Section 1

Rocks and Weathering

Reading Preview

Key Concepts

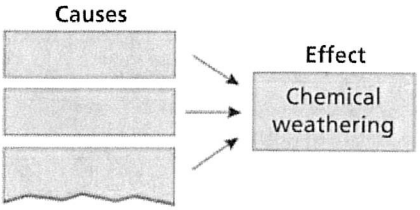
- How do weathering and erosion affect Earth's surface?
- What are the causes of mechanical weathering and chemical weathering?
- What determines how fast weathering occurs?

Key Terms

- weathering
- erosion
- uniformitarianism
- mechanical weathering
- abrasion
- ice wedging
- chemical weathering
- oxidation
- permeable

Target Reading Skill

Relating Cause and Effect A cause makes something happen. An effect is what happens. As you read, identify the causes of chemical weathering. Write them in a graphic organizer like the one below.



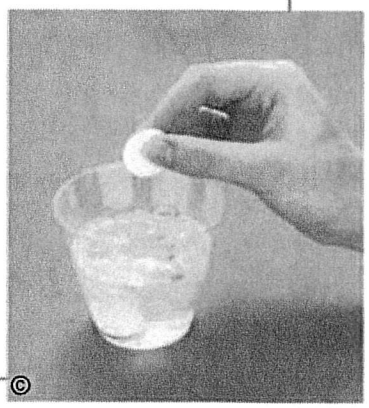
Lab zone Discover Activity

How Fast Can It Fizz?

1. Place a fizzing antacid tablet in a small beaker. Then grind up a second tablet and place it in another beaker. The whole tablet is a model of solid rock. The ground-up tablet is a model of rock fragments.
2. Add 100 mL of warm water to the beaker containing the whole tablet. Then stir with a stirring rod until the tablet dissolves completely. Use a stopwatch to time how long it takes.
3. Add 100 mL of warm water to the beaker containing the ground-up tablet. Then stir until all of the ground-up tablet dissolves. Time how long it takes.

Think It Over

Drawing Conclusions Which dissolved faster, the whole antacid tablet or the ground-up tablet? What variable affected how long it took each of them to dissolve?



Imagine a hike that lasts for months and covers hundreds of kilometers. Each year, many hikers go on such treks. They hike trails that run the length of America's great mountain ranges. For example, the John Muir Trail follows the Sierra Nevada mountains. The Sierras extend about 640 kilometers along the eastern side of California. In the east, the Appalachian Trail follows the Appalachian Mountains. The Appalachians stretch more than 3,000 kilometers from Alabama to Canada.

The two trails cross very different landscapes. The Sierras are rocky and steep, with many peaks rising 3,000 meters above sea level. The Appalachians are more rounded and gently sloping, and are covered with soil and plants. The highest peaks in the Appalachians are less than half the elevation of the highest peaks in the Sierras. Which mountain range do you think is older? The Appalachians formed more than 250 million years ago. The Sierras formed only within the last 10 million years. The forces that wear down rock on Earth's surface have had much longer to grind down the Appalachians.

Weathering and Erosion

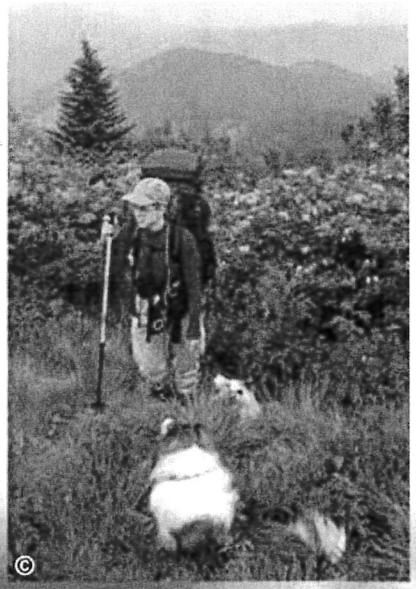
The process of mountain building thrusts rock up to the surface of Earth. There, the rock is exposed to weathering. **Weathering** is the process that breaks down rock and other substances at Earth's surface. Heat, cold, water, and ice all contribute to weathering. So do the oxygen and carbon dioxide in the atmosphere. Repeated freezing and thawing, for example, can crack rock apart into smaller pieces. Rainwater can dissolve minerals that bind rock together. You don't need to go to the mountains to see examples of weathering. The forces that wear down mountains also cause bicycles to rust, paint to peel, sidewalks to crack, and potholes to form.

The forces of weathering break rocks into smaller and smaller pieces. Then the forces of erosion carry the pieces away. **Erosion** (ee ROH zhun) is the removal of rock particles by wind, water, ice, or gravity. **Weathering and erosion work together continuously to wear down and carry away the rocks at Earth's surface.** The weathering and erosion that geologists observe today also shaped Earth's surface millions of years ago. How do geologists know this? Geologists make inferences based on the principle of **uniformitarianism** (yoon uh fawrm uh TAYR ee un iz um). This principle states that the same processes that operate today operated in the past.

There are two kinds of weathering: mechanical weathering and chemical weathering. Both types of weathering act slowly, but over time they break down even the biggest, hardest rocks.

Reading Checkpoint **What is the difference between weathering and erosion?**

FIGURE 1
Effects of Weathering
The jagged peaks of the Sierra Nevadas (bottom) formed within the last 10 million years. The more gently sloping Appalachians (top) have been exposed to weathering for 250 million years.
Inferring *How can you tell that the Sierra Nevadas formed much more recently than the Appalachians?*



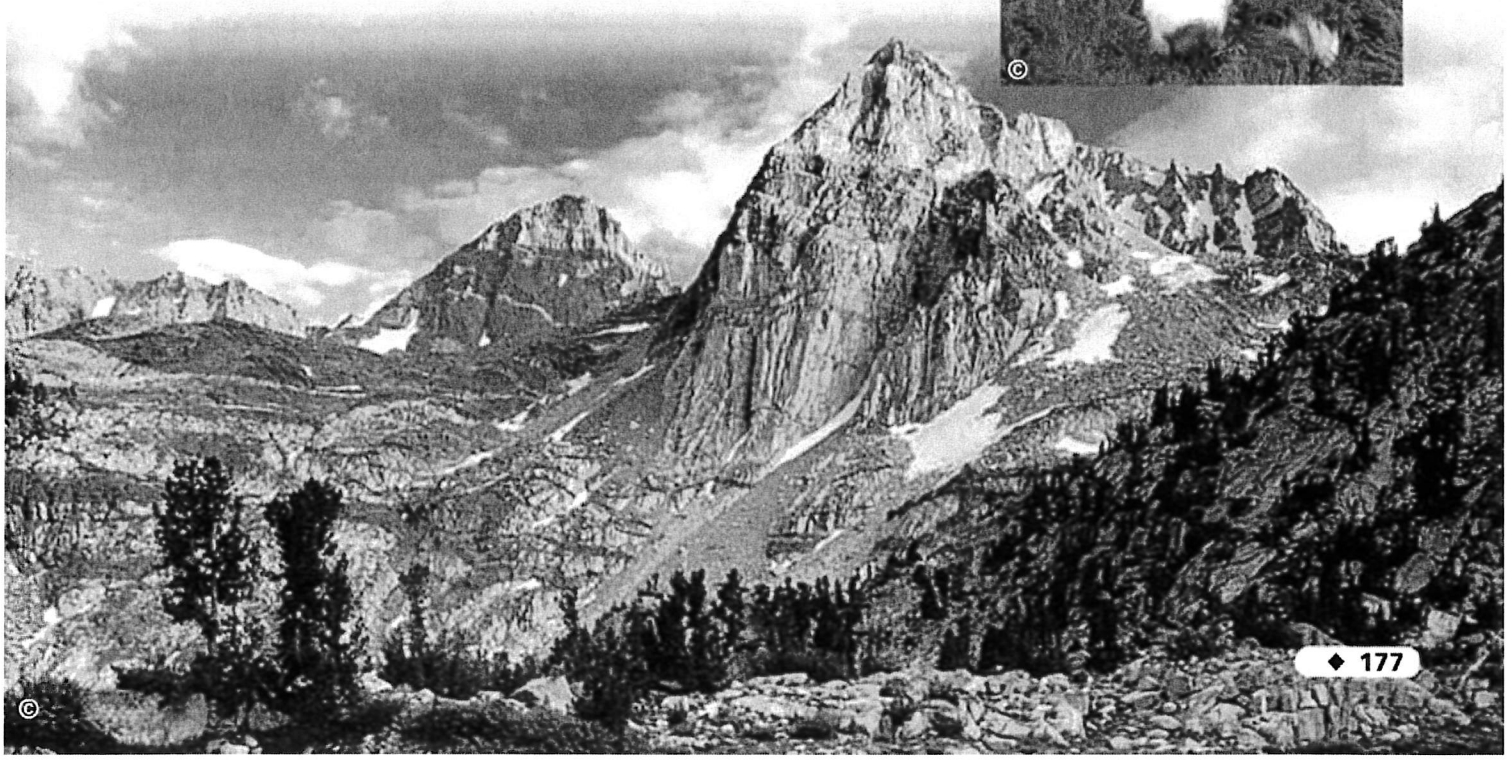
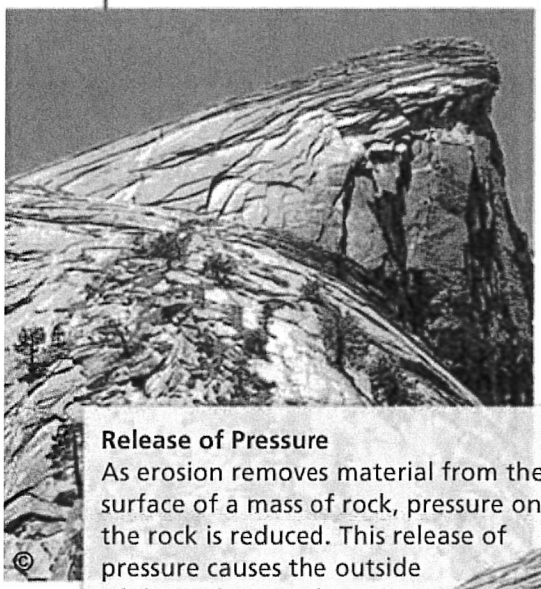


FIGURE 2

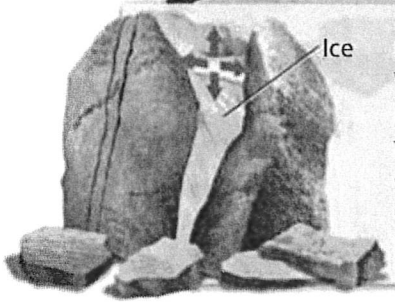
Forces of Mechanical Weathering

Mechanical weathering affects all the rock on Earth's surface.

