Chapter 14

The Solar System

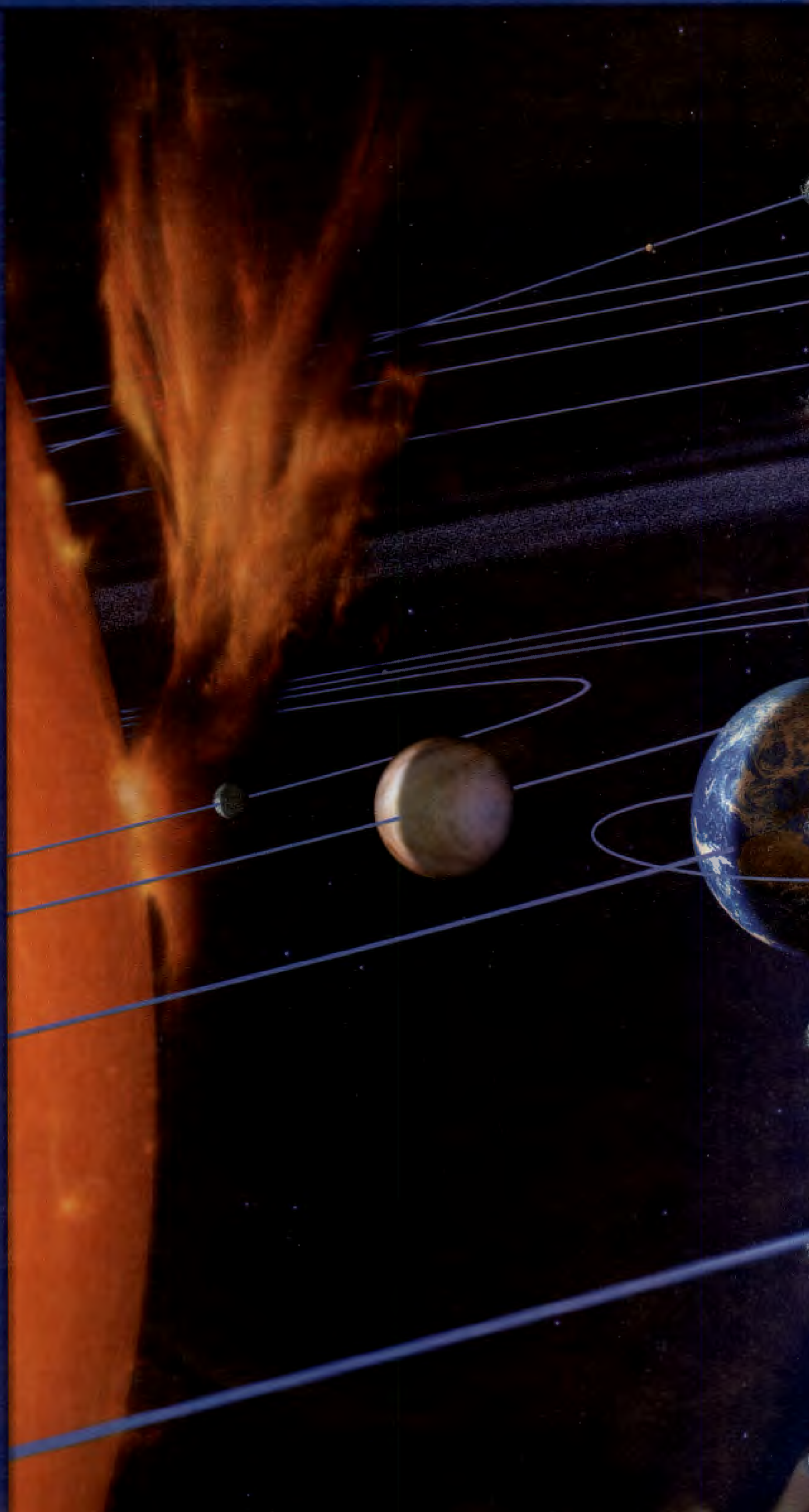
CALIFORNIA Standards Preview

S 8.2 Unbalanced forces cause changes in velocity. As a basis for understanding this concept:

- **g.** Students know the role of gravity in forming and maintaining the shapes of planets, stars, and the solar system.

S 8.4 The structure and composition of the universe can be learned from studying stars and galaxies and their evolution. As a basis for understanding this concept:

- **b.** Students know that the Sun is one of many stars in the Milky Way galaxy and that stars may differ in size, temperature, and color.
- **c.** Students know how to use astronomical units and light years as measures of distance between the Sun, stars, and Earth.
- **d.** Students know that stars are the source of light for all bright objects in outer space and that the Moon and planets shine by reflected sunlight, not by their own light.
- **e.** Students know the appearance, general composition, relative position and size, and motion of objects in the solar system, including planets, planetary satellites, comets, and asteroids.



This illustration shows several planets in orbit around the sun.

