Chapter 2

The Atmosphere

Standard Course of Study

1.01 Identify and create questions and hypotheses.

1.02 Develop appropriate experimental procedures.

1.03 Apply safety procedures.

1.04 Analyze variables.

1.05 Analyze evidence.

1.06 Use mathematics to gather, organize, and present data.

1.07 Prepare models and/or computer simulations.

1.08 Use oral and written language.

1.09 Use technologies and information systems.

2.01 Explore definitions of "technology."

2.02 Use information systems.

3.01 Explain the composition, properties, and structure of the atmosphere.

3.02 Describe observable and measurable properties to predict air quality.

3.03 Conclude that environments and organisms require stewardship.

3.04 Evaluate how humans impact air quality.

3.05 Examine atmospheric properties.

Interactive Textbook

Bubbles are pockets of air surrounded by a thin film of liquid.

End-of-Grade Test Practice

Test-Taking Tip

Eliminating Incorrect Answers

When answering a multiple-choice question, you can often eliminate some answer choices because they are clearly incorrect. By doing this you increase your odds of choosing the correct answer.

Sample Question

Which of the following is usually the first stage in the technology design process?

- **A** apply for a patent
- **B** identify a need
- **C** troubleshoot problems with the new design
- **D** communicate about the design solution

Answer

The answer is **B**. You can eliminate **A** and **D** because these steps occur near the end of the technology design process. Of the remaining choices, **B** must occur first.

Choose the letter of the best answer.

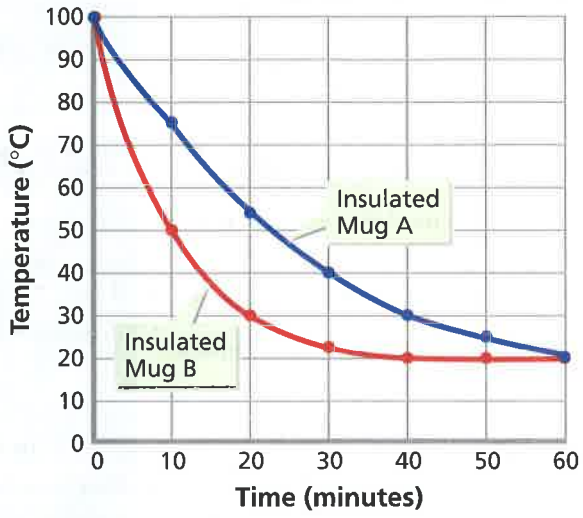
1. What would be the best way to measure the mass of a small object like a rock?
   - **A** using a graduated cylinder
   - **B** using a bathroom scale
   - **C** using a triple-beam balance
   - **D** using a meter stick

2. Engineers have designed a car with a new engine and body design. Which of the following trade-offs would have a negative impact on public safety?
   - **A** choosing lower-cost materials over good results in crash tests
   - **B** choosing the appearance of the car seats over their comfort
   - **C** choosing to install a more powerful music system over a better air conditioning system
   - **D** choosing a more powerful engine over better gas mileage

3. A new sunscreen that has to be applied only once a week has been developed. The sunscreen is an example of
   - **A** energy and power technology
   - **B** communication technology
   - **C** construction technology
   - **D** biological and chemical technology

The graph compares how well two different brands of insulated mugs retained heat. Use the graph to answer question 4.

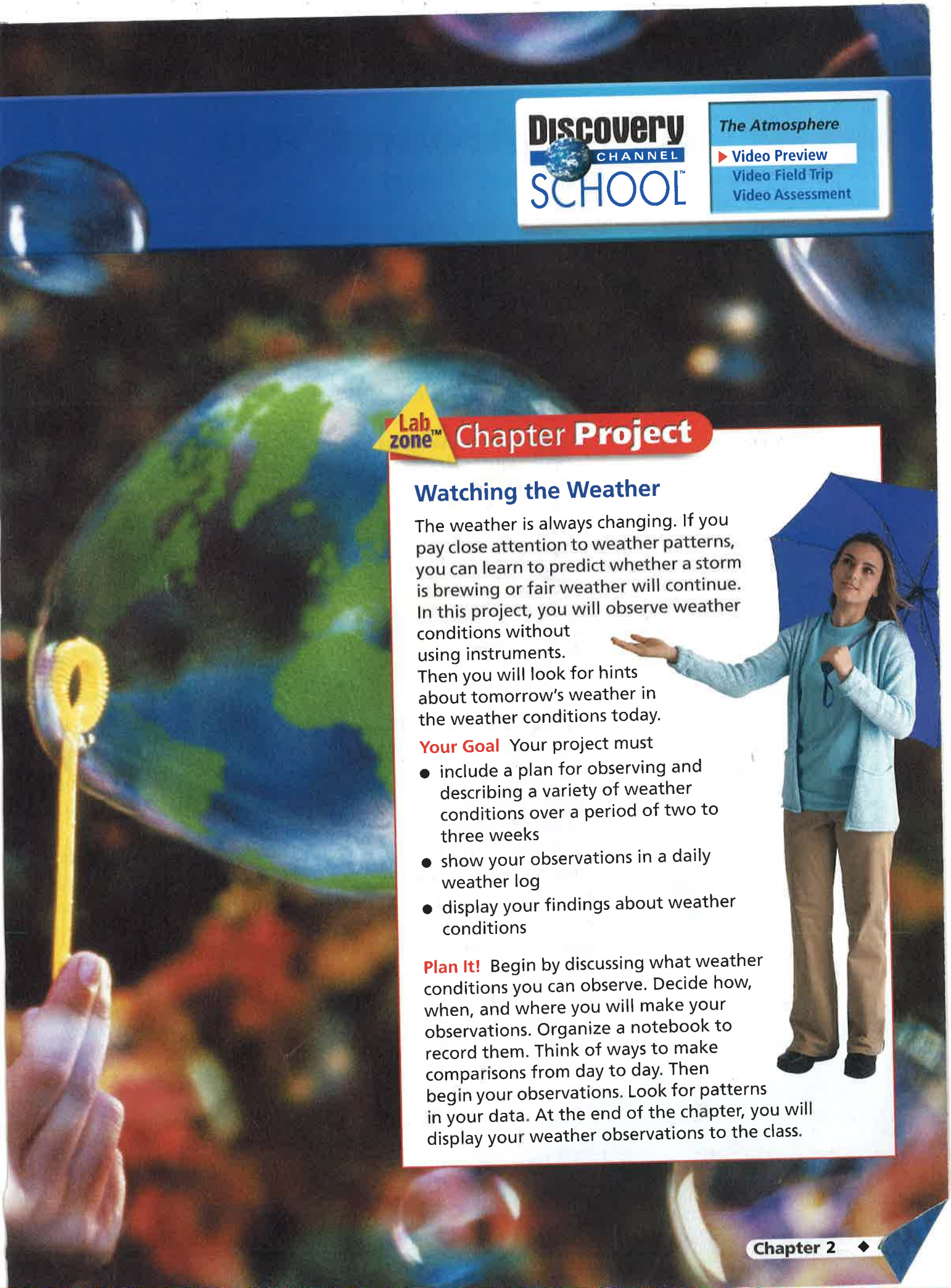
Comparing Insulated Mugs



4. What was the manipulated variable in this experiment?
   - **A** the temperature of the water
   - **B** location of the travel mug
   - **C** brand of travel mug
   - **D** how long the water was allowed to cool

Constructed Response

5. Suppose a newly designed robot automatically scans products at checkout lines in supermarkets. The robot can perform no other function. The cost to install a robot at a cash register is less than the cost of hiring a cashier. Describe some of the positive and negative impacts that this new technology might have on society.



Discovery CHANNEL SCHOOL™

The Atmosphere
- Video Preview
- Video Field Trip
- Video Assessment

Lab zone™ Chapter Project

Watching the Weather

The weather is always changing. If you pay close attention to weather patterns, you can learn to predict whether a storm is brewing or fair weather will continue. In this project, you will observe weather conditions without using instruments. Then you will look for hints about tomorrow's weather in the weather conditions today.

Your Goal Your project must

- include a plan for observing and describing a variety of weather conditions over a period of two to three weeks
- show your observations in a daily weather log
- display your findings about weather conditions

Plan It! Begin by discussing what weather conditions you can observe. Decide how, when, and where you will make your observations. Organize a notebook to record them. Think of ways to make comparisons from day to day. Then begin your observations. Look for patterns in your data. At the end of the chapter, you will display your weather observations to the class.

