from coal, some of which is mined in areas such as the one shown above.



The Ganges River crosses northeastern India and is used to meet the freshwater needs of millions of people. It absorbs almost 4 billion L (more than 1 billion gallons) of waste per day, including sewage and industrial waste.



Brazil contains about 60% of the Amazon rainforest and a growing diversity of known species, including over 40,000 plants and 400 mammals. Cattle ranching, gold mining, and other human activities result in the clearing of 5,000–8,000 square kilometers (1–2 million acres) of land each year.



The Shengli Oil Field is the second largest oil field in China. Despite producing billions of barrels of oil, China must buy oil from other countries to meet its energy needs.



South Africa's Kimberly diamond mine was dug from 1871 to 1914, and yielded 2,722 kg (6,000 pounds) of diamonds. It has left a hole that is 463 meters (1,519 feet) wide and 215 meters (705 feet) deep..



Mexico's Buenavista copper mine is one of the largest copper mines in the world. In 2014, over 37 million L (10 million gallons) of leached copper wastewater leaked into local rivers and affected the drinking water of almost 1 million people.



Once the fourth-largest lake in the world, Russia's Aral Sea has become dry land in most of its basin. Water from two rivers that fed the sea was used to grow cotton over a 40-year period.



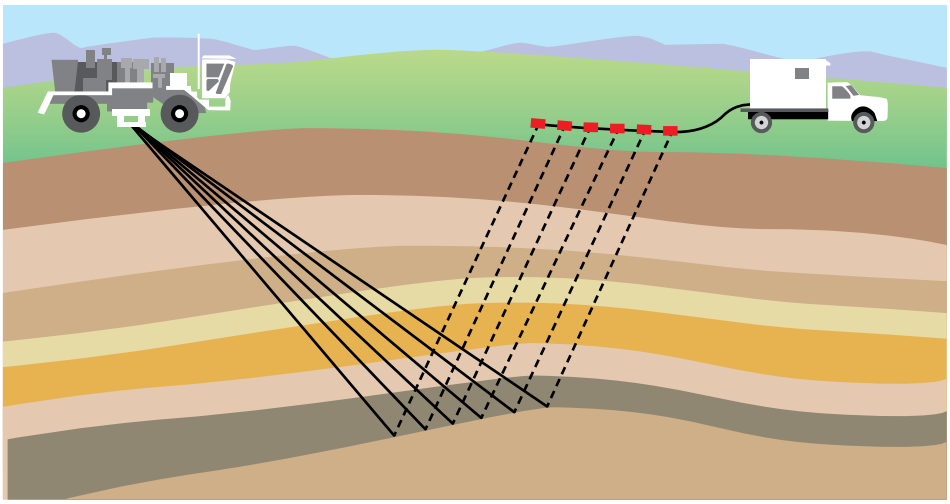
Oil was first discovered in Alaska in 1967. Since that time, there have been conflicts between producing energy and protecting the landscape. Today, the 1.2-meter (4-foot) wide above-ground Alaska pipeline transports oil more than 1,287 km (800 miles) across the state.

5 Finding Resource Deposits

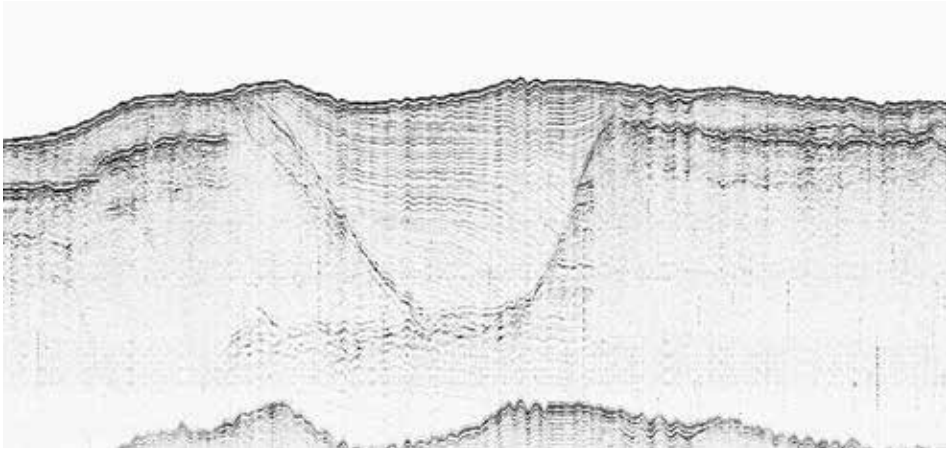
MODELING

Natural resources are not distributed evenly around the planet, and people go to great lengths to find deposits buried deep underground. Certain resources tend to form in certain types of rock, such as sandstone, and in certain settings, such as ancient oceans or streambeds. Recognizing these rocks and environments is often the key to finding resources.

Modern technology has provided new tools for finding resources. **Remote sensing** refers to any technology that provides information about an object that we cannot directly see. A remote sensing method called seismic reflection helps people "see" resources and geological structures that are deeply buried.



The truck on the left releases seismic waves into the ground, and the array of red sensors on the right records the waves after they have reflected off subsurface features.



This diagram shows a profile of a buried river channel produced from remote sensing data.

Seismic reflection works by sending shock waves down into the earth. The timing and shape of the waves reflected back to the surface is recorded. The waves reflect off materials differently based on their properties. Geologists analyze and interpret the reflected waves. They then use this information to map the shapes of structures and the boundaries between different resource types.

In this activity, you will model the collection and interpretation of remote sensing data. A **model** is any representation of a system (or its parts) used to help someone understand and communicate how the system works.

GUIDING QUESTION

How are underground deposits of natural resources located?

MATERIALS

For each group of four students

- 1 Remote Sensing Box
- 2 measuring probes
- 5 colored pencils or crayons: red, yellow, orange, green, and blue

For each student

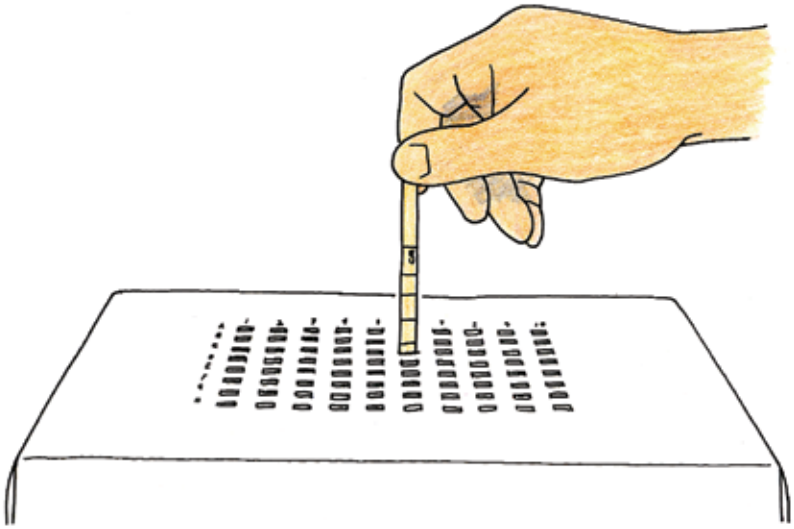
- 1 Student Sheet 5.1, "Mapping Subsurface Structures"

PROCEDURE

Part A: Collecting the Data

1. Compare the top of your Remote Sensing Box with the Part A data table on Student Sheet 5.1, "Mapping Subsurface Structures." Each empty box on the table represents one of the holes in the top of the model. There are 80 holes, and each hole represents the location of a "seismic data point."
2. Each group member is responsible for collecting at least 20 data points. Decide who will collect data from which holes.

3. In this model, the measuring probe represents a reflected seismic wave. At each of your assigned data points, you will collect your data by doing the following:
   - Carefully insert the probe into the hole as close to vertically as possible.
   - Keeping the probe vertical, gently push it down until you feel it hit something.
   - Measure the depth as soon as your probe makes contact. Do not push the probe farther into the box.



4. Round your measurement to the nearest 0.1 cm, and record it in the appropriate box of the table on Student Sheet 5.1.
5. Once your group has collected all 80 data points, share your data so that each group member's table is completed.

Part B: Mapping Structures

6. Complete Part B of Student Sheet 5.1. Use the key to create a false-color map by coloring each square with the appropriate color for its measured probe depth.

7. The following table provides data about the location of some natural resources.

   a. Discuss the information in this table with your group.

Locating Natural Resources

RESOURCE	OFTEN FOUND IN ROCKS . . .
Fossil fuels	formed in ancient bodies of water (e.g., wetlands or seas) and/or as liquids and gases trapped as a result of geological processes.
Dense, resistant materials (e.g., gold, diamonds)	formed by moving water (e.g., river channels and shorelines).
Metals (e.g., silver, copper, lead, zinc)	in areas with evidence of past volcanic activity and/or subsurface magma (hot molten rock).

   b. Using the information in the table, work with your group to figure out what underground or surface features might indicate the presence of each of the listed resources. For example, an ancient body of water may have created a basin that still exists today. Describe these features in your science notebook.

8. Compare the information on your false-color map to the information in Step 7. Describe the subsurface structures revealed by your remote sensing data. Record your response in your science notebook.

9. Discuss the following questions with your group, and record your responses in your science notebook:

   a. Based on your remote sensing data, which areas do you think are most likely to contain fossil fuel deposits? Explain your reasoning.

      Hint: Use the row and hole grid to specify the location. For example, fossil fuel deposits are likely to be found in the area between Rows E and H and Columns 3 and 4.

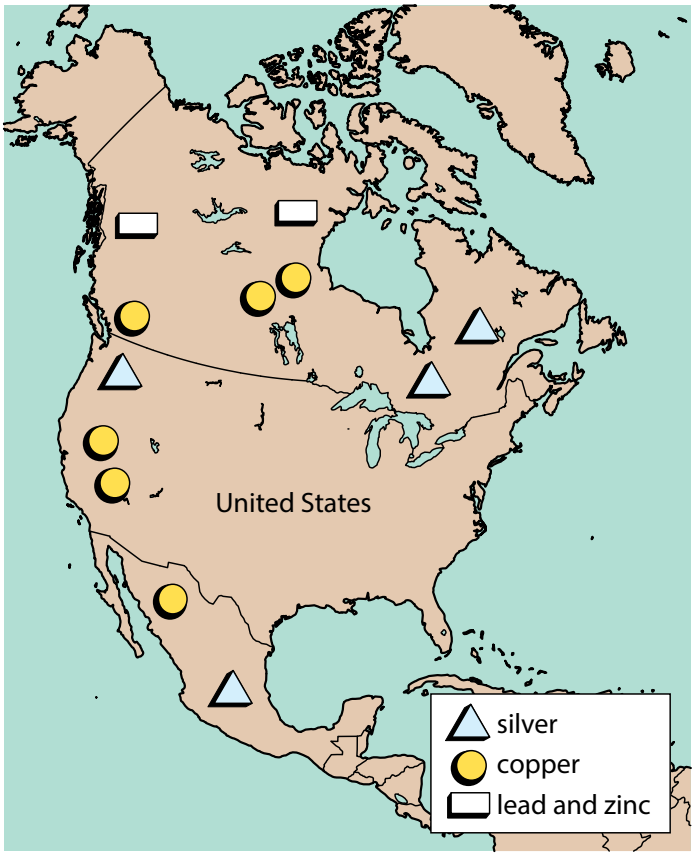
   b. Based on your remote sensing data, which areas do you think are most likely to contain gold deposits? Explain your reasoning.

ANALYSIS

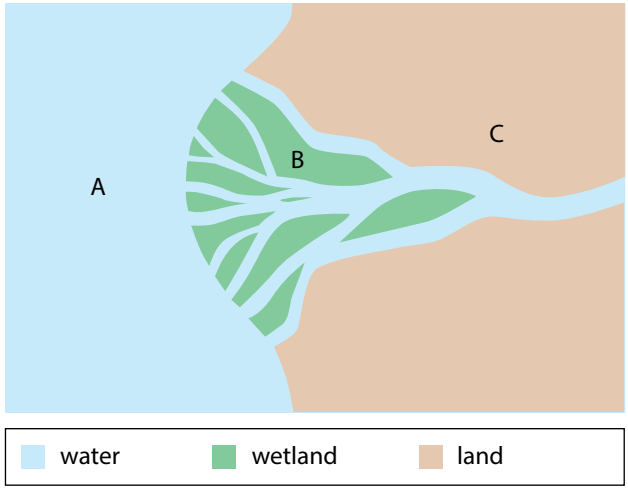
1. Was the box and the probe a good model for seismic reflection? Describe the strengths and weaknesses of this model.

2. In a false-color map, does it matter which color is used for each measurement range? Why or why not?

3. Look at the following map. Do you think you are more likely to find evidence of volcanic activity in the western or eastern parts of the United States? Explain your reasoning.



4. Imagine that you are a geologist for an energy company trying to locate fossil fuel deposits. The following map represents a reconstruction of a past environment. Which area(s) do you think are most likely to contain fossil fuels? Support your answer with evidence from this activity.



5. **Revisit the issue:** Natural resources are distributed unequally around the world.
   a. Why do you think certain natural resources form in one place and not another?
   b. How do you think this affects the value of natural resources?

6 Extracting Resources

LABORATORY

AFTER LOCATING VALUABLE resources, people then obtain them by drilling or mining. Copper is often extracted by digging a large hole, known as **open pit mining**. The ground is opened up because the desired resource is close to the surface or is under an unstable layer of earth.

You learned about Utah's Bingham Canyon open pit copper mine in the "World Resource Consumption" activity. Open pit mining of copper typically removes a variety of copper ores. **Ore** is a rock that contains economically valuable concentrations of a metal or other minerals. Once ores are mined, they are usually crushed and processed to extract the metal. The rest of the ore is often discarded as waste. Processing an ore often involves treatment with acid, heat, or both. In this activity, you will model the process of extracting copper from malachite ore, and examine the wastes produced from this process.



Mining geologists, like the shown here, study the relationship between geology and ore formation in order to locate new mineral resources.

GUIDING QUESTION

How are resources extracted from the earth?

MATERIALS

For each group of four students

- 1 vial of crushed malachite ore
- 1 vial of iron powder
- 1 bottle of 0.5 M sulfuric acid
- 1 dropper bottle of water

For each pair of students

- 1 SEPUP tray
- 1 SEPUP funnel
- 1 filter-paper circle
- 1 30 mL graduated cup
- 1 stir stick
- 1 dropper
- 1 magnifying lens
- 1 metric ruler

For each student

- 1 Student Sheet 6.1, "Observations of Solids and Liquids"
- 1 pair of chemical splash goggles
- 1 lab apron

SAFETY

Use caution when handling chemical solutions. Sulfuric acid is a strong acid. Always wear safety goggles and a lab apron. Thoroughly rinse any area (or piece of clothing) that comes into contact with a chemical solution.

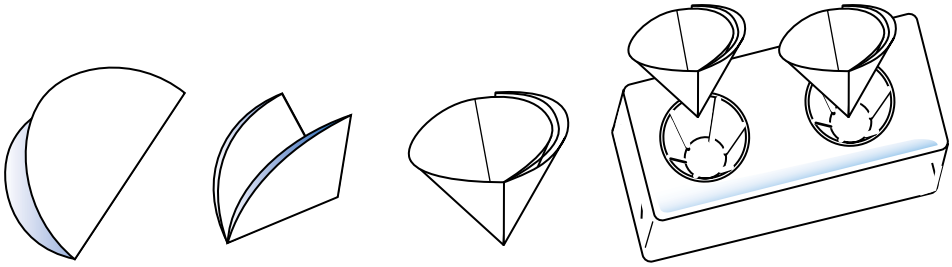
PROCEDURE

Part A: Removing Copper from Malachite

1. Use the magnifying lens and ruler to help you examine the crushed malachite and the iron powder. Record your observations on Student Sheet 6.1, "Observations of Solids and Liquids."
2. Use the stir stick to place 2 level scoops of crushed malachite in a 30-mL graduated cup.
3. Carefully and slowly add sulfuric acid up to the 5-mL mark of the graduated cup.

4. Use your stir stick to gently stir the contents of the cup once a minute for about 5 min. Observe and describe the mixture each time.
5. Fold the filter paper and place it into the SEPUP filter funnel as shown below. Be sure to moisten the filter paper with a few drops of water to hold it in place.

SEPUP Filter Tray Setup



Step 1
Fold filter paper in half.

Step 2
Fold filter paper in half again.

Step 3
Open with three thicknesses of paper on one side of the cone and one thickness on the other.

Step 4
Place in funnel and add 3–5 drops of water from the dropper bottle to hold it in place.

6. Place the funnel over large Cups B and C of your SEPUP tray.
7. Carefully pour the contents of your graduated cup into the filter paper. Use the stir stick to scrape any solids left in the cup into the filter paper.
8. After the liquid has dripped through the filter paper, slide the funnel over Cups D and E and record your observations of Liquid 1 on Student Sheet 6.1.

Part B: Recovering Copper

9. Use a clean stir stick to add 1 level scoop of iron powder to the liquid in the tray.
10. Stir the contents of the cup continuously for 2 min. Observe and record any changes that occur.
11. Use your dropper to carefully remove the liquid from Cup B and transfer it to Cup C.
12. Observe the solid left in Cup B and the liquid in Cup C. Record your observations on Student Sheet 6.1.