Forming Operational Definitions *Study the examples of mechanical weathering, and then write a definition of each term in your own words.*



Release of Pressure
As erosion removes material from the surface of a mass of rock, pressure on the rock is reduced. This release of pressure causes the outside of the rock to crack and flake off like the layers of an onion.



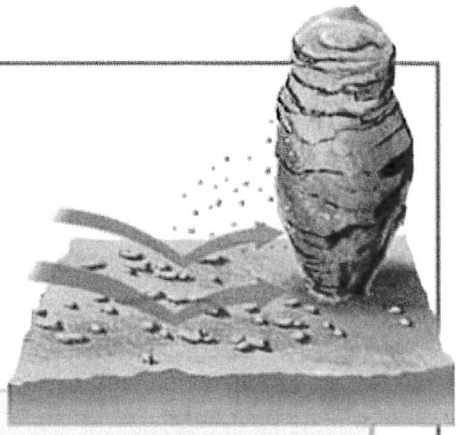
Freezing and Thawing
When water freezes in a crack in a rock, it expands and makes the crack bigger. The process of ice wedging also widens cracks in sidewalks and causes potholes in streets.

Animal Actions
Animals that burrow in the ground—including moles, gophers, prairie dogs, and some insects—loosen and break apart rocks in the soil.

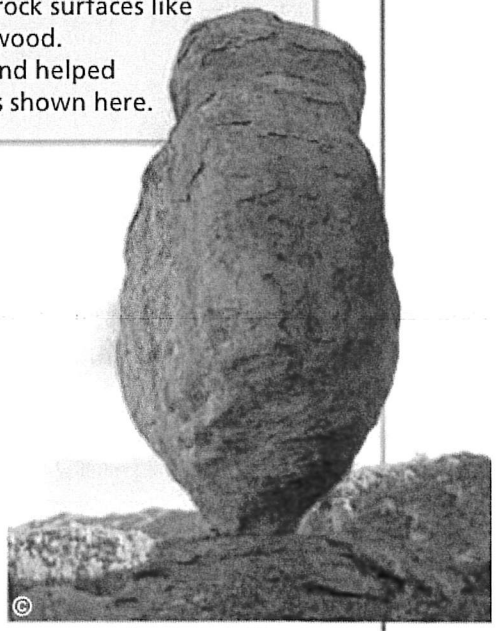
Mechanical Weathering

If you hit a rock with a hammer, the rock may break into pieces. Like a hammer, some forces of weathering break rock into pieces. The type of weathering in which rock is physically broken into smaller pieces is called **mechanical weathering**. These smaller pieces of rock have the same composition as the rock they came from. If you have seen rocks that are cracked or split in layers, then you have seen rocks that are undergoing mechanical weathering. Mechanical weathering works slowly. But over very long periods of time, it does more than wear down rocks. Mechanical weathering eventually wears away whole mountains.

Plant Growth
Roots of trees and other plants enter cracks in rocks. As roots grow, they force the cracks farther apart. Over time, the roots of even small plants can pry apart cracked rocks.



Abrasion
Sand and other rock particles that are carried by wind, water, or ice can wear away exposed rock surfaces like sandpaper on wood. Wind-driven sand helped shape the rocks shown here.



The causes of mechanical weathering include freezing and thawing, release of pressure, plant growth, actions of animals, and abrasion. The term **abrasion** (uh BRAY zhun) refers to the grinding away of rock by rock particles carried by water, ice, wind, or gravity.

In cool climates, the most important force of mechanical weathering is the freezing and thawing of water. Water seeps into cracks in rocks and then freezes when the temperature drops. Water expands when it freezes. Ice therefore acts like a wedge that forces things apart. Wedges of ice in rocks widen and deepen cracks. This process is called **ice wedging**. When the ice melts, the water seeps deeper into the cracks. With repeated freezing and thawing, the cracks slowly expand until pieces of rock break off.

Reading Checkpoint **How does ice wedging weather rock?**

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Chemical Weathering

In addition to mechanical weathering, another type of weathering attacks rock. **Chemical weathering** is the process that breaks down rock through chemical changes. **The causes of chemical weathering include the action of water, oxygen, carbon dioxide, living organisms, and acid rain.**

Each rock is made up of one or more minerals. Chemical weathering can produce new minerals as it breaks down rock. For example, granite is made up of several minerals, including feldspar, quartz, and mica. As a result of chemical weathering, granite eventually changes the feldspar minerals to clay minerals.

Chemical weathering creates holes or soft spots in rock, so the rock breaks apart more easily. Chemical and mechanical weathering often work together. As mechanical weathering breaks rock into pieces, more surface area becomes exposed to chemical weathering. The Discover activity at the beginning of this section shows how increasing the surface area increases the rate of a chemical reaction.

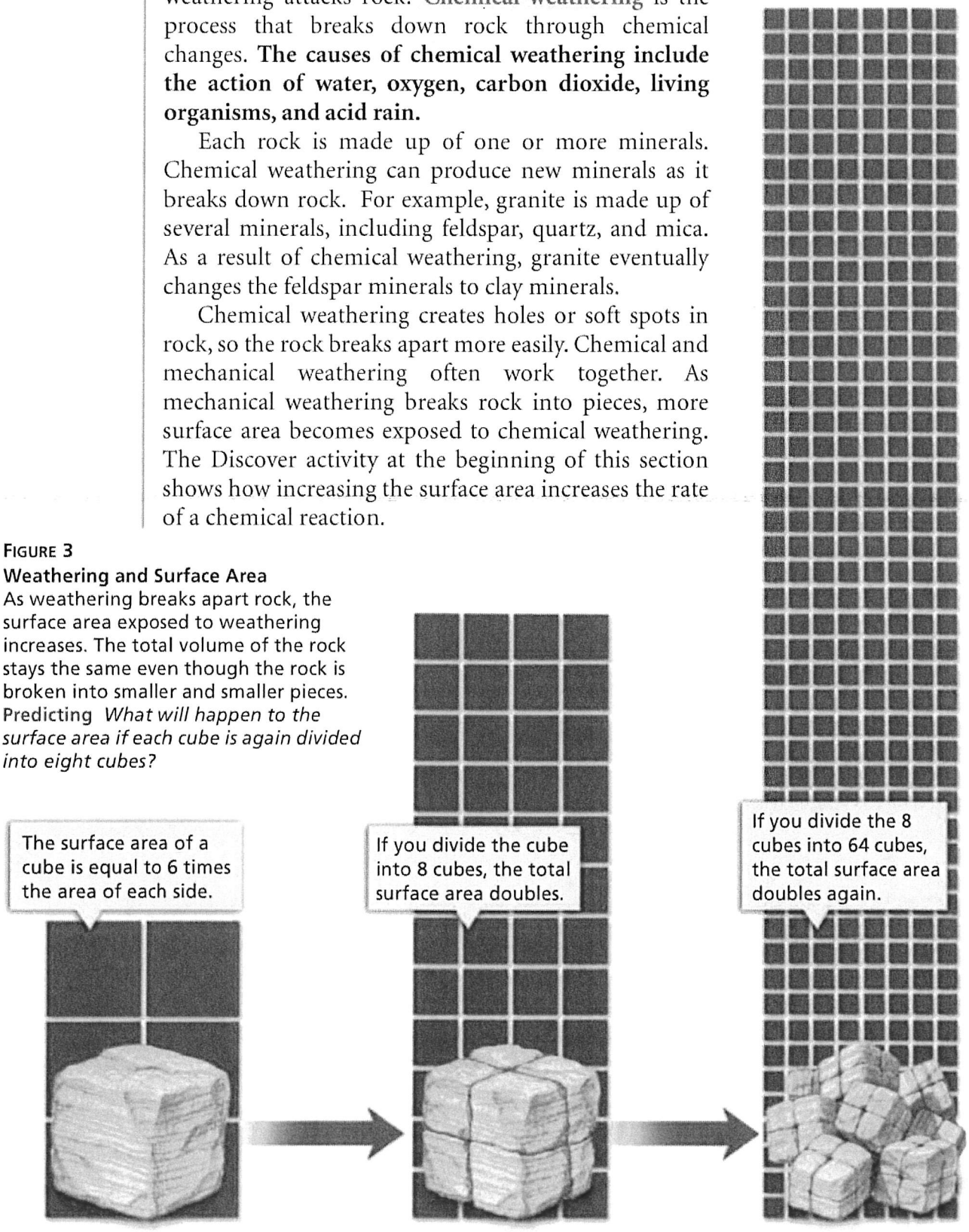


FIGURE 3
Weathering and Surface Area
As weathering breaks apart rock, the surface area exposed to weathering increases. The total volume of the rock stays the same even though the rock is broken into smaller and smaller pieces.
Predicting *What will happen to the surface area if each cube is again divided into eight cubes?*

FIGURE 4
Effects of Chemical Weathering
Acid rain chemically weathered these stone gargoyles on the cathedral of Notre Dame in Paris, France.

Water Water is the most important cause of chemical weathering. Water weathers rock by dissolving it. When a rock or other substance dissolves in water, it mixes uniformly throughout the water to make a solution. Over time, many rocks will dissolve in water.

Oxygen The oxygen gas in air is an important cause of chemical weathering. If you have ever left a bicycle or metal tool outside in the rain, then you have seen how oxygen can weather iron. Iron combines with oxygen in the presence of water in a process called **oxidation.** The product of oxidation is rust. Rock that contains iron also oxidizes, or rusts. Rust makes rock soft and crumbly and gives it a red or brown color.

Carbon Dioxide Another gas found in air, carbon dioxide, also causes chemical weathering. Carbon dioxide dissolves in rainwater and in water that sinks through air pockets in the soil. The result is a weak acid called carbonic acid. Carbonic acid easily weathers rocks such as marble and limestone.

Living Organisms Imagine a seed landing on a rock face. As it sprouts, its roots push into cracks in the rock. As the plant's roots grow, they produce weak acids that slowly dissolve rock around the roots. Lichens—plantlike organisms that grow on rocks—also produce weak acids that chemically weather rock.

Acid Rain Over the past 150 years, people have been burning large amounts of coal, oil, and gas for energy. Burning these fuels can pollute the air with sulfur, carbon, and nitrogen compounds. Such compounds react chemically with the water vapor in clouds, forming acids. These acids mix with raindrops and fall as acid rain. Acid rain causes very rapid chemical weathering.

Reading Checkpoint **How can plants cause chemical weathering?**

Lab zone **Try This Activity**

Rusting Away

Here's how you can observe weathering.