Video Preview

Discovery Channel School

The Solar System

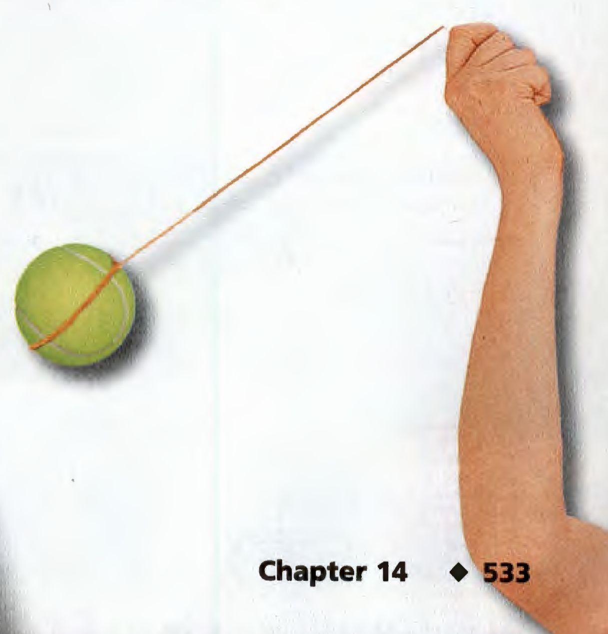
S 8.4.e

Focus on the
BIG Idea

What types of objects are found in the solar system?

Check What You Know

Suppose you were twirling a ball attached to a string over your head. If the string were to suddenly break, what do you think would happen to the ball? Explain your answer.



Build Science Vocabulary

The images shown here represent some of the key terms in this chapter. You can use this vocabulary skill to help you understand the meaning of some key terms in this chapter.

Vocabulary Skill

Greek Word Origins

Many science words related to astronomy come from ancient Greek. In this chapter you will learn the word *geocentric,* which comes from the Greek words *geo,* meaning "Earth" and *kentron,* meaning "center." Early Greeks believed in a *geocentric* universe, one in which Earth was at the center.

geo	+	**kentron**	=	**geocentric**
Earth		center		Earth-centered

Learn these Greek words to help remember key terms.

Greek Word	Meaning	Key Terms
astron	star	astronomy, asteroid
chróma	color	chromosphere
geo	Earth	geocentric
helios	sun	heliocentric
kentron	near the center, central	geocentric, heliocentric
photo	light	photosphere
sphaira	sphere	photosphere, chromosphere

Apply It!

Use what you have learned about *geocentric* to predict what *heliocentric* means. Revise your definition as you read Section 1.

Chapter 14 Vocabulary

Section 1 (page 538)

geocentric
heliocentric
ellipse
moon
astronomical unit

Section 2 (page 545)

nuclear fusion
core
radiation zone
convection zone
photosphere
chromosphere
corona
solar wind
sunspot
prominence
solar flare

Section 3 (page 552)

terrestrial planets
greenhouse effect

Section 4 (page 562)

gas giant
ring

Section 5 (page 572)

comet
coma
nucleus
Kuiper belt
Oort cloud
asteroid
asteroid belt
meteroid
meteor
meteorite

Section 6 (page 576)

extraterrestrial life

Interactive Textbook

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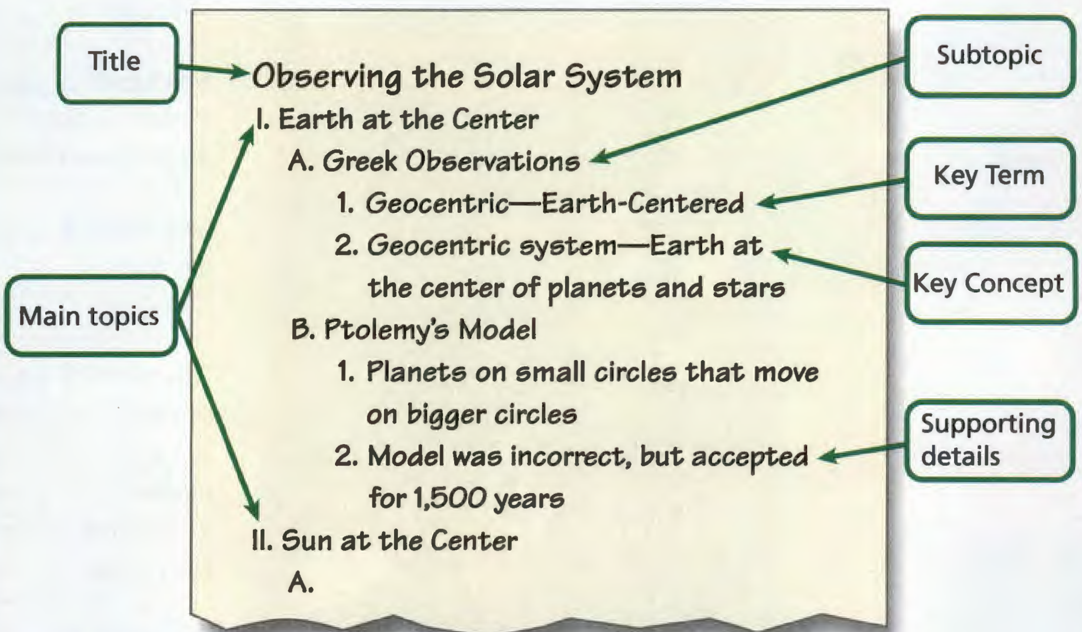
How to Read Science

Reading Skill

Create Outlines

You have learned to identify main ideas and supporting details as you read this textbook. An outline shows the relationship between main ideas and supporting details. An outline has a formal structure as in the example shown below. Roman numerals show the main topics. Capital letters show subtopics. Numbers show supporting details, including key terms.