Section 1

The Air Around You

Reading Preview

Key Concepts

- What is the composition of Earth's atmosphere?
- How is the atmosphere important to living things?

Key Terms

- weather
- atmosphere
- ozone
- water vapor

Target Reading Skill

Using Prior Knowledge Before you read, look at the section headings and visuals to see what this section is about. Then write what you know about the atmosphere in a graphic organizer like the one below. As you read, write what you learn.

What You Know
1. The atmosphere contains oxygen.
2.

What You Learned
1.
2.

Lab zone Discover Activity

How Long Will the Candle Burn?

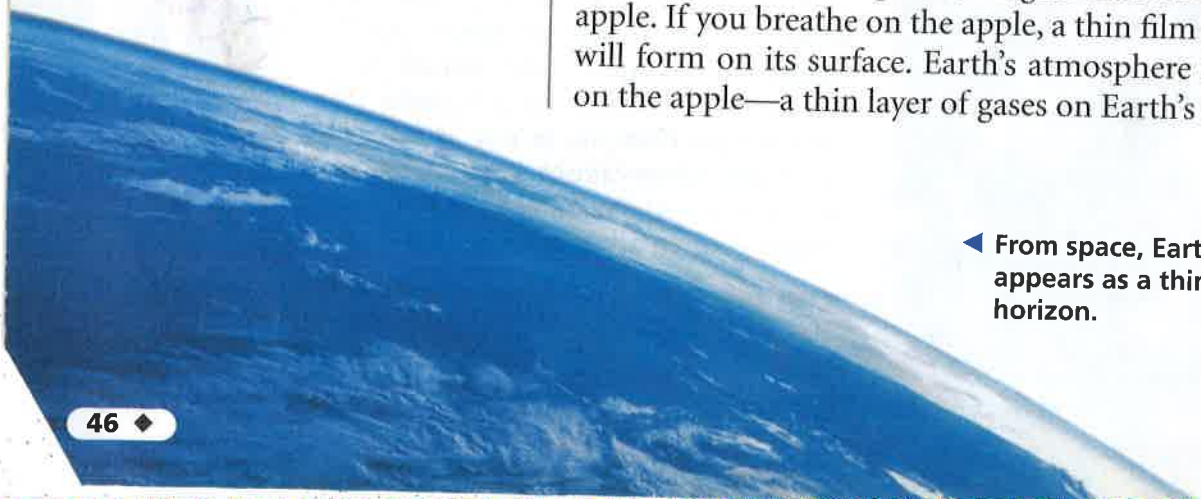
1. Put on your goggles.
2. Stick a small piece of modeling clay onto an aluminum pie pan. Push a short candle into the clay. Carefully light the candle.
3. Hold a small glass jar by the bottom. Lower the mouth of the jar over the candle until the jar rests on the pie pan. As you do this, start a stopwatch or note where the second hand is on a clock.
4. Watch the candle carefully. How long does the flame burn?
5. Wearing an oven mitt, remove the jar. Relight the candle and then repeat Steps 3 and 4 with a larger jar.

Think It Over

Inferring How would you explain any differences between your results in Steps 4 and 5?

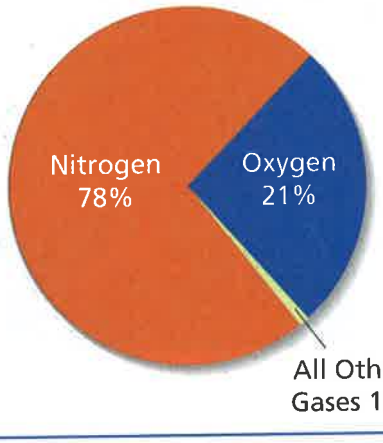
The sky is full of thick, dark clouds. In the distance you see a bright flash. Thirty seconds later, you hear a crack of thunder. You begin to run and reach your home just as the downpour begins. That was close! From your window you look out to watch the storm.

Does the weather where you live change often, or is it fairly constant from day to day? **Weather** is the condition of Earth's atmosphere at a particular time and place. But what is the atmosphere? Earth's **atmosphere** (AT muh sfeer) is the envelope of gases that surrounds the planet. To understand the relative size of the atmosphere, imagine that Earth is the size of an apple. If you breathe on the apple, a thin film of water droplets will form on its surface. Earth's atmosphere is like that water on the apple—a thin layer of gases on Earth's surface.



◀ From space, Earth's atmosphere appears as a thin layer near the horizon.

Gases in Dry Air



Other Gases	Percentage by Volume
Argon	0.93
Carbon dioxide	0.038
Neon	0.0018
Helium	0.00052
Methane	0.00015
Krypton	0.00011
Hydrogen	0.00005

FIGURE 1
Dry air in the lower atmosphere generally has about the same composition of gases.
Interpreting Data
What two gases make up most of the air?

Composition of the Atmosphere

The atmosphere is made up of a mixture of atoms and molecules of different kinds. An atom is the smallest unit of a chemical element that can exist by itself. Molecules are made up of two or more atoms. **Earth's atmosphere is made up of nitrogen, oxygen, carbon dioxide, water vapor, and many other gases, as well as particles of liquids and solids.**

Nitrogen As you can see in Figure 1, nitrogen is the most abundant gas in the atmosphere. It makes up a little more than three fourths of the air we breathe. Each nitrogen molecule consists of two nitrogen atoms.

Oxygen Even though oxygen is the second most abundant gas in the atmosphere, it makes up less than one fourth of the volume. Plants and animals take oxygen directly from the air and use it to release energy from their food.

Oxygen is also involved in many other important processes. Any fuel you can think of, from the gasoline in a car to the candles on a birthday cake, uses oxygen as it burns. Without oxygen, a fire will go out. Burning uses oxygen rapidly. During other processes, oxygen is used slowly. For example, steel in cars and other objects reacts slowly with oxygen to form iron oxide, or rust.

Most oxygen molecules have two oxygen atoms. **Ozone** is a form of oxygen that has three oxygen atoms in each molecule instead of the usual two. Have you ever noticed a pungent smell in the air after a thunderstorm? This is the odor of ozone, which forms when lightning interacts with oxygen in the air.

Reading Checkpoint **What is ozone?**

FIGURE 2
Burning Uses Oxygen
Oxygen is necessary in order for the wood to burn.

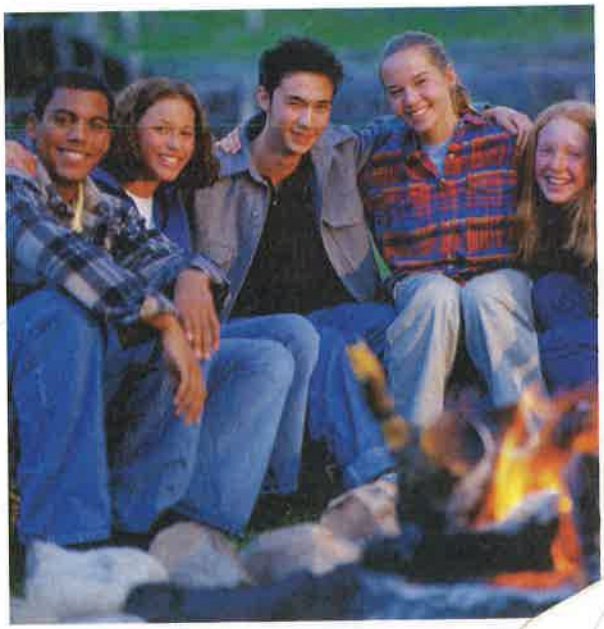
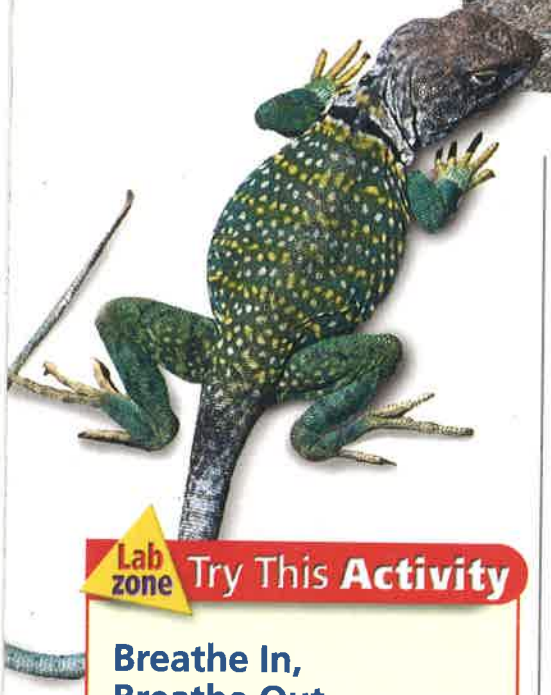


FIGURE 3
Water Vapor in the Air There is very little water vapor in the air over the desert where this lizard lives. In the tropical rain forest (right), where the frog lives, as much as four percent of the air may be water vapor.