13. Use a dropper to remove the liquid from the SEPUP tray and place it in the container your teacher has provided for this purpose.
14. Use the stir stick to remove the solid from the SEPUP tray and place it in the container your teacher has provided for this purpose.
15. Dispose of the filter paper in the trash.

ANALYSIS

1. Model the process of extracting copper from malachite ore.
   a. Draw a diagram showing the steps of extracting copper from malachite ore that you followed in this activity. Be sure to include the solids and liquids that were produced at each step of the process.
   b. Explain the process you drew in Analysis item 1a. Make sure to include how the solid waste produced by the refining process differs from the crushed malachite you began with.
2. In this activity, you observed the wastes produced from extracting metal from an ore. What effect do you think extracting metals on a larger scale, such as from a copper mine, have on the environment?
3. **Revisit the issue:** In 1991, the Flambeau Mine opened in Wisconsin near the Flambeau River, a popular place for activities such as canoeing. By 1999, the mine had closed and the site was restored. You can see photos of the site before, during, and after the mining in the photos on the next page.

   The mine produced 164,200 metric tons of copper, 9,469 kg (20,875 pounds) of gold, and 93,553 kg (206,250 pounds) of silver. It also created 4 million metric tons of high-sulfur waste rock and 3.6 million metric tons of low-sulfur waste.

   Several years later, local water samples showed that metals had contaminated groundwater and surface water, killing life in a nearby stream that flows into the river. In 2012, the company was ordered to address the water pollution. The company removed materials that were polluting surface water. However, any remaining pollutants will continue to seep into the groundwater.

Imagine that you were working for the state of Wisconsin in 1990. Would you recommend allowing the mine to be opened? Support your answer with evidence (including evidence from this activity), and identify the trade-offs of your decision.



Flambeau Copper-Gold-Silver Mine, Wisconsin.
Top left: Before mining (1991)
Top right: During mining (1996)
Bottom: After mining (2002)

4. **Reflection:** What changes, if any, are you willing to make to reduce your own resource consumption? Explain how your actions would reduce resource consumption.

7 Geological Processes

READING

The world's deepest mine is a gold mine in South Africa, and it is already over 3.9 kilometers (2.4 miles) deep. How did this resource form deep in the earth? Earthquakes, volcanoes, erosion, and weathering are some of the processes that form and shape Earth's rocks. Together, these processes that shape Earth's surface layers are known as **geological processes**. In this activity, you will learn about some of the geological processes that have resulted in the formation of natural resources.

GUIDING QUESTION

How are natural resources formed?

MATERIALS

For each student

- 1 Student Sheet 7.1, "Talking Drawing: Natural Resource Formation"
- 1 Student Sheet 7.2, "Directed Reading Table: Geological Processes"



Magma is usually found deep in the earth. When it erupts on Earth's surface, it is known as lava.

READING

Use Student Sheet 7.1, "Talking Drawing: Natural Resource Formation," to prepare you for the following reading. Use Student Sheet 7.2, "Directed Reading Table: Geological Processes," while you read to help you take notes and guide your understanding.

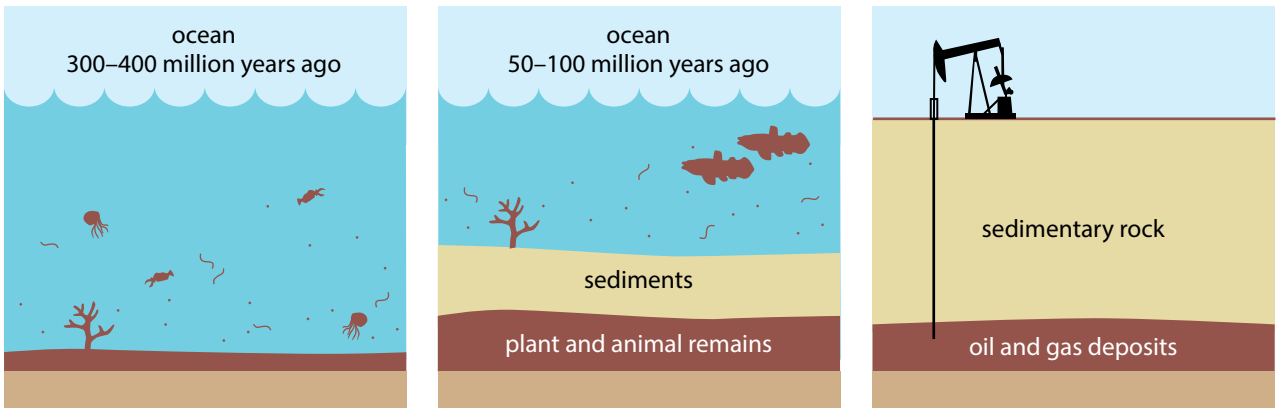
When you have completed the reading, revise your drawings on Student Sheet 7.1 as necessary.

Formation of Fossil Fuels

Digging deeper doesn't always mean that you'll find more natural resources. Petroleum, natural gas, and coal are known as fossil fuels for a reason. They formed through a geological process that took millions of years. For example, petroleum formed when large numbers of plants, algae, and plankton in ancient seas died and sank to the seafloor. They were buried by layers of sediments in an environment with very little oxygen. **Sediments** are small pieces of earth materials such as rocks and shells. When sediments settle on top of each other, they form layers that can eventually harden together. These hard layers form **sedimentary rocks**.

Over millions of years, under conditions of high pressure and high temperature, the remains of the marine organisms transformed into petroleum. Coal and natural gas are other fossil fuels that formed under similar conditions. Over time, the ancient seas dried up, but the fossil fuels formed in the rock layers remained.

The pressure is extremely high deep beneath Earth's surface. Over time, petroleum slowly moved toward the surface, where the pressure



Fossil fuels, such as petroleum, formed from the remains of ancient organisms over millions of years.

is lower. It moved from high to low pressure until it hit a layer of rock that it could not pass through. Today, petroleum is found in underground pockets, known as reservoirs, several hundred meters below Earth's surface. These reservoirs can be found beneath both land and the ocean floor.

Formation of Metal Ores

Earth's outermost layer, known as the lithosphere, is broken into large sections called **plates** that are in constant motion. The movement of these plates is called **plate tectonics** (tek-TAWN-iks). The boundaries of these plates may be sliding past each other, spreading apart, or colliding and causing one plate to move below another plate. Over geological time, important processes—such as volcanoes, earthquakes, and the formation of mountain ranges—have taken place along the boundaries where these plates meet. These processes have created the right conditions for many minerals to be concentrated.

Finding Fossils in Sedimentary Rocks



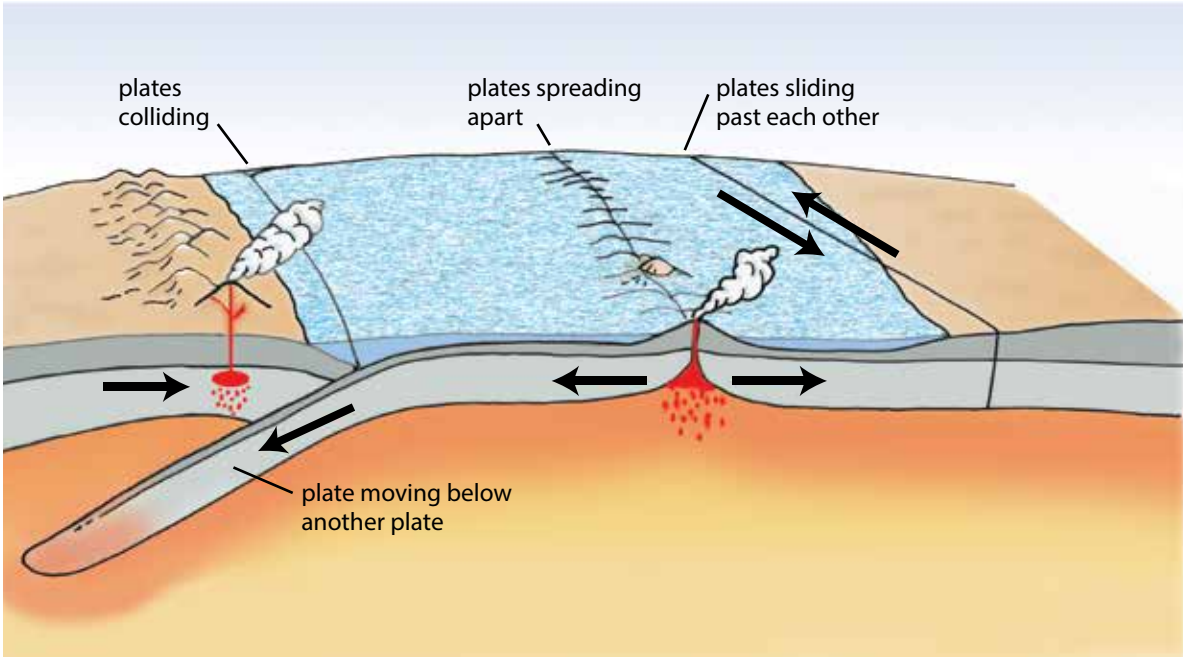
Trilobite fossil

Most fossils are found in sedimentary rocks. Fossils are often formed during the deposition and layering of sediments, such as sand. For example, some plants or animals that died millions of years ago quickly became covered with a layer of sand or mud. If the remains of the plant or animal completely broke down, leaving only an imprint of its shape (or its shell) in the rock, it became one type of fossil. You examined this type of fossil in the activity "Observing Earth's Resources." In other cases, fossils were formed when the organic material of the plant or animal was slowly replaced with minerals, creating a rock that shows details of the dead organism. There are all kinds of fossils in countries all over the world, but they are not always easy to find. Each fossil provides information about the life that has existed on Earth.

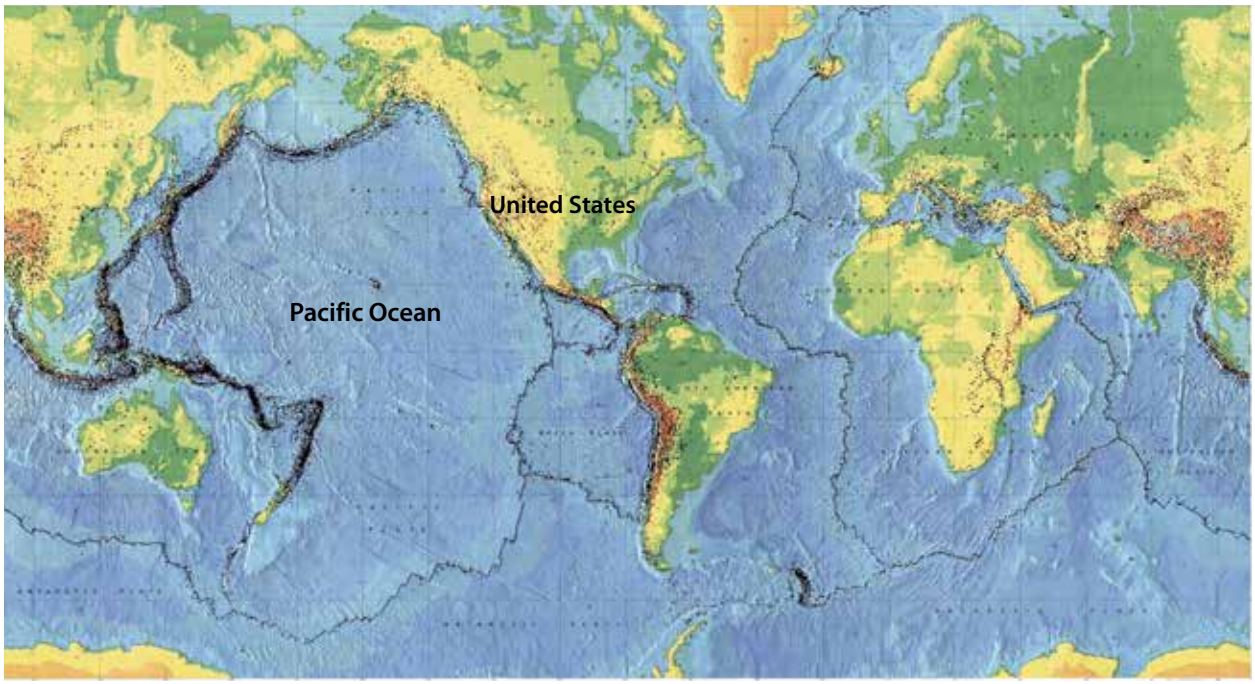
At boundaries where one plate is moving below another, there are often high temperatures and volcanic activity. Magma is very hot "liquid rock" usually found deep inside the earth. Magma can cool within Earth's crust and form ores containing copper, lead, zinc, molybdenum, platinum, gold, tin, tungsten, antimony, mercury, and uranium. The natural forces of uplift and erosion expose some of these ores at Earth's surface. People can also find them by digging mines.

Sometimes plate boundaries are located under the ocean, and large underwater volcanic mountains can form from magma coming to the surface. The plate boundary seen along the middle of the Atlantic Ocean is an example of an underwater boundary that is spreading apart. As the super-heated magma makes contact with the seawater, metals that liquefied out of the surrounding rocks are deposited on the sea floor. Minerals found along this type of boundary include iron, zinc, copper, lead, gold, and silver.

It is important for geologists to know where plate boundaries exist today—but they also need to know where the boundaries were located hundreds of millions of years ago. This information is used to predict areas likely to contain mineral deposits. When two plates collide, Earth's crust tends to crumple and be pushed upward, forming mountains as well as causing earthquakes. Several of the world's highest mountains, including Mount Everest, were formed when the Indian



At Earth's surface, plates are sliding past each other, spreading apart, or colliding. These movements result in many of the earthquakes and volcanoes observed and felt today.



Earthquakes and volcanoes help mark plate boundaries. Black dots mark the locations of recent individual earthquakes and volcanoes.

plate collided with the Eurasian plate. Colliding plates do not have the high temperatures and volcanic activity associated with other types of plate boundaries. As a result, minerals tend to be exposed rather than formed at this type of boundary.

The geological processes that formed today's mineral deposits are still occurring. For example, at the mid-Atlantic ridge, minerals continue to be deposited along the plate boundary. As the global demand for valuable metals continues to grow, there is increasing interest in deep-sea mining along these boundaries. However, the accumulation of new mineral deposits does not happen nearly as fast as the rate at which humans are extracting these minerals.

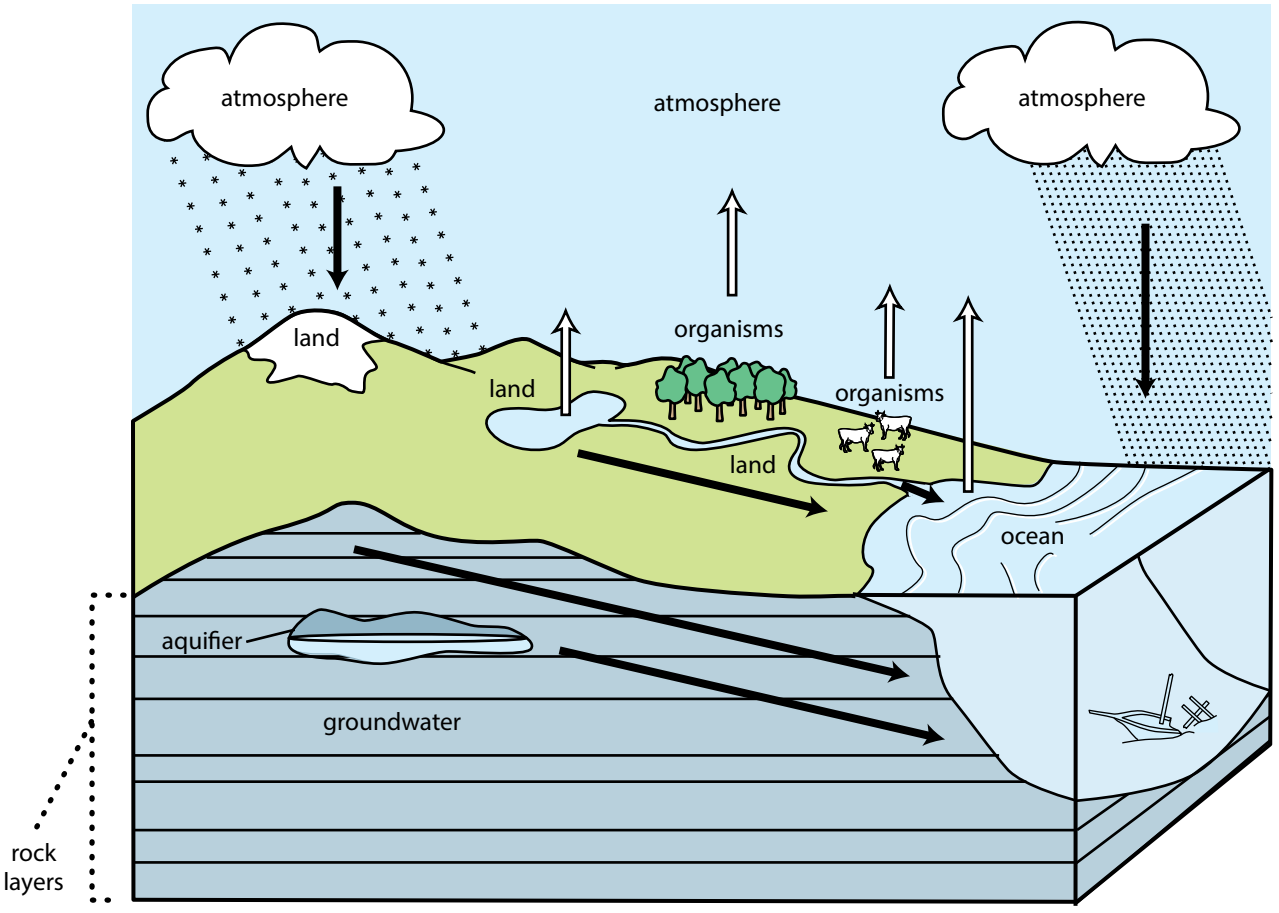
Formation of Groundwater

You have experienced rain, snow, and other forms of precipitation falling to Earth. But once it hits the ground, where does it go? Some runs into and collects on the surface as streams, lakes, rivers, and oceans. Some seeps down below the surface into the soil and rocks. Water moves through, and is sometimes trapped, in the spaces that exist between rocks. **Groundwater** is water found underground in spaces and cracks within earth materials.