Preview Section 1 and then look at the outline below.



Apply It!

Answer each of the following questions in a complete sentence.

1. What are the most important topics in this outline?
2. Where in this outline can you find the definition of the key kerm *geocentric?*
3. Make outlines for the other sections of this chapter.

Lab zone

Standards Investigation

S 8.4.e

Build a Model of the Solar System

The solar system is a vast region containing the sun, planets, and many other objects. To help you understand the huge distances involved, you will design three different scale models of the solar system.

Your Goal

To design scale models of the solar system

To complete this investigation, you will

- design a model to show the planets' distances from the sun
- design a model to show the planets' sizes compared to the sun
- test different scales to see if you can use the same scale for both size and distance in one model

Plan It!

Begin by previewing Figures 13 and 20 in this chapter and Appendix D on pages 654 and 655. With a group of classmates, brainstorm how to build your models.

Then design two models—one to show distances and one to show diameters. Next, design a third model that uses the same scale for both size and distance. Try several different scales to find which works best.

Prepare a data table to record your calculations. You will present your scale models and graphs at the end of the chapter.

Section 1

Observing the Solar System

CALIFORNIA
Standards Focus

S 8.4.c Students know how to use astronomical units and light years as measures of distance between the Sun, stars, and Earth.

S 8.4.d Students know that stars are the source of light for all bright objects in outer space and that the Moon and planets shine by reflected sunlight, not by their own light.

- What are the geocentric and heliocentric systems?
- How did Copernicus, Galileo, and Kepler contribute to our knowledge of the solar system?
- What objects make up the solar system?

Key Terms

- geocentric
- heliocentric
- ellipse
- moon
- astronomical unit

Lab zone **Standards Warm-Up**

What Is at the Center?

1. Stand about 2 meters from a partner who is holding a flashlight. Have your partner shine the flashlight in your direction. Tell your partner not to move the flashlight.
2. Continue facing your partner, but move sideways in a circle, staying about 2 meters away from your partner.
3. Record your observations about your ability to see the light.
4. Repeat the activity, but this time remain stationary and continually face one direction. Have your partner continue to hold the flashlight toward you and move sideways around you, remaining about 2 meters from you.
5. Record your observations about your ability to see the light.

Think It Over

Drawing Conclusions Compare your two sets of observations. If you represent Earth and your partner represents the sun, is it possible, just from your observations, to tell whether Earth or the sun is in the center of the solar system?

Have you ever gazed up at the sky on a starry night? If you watch for several hours, the stars seem to move across the sky. The sky seems to be rotating right over your head. In fact, from the Northern Hemisphere, the sky appears to rotate completely around the North Star once every 24 hours.

Now think about what you see every day. During the day, the sun appears to move across the sky. From here on Earth, it seems as if Earth is stationary and that the sun, moon, and stars are moving around Earth. But is the sky really moving above you? Centuries ago, before there were space shuttles or even telescopes, there was no easy way to find out.

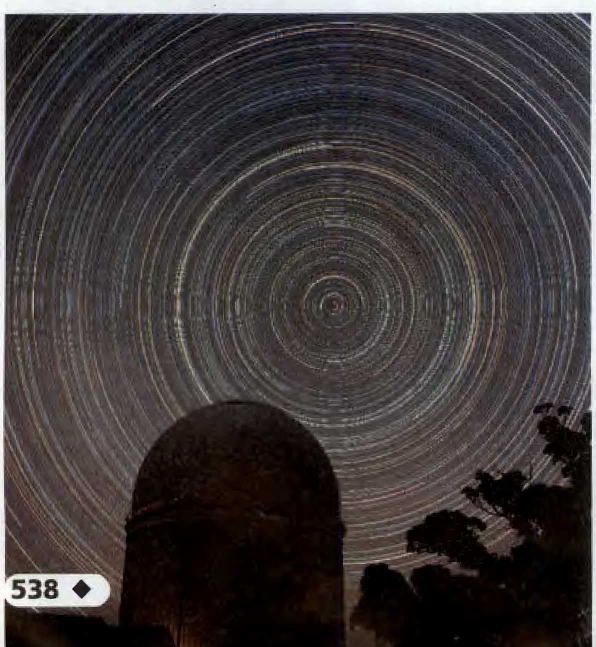


FIGURE 1
Star Trails
This photo was made by exposing the camera film for several hours. Each star trails along a circle, and all the stars seem to revolve around the North Star.