Carbon Dioxide Each molecule of carbon dioxide has one atom of carbon and two atoms of oxygen. Carbon dioxide is essential to life. Plants must have carbon dioxide to produce food. When the cells of plants and animals break down food to produce energy, they give off carbon dioxide as a waste product.

When fuels such as coal and gasoline are burned, they release carbon dioxide. Burning these fuels increases the amount of carbon dioxide in the atmosphere.

Other Gases Oxygen and nitrogen together make up 99 percent of dry air. Argon and carbon dioxide make up most of the other one percent. The remaining gases are called trace gases because only small amounts of them are present.

Water Vapor So far, we have discussed the composition of dry air. In reality, air is not dry because it contains water vapor. **Water vapor** is water in the form of a gas. Water vapor is invisible. It is not the same thing as steam, which is made up of tiny droplets of liquid water. Each water molecule contains two atoms of hydrogen and one atom of oxygen.

The amount of water vapor in the air varies greatly from place to place and from time to time. Water vapor plays an important role in Earth's weather. Clouds form when water vapor condenses out of the air to form tiny droplets of liquid water or crystals of ice. If these droplets or crystals become heavy enough, they can fall as rain or snow.

Particles Pure air contains only gases. But pure air exists only in laboratories. In the real world, air also contains tiny solid and liquid particles of dust, smoke, salt, and other chemicals. You can see some of these particles in the air around you, but most of them are too small to see.

Reading Checkpoint **What is water vapor?**

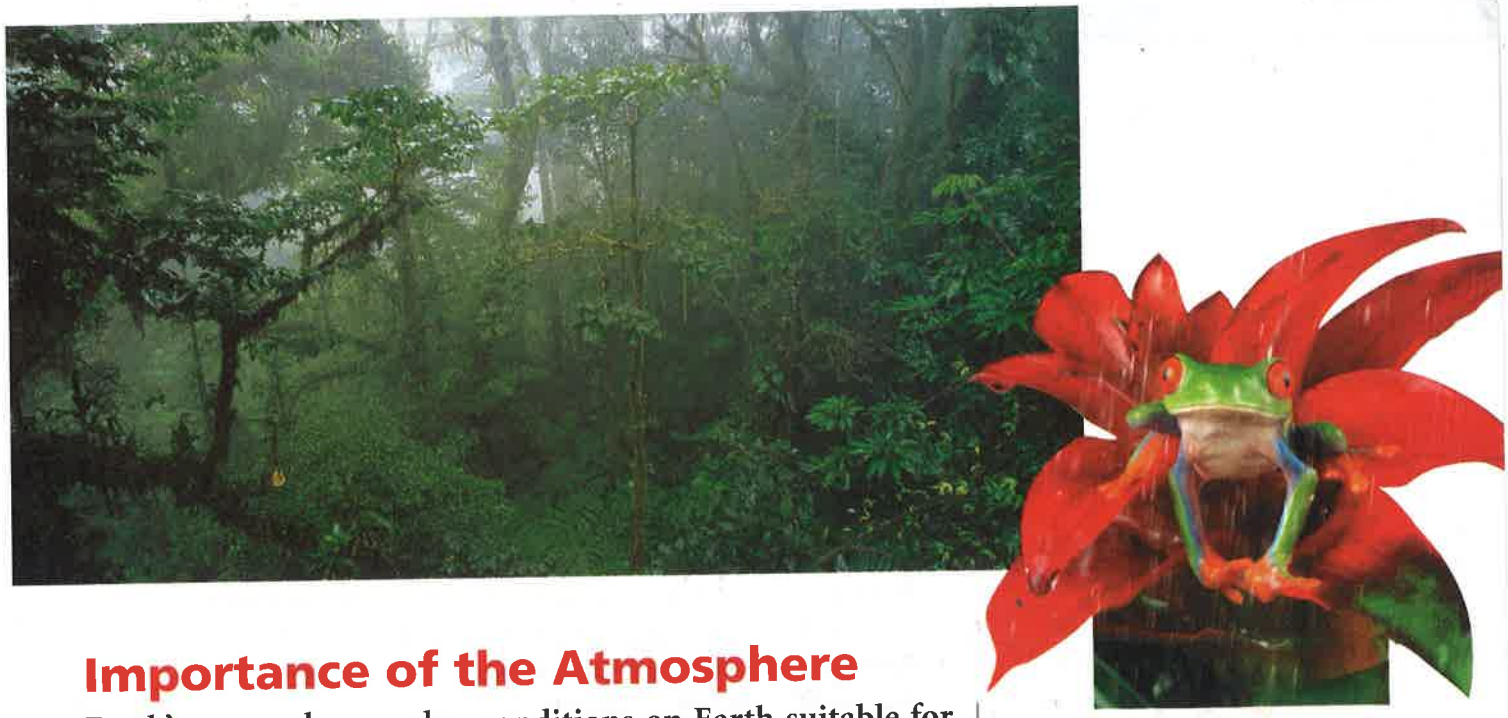
Lab zone **Try This Activity**

Breathe In, Breathe Out

How can you detect carbon dioxide in the air you exhale?

1. Put on your goggles.
2. Fill a glass or beaker halfway with limewater.
3. Using a straw, slowly blow air through the limewater for about a minute. **CAUTION:** *Do not suck on the straw or drink the limewater.*
4. What happens to the limewater?

Developing Hypotheses
What do you think would happen if you did the same experiment after jogging for 10 minutes? What would your results tell you about exercise and carbon dioxide?



Importance of the Atmosphere

Earth's atmosphere makes conditions on Earth suitable for living things. The atmosphere contains oxygen and other gases that you and other living things need to survive. In turn, living things affect the atmosphere. The atmosphere is constantly changing, with gases moving in and out of living things, the land, and the water.

Living things need warmth and liquid water. By trapping energy from the sun, the atmosphere keeps most of Earth's surface warm enough for water to exist as a liquid. In addition, Earth's atmosphere protects living things from dangerous radiation from the sun. The atmosphere also prevents Earth's surface from being hit by most meteoroids, or rocks from outer space.

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Section 1 Assessment

Target Reading Skill Using Prior Knowledge
Review your graphic organizer and revise it based on what you just learned in the section.

Reviewing Key Concepts

1. a. Defining What is the atmosphere?
   b. Listing What are the four most common gases in dry air?
   c. Explaining Why are the amounts of gases in the atmosphere usually shown as percentages of dry air?
2. a. Describing What are three ways in which the atmosphere is important to life on Earth?
   b. Predicting How would the amount of carbon dioxide in the atmosphere change if there were no plants?
   c. Developing Hypotheses How would Earth be different without the atmosphere?

Writing in Science

Summary Write a paragraph that summarizes in your own words how oxygen from the atmosphere is important. Include its importance to living things and in other processes.

Section 2

Integrating Physics

Air Pressure

Reading Preview

Key Concepts

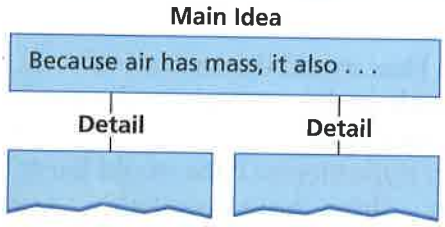
- What are some of the properties of air?
- What instruments are used to measure air pressure?
- How does increasing altitude affect air pressure and density?