1. Moisten some steel wool and place it in a closed container so it will not dry out.
2. Observe the steel wool after a few days. What has happened to it?
3. Take a new piece of steel wool and squeeze it between your fingers. Remove the steel wool from the container and squeeze it between your fingers. What happens? Wash your hands when you have finished.

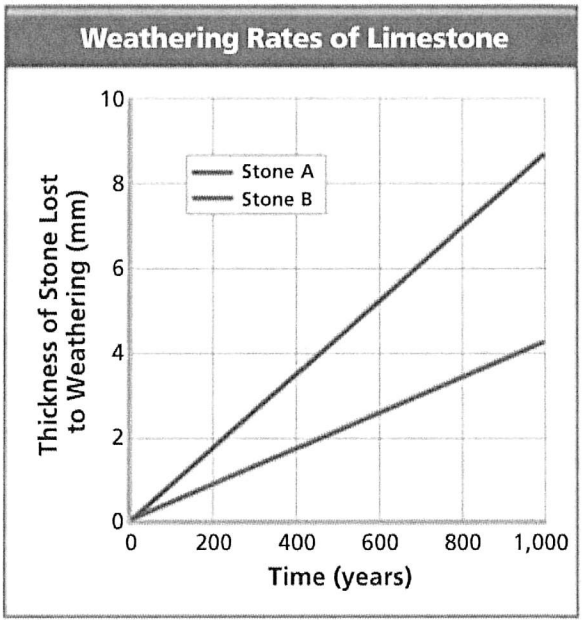
Predicting If you kept the steel wool moist for a longer time, what would eventually happen to it? How is the weathering of steel wool like the weathering of a rock?

Math Analyzing Data

Which Weathered Faster?

The graph shows the rate of weathering for two identical pieces of limestone that weathered in different locations.

1. **Reading Graphs** What does the *x*-axis of the graph represent?
2. **Reading Graphs** What does the *y*-axis of the graph represent?
3. **Reading Graphs** How much thickness did Stone A lose in 1,000 years? How much thickness did Stone B lose in the same period?
4. **Drawing Conclusions** Which stone weathered at a faster rate?
5. **Inferring** Since the two identical pieces of limestone weathered at different rates, what can you infer caused the difference in their rates of weathering?



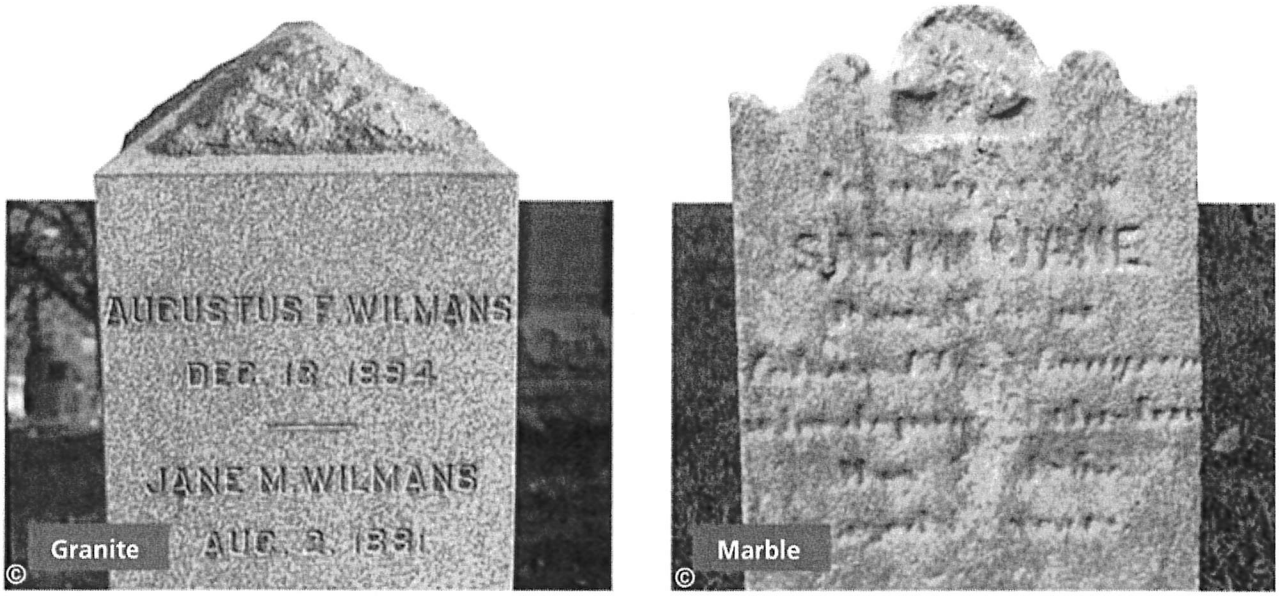
Rate of Weathering

Visitors to New England's historic cemeteries may notice a surprising fact. Slate tombstones carved in the 1700s are less weathered and easier to read than marble gravestones from the 1800s. Why is this so? Some kinds of rocks weather more rapidly than others. **The most important factors that determine the rate at which weathering occurs are the type of rock and the climate.**

Type of Rock The minerals that make up the rock determine how fast it weathers. Rock made of minerals that do not dissolve easily in water weathers slowly. Rock made of minerals that dissolve easily in water weathers faster.

Some rock weathers more easily because it is permeable. **Permeable** (PUR mee uh bul) means that a material is full of tiny, connected air spaces that allow water to seep through it. Permeable rock weathers chemically at a fast rate. Why? As water seeps through the spaces in the rock, it dissolves and removes material broken down by weathering.

Climate Climate refers to the average weather conditions in an area. Both chemical and mechanical weathering occur faster in wet climates. Rainfall provides the water needed for chemical changes as well as for freezing and thawing.



Chemical reactions occur faster at higher temperatures. That is why chemical weathering occurs more quickly where the climate is both hot and wet. Granite, for example, is a very hard rock that forms when molten material cools inside Earth. Granite weathers so slowly in cool climates that it is often used as a building stone. But in hot and wet climates, granite weathers more rapidly and eventually crumbles apart.

Reading Checkpoint **How does rainfall affect the rate of weathering?**

FIGURE 5
Which Rock Weathers Faster? These two tombstones are about the same age and are in the same cemetery, yet one has weathered much less than the other.
Inferring *Which type of stone weathers faster, granite or marble? Explain.*

Section 1 Assessment

Vocabulary Skill Suffixes Complete the sentence with the correct words (*wedges/ice wedging*). _____ of ice in rocks widen and deepen cracks in the process of _____.

Reviewing Key Concepts

HINT 1. a. Defining What is weathering?
HINT b. Defining What is erosion?
HINT c. Predicting Over millions of years, how do weathering and erosion change a mountain made of solid rock?
HINT 2. a. Defining What is chemical weathering?
HINT b. Comparing and Contrasting Compare and contrast mechanical weathering and chemical weathering.
HINT c. Classifying Classify each as chemical or mechanical weathering: freezing or thawing, oxidation, water dissolving chemicals in rock, abrasion, acid rain.
HINT 3. a. Identifying What are two factors that affect the rate of weathering?
HINT b. Relating Cause and Effect A granite monument is placed outside for 200 years in a region with a cool, dry climate. What would its rate of weathering be? Explain.

Lab zone At-Home Activity

Ice in a Straw Demonstrate one type of weathering for your family. Plug one end of a drinking straw with a small piece of clay. Fill the straw with water. Now plug the top of the straw with clay. Make sure that the clay plugs do not leak. Lay the straw flat in the freezer overnight. Remove the straw the next day. What happened to the clay plugs? What process produced this result? Be sure to dispose of the straw so that no one will use it for drinking.

Rock Shake

Problem

How will shaking and acid conditions affect the rate at which limestone weathers?

Skills Focus

interpreting data, calculating, drawing conclusions

Materials

- 300 mL of water
- balance
- paper towels
- masking tape
- 2 pieces of thin cloth
- marking pen or pencil
- 300 mL of vinegar, an acid
- plastic graduated cylinder, 250 mL
- 80 small pieces of water-soaked limestone
- 4 watertight plastic containers with screw-on caps, 500 mL

Procedure

PART 1 Day 1

1. Using masking tape, label the four 500-mL containers A, B, C, and D.
2. Separate the 80 pieces of limestone into four sets of 20.
3. Copy the data table in your notebook. Then place the first 20 pieces of limestone on the balance and record their mass in the data table. Place the rocks in container A.
4. Repeat Step 3 for the other sets of rocks and place them in containers B, C, and D.
5. Pour 150 mL of water into container A and container B. Put caps on both containers.
6. Pour 150 mL of vinegar into container C and container D. Put caps on both containers.
7. Predict the effect of weathering on the mass of the limestone pieces. Which will weather more: the limestone in water or the limestone in vinegar? (*Hint:* Vinegar is an acid.) Also predict the effect of shaking on the limestone in containers B and D. Record your predictions in your notebook.
8. Allow the pieces to soak overnight.

Data Table

Container	Total Mass at Start	Total Mass Next Day	Change in Mass	Percent Change in Mass
A (water, no shaking)				
B (water, shaking)				
C (vinegar, no shaking)				
D (vinegar, shaking)				

PART 2 Day 2

9. Screw the caps tightly on containers B and D. Shake both containers for 10 to 15 minutes. Make sure that each container is shaken for exactly the same amount of time and at the same intensity. After shaking, set the containers aside. Do not shake containers A and C.
10. Open the top of container A. Place one piece of thin cloth over the opening of the container. Carefully pour all of the water out through the cloth into a waste container. Be careful not to let any of the pieces flow out with the water. Dry these pieces carefully and record their mass in your data table.
11. Next, determine how much limestone was lost through weathering in container A. (*Hint*: Subtract the mass of the limestone pieces remaining on Day 2 from the mass of the pieces on Day 1.)
12. Repeat Steps 10 and 11 for containers B, C, and D.

Analyze and Conclude

1. Calculating Calculate the percent change in mass of the 20 pieces for each container.

$$\% \text{ change} = \frac{\text{Change in mass} \times 100}{\text{Total mass at start}}$$

Record the results in the data table.

2. Interpreting Data Do your data show a change in mass of the 20 pieces in each of the four containers?
3. Interpreting Data Is there a greater change in total mass for the pieces in one container than for the pieces in another? Explain.
4. Drawing Conclusions How correct were your predictions of how shaking and acid would affect the weathering of limestone? Explain.
5. Developing Hypotheses If your data showed a greater change in the mass of the pieces in one of the containers, how might this change be explained?
6. Drawing Conclusions Based on your data, which variable do you think was more responsible for breaking down the limestone: the vinegar or the shaking? Explain.
7. Communicating Write a paragraph that explains why you allowed two of the containers to stand without shaking, and why you were careful to shake the other two containers for the same amount of time.