A rock layer that allows groundwater to flow through it and collect is called an **aquifer**. Aquifers, like copper or petroleum deposits, are important natural resources. About 50% of the water used in U.S. homes is groundwater that comes from aquifers.

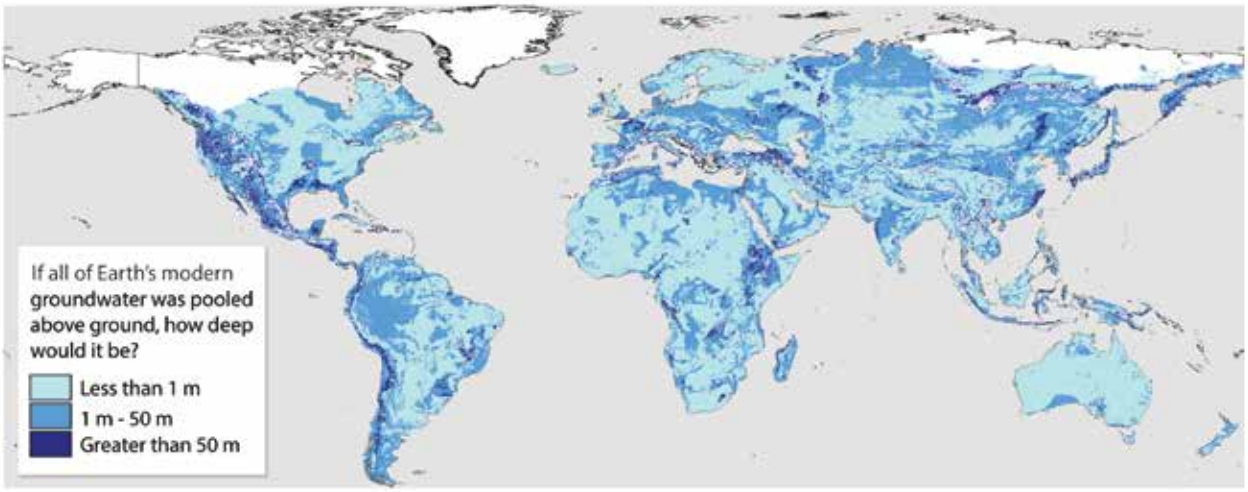
Natural refilling of deep aquifers is a slow process because groundwater moves slowly. For example, it is estimated that if the aquifer that underlies the High Plains of Texas and New Mexico were emptied, it would take centuries to refill it at the current rate of low precipitation. In contrast, a shallow aquifer in an area of lots of precipitation could be refilled very quickly.

People continue to dig into Earth's crust to gather natural resources and learn more about this planet. As they go deeper, they too are faced with the challenge of handling high temperatures and pressures. Only time will tell how far down humans will safely dig in the future.



Water cycles through the environment, making it a renewable resource.

Global Groundwater Resources



Tom Gleeson, Kevin M. Befus, Scott Jasechko, Elco Luijendijk and M. Bayani Cardenas (2015). *Nature Geoscience*, DOI: 10.1038/NGEO2590.

Groundwater is not distributed evenly on Earth, causing some parts of the world to experience severe water shortages.

ANALYSIS

1. Copy the three lists of words shown below:

List 1	List 2	List 3
mineral	petroleum	aquifers
copper	fossil fuel	lakes
metal	natural gas	oceans
resource	coal	groundwater
model	solar	freshwater

   a. In each list, look for a relationship among the words, and cross out the word or phrase that does not belong.
   b. In each list, circle the word or phrase that includes all the other words.
   c. Explain how the word or phrase you circled is related to the other words in the list.

2. Create a concept map using the following 14 terms:

coal	natural gas
fossil fuels	geological processes
groundwater	sediments
layers	rock
plants	subduction
copper	plates
oceans	aquifer

3. Look again at the map "Estimated Global Petroleum Deposits" in the activity "World Resource Consumption." Knowing how petroleum is formed, what does this map tell you about the location of ancient seas?

4. **Revisit the issue:** Look at the map in this activity showing plate boundaries marked by earthquakes and volcanoes.

   a. Predict where you would likely find large copper deposits. Explain your reasoning.

   b. Compare your prediction to the map "Global Copper Deposits" in the activity "World Resource Consumption." Were there copper deposits where you predicted? Support your answer with evidence.

   c. Is copper a renewable resource? Explain your reasoning.

5. Explain how the uneven distributions of mineral, energy, and groundwater resources are the result of geological processes. Support your answer with evidence.

6. a. Do you think fossils are still being formed on Earth? Why or why not?

   b. What questions do you have about fossil formation on Earth today?

8 Groundwater Formation

LABORATORY

LIKE OTHER NATURAL resources, water tends to collect more in some places than in others. One factor that affects the movement of water is the land itself. Different parts of the world have different types of soil and rock. Over time, rocks crack, crumble, and are broken apart by water and wind. Drops of water on a rock may repeatedly freeze and melt, causing the rock to crack. Rocks sometimes fall from higher places, breaking as they fall and roll. This breaking down of rocks by natural forces such as wind, water and ice is called **weathering**. The weathering of rocks forms smaller pieces ranging in size from boulders to microscopic particles. In this activity you will investigate how water interacts with earth materials made from different- sized particles.

GUIDING QUESTION

How does groundwater form, and how is it extracted?



The particles in sand layers (left) are small, but visible. The particles in clay layers (right) are too small to be visible without using a microscope.

MATERIALS

For each group of four students

- 1 sandstone sample (marked with a black dot)
- 1 shale sample (marked with a white dot)
- 1 cup containing sand
- 1 cup containing modeling clay
- 1 cup containing water

For each pair of students

- 1 magnifying lens
- 1 50-mL graduated cylinder
- 2 30-mL graduated cups
- 1 pipette

For each student

- 1 Student Sheet 8.1, "Data and Predictions"

PROCEDURE

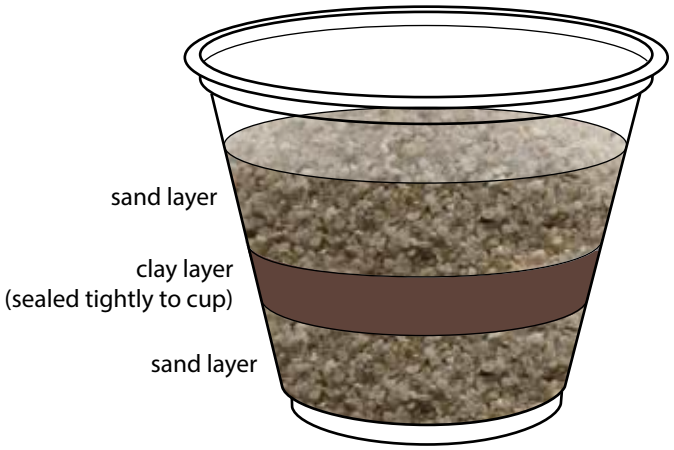
Part A: Examining Earth Materials

1. Working with your partner, use the magnifying lens to carefully examine the four earth materials provided: sandstone, shale, sand, and clay. Describe each material's properties on Student Sheet 8.1, "Data and Predictions."
2. What do you predict will happen when light rain falls on parts of Earth's surface covered with each material? Record your response on Student Sheet 8.1.
3. Test your predictions by using the pipette to carefully put 10 drops of water on each material. When testing sand and clay, fill a graduated cup ¼–½ full before adding the water. Record your observations on Student Sheet 8.1.

Part B: Interactions with Water

4. Add 20 milliliters (mL) of sand to an empty graduated cup.
5. Measure 10 mL of water with your graduated cylinder.
6. Predict the volume of water that you think you can add to the graduated cup before water starts to pool on top of the sand. Record your prediction in the "Predicted Storage" table on Student Sheet 8.1.
7. Slowly pour water from your graduated cylinder into the cup of sand until water just begins to pool on top of the sand.

8. Record the volume of water added in the "Measured Storage" table on Student Sheet 8.1.
9. Squeeze the bulb of the pipette and keep it squeezed. Poke the pipette tip down into the center of the sand until it hits the bottom. Slowly release the bulb while trying to suction only water (not sand).
10. Remove the pipette and then empty its contents into an empty graduated cylinder.
11. Repeat Steps 9 and 10 until you have extracted all the water from the sand that you can. Record the volume of water extracted in the "Measured Extraction" table on Student Sheet 8.1.
12. Remove the sand from your graduated cup, and empty your graduated cylinder.
13. Repeat Steps 4–12 using modeling clay instead of sand. You may have to work the clay a bit to get it pliable enough to form a tight seal with the cup's side as you press it firmly into the cup.
14. Add the following layers to your graduated cup:



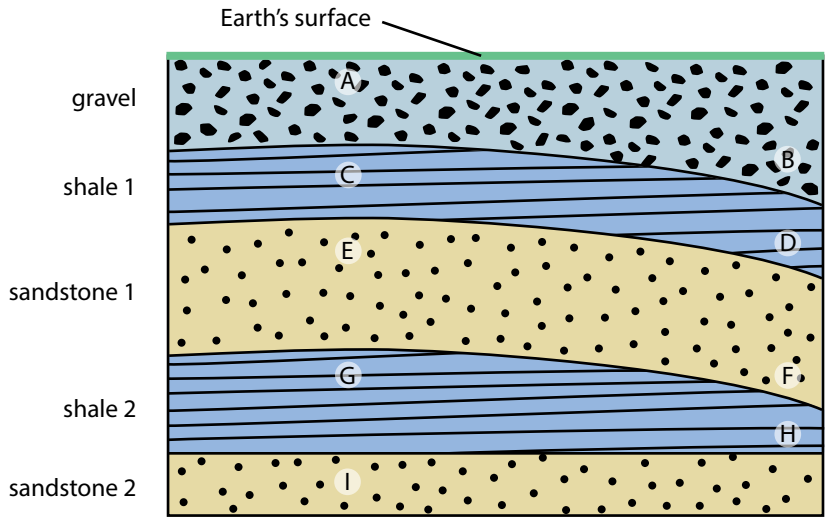
15. Repeat Steps 5–8 (you will not use the pipette to extract any water). Describe and sketch what you observed in your science notebook.
16. Carefully drain and then remove the earth materials from your graduated cup.

17. Discuss the following questions with your group, and then record your responses in your science notebook. Include any helpful sketches.
    a. Think about what you now know about the interaction of water and earth materials. Describe two layers of earth materials that are necessary for an aquifer to form and what properties each material has that support aquifer formation.
    b. What ancient environment(s) and/or past geological processes could produce the layers you described in Step 17a?

ANALYSIS

1. In this activity, you examined four earth materials.
    a. Which material (or materials) are likely to store groundwater?
    b. Which property (or properties) of a material make it better at storing groundwater?
2. What is the relationship between the weathering of rocks and groundwater?
3. Some aquifers lose storage capacity and become less productive each year. Others retain their capacity and production year after year. What could explain why this happens?
4. **Revisit the issue:** Look again at the "Global Groundwater Resources" map in the "Geological Processes" activity.
    a. Based on the map, what can you conclude about the distribution of groundwater?
    b. What did you learn in this activity that helps explain the distribution of groundwater?
    c. Would you consider an aquifer a renewable resource? Why or why not?
5. The best locations for extracting underground resources are the places where those resources accumulate. Use the diagram below to answer the following questions:
    a. What is likely to be the best location (A–I) for extracting rainwater that has seeped down to become groundwater? Why did you choose this location?

b. When oil and water are mixed, oil floats on top of the water. If oil and water were both in sandstone 1, what is likely to be the best location (A–I) for extracting the oil? Why did you choose this location?



6. What do you think happens to Earth's surface directly above an aquifer or oil field when large volumes of liquid are removed and not replaced?

EXTENSION

Where does your drinking water come from? Contact your local water district or go to the *SEPUP Third Edition Earth's Resources* page of the SEPUP website at **www.sepuplhs.org/middle/third-edition** to link to sites with more information about drinking water.

9 Modeling Rock Layers

MODELING

YOU HAVE LEARNED that for petroleum to form, huge numbers of dead marine organisms had to collect on the sea floor. Over time, this organic material was buried under layers of sediment and rock. In some places, such as the walls of a deep river canyon, hundreds of rock layers—or **rock strata**—are visible, one on top of the other. As rock strata form, each new layer is deposited on top of an existing layer.

In this activity, you will model how rock strata form over time. You will use plastic chips to represent the accumulation of Earth's sediments.



Layers of sedimentary rocks can be seen at the Grand Canyon in the western United States (top). Rock layers can also be seen alongside roads that have been built in hilly areas (bottom).

GUIDING QUESTION

Which rock layers are the oldest?

MATERIALS

For each pair of students

- 1 vial
- 1 metric ruler
- 20 light-brown plastic chips
- 20 dark-brown plastic chips
- watch or clock with second hand

PROCEDURE

1. In your science notebook, make a table like the one shown below. You will measure time in seconds (s) and the height of the rock layer in centimeters (cm).

Forming Rock Layers

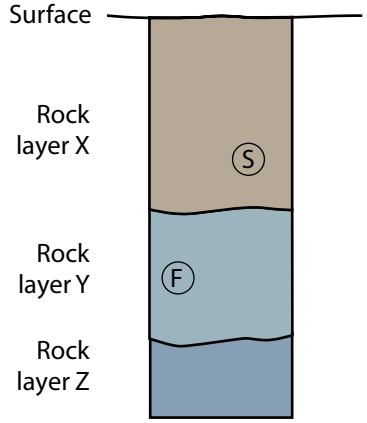
	Time (s)	***Height of rock layer (cm)***
Rock Layer A	*15*	
Rock Layer B	*15*	

2. You will use plastic chips to represent sediments. Each partner should use chips of a single color. Decide which chip color you will use during this activity.
3. Use one hand to hold the base of the plastic tube to keep it steady. Use your other hand to practice picking up one "sediment" chip at a time and placing it in the tube while your partner counts how many "sediments" you put in.
4. Switch roles and have your partner complete Step 3.
5. Empty the tube.
6. The first person placing sediments in the tube will form Rock Layer A. With your partner acting as the timer, try to put as many sediments as you can into the tube in 15 seconds. Be sure to pick up one sediment at a time and to use only one hand to put it in the tube. Use your other hand to hold the base of the tube steady.

7. Switch roles and have your partner complete Step 6. Your partner will form Rock Layer B.
8. Use a ruler to measure the height of each "rock layer" in centimeters.
9. Share your data for each layer with the class.
10. Record the class range of rock layer heights.

ANALYSIS

1. Compare the activity to real rock layers.
   a. Was the thickness of the rock layers the same?
   b. Which rock layer—A (on the bottom) or B (on the top)—formed first?
2. Consider how the activity modeled rock formation.
   a. Draw and label the two rock layers in your science notebook.
   b. Explain how your drawing models real rock layers and their formation.
   c. Do you think that placing chips in a tube was a good model of how rock layers form? Describe the strengths and weaknesses of this model.
3. Look again at the photo in the introduction showing rock layers at the Grand Canyon. Which layer (the highest or lowest) is most likely the oldest? How do you know?
4. Look at the diagram of rock layers on the right. Imagine digging through the rock layers shown in the diagram. As you dig, you uncover fossils. The "S" marks the place where you find a snake fossil. The "F" marks the place where you find a fish fossil.
   a. Which fossil—snake or fish—is most likely older? Explain how you came to this conclusion.
   b. In a nearby area, petroleum has been found in a rock layer that is younger than the rocks containing fish fossils. Knowing this, in which rock layer would you first look for petroleum? Explain.



5. Sometimes very old rocks are found on Earth's surface. Use your knowledge of geological processes to explain how this may have happened.

EXTENSION

In the Analysis, you identified the strengths and weaknesses of the model you used in this activity. Design a different model, or explain how you would change this model to better represent rock layering.

10 Earth's History

INVESTIGATION

Earth is around 4.6 billion years old. The formation of fossil fuels occurred over millions of years, but modern humans have been around for only hundreds of thousands of years. **Paleontologists** (pay-lee-un-TALL-oh-jists) are scientists who use fossils to understand when events occurred, such as the formation of different resources, in Earth's history. As you learned in the previous activity, when you observe a sequence of rock strata, the top layer, along with any fossils it contains, is younger than any other layer in that sequence. The bottom layer, along with any fossils it contains, is the oldest layer in that sequence. Paleontologists use fossil evidence, as well as the radioactive decay in rocks, to figure out when things happened.