Key Terms

- density
- pressure
- air pressure
- barometer
- mercury barometer
- aneroid barometer
- altitude

Target Reading Skill

Identifying Main Ideas As you read the Properties of Air section, write the main idea—the biggest or most important idea—in a graphic organizer like the one below. Then write two supporting details. The supporting details give examples of the main idea.



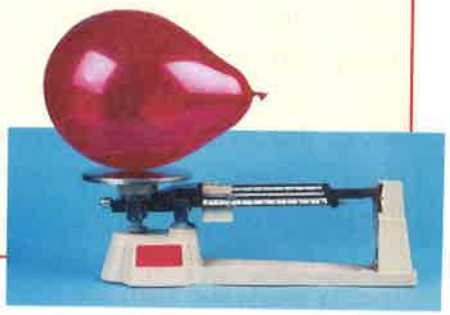
Lab zone Discover Activity

Does Air Have Mass?

1. Use a balance to find the mass of a deflated balloon.
2. Blow up the balloon and tie the neck closed. Predict whether the mass of the balloon plus the air you have compressed into it will differ from the mass of the deflated balloon.
3. Find the mass of the inflated balloon. Compare this to the mass of the deflated balloon. Was your prediction correct?

Think It Over

Drawing Conclusions What can you conclude about whether air has mass? Explain your conclusion.



The air is cool and clear—just perfect for an overnight hiking trip. You've stuffed your backpack with your tent, sleeping bag, stove, and food. When you hoist your pack onto your back, its weight presses into your shoulders. That pack sure is heavy! By the end of the day, you'll be glad to take it off and get rid of all that weight.

But here's a surprise: Even when you take off your pack, your shoulders will still have pressure on them. The weight of the atmosphere itself is constantly pressing on your body.

Like a heavy backpack pressing on your shoulders, the weight of the atmosphere causes air pressure. ▶

Properties of Air

It may seem to you that air has no mass. But in fact, air consists of atoms and molecules, which have mass. So air must have mass. **Because air has mass, it also has other properties, including density and pressure.**

Density The amount of mass in a given volume of air is its **density.** You can calculate the density of a substance by dividing its mass by its volume.

$$\text{Density} = \frac{\text{Mass}}{\text{Volume}}$$

If there are more molecules in a given volume, the density is greater. If there are fewer molecules, the density is less.

Pressure The force pushing on an area or surface is known as **pressure.** The weight of the atmosphere exerts a force on surfaces. **Air pressure** is the result of the weight of a column of air pushing down on an area. The column of air extends upward through the entire atmosphere, as shown in Figure 4.

The atmosphere is heavy. The weight of the column of air above your desk is about the same as the weight of a large schoolbus. So why doesn't air pressure crush your desk? The reason is that the molecules in air push in all directions—down, up, and sideways. The air pushing down on top of your desk is balanced by the air pushing up on the bottom of your desk.

Air pressure can change from day to day. A denser substance has more mass per unit volume than a less dense one. So denser air exerts more pressure than less dense air.

Reading Checkpoint **How does the density of air affect air pressure?**

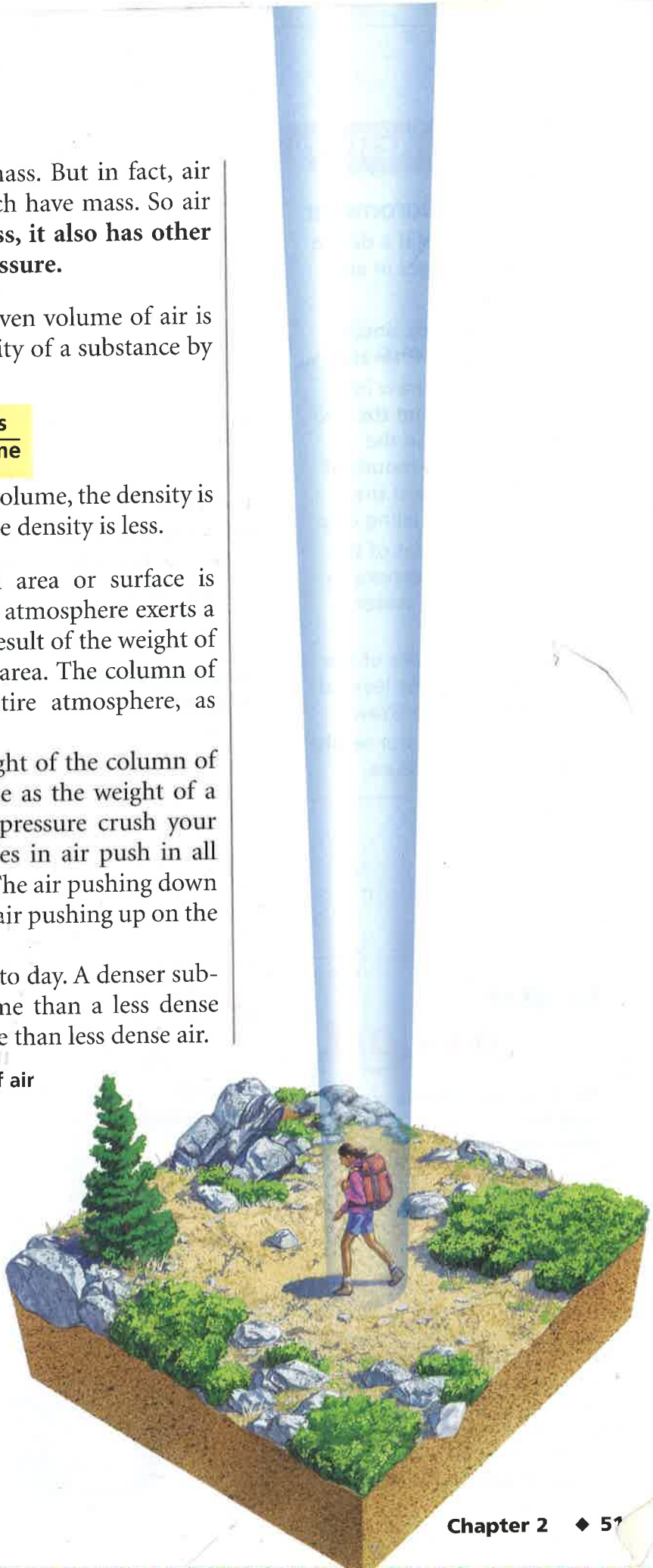


FIGURE 4
Air Pressure
There is a column of air above you all the time. The weight of the air in the atmosphere causes air pressure.

Lab zone Try This Activity

Soda-Bottle Barometer

Here's how to build a device that shows changes in air pressure.

1. Fill a 2-liter soda bottle one-half full with water.
2. Lower a long straw into the bottle so that the end of the straw is in the water. Seal the mouth of the bottle around the straw with modeling clay.
3. Squeeze the sides of the bottle. What happens to the level of the water in the straw?
4. Let go of the sides of the bottle. Watch the level of the water in the straw.

Inferring Explain your results in terms of air pressure.

Measuring Air Pressure

A **barometer** (buh RAHM uh tur) is an instrument that is used to measure air pressure. **Two common kinds of barometers are mercury barometers and aneroid barometers.**

Mercury Barometers Figure 5 shows the way a mercury barometer works. A **mercury barometer** consists of a glass tube open at the bottom end and partially filled with mercury. The space in the tube above the mercury is almost a vacuum—it contains very little air. The open end of the tube rests in a dish of mercury. The air pressure pushing down on the surface of the mercury in the dish is equal to the pressure exerted by the weight of the column of mercury in the tube. When the air pressure increases, it presses down more on the surface of the mercury. Greater air pressure forces the column of mercury higher. At sea level the mercury column is about 76 centimeters high, on average.

Aneroid Barometers If you have a barometer at home, it is probably an aneroid barometer. The word aneroid means "without liquid." An **aneroid barometer** (AN uh royd) has an airtight metal chamber, as shown in Figure 6. The metal chamber is sensitive to changes in air pressure. When air pressure increases, the thin walls of the chamber are pushed in. When the pressure drops, the walls bulge out. The chamber is connected to a dial by a series of springs and levers. As the shape of the chamber changes, the needle on the dial moves.