Design an Experiment

Would your results for this experiment change if you changed the variables? For example, you could soak or shake the pieces for a longer time, or test rocks other than limestone. You could also test whether adding more limestone pieces (30 rather than 20 in each set) would make a difference in the outcome. Design an experiment on the rate of weathering to test the effects of changing one of these variables. *Have your teacher approve your plan before you begin.*

Section 2

How Soil Forms

Reading Preview

Key Concepts

- What is soil made of and how does it form?
- How do scientists classify soils?
- What is the role of plants and animals in soil formation?

Key Terms

- soil
- bedrock
- humus
- fertility
- loam
- soil horizon
- topsoil
- subsoil
- litter
- decomposer

Target Reading Skill

Building Vocabulary A definition states the meaning of a word or phrase by telling about its most important feature or function. Carefully read the definition of each key term and also read the neighboring sentences. Then write a definition of each key term in your own words.

Lab zone **Discover Activity**

What Is Soil?

1. Use a toothpick to separate a sample of soil into individual particles. With a hand lens, try to identify the different types of particles in the sample. Wash your hands when you are finished.
2. Write a "recipe" for the sample of soil, naming each of the "ingredients" that you think the soil contains. Include what percentage of each ingredient would be needed to make up the soil.
3. Compare your recipe with those of your classmates.

Think It Over

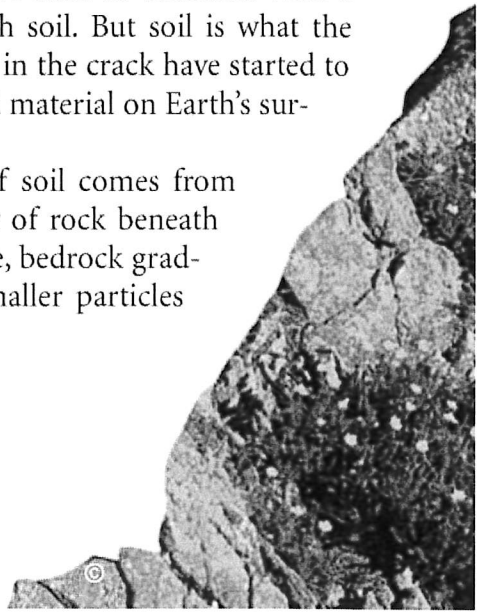
Forming Operational Definitions Based on your observations, how would you define *soil*?

A bare rock surface does not look like a spot where a plant could grow. But look more closely. In that hard surface is a small crack. Over many years, mechanical and chemical weathering will slowly enlarge the crack. Rain and wind will bring bits of weathered rock, dust, and dry leaves. The wind also may carry tiny seeds. With enough moisture, a seed will sprout and take root. Then, a few months later, the plant blossoms.

What Is Soil?

The crack in the rock seems to have little in common with a flower garden containing thick, rich soil. But soil is what the weathered rock and other materials in the crack have started to become. **Soil** is the loose, weathered material on Earth's surface in which plants can grow.

One of the main ingredients of soil comes from bedrock. **Bedrock** is the solid layer of rock beneath the soil. Once exposed at the surface, bedrock gradually weathers into smaller and smaller particles that are the basic material of soil.



Soil Composition Soil is more than just particles of weathered bedrock. **Soil is a mixture of rock particles, minerals, decayed organic material, water, and air.** Together, sand, silt, and clay make up the portion of soil that comes from weathered rock.

The decayed organic material in soil is called humus. **Humus** (HYOO mus) is a dark-colored substance that forms as plant and animal remains decay. Humus helps create spaces in soil for the air and water that plants must have. Humus also contains substances called nutrients, including nitrogen, sulfur, phosphorus, and potassium. Plants need nutrients in order to grow. As plants grow, they absorb nutrients from the soil.

Fertile soil is rich in the nutrients that plants need to grow. The **fertility** of soil is a measure of how well the soil supports plant growth. Soil that is rich in humus has high fertility. Sandy soil containing little humus has low fertility.

Soil Texture Sand feels coarse and grainy, but clay feels smooth and silky. These differences are differences in texture. Soil texture depends on the size of individual soil particles.

The particles of rock in soil are classified by size. As you can see in Figure 7, the largest soil particles are gravel. The smallest soil particles are clay. Clay particles are smaller than the period at the end of this sentence.

Soil texture is important for plant growth. Soil that is mostly clay has a dense, heavy texture. Some clay soils hold a lot of water, so plants grown in them may "drown" for lack of air. In contrast, sandy soil has a coarse texture. Water quickly drains through it, so plants may die for lack of water.

Soil that is made up of about equal parts of clay, sand, and silt is called **loam.** It has a crumbly texture that holds both air and water. Loam is best for growing most types of plants.

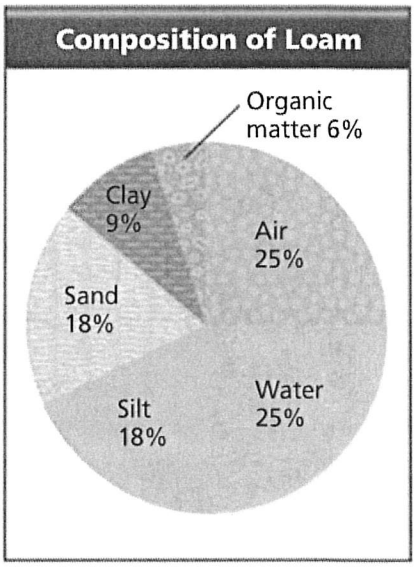
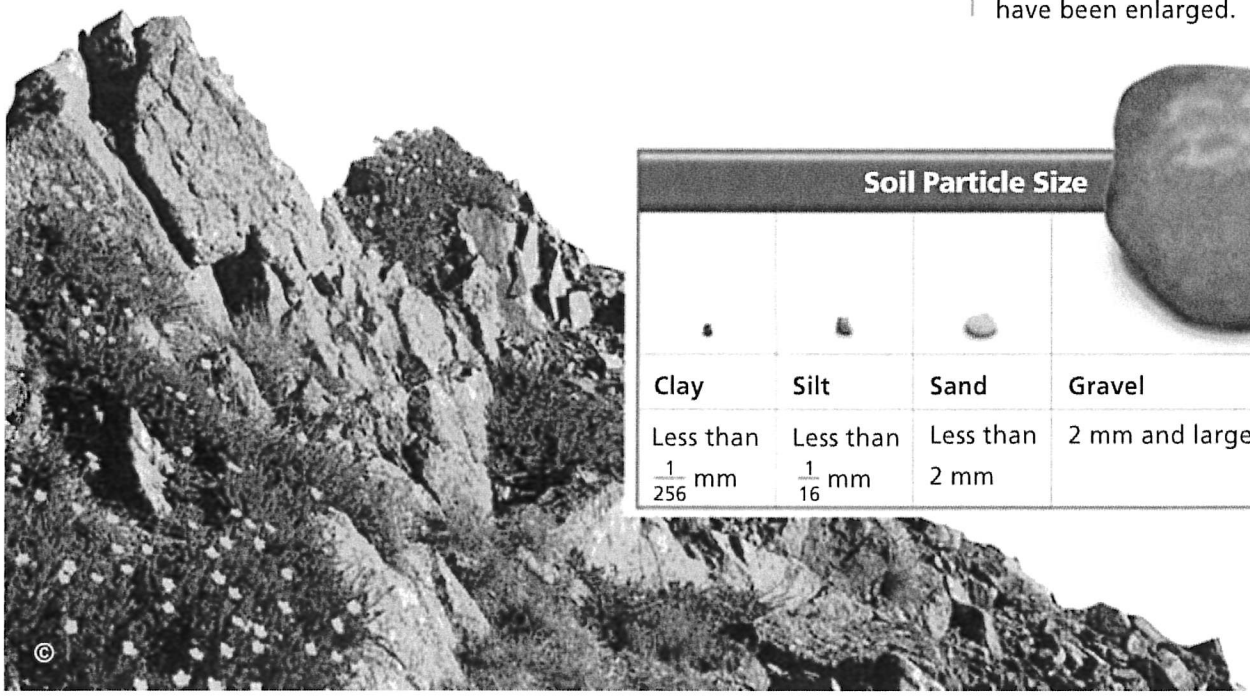


FIGURE 6
Loam, a type of soil, is made up of air, water, and organic matter as well as materials from weathered rock. Interpreting Graphs *What two materials make up the major portion of this soil?*

FIGURE 7
Soil particles range in size from gravel to clay particles too small to be seen by the unaided eye. The sand, silt, and clay shown here have been enlarged.



Soil Particle Size

Clay	Silt	Sand	Gravel
Less than $\frac{1}{256}$ mm	Less than $\frac{1}{16}$ mm	Less than 2 mm	2 mm and larger

The Process of Soil Formation

Soil forms as rock is broken down by weathering and mixes with other materials on the surface. Soil is constantly being formed wherever bedrock is exposed. Soil formation continues over a long period of time.

Gradually, soil develops layers called horizons. A **soil horizon** is a layer of soil that differs in color and texture from the layers above or below it.

If you dug a hole in the ground about half a meter deep, you would see the different soil horizons. Figure 8 shows how soil scientists classify the soil into three horizons. The A horizon is made up of **topsoil,** a crumbly, dark brown soil that is a mixture of humus, clay, and other minerals. The B horizon, often called **subsoil,** usually consists of clay and other particles washed down from the A horizon, but little humus. The C horizon contains only partly weathered rock.

The rate at which soil forms depends on the climate and type of rock. Remember that weathering occurs most rapidly in areas with a warm, rainy climate. As a result, soil develops more quickly in these areas. In contrast, weathering and soil formation take place slowly in areas where the climate is cold and dry.

Some types of rock weather and form soil faster than others. For example, limestone, a type of rock formed from the shells and skeletons of once-living things, weathers faster than granite. Thus, soil forms more quickly from limestone than from granite.