GUIDING QUESTION

When did particular events in Earth's history occur?



Argentinian paleontologist Rodolfo Coria prepares a display of the fossilized vertebrae of a dinosaur.

MATERIALS

For each group of four students

1 set of 10 Events on Earth Cards

For each student

1 Student Sheet 10.1, "Personal Time Scale"
1 Student Sheet 10.2, "Ordering Events"
1 Student Sheet 10.3, "Paleontology Student's Notes"

PROCEDURE

Part A: Personal Time Scale

1. Look at the following list of events. Write the event that occurred most recently at the top of the column labeled "Order of Events" on Student Sheet 10.1, "Personal Time Scale."

   I started fourth grade.

   I learned to walk.

   I woke up.

   I was born.

   I took a breath.

   I started kindergarten.

   I learned to read.

   My parents were born.

2. Use the remaining spaces in the "Order of Events" column to write down the other events from most recent (at the top) to most distant (at the bottom).

3. In the column "Number of Years Ago," write the number of years ago that each event occurred (you can round off to the nearest year or half-year). Like a paleontologist, count time backward from the present day. For example, if the event occurred 10 years ago, write "10 ya" as the time of the event. The unit "ya" means "years ago."



These students were born about 14 ya.

4. Think of a major event in your life that is important to you. (It may or may not already be described in your "Order of Events" column.) Use this event to divide your time scale into two time periods by drawing a horizontal line to mark when the event occurred. For example, if you choose entering school as the major event, you could draw a line right below "I started kindergarten."
5. Name the two time periods that you just created. For example, if you drew a line at the time you first started school, the time period before that could be called "Pre-Schoolian."
6. As a class, compare the events that you and your classmates chose for dividing your personal time scales into two periods. Work together to agree on a single event that was important to everyone in the class. Agree on names for the time periods before and after that event.

Part B: Geological Time

7. Imagine that your friend is studying to be a paleontologist. She asks you to help her list some events in the history of Earth in order. She's interested in organizing her ideas into the four time periods shown on Student Sheet 10.2, "Ordering Events."
8. With your group, carefully read the information on the front of each Events on Earth Card.
9. With your group, place each event in order, from oldest to most recent. Remember to listen to and consider the explanations and ideas of other members of your group. If you disagree with the others, explain why you disagree.

   Hint: If you need help, read the clue on the back of the card. Some clues will help you put the events in order; other clues will help you identify the time period in which an event occurred.



This coal train is carrying a resource that was formed millions of years ago.

10. Discuss with your group during which time period you think each event occurred.
11. On Student Sheet 10.2, "Ordering Events," record the order of events that you decided on with your group. Be sure to place each event in the time period in which you think it occurred.
12. Your friend suddenly remembers that she wrote down the order of these events in her science notebook. Ask your teacher for a copy of Student Sheet 10.3, "Paleontology Student's Notes," for your group.
13. Use the information on Student Sheet 10.3 to rearrange the cards in the order that scientists have determined from geological evidence.
14. Record this revised order on Student Sheet 10.2.

ANALYSIS

1. Think back to how you and your classmates divided your personal time scales into periods. How do you think scientists determined how to divide geological time into its periods?
2. How did your group's original order of events differ from that of paleontologists? Explain.
3. Would units of time such as minutes and hours be useful in measuring events in Earth's history? Why or why not?
4. Your younger brother tells you about a television show he watched where humans ride dinosaurs instead of cars. He says he wishes he could go back to the time when people lived with dinosaurs. Based on what you learned in this activity, what do you tell him?
5. **Reflection:** How did placing these events in order help you understand Earth's history?

   Hint: Think about how your understanding of events in geological time has changed.

11 Fossils Through Time

INVESTIGATION

THE HISTORY OF Earth is divided into time spans, but these time spans do not last a specific number of years. The beginning and end of each time span is determined by fossils—either the appearance of new types of fossils not found in any older rocks or the disappearance of fossils commonly found in older rocks. With the help of radioactive dating technology, scientists have made good estimates of how many years each time span lasted.

GUIDING QUESTION

How long have organisms been living on Earth?



These sea star fossils are over 145 million years old.

MATERIALS

For each pair of students

- 1 set of 6 Fossil Time Cards
- 1 set of 6 Geological Event Cards
- 1 metric ruler
- 1 90-cm strip of paper

For each student

- 1 Student Sheet 11.1, "Major Divisions of Geological Time"

PROCEDURE

1. With your partner, carefully read the information on the six Fossil Time Cards, and arrange them with the oldest on the left and the most recent on the right.
2. In your science notebook, record the order in which you placed the cards.
3. View the work of other student groups. Observe the similarities and differences between their orderings and yours. Discuss your choices.
4. Obtain Student Sheet 11.1, "Major Divisions of Geological Time," and a 90-cm strip of paper from your teacher. Use the information on Student Sheet 11.1 to arrange the cards in the order that scientists have determined from geological evidence. In your science notebook, record any changes that you needed to make to your original order.



Few fossil remains are as complete as this 10 million year-old rhinoceros in Nebraska.

5. Follow Steps 5a–d to construct a timeline of the past 4,500 million years:

   a. Using Student Sheet 11.1, work with your partner to calculate the distance (in centimeters) that each time span will cover on your timeline.

      Hint: Since your timeline must represent 4,500 million years over 90 cm, first divide 4,500 by 90 to determine how many years each centimeter will represent.

   b. Draw a vertical line near one end of your long strip of paper, and label it "Origin of Earth."

   c. Using "Origin of Earth" as a starting line, use a ruler and your calculations from Student Sheet 11.1 to mark the boundaries between the time spans.

   d. Label each time span with its name and each boundary with its defining event.



Fossils such as these ammonite fossils are used to determine geological time.

6. Discuss this question with your partner: What do you think might be the reason for the major appearances and disappearances of fossils that mark the beginnings and ends of the geological time periods? Record your ideas in your science notebook.

7. Get a set of six Geological Event Cards from your teacher. With your partner, carefully read the information on the cards, and arrange them with the oldest on the left and the most recent on the right.

8. Record where each major extinction event falls on your timeline. Discuss with your partner how some of the geological events relate to the appearance and disappearance of groups of fossils. Share your ideas with the class.

ANALYSIS

1. List two events that are used to separate geological time periods.

2. Does fossil evidence provide specific dates when events in Earth's history occurred? Explain what type of evidence fossils provide about when events occurred.

3. The total length of your timeline of Earth's history is 90 cm. Use your timeline to determine the fraction of Earth's history when the following occurred:
   a. single-celled organisms lived on our planet
   b. multicellular organisms lived on our planet
4. How is evidence from rock strata used to organize Earth's history?
5. **Revisit the issue:** Since geological processes that have occurred in the past continue to occur today, why aren't fossil fuels considered renewable resources? Support your answer with evidence from this activity.

EXTENSION 1

Obtain a more detailed geologic time scale of Earth to construct a timeline that represents only the past 550 million years. Label all the periods with their names, and be sure to distinguish them from the eras. Explain the advantages and disadvantages of creating timelines for shorter time periods.

EXTENSION 2

As a class, create a giant timeline that represents some of the major events (such as the first fossils of interesting life forms, and mass extinctions) that have occurred during the 4.6 billion-year history of Earth. Stand at appropriately scaled distances from your classmates, and together hold up signs representing major events in the history of life on Earth.

12 Reading Rock Strata

INVESTIGATION

No single location contains a complete set of all the rock layers or fossils that exist on Earth. To study a particular fossil organism or find out which organisms lived during which geologic era, paleontologists must compare rocks from different places throughout the world.

A diagram representing a series of rock layers, such as the one on the right, is called a **stratigraphic column**. The data needed to create stratigraphic columns may come from viewing the sides of cliffs or viewing drill cores. A drill core is a cylindrical piece of rock removed from the earth by a large drill, similar to the drills that are used to make oil wells. Drill cores can provide samples from many miles beneath Earth's surface. You will examine and compare four different drill cores, each representing the rock layers found on different fictional continents.

GUIDING QUESTION

How are rock strata and fossils used to sequence Earth's history?



Rock layers in the Grand Canyon, United States



Schematic diagram of fossils in rock layers

MATERIALS

For each group of four students

- 2 simulated drill cores
- 1 pair of scissors
- 1 metric ruler
- colored pencils

For each student

- 1 Student Sheet 12.1, "Stratigraphic Columns from Drill Cores"

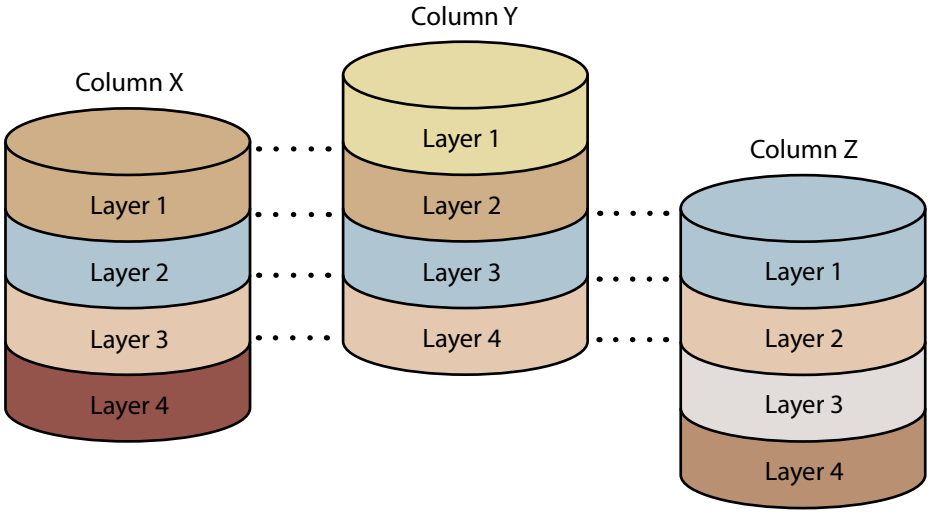
PROCEDURE

1. Each group of four students will receive two drill cores. Work with your partner to examine your drill core. The top of each drill core is marked with its number.
2. Create a stratigraphic column by sketching in the boundaries of the layers and the fossils found within each layer in the appropriate spot on Student Sheet 12.1, "Stratigraphic Columns from Drill Cores." Do this for both drill cores.
3. Based on the evidence within the layers of these drill cores, list the fossils in order from youngest to oldest.
4. When directed by your teacher, exchange your group's drill cores with a group that has two drill cores with different numbers.
5. Based on the appearance of the rock layers and the fossils found within each layer, match, or *correlate*, the layers from each core as best as you can.
6. Make a chart, similar to the one shown on the top of the next page, that shows your correlation of the rock layers from the four different drill cores.

   Hint 1: You may want to cut out each column from the Student Sheet so you can move them around as you try to match up the layers.

   Hint 2: Layers don't have to be exactly the same to correlate.
7. Use your chart to list all four of the fossils in order from youngest to oldest.

   Hint: If you think a layer found in one drill core is the same as a layer found in another drill core, you can infer that those layers, and the fossils in them, are the same age.



Sample correlation of stratigraphic columns

ANALYSIS

1. Describe some of the difficulties you had trying to match evidence found in one drill core with evidence found in other drill cores. What additional evidence would have helped you make your correlations?
2. Based on evidence from all four drill cores, which, if any, of the organisms represented by the fossils may be from species now extinct? Explain.
3. Which fossil species in the drill cores could have lived at the same time?
4. Using the information below and the list you made in Step 7 of the Procedure, make a timeline that shows the time span when each species is believed to have lived. Explain how you determined your answer.

CORE	LAYER	GEOLOGIC ERA
4	1	Early Cenozoic
1	2	Early Mesozoic
3	5	Middle Paleozoic
2	5	Early Paleozoic

5. Explain the following:
   a. How is a geologic time scale based on evidence from rock strata?
   b. How is that evidence used to divide Earth's 4.6 billion-year history?

6. **Reflection:** Propose what might have caused the changes through time shown on your timeline. Explain your thinking.

EXTENSION

In 2017, scientists discovered what they believe to be the oldest fossil eye. Part of an extinct organism known as a trilobite, the fossil is 530 million years old. Find links to the latest fossil discoveries on the *SEPUP Third Edition Earth's Resources* page of the SEPUP website at **www.sepuplhs.org/middle/third-edition**.



Trilobite fossil

13 Impact on Earth's Systems

READING

PEOPLE USE EARTH'S natural resources to satisfy their basic needs for food, clothing, and shelter. But for many people, daily activities depend on processed resources, such as the gasoline used to power cars or the electricity produced by coal burned in power plants. People also use products made from minerals in things like bridges or jewelry. The use of all these resources has an impact on Earth's systems.

GUIDING QUESTION

How is a growing human population and increasing resource consumption impacting the earth?



An average of 112,000 cars cross the Golden Gate Bridge every day. All these commuters depend on natural resources.

MATERIALS

For each student

1 Student Sheet 13.1, "Anticipation Guide: Resource Consumption"

READING

Use Student 13.1, "Anticipation Guide: Resource Consumption," to guide you as you complete the following reading.

Humans depend on natural resources from the earth. Extracting some of these resources has consequences, both positive and negative, for people and the environment. This reading presents four resources used in the United States. These examples show how the resources are gathered, how they benefit people, and how their use affects the environment.

Copper Extraction

Copper has been used by people for thousands of years. Because copper metal is relatively soft, it has often been combined with other harder metals to form bronze. Copper has been and is still used to make items such as tools, sculpture, and even money. For example, the modern nickel and dime have copper cores covered in other metals.



These copper artifacts, found in Wisconsin, are from the Late Archaic period (3000 BC–1000 BC).



A bulldozer is being used to mine gold.

Mining for minerals, such as copper, is essential to meeting rising global demand. Historically, there were few restrictions because people did not realize the negative impact of mining on the environment. Today, environmental regulations are intended to limit this impact. But, around the world, there are nearly as many old, inactive mines as there are active ones. Some of these old mines continue to pose environmental hazards.

Most copper mines have been open pit mines, because copper is found relatively close to Earth's surface. This has resulted in holes that can be hundreds of meters wide and thousands of meters deep. These large holes have increased soil erosion, where surface soil and rock are worn away through the action of wind and water. Mine shafts and underground tunnels have sometimes formed sinkholes in which the land surface collapses. The removal of large quantities of earth has also reduced the number of plant and animal species in an area.

Processing copper ore at a mine site produces byproducts, such as silver, gold, and sulfur dioxide. Today, these byproducts are mostly captured and reused. In the past, chemicals containing these byproducts leaked into the environment and contaminated soil and water. For example, after the Berkeley Pit in Montana closed in 1982, water formed a lake at the bottom of the pit. The water is as acidic as lemon juice. In 2016, thousands of geese died after a large flock landed in the pit's water.

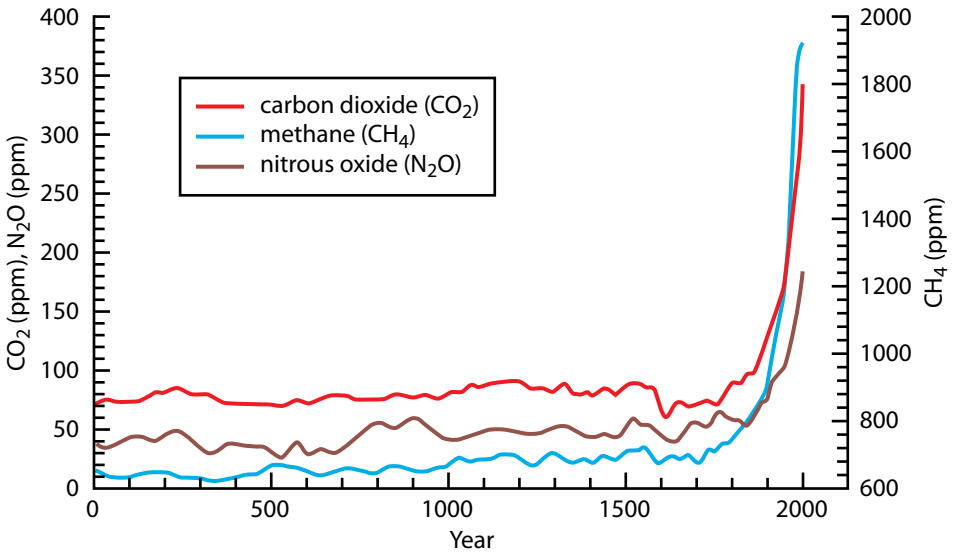
Some modern copper mining companies are using new technologies to mine copper. One goal is to reduce the environmental impact of traditional mining methods. For example, global positioning systems (GPS) and data imaging are being used in exploration, reducing both the cost and the effect of historical exploration methods.

Burning Fossil Fuels

Fossil fuels are the primary energy sources for the world. Fossil fuels are extracted from the earth through mining and drilling. As with extracting mineral resources, mining and drilling for fossil fuels has had environmental impacts on Earth. Today, the greatest concern with the use of fossil fuels is the impact of burning them.