Earth at the Center

When the ancient Greeks watched the stars move across the sky, they noticed that the patterns of the stars didn't change. Although the stars seemed to move, they stayed in the same position relative to one another. These patterns of stars, called constellations, kept the same shapes from night to night and from year to year.

Greek Observations As the Greeks observed the sky, they noticed something surprising. Several points of light seemed to wander slowly among the stars. The Greeks called these objects *planets,* from the Greek word meaning "wanderers." The Greeks made careful observations of the motions of the planets that they could see. You know these planets by the names the ancient Romans later gave them: Mercury, Venus, Mars, Jupiter, and Saturn.

Most early Greek astronomers believed the universe to be perfect, with Earth at the center. The Greeks thought that Earth is inside a rotating dome they called the celestial sphere. Since *geo* is Greek for "Earth," an Earth-centered model is known as a **geocentric** (jee oh SEN trik) system. **In a geocentric system, Earth is at the center of the revolving planets and stars.**

Ptolemy's Model About A.D. 140, the Greek astronomer Ptolemy (TAHL uh mee) further developed the geocentric model. Like the earlier Greeks, Ptolemy thought that Earth is at the center of a system of planets and stars. In Ptolemy's model, however, the planets move on small circles that move on bigger circles.

Even though Ptolemy's geocentric model was incorrect, it explained the motions observed in the sky fairly accurately. As a result, the geocentric model of the universe was widely accepted for nearly 1,500 years after Ptolemy.

Reading Checkpoint What is a geocentric system?

FIGURE 2
Geocentric System
In a geocentric system, the planets and stars are thought to revolve around a stationary Earth. In the 1500s, an astronomy book published the illustration of Ptolemy's geocentric system shown below.
Interpreting Diagrams *Where is Earth located in each illustration?*

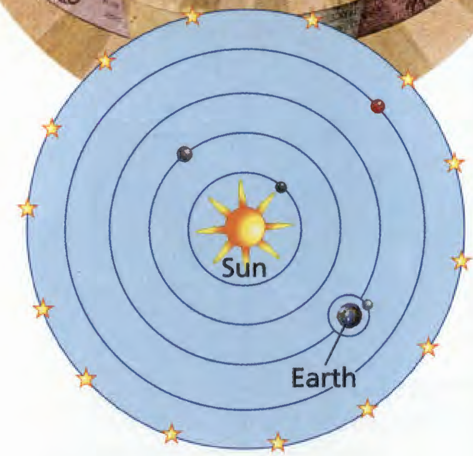


FIGURE 3
Heliocentric System
In a heliocentric system, Earth and the other planets revolve around the sun. The illustration by Andreas Cellarius (top) was made in the 1660s.
Interpreting Diagrams *In a heliocentric model, what revolves around Earth?*

Sun at the Center

Not everybody believed in the geocentric system. An ancient Greek scientist developed another explanation for the motion of the planets. This sun-centered model is called a **heliocentric** (hee lee oh SEN trik) system. **In a heliocentric system, Earth and the other planets revolve around the sun.** This model was not well received in ancient times, however, because people could not accept that Earth is not at the center of the universe.

The Copernican Revolution In 1543, the Polish astronomer Nicolaus Copernicus further developed the heliocentric model. **Copernicus worked out the arrangement of the known planets and how they move around the sun.** Copernicus's theory would eventually revolutionize the science of astronomy. But at first, many people were unwilling to accept his theory. In the 1500s and early 1600s, most people still believed in the geocentric model. However, evidence collected by the Italian scientist Galileo Galilei eventually proved that the heliocentric model was correct.

Galileo's Evidence **Galileo used the newly invented telescope to make discoveries that supported the heliocentric model.** For example, in 1610, Galileo used a telescope to discover four moons revolving around Jupiter. This proved that not every body in space revolves around Earth.

Galileo's observations of Venus also supported the heliocentric system. Galileo knew that Venus is always seen near the sun. He discovered that Venus goes through a series of phases similar to those of Earth's moon. But Venus would not have a full set of phases if it circled around Earth. Therefore, Galileo reasoned, the geocentric model must be incorrect.

Nicolaus Copernicus
1473–1543

Galileo Galilei
1564–1642

▼ A reconstruction of Galileo's telescope

FIGURE 4
Major Figures in the History of Astronomy

Motions of the Planets

Copernicus correctly placed the sun at the center of the planets. But he incorrectly assumed that the planets travel in orbits that are perfect circles. Copernicus had based his ideas on observations made by the ancient Greeks.

Tycho Brahe's Observations In the late 1500s, the Danish astronomer Tycho Brahe (TEE koh BRAH uh) and his assistants made much more accurate observations. For more than 20 years, they carefully observed and recorded the positions of the planets. Surprisingly, these observations were made without using a telescope. Telescopes had not yet been invented!