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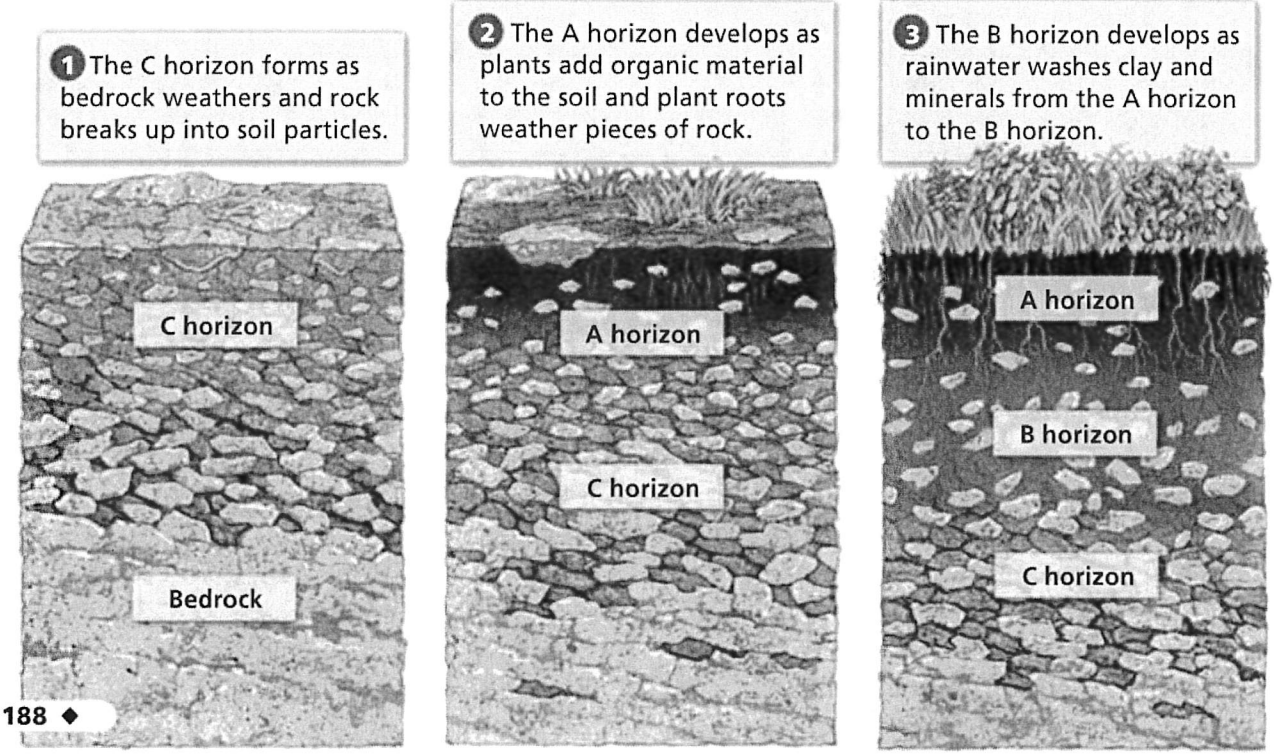


FIGURE 8
Soil Layers
Soil horizons form in three steps.
Inferring *Which soil horizon is responsible for soil's fertility? Explain.*

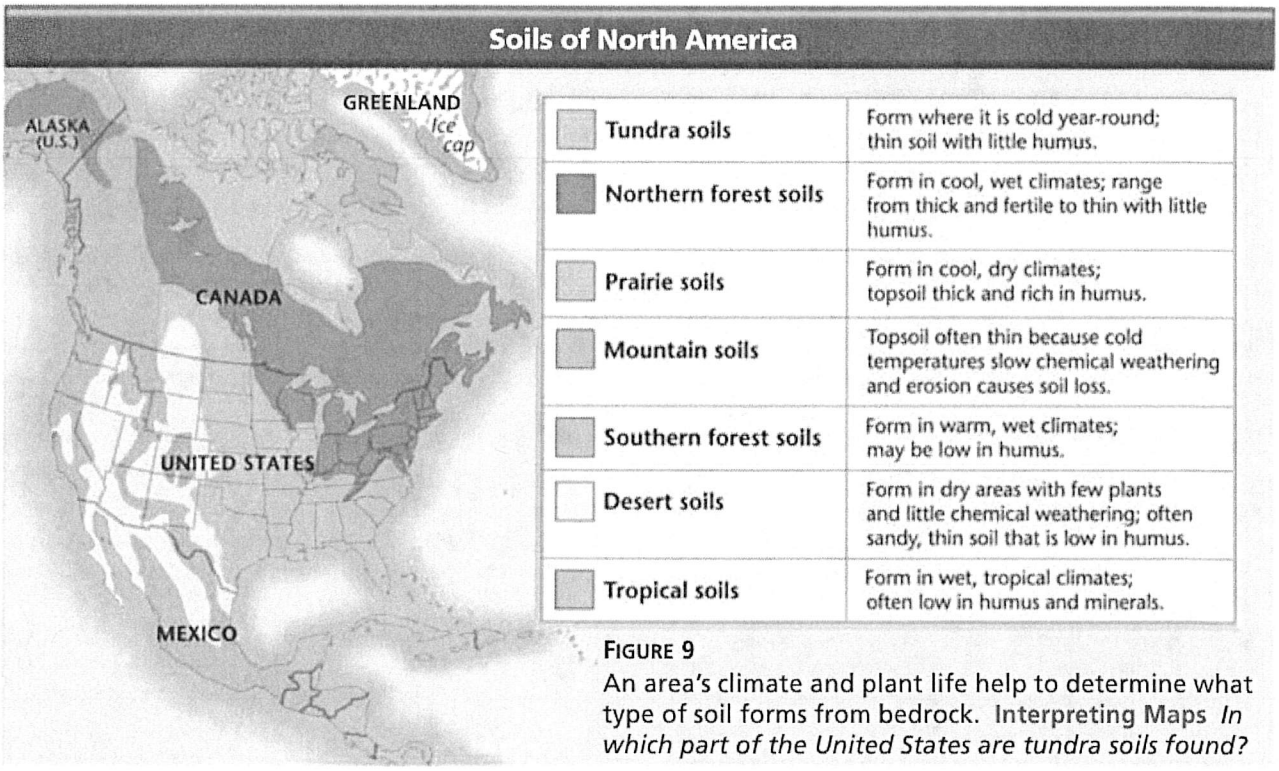


FIGURE 9
An area's climate and plant life help to determine what type of soil forms from bedrock. **Interpreting Maps** *In which part of the United States are tundra soils found?*

Soil Types

If you were traveling across the hills of north-central Georgia, you would see soils that seem to be made of red clay. In other parts of the country, soils can be black, brown, yellow, or gray. In the United States alone, there are thousands of different types of soil.

Scientists classify the different types of soil into major groups based on climate, plants, and soil composition. Fertile soil can form in regions with hot, wet climates, but rain may wash humus and minerals out of the A horizon. In mountains and polar regions with cold, dry climates, the soil is often very thin. The thickest, most fertile soil forms in climate regions with moderate temperatures and rainfall.

The most common plants found in a region are also used to help classify the soil. For example, grassland soils are very different from forest soils. In addition, scientists classify soil by its composition—whether it is rocky, sandy, or rich in clay. Other factors in the classification of soil include the type of bedrock and the amount of time the soil has been developing.

Major soil types found in North America include forest, prairie, desert, mountain, tundra, and tropical soils. Look at Figure 9 to see where each of the major soil types is found.

Reading Checkpoint **What major soil types are found in North America?**

Lab zone **Try This Activity**

A Square Meter of Soil

1. Outdoors, measure an area of one square meter. Mark your square with string.
2. Observe the color and texture of the soil at the surface and a few centimeters below the surface. Is it dry or moist? Does it contain sand, clay, or gravel? Are there plants, animals, or humus?
3. When you finish, leave the soil as you found it. Wash your hands.

Drawing Conclusions What can you conclude about the soil's fertility? Explain.

Living Organisms in Soil

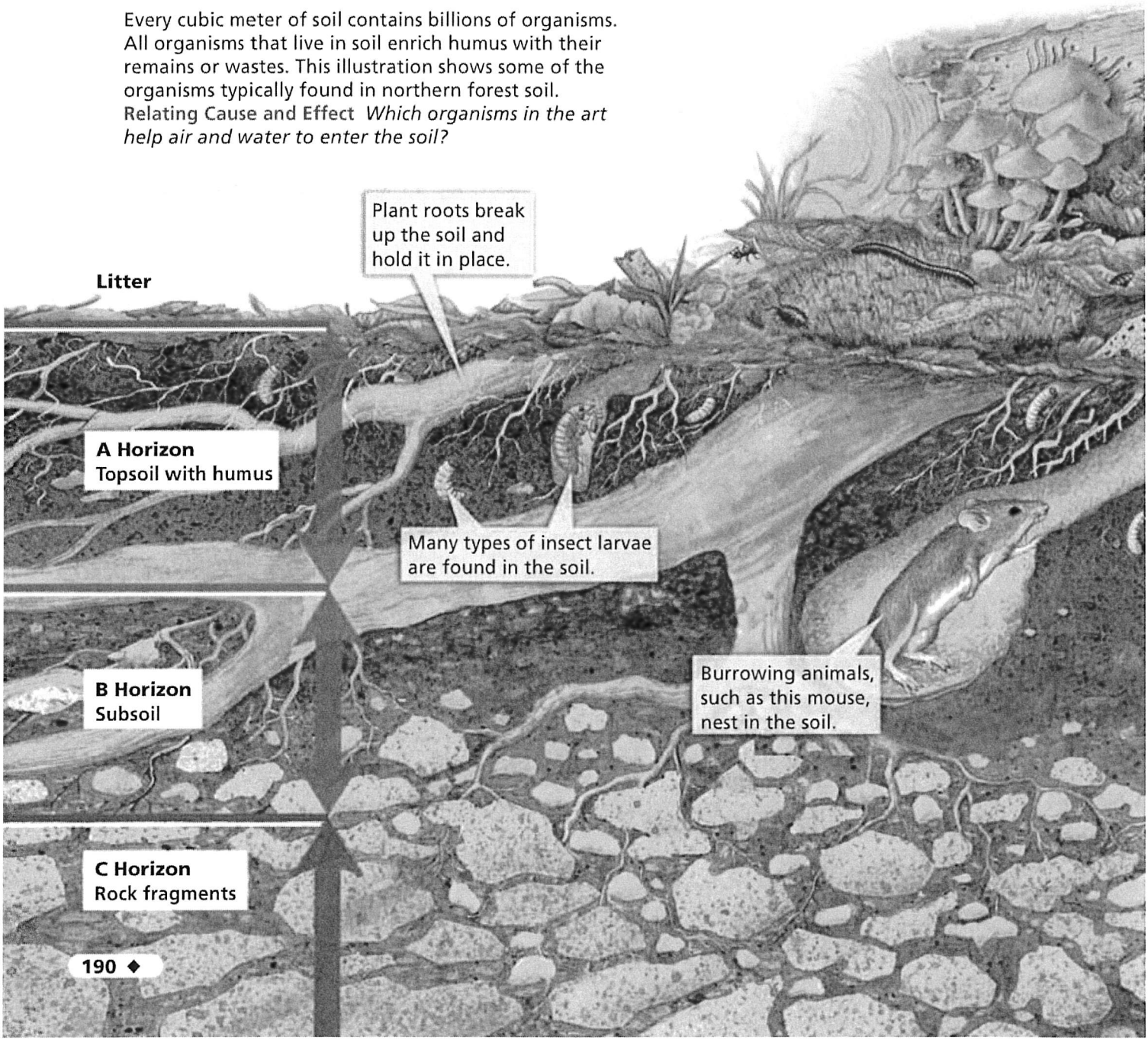
If you look closely at soil, you can see that it is teeming with living things. **Some soil organisms make humus, the material that makes soil fertile. Other soil organisms mix the soil and make spaces in it for air and water.**

Forming Humus Plants contribute most of the organic remains that form humus. As plants shed leaves, they form a loose layer called **litter.** When plants die, their remains fall to the ground and become part of the litter. Plant roots also die and begin to decay underground. Although plant remains are full of stored nutrients, they are not yet humus.