Burning fossil fuels releases gases in the air. Over time, the amount of these gases—which include carbon dioxide, methane, and nitrous oxide—has increased significantly. In fact, global carbon dioxide emissions were 150 times as high in 2011 than they were in 1850. You can see a graph of these changes over time below. These changes are due in part to the Industrial Age (starting approximately 200 years ago), when the use of fossil fuel-powered machines replaced hand tools. These released gases are known as *greenhouse gases* because of the impact they have on Earth's atmosphere. These gases are trapped in Earth's atmosphere and have resulted in an increase in global temperatures. You may have heard of this effect as *global warming*.

Atmospheric Greenhouse Gases Over Time



Source: Intergovernmental Panel on Climate Change (2007)

As demand for fossil fuels has increased, there have been concerns about their supply. New technologies have been developed to extract more oil from the earth. For example, hydraulic fracturing, also known as *fracking*, involves injecting water, sand, and chemicals underground at high pressure. This forces open existing cracks that can be used to extract oil and gas. Because fracking has begun on a large scale in the United States, there are growing concerns about its impact on Earth's systems. Fracking requires millions of gallons of water. This water is exposed to contaminants, which can potentially leak out into the environment. It is now known that injecting large amounts of materials underground can cause earthquake tremors, and small earthquakes have been recorded in areas of fracking. Fracking is increasingly being used to extract fuels before its environmental impact is completely understood.

Groundwater Removal

The San Joaquin Valley in California is one of the most productive agricultural areas in the world. There are areas in the valley, however, where the land is sinking at a rate of up to 60 cm (2 feet) per year. Other places in the area have been measured to have sunk 8.5 m (28 feet). The land is sinking because earth materials are becoming more compact.

The compaction in California and elsewhere is due to the removal of groundwater from the earth and from aquifers. This sinking of land is known as **subsidence** (SUB-sih-dens). About 80% of the subsidence in the United States is due to groundwater removal. Increasing amounts of water pumped from the ground are being used to water crops and irrigate land. As more food is grown for a growing population, more water is needed. The rate of subsidence has increased in recent years. This is in part due to agriculture. For example, hay (to feed cattle) and almonds are water-intensive crops.



Subsidence has caused the land under this driveway to collapse.



California's San Joaquin Valley is one of the most productive agricultural areas in the United States. It also has high levels of land subsidence (shown in pink). Large amounts of groundwater are pumped to water the crops that are grown there.

In some areas, the subsidence is permanent. That means that even if water levels rose, the sediments are too compacted to rise. The capacity for water to be stored underground is permanently affected in such areas. In addition, land subsidence affects the flow of surface water. Rivers may change their course, and erosion patterns may be altered. In this way, subsidence can cause long-term changes to the local landscape.

Recently, states including Arizona and California have created laws to limit the removal of groundwater. As population grows and water consumption increases, people will have to find other solutions to global water needs.

Growing Food

Over the past 50 years, changes in farming practices have increased the world's ability to provide food to a growing population. The total consumption of food per capita has also increased. In 1967, the average energy intake, measured in food Calories, (1,000 calories = 1 food Calorie) in the industrial world was 3,003 Calories (Cal) per person per day. By 2015, it had increased to 3,440 Cal per person per day. Over the same period of time, the average food consumption in developing countries increased from 2,059 Cal to 2,850 Cal per

person per day. As the world's per capita consumption and total population increases, the ability to grow food efficiently becomes more important.



The popularity of seafood around the world has caused the collapse of some fish populations.

However, an increase in the production of food has environmental consequences. For example, seafood and freshwater fish consumption has significantly increased in the past 50 years. One effect has been smaller populations of popular fish in lakes and oceans. The collapse of the cod population off the coast of Newfoundland, Canada, is an example of a population decline due to overfishing. It is estimated that up to 70% of the world's fish are overfished. Some fishing techniques, such as trawling (pulling a fishing net along the sea floor), also damage the sea floor because it can remove up to 25% of the life in the seabed in a single run. This changes the ecology of the environment and disrupts food webs.

To compensate for overfished areas, the number of fish farms has rapidly increased. More than half the fish consumed by humans come from fish farms or are raised in captivity. The impact of fish farming varies depending on farming method, species, and location. For example, there are concerns that farmed carnivorous fish, such as salmon, require such high levels of protein that more kilograms of fish are used to feed them than are produced. As a result, there is debate whether fish farming helps the situation or makes the problem worse. Other possible approaches to reducing impacts on wild fish populations include establishing limits on the total catch of particular species, restricting the length of the fishing season, or limiting the number of fishing boats allowed in specific areas.

Looking to the Future

As population increases and demand for resources goes up, people are looking for other solutions. Using fewer resources and creating new technologies are two possible solutions. One way to reduce resource consumption is to recycle and reuse materials. Aluminum, for example, is a widely used metal that is recyclable. About one-third of all aluminum produced in the United States comes from recycled

scrap aluminum, and recycling requires only 5% of the energy used to make new aluminum. Since the properties of the metal are not changed in the process, aluminum can be recycled indefinitely. Copper is another mined product that has been successfully recycled. In general, recycling of metals is energy efficient.

EXTENSION

While cities occupy just 3% of the world's surface, they consume about 75% of the world's resources. City leaders are increasingly looking at technology to provide ideas and solutions to reduce resource use. For example, the city of Oberlin, Ohio, constructed a computer program that allows people to monitor both their own and the city's electricity and water use. Find links to the latest technological advances on the *SEPUP Third Edition Earth's Resources* page of the SEPUP website at **www.sepuplhs.org/middle/third-edition**.

ANALYSIS

1. Provide an example of the following:
   a. A way that humans have kept up with increased demand for resources
   b. A negative impact on the environment as a result of keeping up with the demand
   c. A possible approach to reducing the use of natural resources
2. Do you think the risks of fracking are worth the benefits? Support your answer with evidence, and identify the trade-offs of your decision.
3. How have human population growth and increases in consumption of natural resources affected the appearance, structure, and/or composition of the earth? Support your answer with evidence from this unit.
4. **Revisit the issue:** What are the positive consequences of natural resource use by people?
5. Many experts believe that the main problem created by current patterns of resource use is the environmental impact, and not the possible shortage of nonrenewable resources. What questions do you have about this perspective?

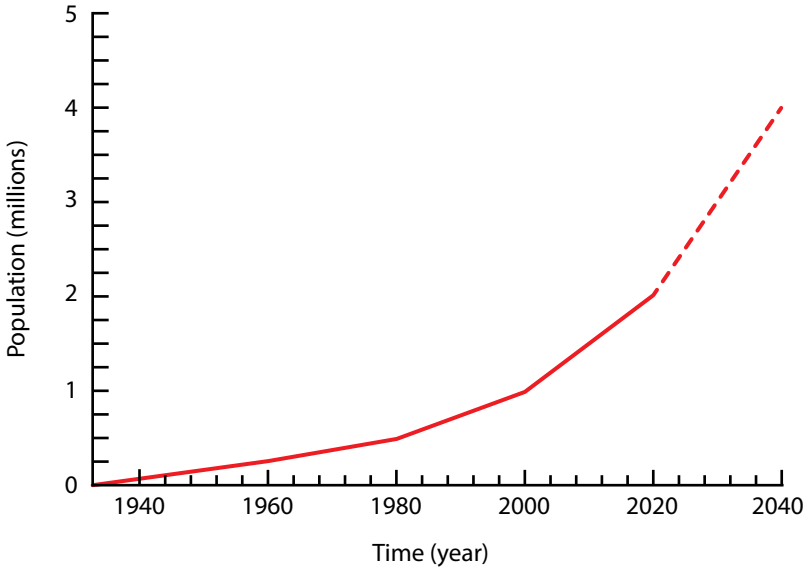
14 The Rockford Range Decision

TALKING IT OVER

IN THIS UNIT, you have learned about human consumption of natural resources. Consumption patterns are changing with a growing world population. Science can provide information about the effects of these changes. People then have to decide what actions to take. In this activity, you will balance a community's need for natural resources with conservation of the environment.

Rockford Range is a nearby area of land that local geologists have determined contains various underground resources. The city has to make some decisions about Rockford Range, and they have only enough funds to support one course of action. The Rockford City Council has gathered to decide what to do.

The community of Rockford has been growing in population, as shown in the graph below.



GUIDING QUESTION

What action should be taken to meet the needs of a growing population?

MATERIALS

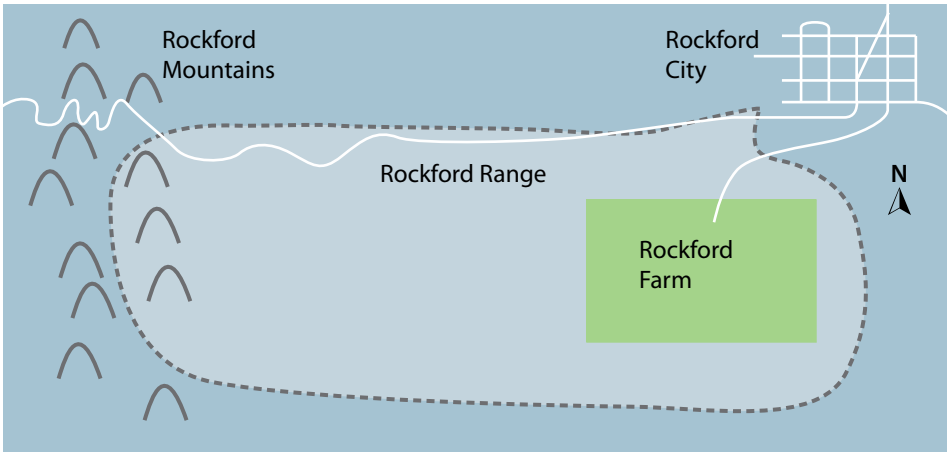
For each student

1 Student Sheet 14.1, "Mining Effects"

PROCEDURE

1. Look at the street map of Rockford Range below. Identify the location of Rockford City, Rockford Farm, and the mountain area.

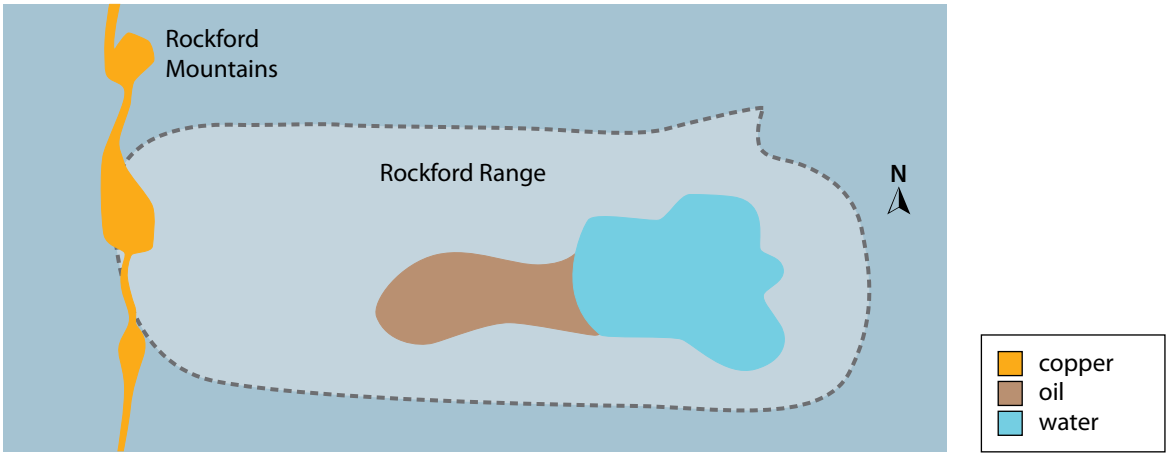
Street Map of Rockford Range



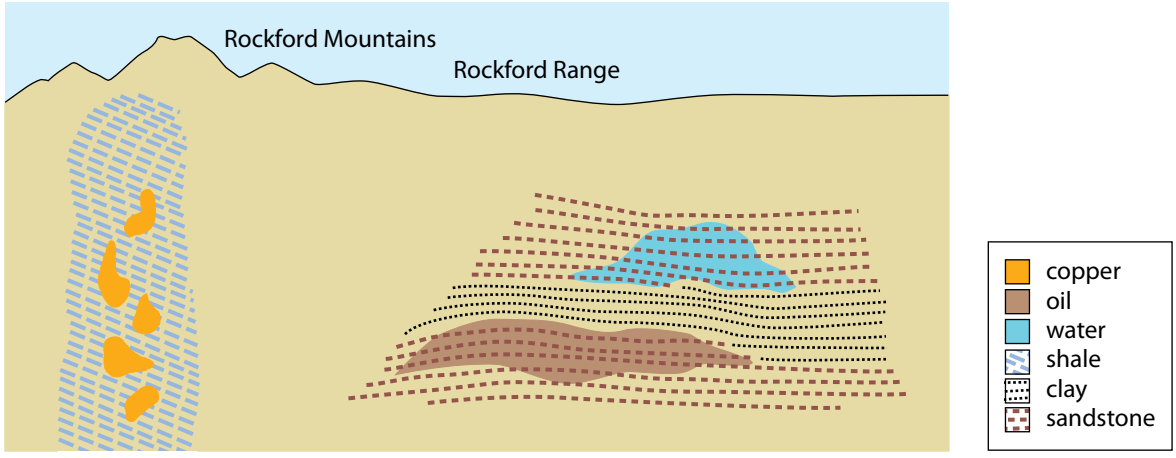
2. Look at the two geological maps of Rockford Range on the top of the next page. Identify the three natural resources found there.
3. Using the information you've gathered throughout this unit, fill in Student Sheet 14.1, "Mining Effects." Identify whether each resource is renewable or nonrenewable, and the specific positive and negative effects caused by using and extracting each resource.

   Hint: Think about how humans depend on the resource and the effects of extracting it.
4. Discuss with your group which effects (both positive and negative) are most important when deciding which resource to extract.

Geological Map of Rockford Range: Top View

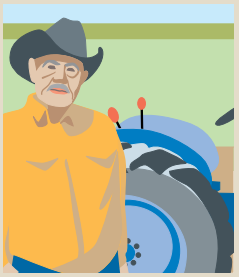


Geological Map of Rockford Range: Side View



5. Read the perspectives from some members of the Rockford community on the next two pages.
6. With your group, identify the possible effect of each course of action proposed by a community member.
7. Use Student Sheet 14.1, the community members' perspectives, and your discussion to determine which course of action you recommend. Follow your teacher's instructions on how to hold a Walking Debate about your recommendation.

Rice farmer



I would like to see the water resource used because the water can be used to grow more rice. Growing rice uses a lot of water, but food is an important resource needed to feed the increasing population of our community. Farming also brings jobs and business to the community. Because water is becoming scarcer and more expensive, being able to use the groundwater from this large aquifer will make the cost of food lower. Since the petroleum is below the aquifer, drilling for the oil could contaminate the water supply.

Oil company representative



Petroleum is the best choice because energy is one of the country's biggest resource needs. Just about all of our everyday activities here in Rockford use fossil fuels. Extracting petroleum would allow us to keep our factories, cars, and buildings running. It would be immediately useful for the community and reduce energy costs for our increasing population.

Owner of a copper wire company



I support extracting copper. Right now I have the copper needed for my company delivered from other parts of the country. Mining the copper locally would make my company more profitable because I would not have to pay to transport the copper. I could then hire more people from the Rockford community. It would be better for the environment too by reducing the amount of fuel and resources required to transport the copper. Mining for copper will help support our growing population.

Environmentalist

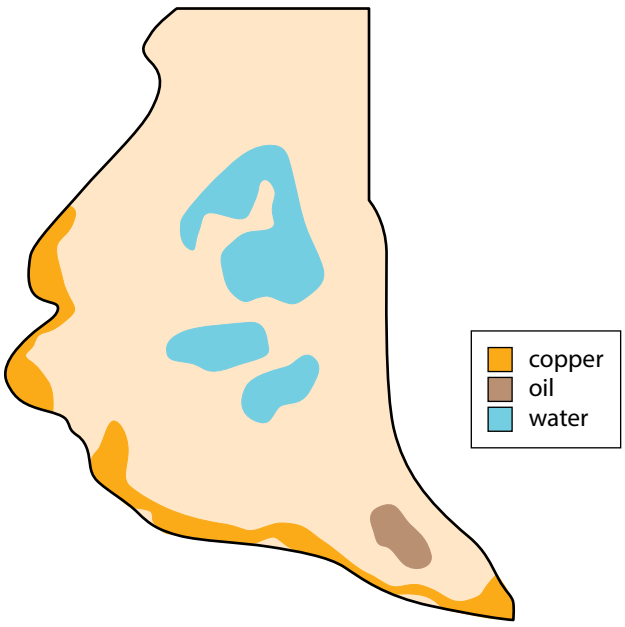


I think the best choice is to make the area into a wildlife refuge. There would be no short-term or long-term negative environmental impacts. It would also protect the local frog population, which has been declining for the past 50 years. Any resource extraction will change the environment and is likely to further negatively affect the frogs. A wildlife refuge could attract tourists, which could bring in tourism money and help support our population.

ANALYSIS

1. What do you recommend that the city do with Rockford Range? Be specific about your recommendation. Support your answer with evidence, and identify the trade-offs of your decision.
2. Rockford is a small community within Big Country. The map below shows the largest reserves of copper, freshwater, and petroleum in the country. Does this additional information change your opinion about which resource Rockford should extract? Explain why or why not.