Kepler's First Law Tycho Brahe died in 1601. His assistant, Johannes Kepler, went to work analyzing the observations. **Kepler used Tycho Brahe's data to develop three laws that describe the motions of the planets.**

Kepler began by trying to figure out the shape of Mars's orbit. At first, he assumed that the orbit was a perfect circle. But his calculations did not fit the observations. Kepler eventually found out that Mars's orbit was a slightly flattened circle, or ellipse. An **ellipse** is an oval shape, which may be elongated or nearly circular.

After years of detailed calculations, Kepler reached a remarkable conclusion about the motion of the planets. Kepler found that the orbit of each planet is an ellipse. This is now known as Kepler's first law of motion. Kepler had used the evidence gathered by Tycho Brahe to disprove the long-held belief that the planets move in perfect circles.

Reading Checkpoint What is the heliocentric system?

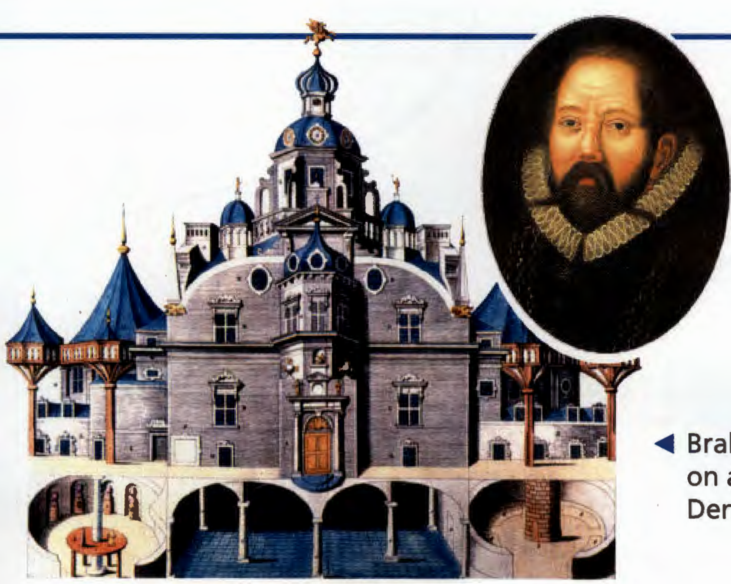
Lab zone Try This Activity

A Loopy Ellipse

You can draw an ellipse.

1. Carefully stick two pushpins about 10 cm apart through a sheet of white paper on top of corrugated cardboard. One pushpin represents the sun.
2. Tie the ends of a 30-cm piece of string together. Place the string around the pushpins.
3. Keeping the string tight, move a pencil around inside the string.
4. Now place the pushpins 5 cm apart. Repeat Step 3.

Predicting How does changing the distance between the pushpins affect the ellipse's shape? What shape would you draw if you used only one pushpin? Is the "sun" at the center of the ellipse?