FIGURE 10

Life in Soil

Every cubic meter of soil contains billions of organisms. All organisms that live in soil enrich humus with their remains or wastes. This illustration shows some of the organisms typically found in northern forest soil.
Relating Cause and Effect *Which organisms in the art help air and water to enter the soil?*



Humus forms in a process called decomposition. During decomposition, organisms that live in soil turn dead organic material into humus. These organisms are called decomposers. **Decomposers** are the organisms that break the remains of dead organisms into smaller pieces and digest them with chemicals.

Soil decomposers include fungi, bacteria, worms, and other organisms. Fungi are organisms such as molds and mushrooms. Fungi grow on, and digest, plant remains. Bacteria are microscopic decomposers that cause decay. Bacteria attack dead organisms and their wastes in soil. Very small animals, such as mites and worms, also decompose dead organic material and mix it with the soil.

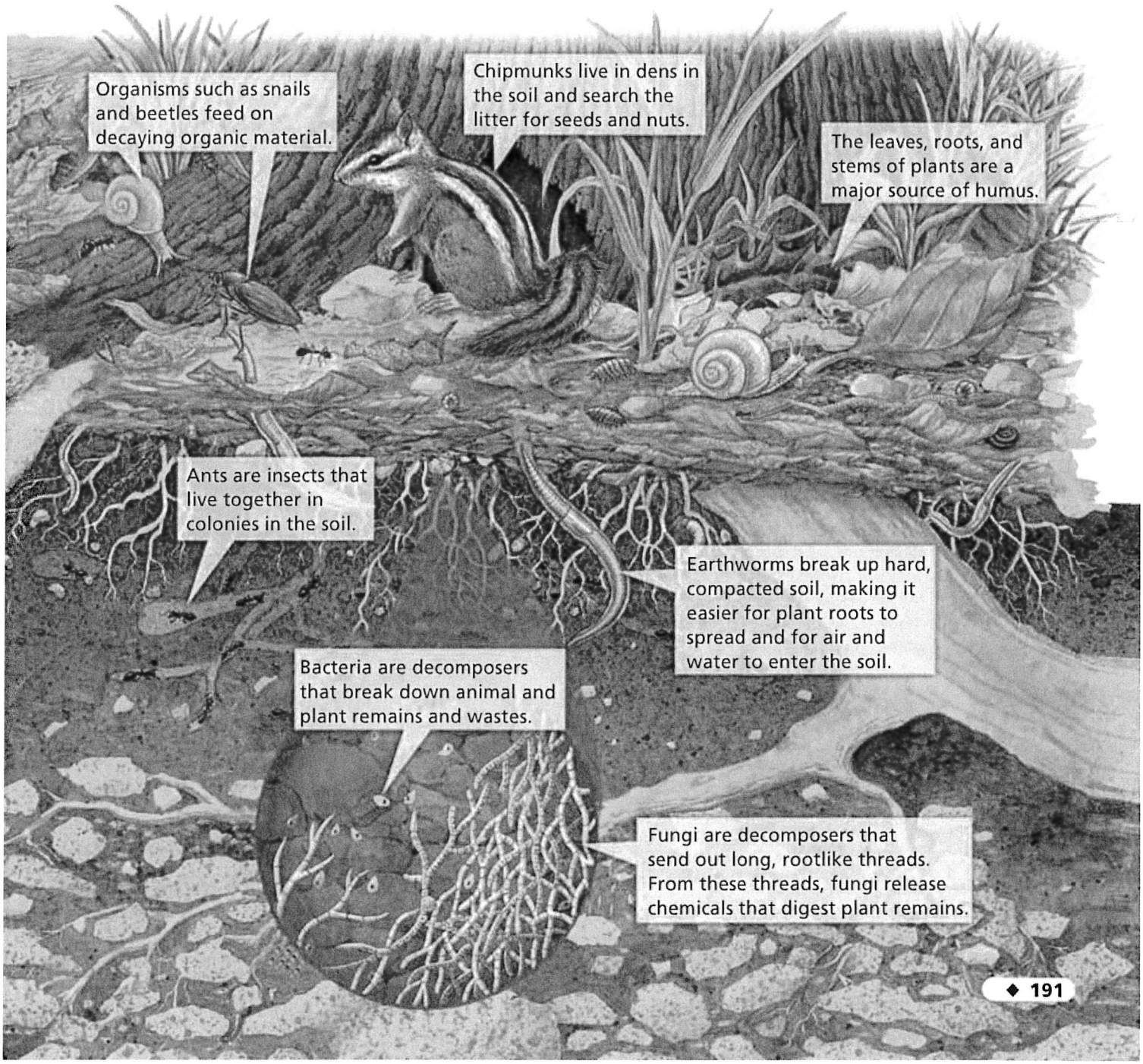


FIGURE 11
Soil Mixers
Earthworms break up the soil, allowing in air and water. An earthworm eats its own weight in soil every day. Predicting *How fertile is soil that contains many earthworms likely to be? Explain.*

Mixing the Soil Earthworms do most of the work of mixing humus with other materials in soil. As earthworms eat their way through the soil, they carry humus down to the subsoil and subsoil up to the surface. Earthworms also pass out the soil they eat as waste. The waste soil is enriched with substances that plants need to grow, such as nitrogen.

Many burrowing mammals such as mice, moles, prairie dogs, and gophers break up hard, compacted soil and mix humus through it. These animals also add nitrogen to the soil when they produce waste. They add organic material when they die and decay.

Earthworms and burrowing animals also help to aerate, or mix air into, the soil. Plant roots need the oxygen that this process adds to the soil.

Reading Checkpoint **Which animals are most important in mixing humus into the soil?**

Section 2 Assessment

Target Reading Skill

Building Vocabulary Use your definitions to help you answer the questions below.

Reviewing Key Concepts

HINT 1. a. Describing What five materials make up soil?

HINT b. Explaining How do soil horizons form?

HINT c. Sequencing Place these terms in the correct order starting from the surface: C horizon, subsoil, bedrock, topsoil.

HINT 2. a. Reviewing What are three main factors used to classify soils?

HINT b. Interpreting Maps Soil forms more rapidly in warm, wet areas than in cold, dry areas. Study the map in Figure 9. Which soil type on the map would you expect to form most slowly? Explain.

HINT 3. a. Identifying What are two main ways in which soil organisms contribute to soil formation?

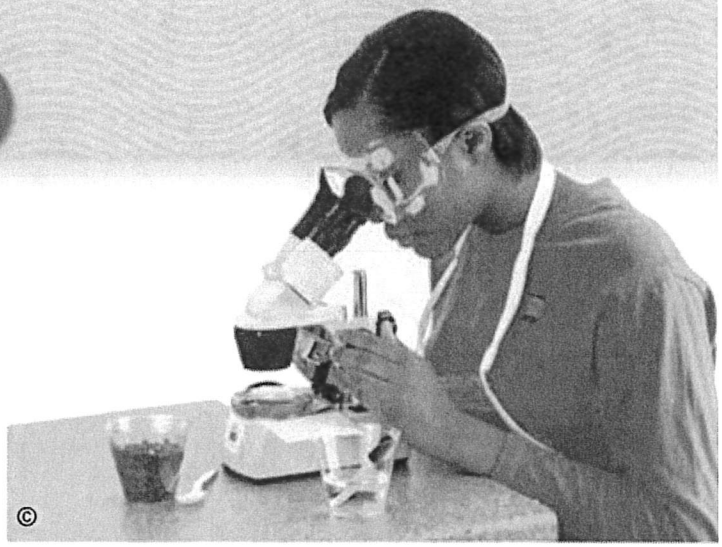
HINT b. Describing Give examples of three types of decomposers and describe their effects on soil.

HINT c. Predicting What would happen to the fertility of a soil if all decomposers were removed? Explain.

Writing in Science

Product Label Write a product label for a bag of topsoil. Your label should give the soil a name that will make consumers want to buy it, state how and where the soil formed, give its composition, and suggest how it can be used.

Lab zone **Consumer Lab**



Comparing Soils

Problem

What are the characteristics of two samples of soil?

Skills Focus

observing, inferring, developing hypotheses

Materials

- 20–30 grams of local soil
- 20–30 grams of bagged topsoil
- plastic spoon • plastic dropper • toothpick
- water • stereomicroscope
- plastic petri dish or jar lid
- graph paper ruled with 1- or 2-mm spacing

Procedure

1. Obtain a sample of local soil. As you observe the sample, record your observations in your lab notebook.
2. Spread half of the sample on the graph paper. Spread the soil thinly so that you can see the lines on the paper through the soil. Using the graph paper as a background, estimate the sizes of the particles that make up the soil.
3. Place the rest of the sample in the palm of your hand, rub it between your fingers, and squeeze it. Is it soft or gritty? Does it clump together or crumble when you squeeze it?
4. Place about half the sample in a plastic petri dish. Using the dropper, add water one drop at a time. Watch how the sample changes. Does any material in the sample float? As the sample gets wet, do you notice any odor? (*Hint:* If the wet soil has an odor or contains material that floats, it is likely to contain organic material.)
5. Look at some of the soil under the stereomicroscope. (*Hint:* Use the toothpick to separate the particles in the soil.) Sketch what you see. Label the particles, such as gravel, organic matter, or strangely shaped grains.
6. Repeat Steps 1–5 with the topsoil. Be sure to record your observations.
7. Clean up and dispose of your samples as directed by your teacher. **CAUTION:** *Wash your hands when you finish handling soil.*

Analyze and Conclude

1. **Observing** Did you observe any similarities between the local soil sample and the topsoil? Any differences?
2. **Inferring** What can you infer about the composition of both types of soil from the different sizes of their particles? From your observations of texture? From how the samples changed when water was added?
3. **Inferring** Do you think that both types of soil were formed in the same way? Explain.
4. **Developing Hypotheses** Based on your observations and study of the chapter, develop a hypothesis about which soil would be better for growing flowers and vegetables.
5. **Communicating** Write a report for consumers that summarizes your analysis of the two soil samples. Be sure to describe what factors you analyzed and give a suggestion for which soil consumers should use for growing flowers and vegetables.