Big Country



3. Use the maps of Big Country and Rockford Range and your knowledge from the unit to explain how the uneven distribution of each of the following resources is a result of past geological processes and present human action:
   a. groundwater
   b. minerals such as copper
   c. petroleum
4. **Revisit the issue:** What determines how a resource is valued?
5. **Reflection:** What are some solutions to the increased use of natural resources as the world population and the per capita usage of resources increases?

Earth's Resources

UNIT SUMMARY

Resource Use and Population Growth

The human population has grown to over 7.5 billion people. Throughout their lives, every person on Earth uses some amount of food, water, and other natural resources. This growing population has put an increasing strain on the quality and quantity of natural resources available for use by humans and other organisms on Earth. In some parts of the world, the per capita use of resources has also increased significantly. This trend has an impact on natural resources and the earth systems with which they interact. Some of the negative impacts include decreased air and water quality due to pollution, changes in the atmosphere that have impacted the climate, changes in the topography due to resource extraction, and changes in the flow and movement of water.

Resource Formation and Distribution

Natural resources can be organized into categories based on the time it takes for them to be replenished naturally. Renewable resources (including food, water, air, and wood) are recycled or replenished by Earth's systems each day. Most nonrenewable resources (such as fossil fuels, metals, and other minerals) formed millions of years ago.

The formation of these resources and their patterns of distribution are closely related to past environmental and geological processes. For example, fossil fuels formed where conditions favored the collection of plant and animal remains in shallow seas or wetlands. This material was later exposed to geological conditions that were just right to form fossil fuels. In contrast, many metal ores formed in areas of past volcanic activity linked to moving plate boundaries. Resource extraction has already significantly decreased the resources available in some areas. With increased demand, resource distribution will continue to change as a result of removal by humans.

Geological Time and Earth's History

Planet Earth has existed for about 4.6 billion years. Many important geological events have occurred during this period, including the formation of continents, oceans, volcanoes, mountain ranges, and natural resources. A wide variety of life forms have appeared, evolved, and become extinct. Water has collected and recycled, the chemistry of the atmosphere has evolved, and Earth's climate has changed. Scientists have analyzed rock layers and the fossilized organisms they contain to establish the relative time frame of the major events in Earth's history. The geologic time scale, a chart that divides Earth's history into several different sections, was developed using the relative ages of rock layers and fossils.

Essential Scientific Terms

consumption

evidence

geological processes

geological time

groundwater

mineral

natural resources

nonrenewable/renewable

per capita

petroleum

population

trade-offs

APPENDIX

A Science and Engineering

THE NATURE OF SCIENCE AND ENGINEERING

IF SOMEONE ASKED YOU the question, "What is science?" how would you answer?

You might reply that it is knowledge of such subjects as Biology, Chemistry, Earth Science, and Physics. That would be only partly correct. Although science is certainly related to the accumulation and advancement of knowledge, it is much more than that. Science is a way of exploring and understanding the natural world.

According to the American Association for the Advancement of Science (AAAS), two of the most fundamental aspects of science are that the world is understandable and that scientific ideas are subject to change.

Scientists believe that the world is understandable because things happen in consistent patterns that we can eventually understand through careful study. Observations must be made and data collected for us to discover the patterns that exist in the universe. At times scientists have to invent the instruments that allow them to collect this data. Eventually, they develop theories to explain the observations and patterns. The principles on which a theory is based apply throughout the universe.

When new knowledge becomes available, it is sometimes necessary to change theories. This most often means making small adjustments, but on rare occasions it means completely revising a theory. Although scientists can never be 100% certain about a theory, as knowledge about the universe becomes more sophisticated most theories become more refined and more widely accepted. You will see examples of this process as you study the history of scientists' understanding of such topics as elements and the periodic table, the cellular basis of life, genetics, plate tectonics, the solar system, and the universe in this middle school science program.

While the main goal of science is to understand phenomena, the main goal of engineering is to solve problems. Like science, engineering involves both knowledge and a set of practices common across a range of engineering problems. Just as scientists start by asking questions, engineers start by defining problems. Just as scientists search for explanations for phenomena, engineers search for solutions to problems.

Science and engineering often build on each other. For example, scientists use instruments developed by engineers to study the natural world. And engineers use scientific principles when designing solutions to problems.

Scientific Inquiry

Inquiry is at the heart of science, and an important component of inquiry is scientific investigation, including experimentation. Although scientists do not necessarily follow a series of fixed steps when conducting investigations, they share common understandings about the characteristics of a scientifically valid investigation. For example, scientists obtain evidence from observations and measurements. They repeat and confirm observations and ask other scientists to review their results. It is important for scientists to avoid bias in designing, conducting, and reporting their investigations and to have other unbiased scientists duplicate their results. Some types of investigations allow scientists to set up controls and vary just one condition at a time. They formulate and test hypotheses, sometimes collecting data that lead them to develop theories.

When scientists develop theories they are constructing models and explanations of the patterns and relationships they observe in natural phenomena. These explanations must be logically consistent with the evidence they have gathered and with evidence other scientists have gathered. Hypotheses and theories allow scientists to make predictions. If testing turns out to not support a prediction, scientists may have to look at revising the hypothesis or theory on which the prediction was based.

Engineering Design

An engineer uses science and technology to build a product or design a process that solves a problem or makes the world better. Engineering design refers to the process engineers use to design, test, and improve solutions to problems. Like scientists, engineers design investigations to test their ideas, use mathematics, analyze their data, and develop models.

Since most solutions in the real world are not perfect, engineers work to develop the best solutions they can, while balancing such factors as the function, cost, safety, and usability of their solutions. The factors engineers identify as important for solutions to a problem are called criteria and constraints. Most engineering solutions have one or more trade-offs—desired features that must be given up in order to gain other more desirable features.

Science as a Human Endeavor

Science and engineering are human activities. People from all over the world engage in science and engineering and use scientific information and technological solutions. The types of questions a scientist asks and the types of problems an engineer tries to solve are influenced by what they think is important. And what they think is important to investigate often depends on their background, experiences, and perspective. This is why it is essential for all types of people to become scientists and engineers—to be sure science and engineering respond to their interests and needs and to be sure that there are diverse ideas to enrich explanations and arguments. Participation by a wide variety of people in science and engineering will lead to greater and swifter progress toward understanding how the natural world works and solving problems facing individuals, communities, and the environment.

Visit the *SEPUP Third Edition* page for each unit of the SEPUP website at **www.sepuplhs.org/middle/third-edition** to learn more about the interests and accomplishments of diverse scientists and engineers. Each unit highlights examples of people from varied backgrounds in careers that contribute to and depend on the advancement of science and technology.

References

American Association for the Advancement of Science (AAAS). (1990). Project 2061: Science for all Americans. Oxford University Press.

National Research Council. (2012). *A Framework for K–12 Science Education: Practices, Crosscutting Concepts, and Core Ideas*. Committee on a Conceptual Framework for New K–12 Science Education Standards. Board on Science Education, Division of Behavioral and Social Sciences and Education. The National Academies Press.

APPENDIX

B Science Safety

SCIENCE SAFETY GUIDELINES

YOU ARE RESPONSIBLE for your own safety and for the safety of others. Be sure you understand the following guidelines and follow your teacher's instructions for all laboratory and field activities.

Before the Investigation

- Listen carefully to your teacher's instructions, and follow any steps recommended when preparing for the activity.
- Know the location and proper use of emergency safety equipment, such as the safety eye-and-face wash, fire blanket, and fire extinguisher.
- Know the location of exits and the procedures for an emergency.
- Dress appropriately for lab work. Tie back long hair and avoid wearing dangling or bulky jewelry or clothing. Do not wear open-toed shoes. Avoid wearing synthetic fingernails—they are a fire hazard and can tear protective gloves.
- Tell your teacher if you wear contact lenses, have allergies to latex, food, or other items, or have any medical condition that may affect your ability to perform the lab safely.
- Make sure the worksurface and floor in your work area are clear of books, backpacks, purses, or other unnecessary materials.
- Ask questions if you do not understand the procedure or safety recommendations for an activity.
- Review, understand, and sign the Safety Agreement, and obtain the signature of a parent or guardian.

During the Investigation

- Carefully read and follow the activity procedure and safety recommendations.
- Follow any additional written and spoken instructions provided by your teacher.
- Use only those activities and materials approved by your teacher and needed for the investigation.
- Don't eat, drink, chew gum, or apply cosmetics in the lab area.
- Wear personal protective equipment (chemical splash goggles, lab aprons, and protective gloves) appropriate for the activity.
- Do not wear contact lenses when using chemicals. If your doctor says you must wear them, notify your teacher before conducting any activity that uses chemicals.
- Read all labels on chemicals, and be sure you are using the correct chemical.
- Keep chemical containers closed when not in use.
- Do not touch, taste, or smell any chemical unless you are instructed to do so by your teacher.
- Mix chemicals only as directed.
- Use caution when working with hot plates, hot liquids, electrical equipment, and glassware.
- Follow all directions when working with live organisms or microbial cultures.
- Be mature and cautious, and don't engage in horseplay.
- Report any unsafe situations, accidents, or chemical spills to your teacher immediately.
- If you spill chemicals on your skin, wash it for 15 minutes with large amounts of water. Remove any contaminated clothing and continue to rinse. Ask your teacher if you should take other steps, including seeking medical attention.
- Respect and take care of all equipment.

After the Investigation

- Dispose of all chemical and biological materials as instructed by your teacher.
- Clean up your work area, replace bottle caps securely, and follow any special instructions.
- Return equipment to its proper location.
- Wash your hands with soap and warm water for at least 20 seconds after any laboratory activity, even if you wore protective gloves.

Your teacher will give you an agreement similar to the one below to sign.

Science Safety Agreement

STUDENT

I, _____, have read the attached Science Safety Guidelines for students and have discussed them in my classroom. I understand my responsibilities for maintaining safety in the science classroom. I agree to follow these guidelines and any additional rules provided by the school district or my teacher.

Student Signature_____

Date_____

PARENT OR GUARDIAN

Please review with your student the attached Science Safety Guidelines, which include the safety responsibilities and expectations for all students. It is important that all students follow these guidelines in order to protect themselves, their classmates, and their teachers from accidents. Please contact the school if you have any questions about these guidelines.

I, _____, have read the attached guidelines and discussed them with my child. I understand that my student is responsible for following these guidelines and any additional instructions at all times.

Parent or Guardian Signature_____

Date_____

APPENDIX C

Science Skills

THE FOLLOWING PAGES include instructional sheets that you can use to review important science skills:

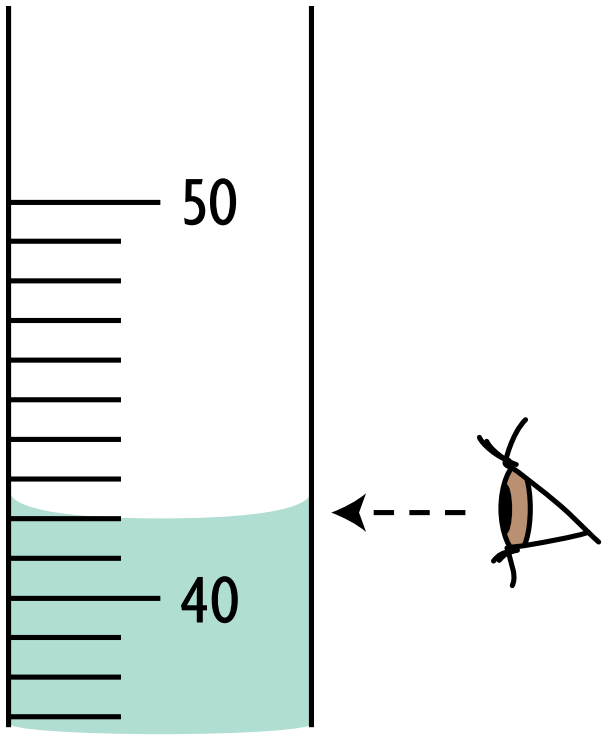
- Reading a Graduated Cylinder
- Using a Dropper Bottle
- Bar Graphing Checklist
- Scatterplot and Line Graphing Checklist
- Interpreting Graphs
- Elements of Good Experimental Design
- Using Microscopes

READING A GRADUATED CYLINDER

A graduated cylinder measures the volume of a liquid, usually in milliliters (mL). To measure correctly with a graduated cylinder:

1. Determine what measurement each unmarked line on the graduated cylinder represents.
2. Set the graduated cylinder on a flat surface and pour in the liquid to be measured.
3. Bring your eyes to the level of the fluid's surface. (You will need to bend down!)
4. Read the graduated cylinder at the lowest point of the liquid's curve (called the *meniscus*).
5. If the curve falls between marks, estimate the volume to the closest milliliter.

The example below shows a plastic graduated cylinder that contains 42 mL of liquid.

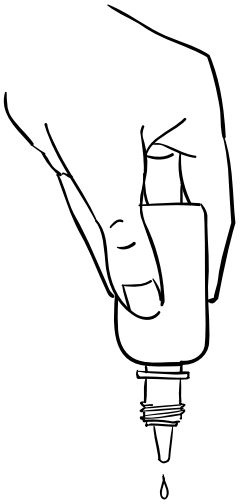


USING A DROPPER BOTTLE



Incorrect

Holding the dropper bottle at an angle creates drops that vary in size.



Correct

Holding the dropper bottle vertically creates drops that are more consistent in size.

BAR GRAPHING CHECKLIST

Sample Graph

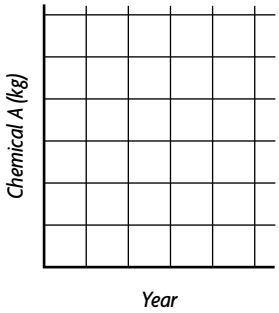
Follow the instructions below to make a sample bar graph.

☐ Start with a table of data. This table represents the amount of Chemical A that the Acme Company used each year from 2011 to 2015.

Year	Chemical A used (kg)
2011	100
2012	80
2013	110
2014	90
2015	105

☐ Determine whether a bar graph is the best way to represent the data.

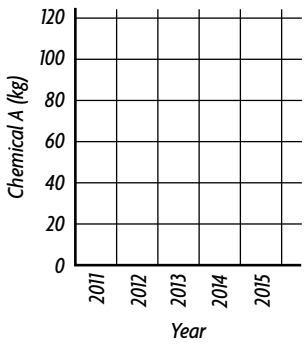
☐ Draw the *x*- and *y*-axes for the graph. Label them with the names and units of the data.



☐ Decide on a scale for each axis. Be sure there is enough space for all the data and that it's not too crowded.

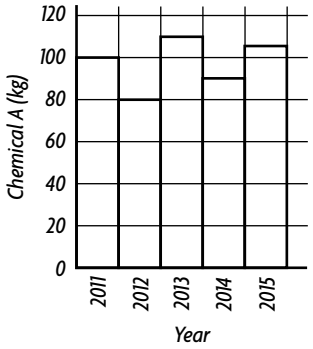
Year axis: *1 block = 1 year*
Chemical A axis: *1 block = 20 kilograms*

☐ Mark intervals on the graph, and label them clearly.

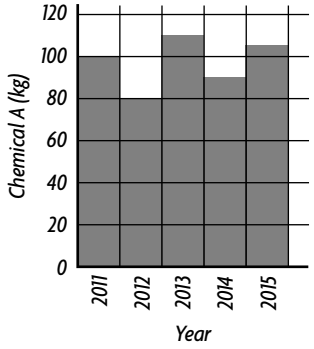


BAR GRAPHING CHECKLIST (continued)

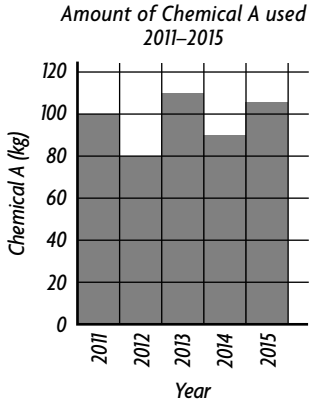
☐ Plot your data on the graph.



☐ Fill in the bars.



☐ Title your graph. The title should describe what the graph shows.



SCATTERPLOT AND LINE GRAPHING CHECKLIST

Sample Graph

Follow the instructions below to make a sample graph.

☐ Start with a table of data.

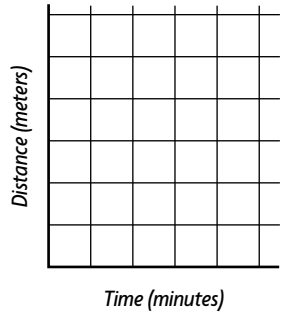
MOTION OF A BALL

Time (minutes)	*Distance (meters)*
0	*0*
1	*5*
2	*9*
3	*16*
4	*20*
5	*27*

☐ Determine whether a line graph or a scatterplot is the best way to represent the data.

LINE GRAPH

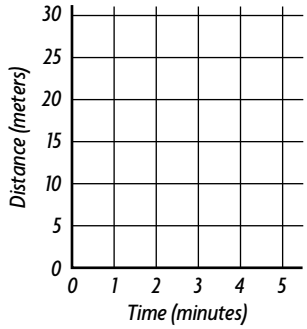
☐ Draw the *x*- and *y*-axes for the graph. Label them with the names and units of the data.