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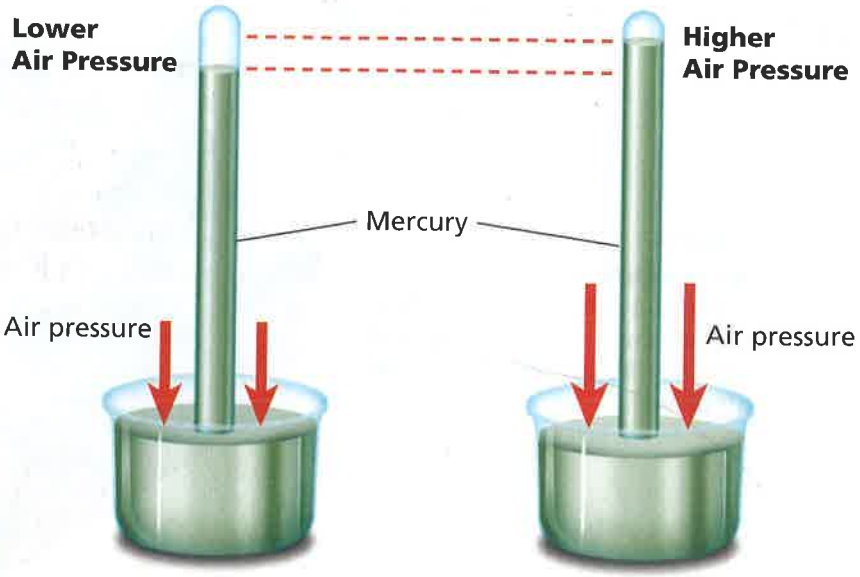


FIGURE 5
Mercury Barometer
Air pressure pushes down on the surface of the mercury in the dish, causing the mercury in the tube to rise. The air pressure is greater on the barometer on the right, so the mercury is higher in the tube.
Predicting *What happens to the level of mercury in the tube when the air pressure decreases?*

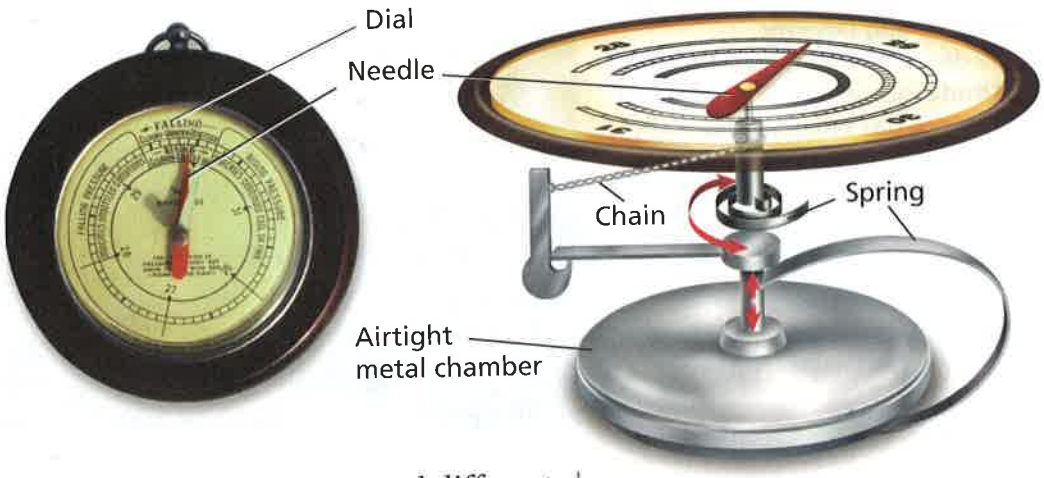


FIGURE 6
Aneroid Barometer
This diagram shows an aneroid barometer. Changes in air pressure cause the walls of the airtight metal chamber to flex in and out. The needle on the dial indicates the air pressure.

Units of Air Pressure Weather reports use several different units for air pressure. Most weather reports for the general public use inches of mercury. For example, if the column of mercury in a mercury barometer is 30 inches high, the air pressure is "30 inches of mercury" or just "30 inches."

National Weather Service maps indicate air pressure in millibars. One inch of mercury is approximately 33.87 millibars, so 30 inches of mercury is approximately equal to 1,016 millibars.

Reading Checkpoint **What are two common units that are used to measure air pressure?**

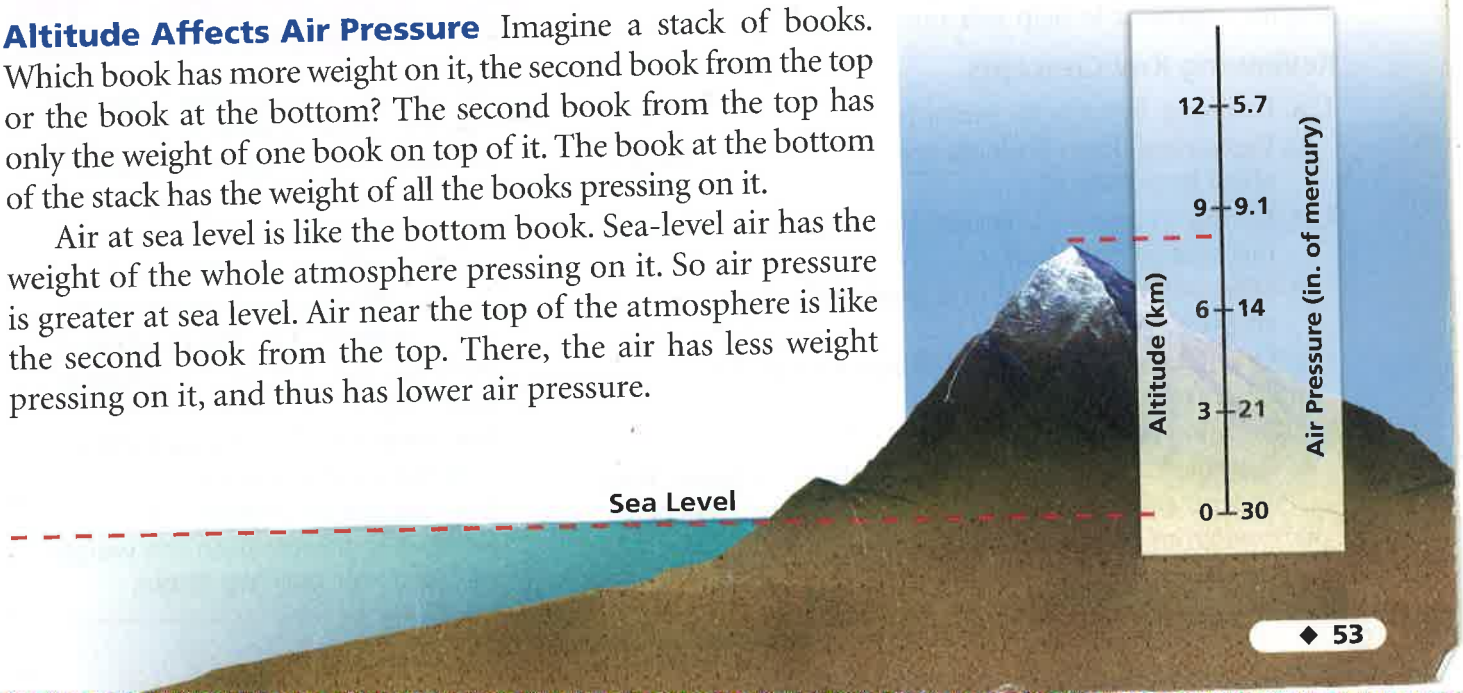
Altitude and the Properties of Air

At the top of a mountain, the air pressure is less than the air pressure at sea level. **Altitude,** or elevation, is the distance above sea level, the average level of the surface of the oceans. **Air pressure decreases as altitude increases. As air pressure decreases, so does density.**

Altitude Affects Air Pressure Imagine a stack of books. Which book has more weight on it, the second book from the top or the book at the bottom? The second book from the top has only the weight of one book on top of it. The book at the bottom of the stack has the weight of all the books pressing on it.

Air at sea level is like the bottom book. Sea-level air has the weight of the whole atmosphere pressing on it. So air pressure is greater at sea level. Air near the top of the atmosphere is like the second book from the top. There, the air has less weight pressing on it, and thus has lower air pressure.

FIGURE 7
Air Pressure and Altitude
Air pressure is greater at sea level and decreases as the altitude increases.