Tycho Brahe
1546–1601

◀ Brahe's observatory on an island between Denmark and Sweden

Johannes Kepler
1571–1630

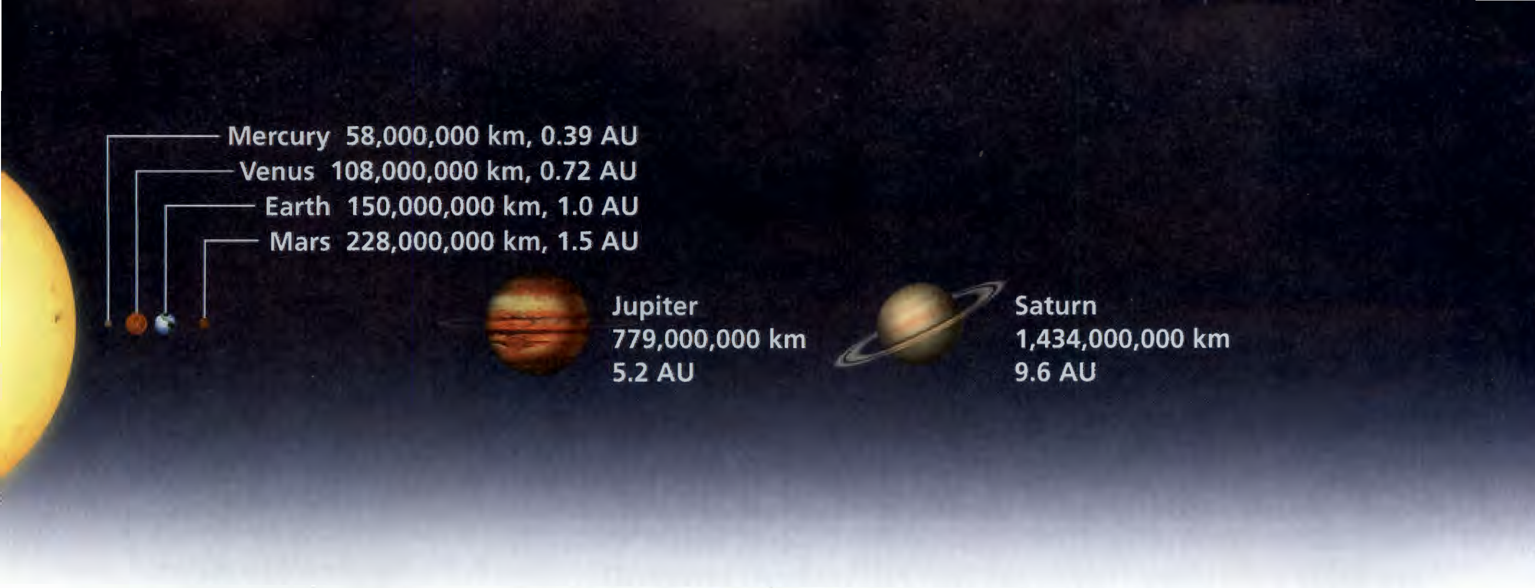


FIGURE 5
The Sun and Planets
This illustration shows the average distances of the planets from the sun. The solar system also includes smaller objects, such as Pluto. These distances are drawn to scale, but the sizes of the planets are not drawn to the same scale.
Observing *Which planet is closest to the sun?*

Kepler's Second Law Kepler also discovered how the speed of a given planet changes as it revolves around the sun. Kepler found that each planet moves faster when it is closer to the sun and slower when it is farther away from the sun. This is Kepler's second law of motion.

Kepler's Third Law Kepler also found that the time that it takes a planet to orbit the sun and its average distance from the sun are related. He found planets that are closer to the sun orbit the sun faster than planets that are farther from the sun. You can use Kepler's third law of motion to calculate a planet's average distance from the sun if you know how long it takes for the planet to complete one orbit.

Reviewing Math: Algebra and Functions 7.1.5

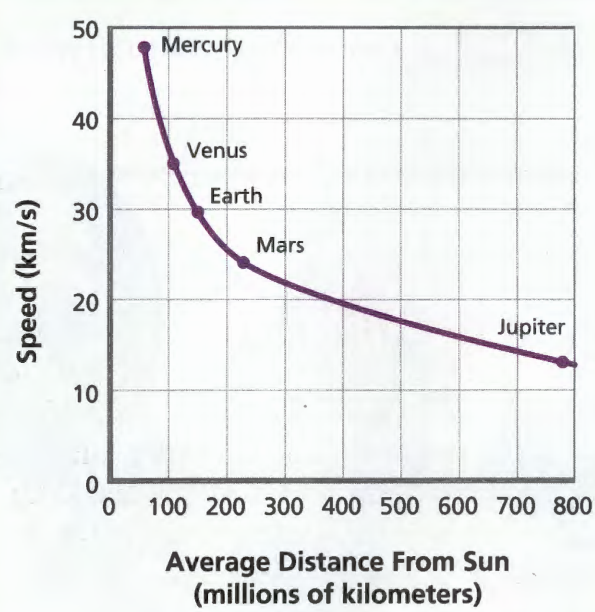
Math Analyzing Data

Planet Speed Versus Distance

Use the graph to help discover what Kepler learned about the relationship between the speed of a planet and its distance from the sun.

1. **Reading Graphs** According to the graph, what is Earth's average speed?
2. **Interpreting Data** Which is closer to the sun, Mercury or Mars? Which moves faster?
3. **Drawing Conclusions** What is the general relationship between a planet's speed and its average distance from the sun?
4. **Predicting** The planet Uranus is about 2,900 million km from the sun. Predict whether its speed is greater or less than Jupiter's speed. Explain your answer.

Speed of Planets



Modern View of the Solar System

Today, people talk about the "solar system" rather than the "Earth system." This shows that people accept the idea that Earth and the other planets revolve around the sun.

Components of the Solar System Since Galileo's time, our knowledge of the solar system has increased dramatically. Galileo knew the same planets that the ancient Greeks had known—Mercury, Venus, Earth, Mars, Jupiter, and Saturn. Since Galileo's time, astronomers have discovered two more planets—Uranus and Neptune, as well as Pluto, which is no longer considered to be a planet.

The planets vary greatly in size and appearance. They also differ in terms of mass, composition, distance from the sun, tilt of their axis, and other characteristics. Appendix D provides detailed data for each of the planets. All of the planets except Mercury and Venus have moons. A **moon** is a natural satellite that revolves around a planet. Astronomers have also identified many other objects in the solar system, such as comets and asteroids. **Today we know that the solar system consists of the sun, the planets and their moons, and several kinds of smaller objects that revolve around the sun.**

Measuring Distances in the Solar System The distances between the sun and the planets are very large compared to distances that are typically used on Earth. As a result, astronomers commonly describe distances within the solar system using astronomical units. One **astronomical unit**, or 1 AU, equals Earth's average distance from the sun (about 150 million kilometers). In Figure 5, you can see that Saturn's distance from the sun is 9.6 AU. This means that, on average, Saturn is 9.6 times farther from the sun than Earth.

Reading Checkpoint What is an astronomical unit?