Design an Experiment

In Question 4 you developed a hypothesis about which soil would be better for growing flowers and vegetables. Design an experiment that would test this hypothesis. Be sure to indicate how you would control variables. *After you receive your teacher's approval, carry out your experiment.*

Soil Conservation

Reading Preview

Key Concepts

- Why is soil a valuable resource?
- How can soil lose its value?
- What are some ways that soil can be conserved?

Key Terms

- sod
- natural resource
- Dust Bowl
- soil conservation
- contour plowing
- conservation plowing
- crop rotation

Target Reading Skill

Previewing Visuals Before you read, preview Figure 13, The Dust Bowl. Then write two questions that you have about the photo and map in a graphic organizer like the one below. As you read, answer your questions.

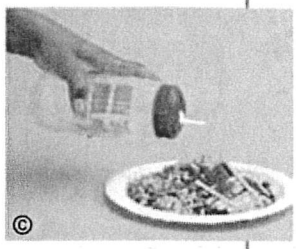
The Dust Bowl

Q. Where was the Dust Bowl?
A.
Q.

Lab zone Discover Activity

How Can You Keep Soil From Washing Away?

1. Pour about 500 mL of soil into a pie plate, forming a pile.
2. Devise a way to keep the soil from washing away when water is poured over it. To protect the pile of soil, you may use craft sticks, paper clips, pebbles, modeling clay, strips of paper, or other materials approved by your teacher.
3. After arranging your materials to protect the soil, hold a container filled with 200 mL of water about 20 cm above the center of the soil. Slowly pour the water in a stream onto the pile of soil.
4. Compare your pan of soil with those of your classmates.



Think It Over

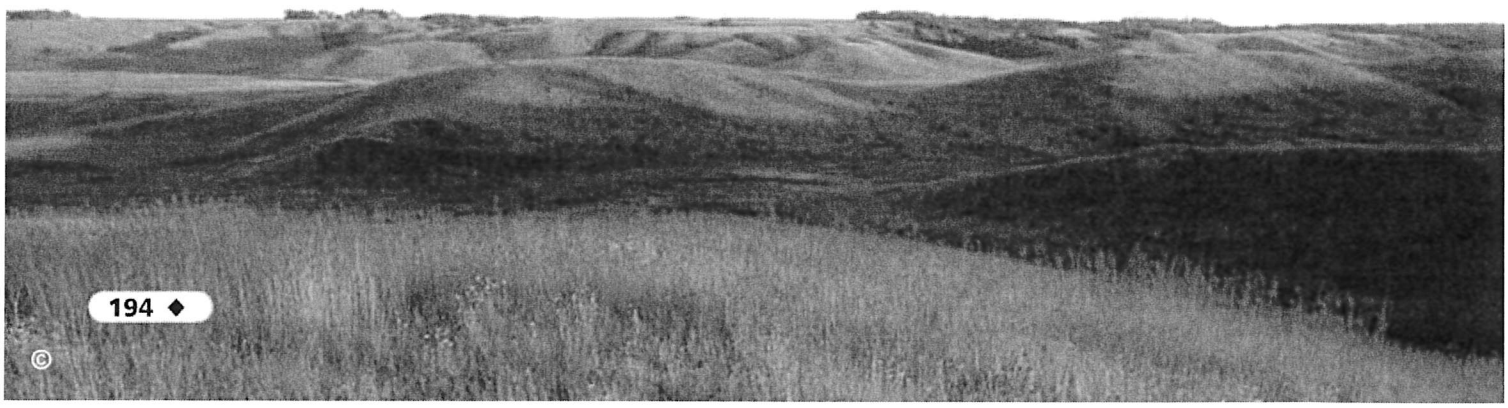
Observing Based on your observations, what do you think is the best way to prevent soil on a slope from washing away?

Suppose you were a settler traveling west in the mid 1800s. Much of your journey would have been through vast, open grasslands called prairies. After the forests and mountains of the East, the prairies were an amazing sight. Grass taller than a person rippled and flowed in the wind like a sea of green.

The prairie soil was very fertile. It was rich with humus because of the tall grass. The **sod**—the thick mass of tough roots at the surface of the soil—kept the soil in place and held onto moisture.

The prairies covered a vast area. They included Iowa and Illinois, as well as the eastern parts of Kansas, Nebraska, and North and South Dakota. Today, farms growing crops such as corn, soybeans, and wheat have replaced the prairies. But prairie soils are still among the most fertile in the world.

Prairie grasses and wildflowers ▼



The Value of Soil

A **natural resource** is anything in the environment that humans use. **Soil is one of Earth's most valuable natural resources because everything that lives on land, including humans, depends directly or indirectly on soil.** Plants depend directly on the soil to live and grow. Humans and animals depend on plants—or on other animals that depend on plants—for food.

Fertile soil is valuable because there is a limited supply. Less than one eighth of the land on Earth has soils that are well suited for farming. Soil is also in limited supply because it takes a long time to form. It can take hundreds of years for just a few centimeters of soil to form. The thick, fertile soil of the prairies took many thousands of years to develop.

Reading Checkpoint **Why is fertile soil valuable?**

Soil Damage and Loss

Human activities and changes in the environment can affect the soil. **The value of soil is reduced when soil loses its fertility and when topsoil is lost due to erosion.**

Loss of Fertility Soil can be damaged when it loses its fertility. Soil that has lost its fertility is said to be exhausted. This type of soil loss occurred in large parts of the South in the late 1800s. Soils in which only cotton had been grown were exhausted. Many farmers abandoned their farms. Early in the 1900s in Alabama, a scientist named George Washington Carver developed new crops and farming methods that helped to restore soil fertility in the South. Peanuts were one crop that helped make the soil fertile again. Peanut plants are legumes. Legumes have small lumps on their roots that contain nitrogen-fixing bacteria. These bacteria make nitrogen, an important nutrient, available in a form that plants can use.

FIGURE 12
Restoring Soil Fertility
George Washington Carver (1864–1943) taught new methods of soil conservation. He also encouraged farmers to plant peanuts, which helped restore soil fertility.
Applying Concepts *What nutrient do peanut plants add to the soil?*

FIGURE 13
The Dust Bowl
The Dust Bowl ruined farmland in western Oklahoma and parts of the surrounding states. Wind blew dry particles of soil into great clouds of dust that traveled thousands of kilometers.

Loss of Topsoil Whenever soil is exposed, water and wind can quickly erode it. Plant cover can protect soil from erosion. Plants break the force of falling rain, and plant roots hold the soil together. Wind is another cause of soil loss. Wind erosion is most likely in areas where farming methods are not suited to dry conditions. For example, wind erosion contributed to the Dust Bowl on the Great Plains.

Soil Loss in the Dust Bowl Toward the end of the 1800s, farmers settled the Great Plains. The soil of the Great Plains is fertile. But rainfall decreases steadily from east to west across the Great Plains. The region also has droughts—years when rainfall is scarce. Plowing removed the grass from the Great Plains and exposed the soil. In times of drought, the topsoil quickly dried out, turned to dust, and blew away.

By 1930, almost all of the Great Plains had been turned into farms or ranches. Then, a long drought turned the soil on parts of the Great Plains to dust. The wind blew the soil east in great, black clouds that reached Chicago and New York City. The erosion was most serious in the southern Plains states. This area, shown in Figure 13, was called the **Dust Bowl.** The Dust Bowl helped people appreciate the value of soil. With government support, farmers in the Great Plains and throughout the country began to take better care of their land. They adopted methods of farming that helped save the soil. Some methods were new. Others had been practiced for hundreds of years.

Reading Checkpoint **What caused the Dust Bowl?**

Go Online NSTA SCILINKS
For: Links on soil conservation
Visit: www.SciLinks.org
Web Code: scn-0723

Soil Conservation

Since the Dust Bowl, farmers have adopted modern methods of soil conservation. **Soil conservation** is the management of soil to prevent its destruction. **Soil can be conserved through contour plowing, conservation plowing, and crop rotation.**

In **contour plowing,** farmers plow their fields along the curves of a slope. This helps slow the runoff of excess rainfall and prevents it from washing the soil away.

In **conservation plowing,** farmers disturb the soil and its plant cover as little as possible. Dead weeds and stalks of the previous year's crop are left in the ground to help return soil nutrients, retain moisture, and hold soil in place. This method is also called low-till or no-till plowing.

In **crop rotation,** a farmer plants different crops in a field each year. Different types of plants absorb different amounts of nutrients from the soil. Some crops, such as corn and cotton, absorb large amounts of nutrients. The year after planting these crops, the farmer plants crops that use fewer soil nutrients, such as oats, barley, or rye. The year after that the farmer sows legumes such as alfalfa or beans to restore the nutrient supply.

Reading Checkpoint **How does conservation plowing help conserve soil?**

FIGURE 14
Soil Conservation Methods
This farm's fields show evidence of contour plowing and crop rotation. Predicting *How might contour plowing affect the amount of topsoil?*

Section 3 Assessment

Vocabulary Skill Suffixes Complete the following sentence with the correct word (*conserve/conservation*). Farmers can _____ soil by crop rotation.

Reviewing Key Concepts

HINT HINT HINT
1. a. Defining What is a natural resource?
   b. Explaining Why is soil valuable as a natural resource?
2. a. Listing What are two ways in which the value of soil can be reduced?

HINT HINT HINT HINT HINT
   b. Explaining Explain how topsoil can be lost.
   c. Relating Cause and Effect What caused the Dust Bowl?
3. a. Defining What is soil conservation?
   b. Listing What are three methods by which farmers can conserve soil?
   c. Problem Solving A farmer growing corn wants to maintain soil fertility and reduce erosion. What conservation methods could the farmer try? Explain.

Writing in Science

Public Service Announcement
A severe drought in a farming region threatens to produce another Dust Bowl. Write a paragraph about soil conservation to be read as a public service announcement on radio stations. The announcement should identify the danger of soil loss due to erosion. It should also describe the steps farmers can take to conserve the soil.