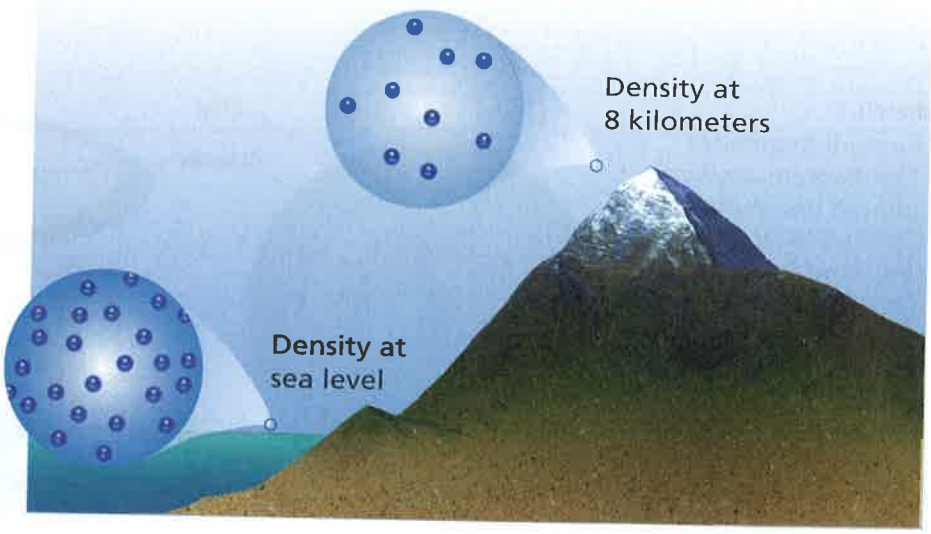


FIGURE 8
Altitude and Density
The density of air decreases as altitude increases. Air at sea level has more gas molecules in each cubic meter than air at the top of a mountain.

Altitude Also Affects Density As you go up through the atmosphere, the density of the air decreases. This means the gas molecules that make up the atmosphere are farther apart at high altitudes than they are at sea level. If you were near the top of a tall mountain and tried to run, you would quickly get out of breath. Why? The air contains 21 percent oxygen, whether you are at sea level or on top of a mountain. However, since the air is less dense at a high altitude, there are fewer oxygen molecules to breathe in each cubic meter of air than at sea level. So you would become short of breath quickly at high altitudes.

Reading Checkpoint **Why is it hard to breathe at the top of a mountain?**

Section 2 Assessment

Target Reading Skill Identifying Main Ideas Use your graphic organizer to help you answer Question 1 below.

Reviewing Key Concepts

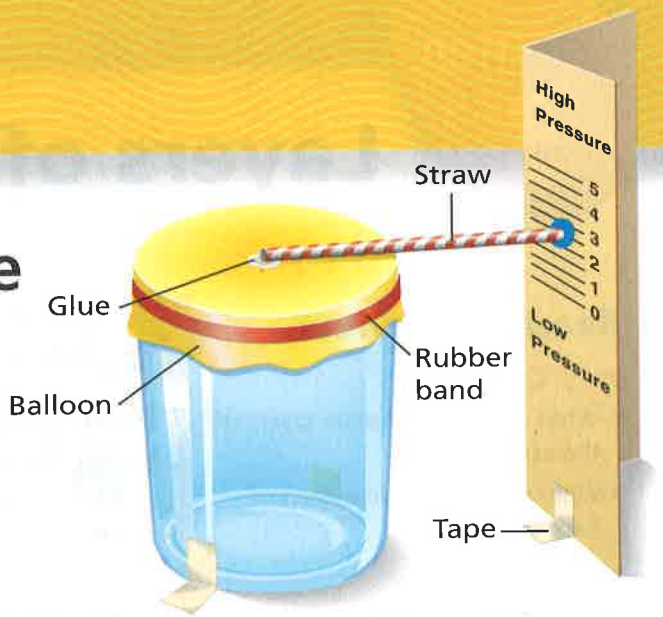
1. a. Defining What is air pressure?
   b. Explaining How does increasing the density of a gas affect its pressure?
2. a. Listing What two instruments are commonly used to measure air pressure?
   b. Measuring What units are commonly used to measure air pressure?
   c. Calculating How many millibars are equal to 27.23 inches of mercury?
3. a. Defining What is altitude?
   b. Relating Cause and Effect As altitude increases, how does air pressure change? How does density change?
   c. Predicting What changes in air pressure would you expect if you carried a barometer down a mine shaft?

Lab zone **At-Home Activity**

Model Air Pressure Here's how you can show your family that air has pressure. Fill a glass with water. Place a piece of cardboard over the top of the glass. Hold the cardboard in place with one hand as you turn the glass upside down. **CAUTION:** *Be sure the cardboard does not bend.* Now remove your hand from the cardboard. What happens? Explain to your family that the cardboard doesn't fall because the air pressure pushing up on it is greater than the weight of the water pushing down.

Skills Lab

Working Under Pressure



Problem

How can a barometer detect changes in air pressure?

Skills Focus

interpreting data, drawing conclusions

Materials

- modeling clay
- scissors
- white glue
- tape
- pencil
- wide-mouthed glass jar
- metric ruler
- cardboard strip, 10 cm × 25 cm
- rubber band
- large rubber balloon
- drinking straw, 12–15 cm long

Procedure

1. Cut off the narrow opening of the balloon.
2. Fold the edges of the balloon outward. Carefully stretch the balloon over the open end of the glass jar. Use a rubber band to hold the balloon on the rim of the glass jar.
3. Place a small amount of glue on the center of the balloon top. Attach one end of the straw to the glue. Allow the other end to extend several centimeters beyond the edge of the glass jar. This is your pointer.
4. While the glue dries, fold the cardboard strip lengthwise and draw a scale along the edge with marks 0.5 cm apart. Write "High pressure" at the top of your scale and "Low pressure" at the bottom.
5. After the glue dries, add a pea-sized piece of modeling clay to the end of the pointer. Place your barometer and its scale in a location that is as free from temperature changes as possible. Note that the pointer of the straw must just reach the cardboard strip, as shown in the diagram.
6. Tape both the scale and the barometer to a surface so they do not move during your experiment.
7. Make a data table like the one below in your notebook. Record the date and time. Note the level of the straw on the cardboard strip.

Data Table

Date and Time	Air Pressure	Weather Conditions

8. Check the barometer twice a day. Record your observations in your data table.
9. Record the weather conditions for at least three days.

Analyze and Conclude

1. **Interpreting Data** What change in atmospheric conditions must occur to cause the free end of the straw to rise? What change must occur for it to fall?
2. **Drawing Conclusions** Based on your observations, what kind of weather is usually associated with high air pressure? With low air pressure?
3. **Communicating** Write a paragraph in which you discuss what effect, if any, a large temperature change might have on the accuracy of your barometer.

More to Explore

Compare your pressure readings with high and low pressure readings shown in newspaper weather maps for the same period. How do your readings compare with those in the newspaper?

Section 3

Layers of the Atmosphere

Reading Preview

Key Concepts

- What are the four main layers of the atmosphere?
- What are the characteristics of each layer?

Key Terms

- troposphere
- stratosphere
- mesosphere
- thermosphere
- ionosphere
- exosphere

Target Reading Skill

Previewing Visuals Before you read Section 3, preview Figure 9. Then write at least two questions that you have about the diagram in a graphic organizer like the one below. As you read, answer your questions.

Layers of the Atmosphere

Q. Where is the ozone layer?
A.
Q.

Lab zone Discover Activity

Is Air There?

1. Use a heavy rubber band to tightly secure a plastic bag over the top of a wide-mouthed jar.
2. Gently try to push the bag into the jar. What happens? Is the air pressure higher inside or outside the bag?
3. Remove the rubber band and line the inside of the jar with the plastic bag. Use the rubber band to tightly secure the edges of the bag over the rim of the jar.
4. Gently try to pull the bag out of the jar with your fingertips. What happens? Is the air pressure higher inside or outside the bag?

Think It Over

Predicting Explain your observations in terms of air pressure. How do you think differences in air pressure would affect a balloon as it traveled up through the atmosphere?