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Lab zone Skills Activity

Calculating

If you know an object's distance from the sun in AU, you can convert this distance to kilometers by multiplying it by 150,000,000. (Recall that 1 AU ≈ 150 million km.)

For example, Ceres is the largest of a group of objects called asteroids. Ceres orbits the sun at an average distance of 2.77 AU. How far is Ceres from the sun in kilometers? Between the orbits of which two planets does Ceres' orbit lie? How far is Ceres' orbit from Earth's orbit in both AU and kilometers?

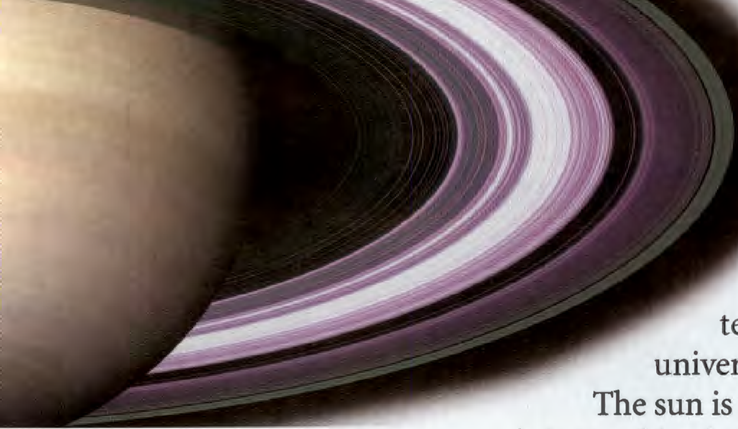

FIGURE 6
Saturn
This false-color image of Saturn and its rings was taken by the Cassini spacecraft, which is currently exploring Saturn and its moons.

Exploring the Solar System Galileo used a telescope to observe distant parts of the solar system from Earth's surface. Astronomers today still use telescopes located on Earth, but they have also placed telescopes in space to gain a better view of the universe beyond Earth.

The sun is the source of visible light in the solar system. You learned in the last chapter that the moon does not produce its own light. Rather, you can see the moon because its surface reflects sunlight. Similarly, the other planets and moons of the solar system don't produce their own light, although they do give off radiation in the form of heat. The planets and moons are visible because sunlight reflects from their surfaces.

In addition to observations made with telescopes, scientists have sent astronauts to the moon and launched numerous space probes to explore the far reaches of the solar system. Our understanding of the solar system continues to grow every day. Who knows what new discoveries will be made in your lifetime!

Section 1 Assessment

S 8.4.c, 8.4.d, ELA: Reading 8.1.2

Vocabulary Skill **Greek Word Origins** How does knowing Greek word origins help you remember the terms *geocentric* and *heliocentric?*

Reviewing Key Concepts

1. a. Explaining What are the geocentric and heliocentric systems?

b. Comparing and Contrasting How was Copernicus's model of the universe different from Ptolemy's model?

c. Drawing Conclusions What discoveries by Galileo support the heliocentric model?

d. Applying Concepts People often say the sun rises in the east, crosses the sky, and sets in the west. Is this literally true? Explain.

2. a. Interpreting Data How did Kepler use Tycho Brahe's data?

b. Describing What did Kepler discover about the shapes of the planets' orbits?

c. Inferring How did Tycho Brahe and Kepler employ the scientific method?

3. a. Describing What objects make up the solar system?

b. Listing What are the planets, in order of increasing distance from the sun?

c. Interpreting Diagrams Use Figure 5 to find the planet with the closest orbit to Earth.

Writing in Science

Dialogue Write an imaginary conversation between Ptolemy and Galileo about the merits of the geocentric and heliocentric systems. Which system would each scientist favor? What evidence could each offer to support his view? Do you think that one scientist could convince the other to change his mind? Use quotation marks around the comments of each scientist.

Section 2

The Sun

CALIFORNIA Standards Focus

S 8.2.g Students know the role of gravity in forming and maintaining the shapes of planets, stars, and the solar system.

S 8.4.b Students know that the Sun is one of many stars in the Milky Way galaxy and that stars may differ in size, temperature, and color.

- How does the sun produce energy?
- What are the layers of the sun's interior and the sun's atmosphere?
- What features form on or above the sun's surface?

Key Terms

- nuclear fusion
- core
- radiation zone
- convection zone
- photosphere
- chromosphere
- corona
- solar wind
- sunspot
- prominence
- solar flare

Lab zone **Standards Warm-Up**

How Can You Safely Observe the Sun?

1. Clamp a pair of binoculars to a ring stand as shown in the photo.
2. Cut a hole in a 20-cm by 28-cm sheet of thin cardboard so that it will fit over the binoculars, as shown in the photo. The cardboard should cover one lens, but allow light through the other lens. Tape the cardboard on securely.
3. Use the binoculars to project an image of the sun onto a sheet of white paper. The cardboard will shade the white paper. Change the focus and move the paper back and forth until you get a sharp image. **CAUTION:** *Never look directly at the sun. You will hurt your eyes if you do. Do not look up through the binoculars.*

Think It Over

Observing Draw what you see on the paper. What do you see on the surface of the sun?