☐ Decide on a scale for each axis. Be sure there is enough space for all the data and that it's not too crowded.

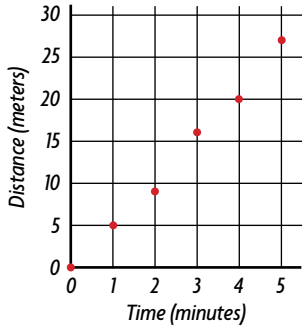
Time axis: *1 block = 1 minute*
Distance axis: *1 block = 5 meters*

☐ Draw intervals on the graph, and label them clearly.



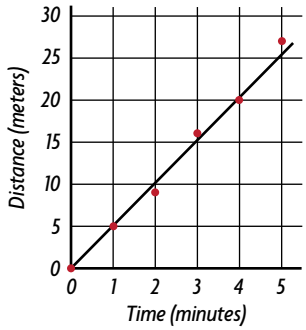
SCATTERPLOT AND LINE GRAPHING CHECKLIST (continued)

☐ Plot your data on the graph.

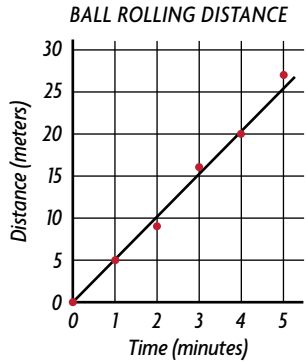


☐ For a scatterplot, leave the points unconnected.

For a line graph, draw a smooth line or curve that follows the pattern indicated by the position of the points.



☐ Title your graph. The title should describe what the graph shows.

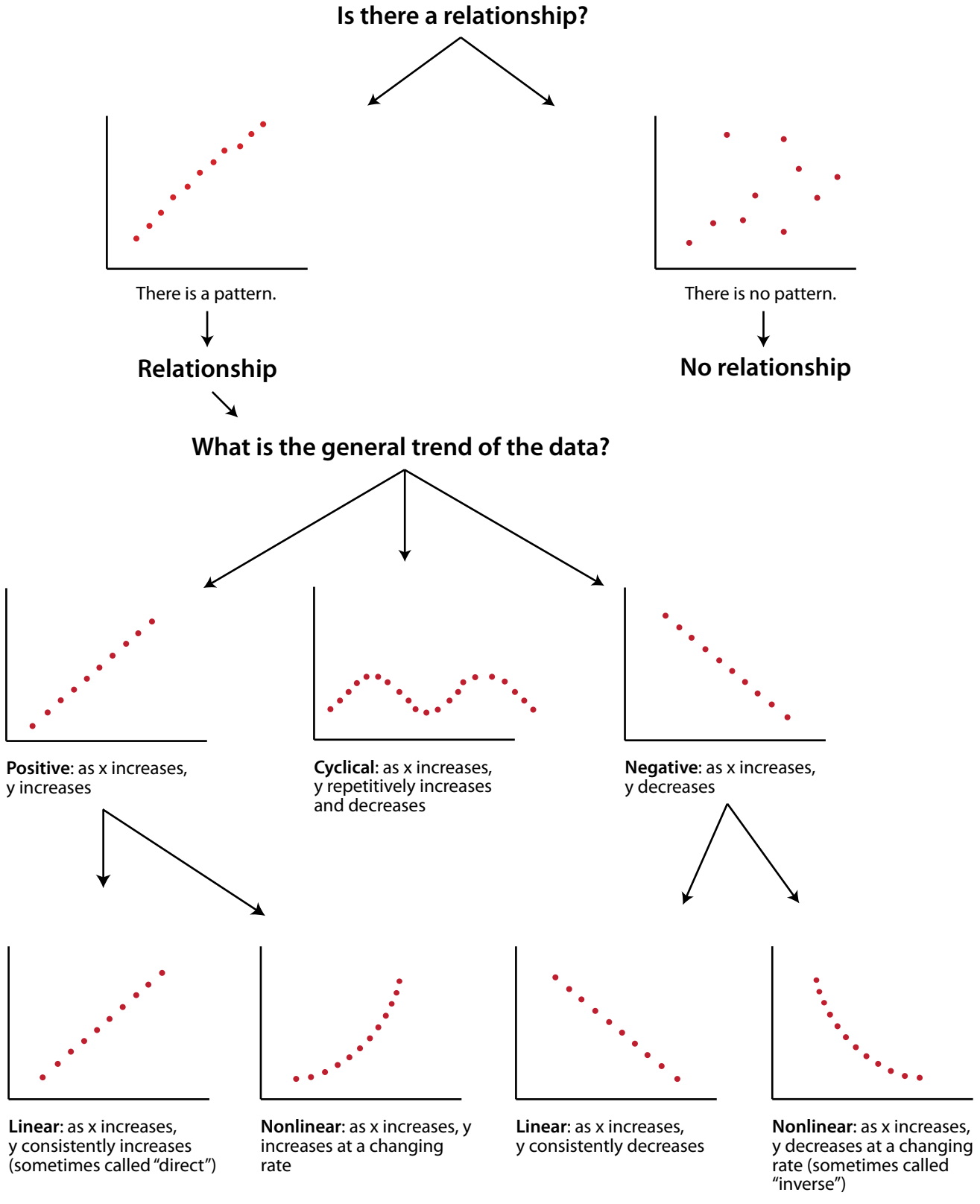


☐ If more than one data set has been plotted, include a key.

● = large ball
○ = small ball

INTERPRETING GRAPHS

Determine the path that describes the data.



INTERPRETING GRAPHS (continued)

Define the components of the graph.

Things you can say:

"The title of the graph is …"

"The independent variable in this graph is …"

"The dependent variable in this graph is …"

"_____ is measured in _____"

Create a description of what the graph reveals.

Things you can say:

"This graph shows that …"

"As the _____ increases, the …"

"The _____ has the highest …"

"_____ is different from _____ because …"

"The_____ peaked at …"

"The rate of _____ increased from …"

Describe how the graph relates to the topic.

Things you can say:

"This graph is important to understanding _____because …"

"This graph supports the claim that _____ because …"

"This graph refutes the claim that _____ because …"

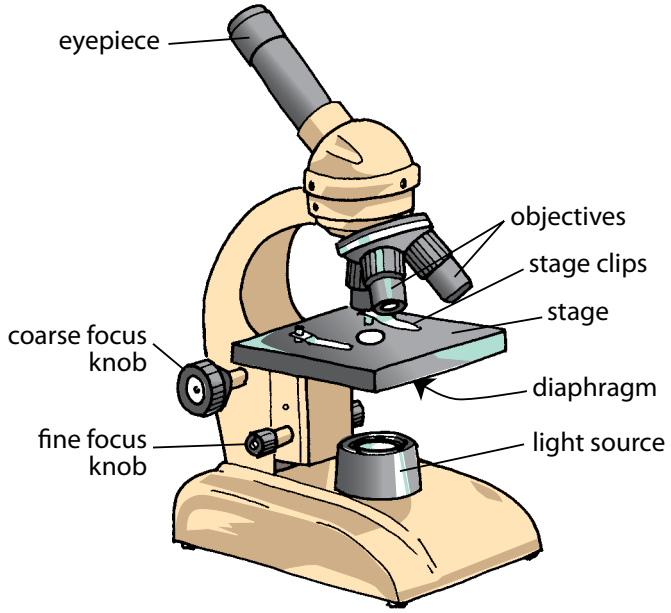
ELEMENTS OF GOOD EXPERIMENTAL DESIGN

An experiment that is well designed

- builds on previous research.
- is based on a question, observation, or hypothesis.
- describes all steps in a procedure clearly and completely.
- includes a control for comparison.
- keeps all variables—except the one being tested—the same.
- describes all data to be collected.
- includes precise measurements and all records of data collected during experiment.
- may require multiple trials.
- can be reproduced by other investigators.
- respects human and animal subjects.

Note: Elements may vary depending on the problem being studied.

USING MICROSCOPES



Focusing a Microscope

Be sure that your microscope is set on the lowest power before placing your slide onto the microscope stage. Place the slide on the microscope stage. Center the slide so that the sample is directly over the light opening, and adjust the microscope settings as necessary. If the microscope has stage clips, secure the slide in position so that it does not move.

- Observe the sample. Focus first with the coarse-focus knob, and then adjust the fine-focus knob.
- After switching to a higher power magnification, be careful to adjust the focus with the fine-focus knob only.
- Return to low power before removing the slide from the microscope stage.

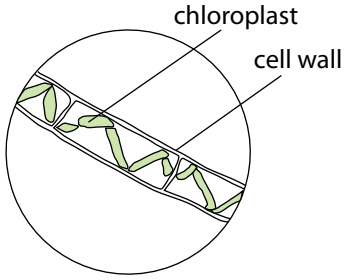
Safety

Always carry a microscope properly with both hands—one hand underneath and one holding the microscope arm. When you are working with live organisms, be sure to wash your hands thoroughly after you finish the laboratory.

Some Tips for Better Drawings

- Use a sharp pencil and have a good eraser available.
- Try to relax your eyes when looking through the eyepiece. You can cover one eye or learn to look with both eyes open. Try not to squint.
- Look through your microscope at the same time as you do your drawing. Look through the microscope more than you look at your paper.
- Don't draw every small thing on your slide. Just concentrate on one or two of the most common or interesting things.
- You can draw things larger than you actually see them. This helps you show all of the details you see.
- Keep written words outside the circle.
- Use a ruler to draw the lines for your labels. Keep lines parallel—do not cross one line over another.
- Remember to record the level of magnification next to your drawing.

Spirogyra (algae) x 400



APPENDIX

D The International System of Units

MEASUREMENTS THAT APPEAR in this program are expressed in metric units from the International System of Units, otherwise known as *SI units* (from Système Internationale d'Unités), which was established by international agreement. Virtually all countries in the world mandate use of the metric system exclusively. The United States does not use the metric system for many measurements, although it has been the standard for the scientific community in the United States for more than 200 years. A U.S. government effort to convert from the United States customary system to metric measurements in all realms of life has yet to extend far beyond governmental agencies, the military, and some industries.

The reason that many countries have replaced their traditional measurement systems with the metric system is its ease of use and to improve international trade. There are far fewer units to understand in comparison to the system commonly used in the United States. The metric system has only one base unit for each quantity and larger or smaller units are expressed by adding a prefix. The table below shows the base units in the International System of Units.

QUANTITY	BASE UNIT
Length	meter (m)
Mass	kilogram (kg)
Time	second (s)
Temperature	kelvin (K)
Electric current	ampere (A)
Luminous intensity	candela (cd)
Mole	mole (mol)

Other international units appearing in SEPUP's *Issues and Science* units are shown in the table below:

QUANTITY	UNIT	COMMON EXAMPLE
Temperature	Celsius (°C)	Room temperature is about 20° Celsius
Volume	liter (L)	A large soda bottle contains 2 liters.
Mass	gram (g)	A dollar bill has the mass of about 1 gram.
Wavelength	nanometer (nm)	Visible light is in the range of 400 to 780 nanometers

The International System's prefixes change the magnitude of the units by factors of 1,000. Prefixes indicate which multiple of a thousand is applied. For example, the prefix *kilo-* means 1,000. Therefore, a kilometer is 1,000 meters and a kilogram is 1,000 grams. To convert a quantity from one unit to another in the metric system, the quantity needs only to be multiplied or divided by multiples of 1,000. The chart below shows the prefixes for the metric system in relation to the base units. *Note*: Although it is not a multiple of 1,000 the prefix *centi-* is commonly used, for example, in the unit centimeter. Centi- represents a factor of one 100th.

METRIC PREFIX	FACTOR	FACTOR (NUMERICAL)
giga (G)	one billion	1,000,000,000
mega (M)	one million	1,000,000
kilo (k)	one thousand	1,000
[UNIT]	one	1
milli (m)	one one-thousandth	1/1,000
micro (μ)	one one-millionth	1/1,000,000
nano (n)	one one-billionth	1/1,000,000,000

APPENDIX

E Literacy Strategies

THE FOLLOWING PAGES include instructional sheets and templates for some of the literacy strategies that are used throughout this book. Use them for reference or to copy into your science notebook.

- Oral Presentations
- Reading Scientific Procedures
- Keeping a Science Notebook
- Writing a Formal Investigation Report
- Constructing a Concept Map
- Developing Communication Skills

ORAL PRESENTATIONS

- Your presentation time is short. Focus your presentation on the most important ideas you need to communicate.
- Communicate clearly by planning your words in advance. When speaking, talk slowly and loudly, and look at your audience.
- Group members should ask for and give each other support if they need help expressing a key word or concept.
- Include graphs and maps when possible. Make sure the type or handwriting and the images are large enough for everyone in the audience to see them.
- While you have your own opinions on a topic, it is important that you present unbiased and complete information. Your audience can then make their own conclusions.
- All the members of a group must participate.
- Since any group member may be asked to answer questions from the class, all group members should fully understand the presentation.
- In a group presentation, you could all play the role of different experts when presenting your information. The class would represent the community members who might be making a decision on the issue.

READING SCIENTIFIC PROCEDURES

The purpose of reading a scientific procedure is to find out exactly what to do, when to do it and with what materials, in order to complete all the steps of an investigation.

If you read a step and are not sure what to do, try these strategies:

- Reread the previous step.
- Reread the step that confuses you. Sometimes rereading clarifies the information.
- Ask your partner if he or she understands what the step says to do.
- Ask your partner if there are words you don't understand.
- Ask your partner to explain what the step says to do.
- Ask your partner to read the step aloud as you listen and try to do what your partner is describing.
- Reread the purpose (guiding question) of the investigation.
- Try to say the purpose of the step out loud in your own words.
- Look at the clues in the pictures of the activity.
- Peek at other groups and listen to see if they are doing the step that confuses you.
- Tell your teacher exactly what you are confused about and why it doesn't make sense.

KEEPING A SCIENCE NOTEBOOK

- Write in blue or black ink.
- Cross out mistakes or changes with a single line. Do not erase or use correction fluid.
- Write neatly.
- Record the date of each entry.
- For each new investigation, write down the following:

  Title:

  Purpose:
  Re-write the guiding question in your own words.
  Hint: What are you going to do? Why are you going to do it?

  Materials:
  Place a "√" here after you have collected the necessary materials.

  Procedure:
  Write down whether you understand the procedure.

  Data:
  Record observations, measurements, and other lab work.
  Include data tables, charts, diagrams, and/or graphs when needed.
  Be sure to label your work clearly.

- Sometimes, you may want to do the following:

  Make inferences or draw conclusions based on the data.
  I think my results mean . . .
  I think that this happened because . . .

  Reflect on how the activity worked in your group.
  This is what went well . . . This is what did not go well . . .
  If I could do this activity again, I would . . .

  Think about what questions you still have.
  I wonder if . . .
  I'm not sure about . . .

  Keep track of new vocabulary and ideas.
  A key word I learned is . . .
  I would like to find out what happens when . . .
  One interesting thing to do would be to . . .

KEEPING A SCIENCE NOTEBOOK

The following is a guide to help you conduct investigations. However, depending on the investigation, you may not always use all of steps below or use them in the same order each time.

Title: Choose a title that describes the investigation.

Purpose: What am I looking for? Write what you are trying to find out in the form of a question.

Background: What do I know about the topic? Write a summary of background information you have on the topic that led to the purpose for the investigation.

Hypothesis: Write a statement about what you predict you will see as data in the experiment to answer the question in the "Purpose" and why you are making that prediction.

Experimental Design: How will you answer the question?

Describe the methods you will use (what you will do) to answer the question.

Use short numbered steps that are easy to follow in the lab.

Make a list of the materials you will use to answer the question.

Outline the variables:

- Independent variable (what is being changed)
- Dependent variable (what is being measured)
- Control (what will be used as baseline comparison)

Data: What did you find?

Record observations and measurements.

Use a data table where appropriate to organize the data.

Don't forget to include proper units and clear labels.

At the end of your investigation, do the following:

Make inferences or draw conclusions about the data:

I think my results mean . . .

I think this happened because . . .

Think about any errors that occurred during the investigation:

What did not go as planned?

What steps were hard to follow while doing the investigation and why?

Think about questions you still have that could lead to new investigations:

I wonder if . . .

I'm not sure about . . .

Keep track of new vocabulary and new ideas that could lead to new investigations

I would like to find out what happens when . . .

One interesting thing to do would be to . . .

Reflect on how the activity worked in your group

This is what went well . . . This is what did not go well . . .

If I could do this investigation again, I would . . .

WRITING A FORMAL INVESTIGATION REPORT

Use the information from your science notebook to write a formal report on the investigation you performed.

Title:

Choose a title that describes the investigation.

Abstract: What were you looking for in this investigation, and what did you find?

Write a paragraph that summarizes what you already knew about the topic, your purpose, your hypothesis, and your results and conclusions.

Experimental Design:

Describe the materials and investigational methods you used to answer the question.

State what variables you worked with and any controls.

Data: What did you find?

Report observations and measurements. Include an organized data table if appropriate to help someone reviewing your report to easily see the results.

Don't forget to use proper units of measurement and write clear labels for your table columns.

Data Analysis: Represent the data in a way that can be easily interpreted.

Use graphs, diagrams, or charts where appropriate to help a reviewer interpret your data.

Conclusion: What do the data mean?

Summarize the data.

Discuss your conclusion based on the accuracy of your hypothesis and the data you collected.