Imagine taking a trip upward into the atmosphere in a hot-air balloon. You begin on a warm beach near the ocean, at an altitude of 0 kilometers above sea level.

You hear a roar as the balloon's pilot turns up the burner to heat the air in the balloon. The balloon begins to rise, and Earth's surface gets farther and farther away. As the balloon rises to an altitude of 3 kilometers, you realize that the air is getting colder. As you continue to rise, the air gets colder still. At 6 kilometers you begin to have trouble breathing. The air is becoming less dense. It's time to go back down.

What if you could have continued your balloon ride up through the atmosphere? As you rose higher, the air pressure and temperature would change dramatically.

Scientists divide Earth's atmosphere into four main layers classified according to changes in temperature. These layers are the troposphere, the stratosphere, the mesosphere, and the thermosphere. The four main layers of the atmosphere are shown in Figure 9. Read on to learn more about each of these layers.

▲ Hot-air balloon

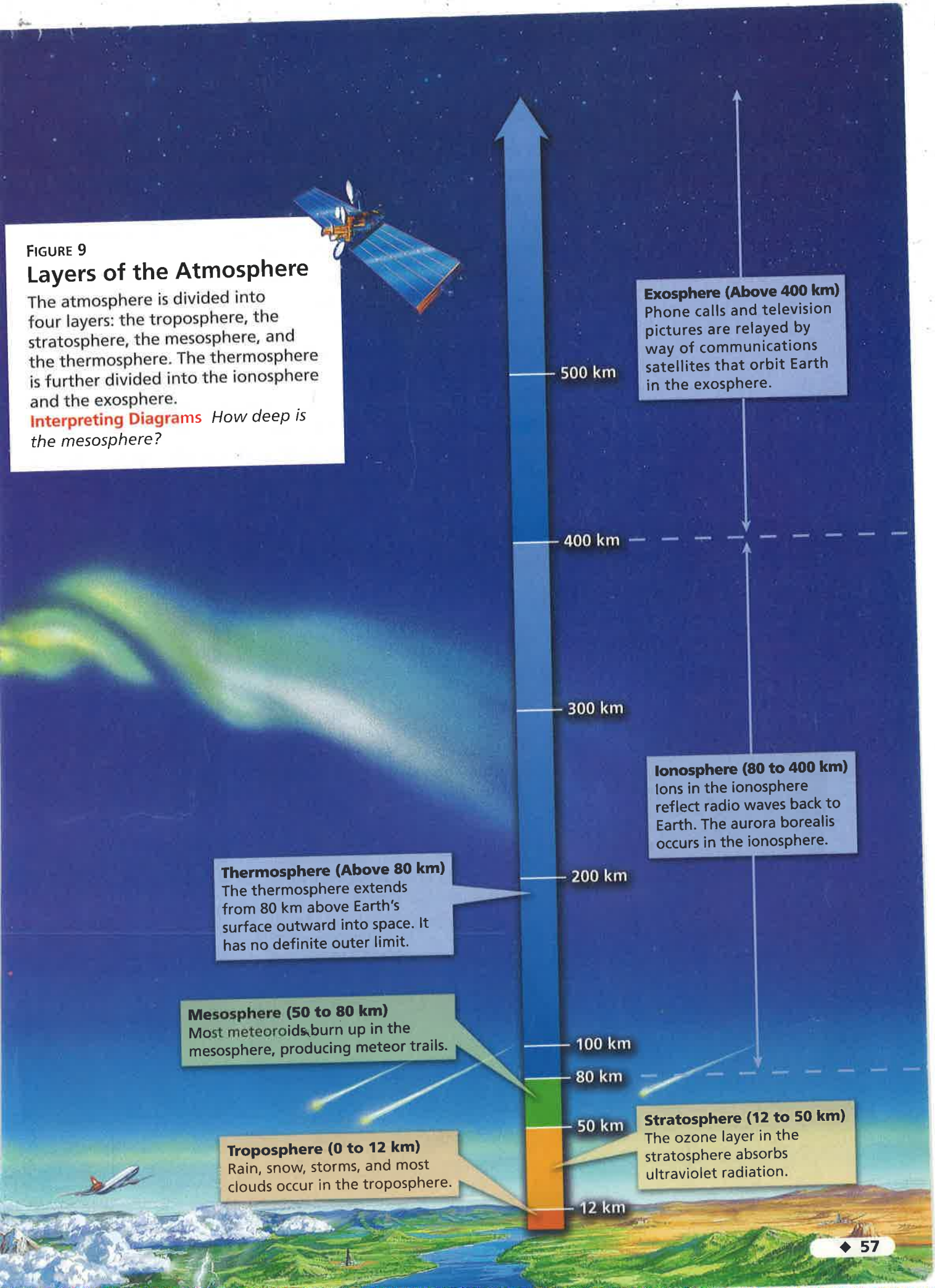


FIGURE 9

Layers of the Atmosphere

The atmosphere is divided into four layers: the troposphere, the stratosphere, the mesosphere, and the thermosphere. The thermosphere is further divided into the ionosphere and the exosphere.

Interpreting Diagrams *How deep is the mesosphere?*

Go Online
PLANET DIARY
For: More on the ozone layer
Visit: PHSchool.com
Web Code: cfd-4013

The Troposphere

You live in the inner, or lowest, layer of Earth's atmosphere, the **troposphere** (TROH puh sfeer). *Tropo-* means "turning" or "changing." Conditions in the troposphere are more variable than in the other layers. **The troposphere is the layer of the atmosphere in which Earth's weather occurs.**

The depth of the troposphere varies from 16 kilometers above the equator to less than 9 kilometers above the North and South poles. Although it is the shallowest layer, the troposphere contains almost all of the mass of the atmosphere.

As altitude increases in the troposphere, the temperature decreases. On average, for every 1-kilometer increase in altitude, the air gets about 6.5 Celsius degrees cooler. At the top of the troposphere, the temperature stops decreasing and stays at about −60°C. Water here forms thin, feathery clouds of ice.

• Tech & Design in History •

Explorers of the Atmosphere

The atmosphere has been explored from the ground and from space.

1643 Torricelli Invents the Barometer
Italian physicist and mathematician Evangelista Torricelli improved existing scientific instruments and invented some new ones. In 1643 he invented the mercury barometer.

1746 Franklin Experiments With Electricity
American statesman and inventor Benjamin Franklin experimented with electricity in the atmosphere. To demonstrate that lightning is a form of electricity, Franklin flew a kite in a thunderstorm. However, Franklin did not hold the kite string in his hand, as this historical print shows.

1804 Gay-Lussac Studies the Upper Troposphere
French chemist Joseph-Louis Gay-Lussac ascended to a height of about 7 kilometers in a hydrogen balloon to study the upper troposphere. Gay-Lussac studied pressure, temperature, and humidity.

1600 1700 1800

The Stratosphere

The **stratosphere** extends from the top of the troposphere to about 50 kilometers above Earth's surface. *Strato-* means "layer" or "spread out." **The stratosphere is the second layer of the atmosphere and contains the ozone layer.**

The lower stratosphere is cold, about −60°C. Surprisingly, the upper stratosphere is warmer than the lower stratosphere. Why is this? The middle portion of the stratosphere contains a layer of air where there is much more ozone than in the rest of the atmosphere. (Recall that ozone is the three-atom form of oxygen.) When the ozone absorbs energy from the sun, the energy is converted into heat, warming the air. The ozone layer is also important because it protects Earth's living things from dangerous ultraviolet radiation from the sun.

Reading Checkpoint **Why is the upper stratosphere warmer than the lower stratosphere?**

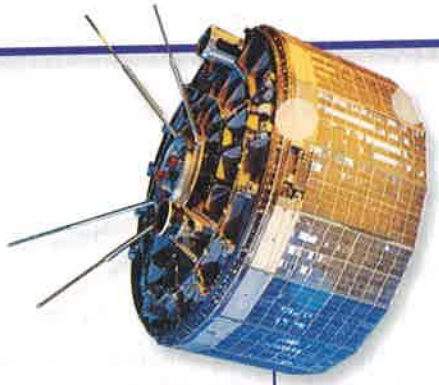
Writing in Science

Research and Write

Imagine you were one of the first people to travel into the atmosphere in a balloon. What would you need to take? Find out what the early explorers took with them in their balloons. Write at least two paragraphs about what you would take and why.