Chapter 6 Study Guide

The BIG Idea **Composition and structure of Earth** The weathering of rock helps to reshape Earth's surface and form soil.

1 Rocks and Weathering

Key Concepts

Weathering and erosion work together continuously to wear down and carry away the rocks at Earth's surface.

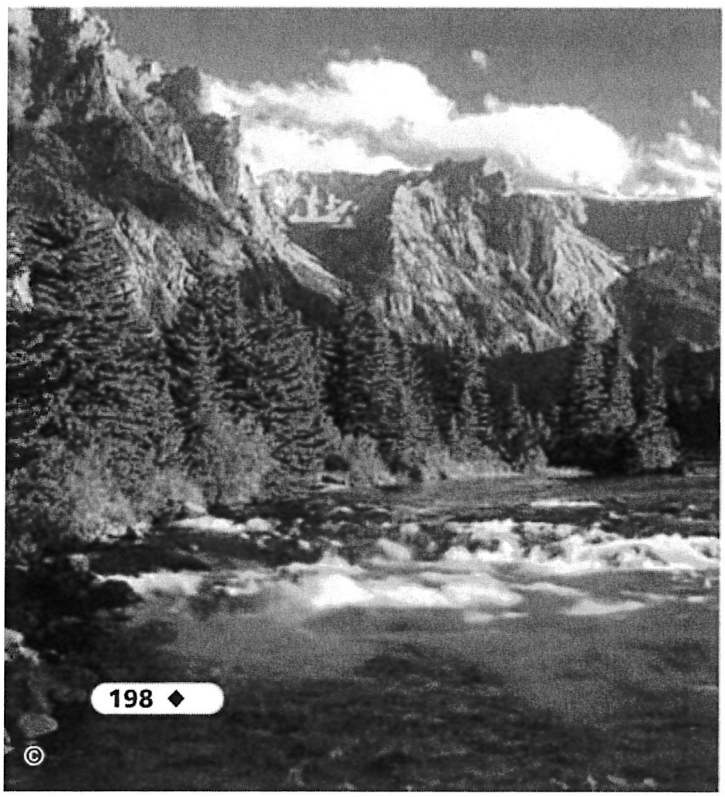
The causes of mechanical weathering include freezing and thawing, release of pressure, plant growth, actions of animals, and abrasion.

The causes of chemical weathering include the action of water, oxygen, carbon dioxide, living organisms, and acid rain.

The most important factors that determine the rate at which weathering occurs are the type of rock and the climate.

Key Terms

weathering
erosion
uniformitarianism
mechanical weathering
abrasion
ice wedging
chemical weathering
oxidation
permeable



2 How Soil Forms

Key Concepts

Soil is a mixture of rock particles, minerals, decayed organic material, water, and air.

Soil forms as rock is broken down by weathering and mixes with other materials on the surface. Soil is constantly being formed wherever bedrock is exposed.

Scientists classify the different types of soil into major groups based on climate, plants, and soil composition.

Some soil organisms make humus, the material that makes soil fertile. Other soil organisms mix the soil and make spaces in it for air and water.

Key Terms

soil
bedrock
humus
fertility
loam
soil horizon
topsoil
subsoil
litter
decomposer

3 Soil Conservation

Key Concepts

Soil is one of Earth's most valuable natural resources because everything that lives on land, including humans, depends directly or indirectly on soil.

The value of soil is reduced when soil loses its fertility and when topsoil is lost due to erosion.

Soil can be conserved through contour plowing, conservation plowing, and crop rotation.

Key Terms

sod
natural resource
Dust Bowl
soil conservation
contour plowing
conservation plowing
crop rotation

Review and Assessment

Go Online
PHSchool.com
For: Self-Assessment
Visit: PHSchool.com
Web Code: cpa-0006

Organizing Information

Sequencing Fill in the flowchart to show how soil horizons form. (For more information on flowcharts, see the Skills Handbook.)

Soil Horizons

Bedrock begins to weather.

↓

a. ?

↓

b. ?

↓

c. ?

Reviewing Key Terms

Choose the letter of the best answer.

HINT

1. The process that splits rock through freezing and thawing is called
   a. erosion.
   b. chemical weathering.
   c. ice wedging.
   d. abrasion.

HINT

2. Acid rain results in
   a. chemical weathering.
   b. abrasion.
   c. oxidation.
   d. mechanical weathering.

HINT

3. Soil that is made up of roughly equal parts of clay, sand, and silt is called
   a. sod.
   b. loam.
   c. tropical soil.
   d. subsoil.

HINT

4. The B horizon consists of
   a. subsoil.
   b. topsoil.
   c. litter.
   d. bedrock.

HINT

5. The humus in soil is produced by
   a. mechanical weathering.
   b. bedrock.
   c. chemical weathering.
   d. decomposers.

If the statement is true, write *true*. If it is false, change the underlined word or words to make the statement true.

HINT

6. Mechanical weathering is the removal of rock particles by gravity, wind, water, or ice.

HINT

7. Rock that is permeable weathers easily because it is full of tiny air spaces.

HINT

8. The decayed organic material in soil is called loam.

HINT

9. The layer of plant remains at the surface of the soil is called litter.

HINT

10. In contour plowing, farmers conserve soil fertility by leaving dead stalks and weeds in the ground.

Writing in Science

Journal Entry You are a farmer on the tall grass prairie in the midwestern United States. Write a journal entry describing prairie soil. Include the soil's composition, how it formed, and how animals helped it develop.

Discovery Channel School

Weathering and Soil Formation
Video Preview
Video Field Trip
▶ Video Assessment

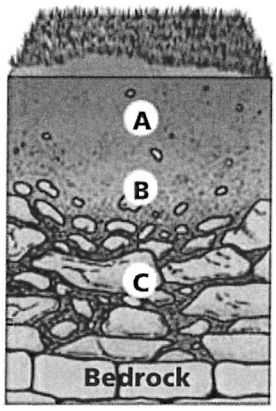
Review and Assessment

Checking Concepts

11. What is the principle of uniformitarianism?
12. Explain how plants can act as agents of both mechanical and chemical weathering.
13. What is the role of gases such as oxygen and carbon dioxide in chemical weathering?
14. Briefly describe how soil is formed.
15. Which contains more humus, topsoil or subsoil? Which has higher fertility? Explain.
16. What organism does most of the work in mixing humus into soil?
17. What role did grass play in conserving the soil of the prairies?
18. How do conservation plowing and crop rotation contribute to soil conservation?

Thinking Critically

19. **Predicting** If mechanical weathering breaks a rock into pieces, how would this affect the rate at which the rock weathers chemically?
20. **Comparing and Contrasting** Compare the layers in the diagram below in terms of their composition and humus content.

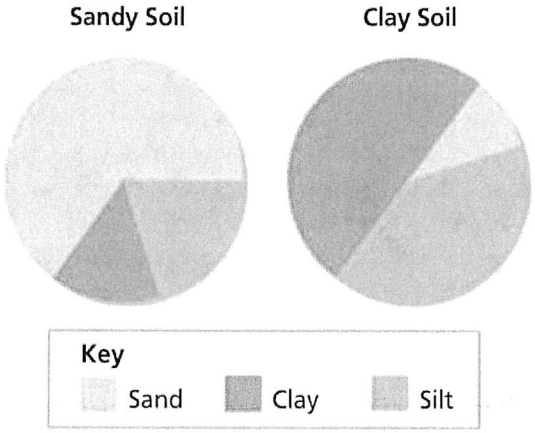


21. **Classifying** Classify as mechanical or chemical weathering: cracks in a sidewalk next to a tree; limestone with holes like Swiss cheese; a rock that slowly turns reddish brown.

Applying Skills

Use the following information to answer Questions 22–24.

You have two samples of soil. One is mostly sand and one is mostly clay.



22. **Developing Hypotheses** Which soil sample would lose water more quickly? Why?
23. **Designing Experiments** Design an experiment to test how quickly water passes through each soil sample.
24. **Posing Questions** You are a farmer who wants to grow soybeans in one of these two soils. What questions would you need to answer before choosing where to plant your soybeans?

Lab zone Chapter Project

Performance Assessment You are ready to present your data and conclusions about what type of material is best for growing bean plants. How did your group's results compare with those of the other groups in your class?

In your journal, describe how well the results of your experiment matched your predictions. What have you learned from this project about soil characteristics that help plants to grow? How could you improve your experiment?

GA Preparing for the CRCT

Test-Taking Tip

Reading All the Answer Choices

Always read *every* answer choice in a multiple-choice question before selecting the answer you think is correct. There may be more than one correct response, but one choice will be more complete and precise than the others. Or "all of the above" may be a possible answer. If you stop reading as soon as you find an answer that seems correct, you won't notice that "all of the above" is an option.

Sample Question

What is the term for the process that breaks down rock through chemical changes?

A acid rain
B ice wedging
C chemical weathering
D all of the above

Answer

The correct answer is **C**. **A** is an agent of chemical weathering, but it is not the term for the process. **B** is a type of mechanical weathering.

Choose the letter of the best answer.

1. Which of the following is a type of mechanical weathering?

A abrasion **B** plant growth
C freezing and thawing **D** all of the above

S6E5.e

2. You are designing an experiment to test the resistance to weathering of various types of materials. What weathering process could be modeled using sandpaper?

A acid rain **B** freezing and thawing
C abrasion **D** all of the above S6E5.e

3. In what type of climate would soil form fastest from limestone bedrock?

A a cold, dry climate **B** a cold, wet climate
C a hot, dry climate **D** a hot, wet climate

S6E5.g

Use the data table below and your knowledge of science to answer Questions 4–5.

Soil Erosion by State

State	Tons per Acre per Year		
	Water Erosion	Wind Erosion	Total Erosion
Montana	1.08	3.8	4.9
Wyoming	1.57	2.4	3.97
Texas	3.47	14.9	18.4
New Mexico	2.00	11.5	13.5
Colorado	2.5	8.9	11.4
Tennessee	14.12	0.0	14.12
Hawaii	13.71	0.0	13.71

4. Of the states listed in the table, which two have the greatest amount of erosion by water?

A Texas and Tennessee
B Texas and Hawaii
C New Mexico and Colorado
D Tennessee and Hawaii S6E5.g

5. What state in the table has the greatest soil erosion?

A Texas
B Hawaii
C Tennessee
D New Mexico S6E5.g

Constructed Response

6. Two rocks, each in a different location, have been weathering for the same amount of time. Mature soil has formed from one rock, but only immature soil has formed from the other. What factors might have caused this difference in rate of soil formation? In your answer, include examples of both mechanical and chemical weathering. S6E5.g