Discuss any errors that occurred that may have interfered with the results.

Describe any changes that need to be made the next time the investigation is performed.

Describe any new questions to be investigated based on the results of this investigation.

CONSTRUCTING A CONCEPT MAP

1. Work with your group to create a list of 15–20 words related to the topic.
2. If you are uncertain of the meaning of a word, look it up in the book or your notes or discuss it with your group.
3. Discuss with your group how all of the words on your list are related, and sort your list of words into 3–5 categories based on these relationships.

   Remember to listen to and consider the ideas of other members of your group. If you disagree with others in your group, explain to the rest of the group why you disagree.
4. Identify words that can be used to describe each category.
5. Work with your group to create a concept map on this topic. Follow these steps:

   a. Write the topic in the center of your paper, and circle it.

   b. Place the words describing each category around the topic. Circle each word.

   c. Draw a line between the topic and each category. On each line, explain the relationship between the topic and the category.

   d. Repeat Steps 5b and 5c as you continue to add all of the words on your list to your concept map.

   e. Add lines to connect other related words. Explain the relationship between the words on the line.
6. View the concept maps of other groups. As you look at their concept maps, observe similarities and differences between their maps and yours. Discuss your observations with your group members.

DEVELOPING COMMUNICATION SKILLS

COMMUNICATION	SENTENCE STARTERS
To better understand	One point that was not clear to me was . . . Are you saying that . . . Can you please clarify . . .
To share an idea	Another idea is to . . . What if we tried . . . I have an idea—we could try . . .
To disagree	I see your point, but what about . . . Another way of looking at it is . . . I'm still not convinced that . . .
To challenge	How did you reach the conclusion that . . . Why do you think that . . . How does it explain . . .
To look for feedback	What would help me improve . . . Does it make sense, what I said about . . .
To provide positive feedback	One strength of your idea is . . . Your idea is good because . . .
To provide constructive feedback	The argument would be stronger if . . . Another way to do it would be . . .
To discuss information presented in text and graphics	I'm not sure I completely understand this, but I think it may mean . . . I know something about this from . . . A question I have about this is . . . If we look at the graphic, it shows . . .

APPENDIX

F Media Literacy

IMAGINE YOURSELF READING a magazine. A feature article summarizes recent studies on the effectiveness of vitamin supplements and concludes that taking vitamin pills and liquids is a waste of money. A few pages later, an advertisement from a vitamin company claims that one of its products will protect you from all sorts of diseases. Such wide differences in claims that you will see in the popular media are common, but how can you tell which one is correct? "Media literacy" is the term that encompasses the skills we need to develop to effectively analyze and evaluate the barrage of information we encounter every day. Media literacy also includes the ability to use various media to create and communicate our own messages.

A strong background in the process of science helps you build two important skills of media literacy: being able to identify valid and adequate evidence behind a claim and evaluating if the claim is a logical conclusion based on the evidence. The skills share much in common with the process of scientific inquiry, in which you learn to seek out information, assess the information, and come to a conclusion based on your findings.

EVALUATING MEDIA MESSAGES

A "media message" is an electronic, digital, print, audible, or artistic visual message created to transmit information. Media messages can include newspaper articles, political advertisements, speeches, artwork, or even billboards. The following are some of the kinds of questions you might ask as you learn to critically analyze and evaluate messages from various kinds of media. On the next page are three examples of media messages, all related to a common theme. Use these three examples to analyze and evaluate the messages.



1. **Who created this message?**
   Is this person an expert in the content of the message? What credentials does this person have that would make them an expert in this topic? Does this person have any conflicts of interest that may make him or her biased in any way? Who sponsored (or paid for) the message? Does the source of funding have any conflicts of interest?

2. **What creative techniques in the message attract a person's attention?**
   Are there any sensational or emotional words, images, or sounds that grab the viewer's attention? Do any of these words, images, or sounds try to stir up emotions and influence the viewer's ideas?

3. **Does the message cite or mention appropriate sources of factual information?**
   Does the author cite first-person sources when reporting facts? Are the author's sources from credible organizations?

4. **Does the presented evidence completely support the claim?**
   Might there be other information that could support or discredit the message? Does the author make logical inferences and conclusions from the evidence presented in the article?

5. **Who is the target audience of this message?**
   How is this message directed at this particular audience?

6. **Is the message promoting certain values, lifestyles, positions, or ideas either directly or indirectly?**
   Are there any positions or ideas that are being promoted that are not explicit in the message?

EVALUATING INTERNET SOURCES

Imagine that you want to search the Internet to find out about the effectiveness of vitamin supplements so that you can come to your own conclusion. When you are searching for information online, a search engine is searching from over one trillion websites. Determining which websites and sources of information are reliable and which are biased is difficult. To make an informed decision about this topic, you will need to identify accurate and unbiased websites. Below is a suggested list of questions that will help you determine if a particular website is an accurate and unbiased source of information.

1. **Are the authors' names, contact information, and credentials clearly labeled on the website?**
   Accurate websites will usually contain information from knowledgeable authors who have their names, credentials, and contact information clearly labeled on the website. Some websites are managed by a collection of people or an organization, and information on the exact author may not be clearly stated. However,

these organizations should state the names, contact information, and credentials somewhere on their website of the people who represent the organization.

2. **Is the information and the website up to date?**
   Some information that you may be seeking needs to be current. For example, if you were looking for the number of cars in the United States, you would want the most recent data. A study conducted in 1982 would not be helpful in this case. When seeking information that needs to be current, determine if the date the article or information was written is clearly indicated on the website so you can be sure you are accessing the most recent information. Credible websites will usually indicate the date the article or information was created or last updated. Also, the person or organization maintaining the website should be regularly updating the website, so that the majority of links to other websites work.

3. **Are sources of information clearly cited?**
   When factual information is stated in a website, is the source clearly cited so you can refer back to it?

4. **Are there links to more resources on this topic?**
   Authoritative websites will often provide links to further information from other sources that support their claim. Authors of websites that contain information that is biased or inaccurate usually do not provide additional information that supports their claims.

5. **What are other people saying about the author or the organization that produced this information?**
   If you come across information from an author or organization that you are unfamiliar with, perform a search for other information about the author or organization. What are experts writing about the author's or organization's other work?

6. **Why is this website on the Internet?**
   Was this information put on the Internet to inform or to persuade people? Is the author selling something? What is the author's motivation for providing this information?

Further Resources

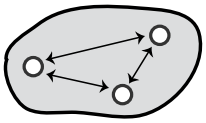
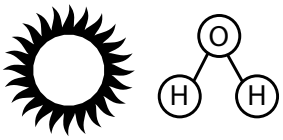
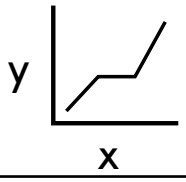
Thier, M., & Daviss, B. (2002). The new science literacy. Portsmouth, NH: Heinemann.

Center for Media Literacy. http://www.medialit.org.

PBS Teachers. Media literacy. http://www.pbs.org/teachers/media_lit.

APPENDIX

G Crosscutting Concepts

PATTERNS 	A pattern is a set of repeating things or events. Scientists observe patterns in their data. Patterns lead to questions about relationships and ideas about what causes these relationships.
CAUSE AND EFFECT 	Events have causes. If "A" causes "B" to happen, they have a cause-and-effect relationship. A major activity of science is to explain how this happens. Sometime the causes are simple and sometimes they are complex. Sometimes both A and B occur, but one does not cause the other.
SCALE, PROPORTION, AND QUANTITY 	Scientific phenomena occur at various scales of size, time, and energy. Phenomena observed at one scale may not be observable at another scale. Scientists use proportional relationships to compare measurements of objects and events. They often use mathematical expressions and equations to represent these relationships.
SYSTEMS AND SYSTEM MODELS 	A system is a group of interacting objects or processes. Describing a system, including its components, interactions and boundaries, and making models of that system helps scientists and engineers understand phenomena and test ideas.
ENERGY AND MATTER 	Tracking changes of energy and matter into, out of, and within systems helps scientists understand the systems' possibilities and limitations. Many cause-and-effect relationships result from changes of energy and matter.
STRUCTURE AND FUNCTION 	The structure (shape, composition, construction) of an object or living thing determines many of its properties and functions (what the structure can do).
STABILITY AND CHANGE 	For natural and built systems alike, conditions are sometimes stable (the same or within a range), and sometimes they change. Scientists study what conditions lead to either stability or change.

Glossary

absorb To take in or soak up. *See* absorption.

absorption The process of absorbing or being absorbed.

advantage A property that in your opinion is favorable.

analysis (of experimental results) Making connections between the results of an experiment and the idea or question being investigated.

aquifer A rock layer that allows groundwater to flow through it and collect.

atmosphere The mixture of gases ("air") that surrounds a planet.

biodiversity The variety of life at every level, from genes to species to ecosystems.

biotic The living components in an ecosystem; the organisms.

byproduct A product that is made as a result of making something else.

Calorie (C) The unit for measuring the energy in food. 1 Calorie = 1,000 calories.

calorie A unit of measurement equivalent to the energy needed to raise the temperature of 1 gram of water 1°C.

carbon dioxide A waste produced from the breakdown of sugars during cellular respiration. Carbon dioxide gas in the atmosphere is essential for photosynthesis.

cause Something that brings about a result or an effect; a reason for an action or condition.

causal relationship A relationship in which a change in one factor causes a change to another factor. The first event is the cause and the result is the effect.

climate The average weather in a place over a fairly long period of time (usually at least 30 years).

climate change The effects that increasing temperatures caused by global warming have on Earth's systems.

consumption The purchase or use of things, including natural resources.

control A standard of comparison for checking or verifying the results of an experiment. The results of the experiment are compared with the control in order to see if the variable changed in the experiment caused any effect.

controlled variable A variable in an investigation or experiment that is held constant.

correlation A measure of how well one set of data relates to another.

cross-section The surface that would be observed after cutting through an object.

data Information gathered from an experiment or observation.

dependent variable The observed phenomenon that is being measured.

deposits Areas containing significant amounts of a resource.

design To develop a plan for a product or structure.

disadvantage A property that in your opinion is not favorable.

drill core A cylindrical piece of rock removed from the earth by a large drill.

ecology The study of the relationships of organisms to one another and to the physical environment.

ecosystem All of the living and nonliving components, and all of the interactions among them.

effect A change that is a result of an action or other cause.

energy The ability to cause objects to change, move, or work.

engineer Someone who uses science and tools to build a product that solves a practical problem.

evidence Information that supports or refutes a claim.

extrapolation Using known data to estimate an answer that lies outside the range of the evidence, such as with a graph. *See also* interpolation.

fluorescence The production of visible light by using higher energy light waves (ultraviolet) to bombard a material. A fluorescent mineral will glow under ultraviolet (UV) light.

fossil Any trace of a living organism (body, part of body, burrow, footprint, etc.) preserved over time.

fossil fuel A fuel produced by living plant materials that have been buried and changed by heat and pressure under layers within the earth over millions of years of time. Natural gas, petroleum, and coal are examples of fossil fuels.

geological processes Processes, such as earthquakes, volcanoes, erosion, and weathering, that form and shape Earth's surface.

geological time scale A chart that divides Earth's history into several different periods of thousands, millions, and billions of years.

geologist A person who studies rocks and other nonliving parts of the earth.

global warming The gradual warming of Earth's average surface temperature. Evidence indicates a relationship between human activity and the current global warming event. *See* greenhouse effect, greenhouse gas.

gram (g) A unit of mass in the metric system; 1 gram is equal to 1,000 milligrams.

greenhouse effect The process by which certain gases in the air absorb and hold thermal energy, making Earth's surface warmer than it would otherwise be. *See* global warming, greenhouse gas.

greenhouse gas A gas that traps thermal energy in the atmosphere. Examples include carbon dioxide, water vapor, and methane. Evidence indicates that human activity has increased the concentration of greenhouse gases in Earth's atmosphere. *See* global warming, greenhouse effect.

groundwater Water found underground in the spaces and cracks within earth materials.

habitat A location in an environment where an organism lives.

hydrologist A scientist who studies the distribution and movement of Earth's water.

hypotheses Plural of hypothesis. *See* hypothesis.

hypothesis A possible explanation for observations, facts, or events that may be tested by further investigation. *See* hypotheses.

independent variable The controlled variable in an experiment.

indicator Any visible sign that shows the condition of the system being studied.

infer To conclude by reasoning from known facts. *See* inference.

inference A conclusion based on observations or what is already known. *See* infer.

interpolation Using known evidence to estimate an answer that falls within the range of the evidence, such as with a graph. *See also* extrapolation.

interpret To explain or give an account of facts with regard to the explainer's conception of what the facts mean.

introduced species A species that exists outside of the species' normal range because of human activity.

mass The amount of matter in an object.

mean A statistical measure of centrality often called the "average." It is calculated by adding up all of the values in a data set and dividing this sum by the total number of values.

median A statistical measure of centrality. It is the middle value after the data set has been listed from smallest to largest OR largest to smallest.

medium The material in which wave energy travels. Mechanical waves, such as sound or seismic waves, move through the ground, water, air, and other materials.

meter (m) A unit of length in the metric system; 1 meter is equal to 100 centimeters or 1,000 millimeters.

metric system The worldwide measuring system used by scientists. Also known as the International System of Units (SI).

mineral A naturally occurring (solid) material that has a specific chemical composition, crystal form, and characteristic physical properties.

mining The process of digging into Earth's surface to remove resources.

mode A statistical measure of centrality. It is the value (or values) that appears most often in a data set.

model Any representation of a system (or its components) used to help one understand and communicate how it works.

natural resources Materials that are found on Earth naturally and used by people.

nonrenewable resource A natural resource that cannot be replaced faster than it is used up by human populations.

observation Any description or measurement gathered by the senses or instruments.

opaque A material that is not able to transmit light.

open pit mining A method of mining where the ground is opened up because the desired resource is close to the surface or is under an unstable layer of earth.

ore Rock that contains economically valuable concentrations of a metal or other minerals.

organism An individual animal, plant, or single-celled life form.

oxygen A gas obtained from the air and used by animals in cellular respiration.

paleontologist A scientists who uses fossil evidence to study life in prehistoric times, including when events occurred in Earth's history.

pattern Something that happens in a repeated and predictable way.

per capita consumption Resource consumption per person. *See* consumption.

permeability The degree to which something can penetrate or go through a material.

plate tectonics The study of Earth's tectonic plates, and their movements: sliding past each other, spreading apart, colliding, or moving below another plate. *See* tectonic plates.

phenomena An observable fact or event.

population A group of organisms of the same species living in the same habitat.

precipitation Any form of water that falls to Earth, including rain, snow, sleet, and hail.

probability The likelihood of an event occurring.

property Particular characteristics of a material such as the material's density, melting point, or color.

range The difference between the lowest and highest values in a data set. For example, the lowest and highest pulse measured in an experiment with exercise. In ecology, the total of all the areas where a species lives.

rate A ratio of two different kinds of measurement.

remote sensing Technology that provides information about an object without directly observing the object.

renewable resource A natural resource that can be replaced or replenished faster than it is used up by human populations.

reproducible Capable of being recreated and repeated.

resistance The trait of not being affected by something.

risk The chance that an action or event could result in something unfavorable happening, such as injury.

rock strata A layer of rock formed on Earth's surface when sediments are deposited.

scale The amount or number of an object or event relative to other objects or events. For example, the geologic time scale is measured on a scale of millions of years, while a human life span is measured on a scale of decades.

scientific method A set of processes used when conducting investigations. These generally involve making observations, collecting and analyzing data, and drawing conclusions, especially when testing scientific hypotheses.

scientific model *See* model.

scientist Someone who pursues understanding of the natural world by using evidence to answer questions.

sedimentary rocks A type of rock made up of sediments that have been cemented together, such as shale, sandstone, and limestone.

sediments Small pieces of earth materials such as rocks, shells, and other debris.

seismic reflection A type of remote sensing used to map underground materials by sending shock waves down into the earth and measuring the timing and shape of the waves reflected back to the surface.

stratigraphic column A diagram representing a series of rock layers made by looking at the sides of cliffs or at drill cores. *See* drill core.

subsidence The compaction of land due to the removal of groundwater from the earth and from aquifers.

technology Any product or process made by engineers and scientists.

tectonic plates Large sections of Earth's surface that are in constant motion. *See* plate tectonics.

tested variable A variable that is changed in a systematic way in an experiment or investigation in order to determine its effect.

trade-off A desirable outcome given up to gain another desirable outcome.

translucent Transmitting light diffusely; semitransparent.

transparent The ability to transmit light clearly so that an object can be distinctly seen through a substance.

ultraviolet Electromagnetic radiation that has a wavelength shorter than visible light but longer than X-rays.

variable A changing factor. In an experiment, the variable is what is studied, such as the effect of amplitude of a wave on the energy it transmits.

volume The amount of space that an object or substance occupies.

wave A disturbance that repeats regularly in space and time and that transmits energy from one place to another with no transfer of matter.

weather The outdoor conditions at a specific time and place. Weather information often includes information related to temperature, precipitation, humidity, and cloud cover.

weathering An earth process that breaks down rocks into smaller pieces. Rocks crack, crumble, and are broken apart by water and wind over time.

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Credits

Abbreviations: t (top), m (middle), b (bottom), l (left), r (right), c (center)

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