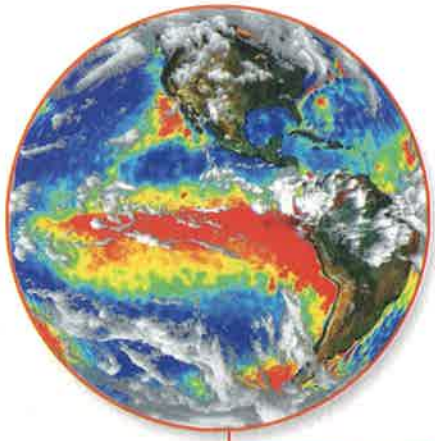
1931 Piccard Explores the Stratosphere

Swiss-Belgian physicist Auguste Piccard made the first ascent into the stratosphere. He reached a height of about 16 kilometers in an airtight cabin attached to a huge hydrogen balloon. Piccard is shown here with the cabin.



1960 First Weather Satellite Launched

TIROS-1, the first weather satellite equipped with a camera to send data back to Earth, was put into orbit by the United States. As later weather satellites circled Earth, they observed cloud cover and recorded temperatures and air pressures in the atmosphere.



1999 *Terra* Satellite Launched

The *Terra* satellite is equipped to study Earth's surface, atmosphere, and oceans from orbit. The data it gathers are used to help understand changes in Earth's climate.

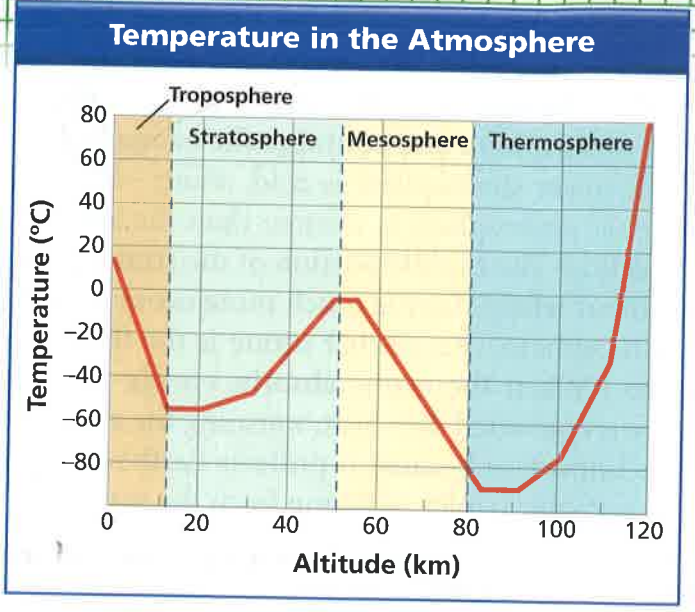
1900 2000 2100

Math Analyzing Data

Changing Temperatures

The graph shows how temperatures in the atmosphere change with altitude. Use it to answer the questions below.

1. **Reading Graphs** What two variables are being graphed? In what unit is each measured?
2. **Reading Graphs** What is the temperature at the bottom of the stratosphere?
3. **Interpreting Data** Which layer of the atmosphere has the lowest temperature?
4. **Making Generalizations** Describe how temperature changes as altitude increases in the troposphere.



The Mesosphere

Above the stratosphere, a drop in temperature marks the beginning of the next layer, the **mesosphere.** *Meso-* means "middle," so the mesosphere is the middle layer of the atmosphere. The mesosphere begins 50 kilometers above Earth's surface and ends at an altitude of 80 kilometers. In the outer mesosphere, temperatures approach –90°C.

The mesosphere is the layer of the atmosphere that protects Earth's surface from being hit by most meteoroids. Meteoroids are chunks of stone and metal from space. What you see as a shooting star, or meteor, is the trail of hot, glowing gases the meteoroid leaves behind in the mesosphere.

The Thermosphere

Near the top of the atmosphere, the air is very thin. At 80 kilometers above Earth's surface, the air is only about 0.001 percent as dense as the air at sea level. It's as though you took a cubic meter of air at sea level and expanded it into 100,000 cubic meters at the top of the mesosphere. **The outermost layer of Earth's atmosphere is the thermosphere.** The **thermosphere** extends from 80 kilometers above Earth's surface outward into space. It has no definite outer limit, but blends gradually with outer space.

The *thermo-* in thermosphere means "heat." Even though the air in the thermosphere is thin, it is very hot, up to 1,800°C. This is because sunlight strikes the thermosphere first. Nitrogen and oxygen molecules convert this energy into heat.

Despite the high temperature, you would not feel warm in the thermosphere. An ordinary thermometer would show a temperature well below 0°C. Why is that? Temperature is the average amount of energy of motion of each molecule of a substance. The gas molecules in the thermosphere move very rapidly, so the temperature is very high. However, the molecules are spaced far apart in the thin air. There are not enough of them to collide with a thermometer and warm it very much.

The thermosphere is divided into two layers. The lower layer, called the **ionosphere** (eye AHN uh sfeer), begins about 80 kilometers above the surface and extends to about 400 kilometers. Energy from the sun causes gas molecules in the ionosphere to become electrically charged particles called ions. Radio waves bounce off ions in the ionosphere back to Earth's surface. Brilliant light displays, such as those shown in Figure 10, also occur in the ionosphere. In the Northern Hemisphere, these displays are called the Northern Lights, or the aurora borealis. Auroras are caused by particles from the sun that enter the ionosphere near the poles. These particles strike atoms in the ionosphere, causing them to glow.

Exo- means "outer," so the **exosphere** is the outer portion of the thermosphere. The exosphere extends from about 400 kilometers outward for thousands of kilometers.

FIGURE 10
Aurora Borealis
The aurora borealis, seen from Fairbanks, Alaska, creates a spectacular display in the night sky.

Reading Checkpoint What is the ionosphere?

Section 3 Assessment

Target Reading Skill Previewing Visuals
Refer to your graphic organizer about Figure 9 to help you answer the following questions.

Reviewing Key Concepts

1. a. Listing List the four main layers of the atmosphere, beginning with the layer closest to Earth's surface.
   b. Classifying What properties are used to distinguish the layers of the atmosphere?
   c. Interpreting Diagrams According to Figure 9, in which layer of the atmosphere do communications satellites orbit?
2. a. Identifying Give at least one important characteristic of each of the four main layers of Earth's atmosphere.
   b. Comparing and Contrasting How does temperature change as height increases in the troposphere? Compare this to how temperature changes with height in the stratosphere.
   c. Applying Concepts Why would you not feel warm in the thermosphere, even though temperatures can be up to 1,800°C?

Writing in Science

Cause and Effect Paragraph How do you think Earth's surface might be different if it had no atmosphere? Write a paragraph explaining your ideas.

Section 4

Integrating Environmental Science

Air Quality

Reading Preview

Key Concepts

- What are the major sources of air pollution?
- What causes smog and acid rain?
- What can be done to improve air quality?

Key Terms

- pollutants
- photochemical smog
- acid rain

Target Reading Skill

Outlining As you read, make an outline about air quality that you can use for review. Use the red headings for the main topics and the blue headings for the subtopics.

Air Quality
I. Sources of air pollution
A. Natural sources
B.
C.
II. Smog and acid rain
A.

Lab zone Discover Activity

What's on the Jar?

1. Put on your goggles.
2. Put a small piece of modeling clay on a piece of aluminum foil. Push a candle into the clay. Light the candle.
3. Wearing an oven mitt, hold a glass jar by the rim so that the bottom of the jar is just above the flame.

Think It Over

Observing What do you see on the jar? Where did it come from?

As you are reading this page, you are breathing without even thinking about it. Breathing brings air into your lungs, where the oxygen you need is taken into your body. But not everything in the air is healthful. You may also breathe in tiny particles or even a small amount of harmful gases.

If you live in a large city, you may have noticed a brown haze in the air. Even if you live far from a city, the air around you may contain pollutants. **Pollutants** are harmful substances in the air, water, or soil. Air that contains harmful particles and gases is said to be polluted.

Air pollution can affect the health of humans and other living things. Figure 12 identifies the effects of some pollutants.

FIGURE 11
Air Pollution
Air pollution in large cities, such as Mexico City, can cause serious health problems.