Suppose you are aboard a spaceship approaching the solar system from afar. Your first impression of the solar system might be that it consists of a single star, the sun, with a few tiny objects orbiting around it.

Your first impression wouldn't be that far off. In fact, the sun accounts for 99.8 percent of the solar system's total mass. As a result of its huge mass, the sun exerts a powerful gravitational force throughout the solar system. Although this force decreases rapidly with distance, it is strong enough to hold all the planets and many other distant objects in orbit.

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Energy from the Sun

Unlike Earth, the sun does not have a solid surface. Rather, the sun is a huge ball of ionized gas, or plasma, throughout. About three-quarters of the sun's mass is hydrogen. About one-quarter of the sun's mass is helium. There are also small amounts of other elements.

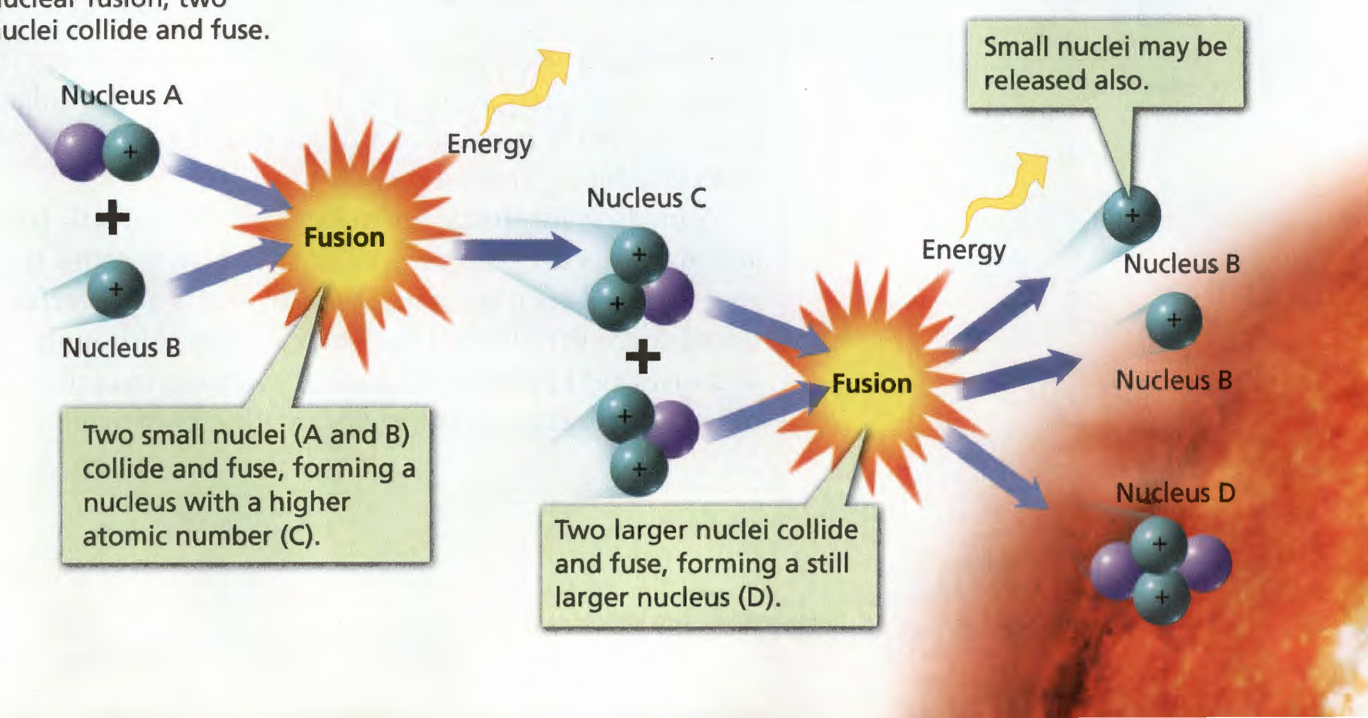
Nuclear Fusion The sun shines brightly, providing energy needed for life on Earth. But how is this energy produced? Early scientists hypothesized that the sun produced its energy through a chemical reaction, such as burning fuel. However, if this were the case, the sun would have lasted for just a few thousand years before its fuel ran out. Since the sun is actually about 4.6 billion years old, this hypothesis is clearly wrong.

In the early 1900s, scientists discovered the real source of the sun's energy. **The sun produces energy through nuclear fusion.** As shown in Figure 7, in the process of **nuclear fusion,** two atomic nuclei combine, forming a larger, more massive nucleus and releasing energy. Within the sun, hydrogen atoms join together to form helium.

Nuclear fusion can occur only under conditions of extremely high pressure and temperature. Such conditions exist in the sun's **core,** or central region. The temperature within the core reaches about 15 million degrees Celsius, high enough for nuclear fusion to take place.

The total mass of the helium produced by nuclear fusion is slightly less than the total mass of the hydrogen that goes into it. The missing mass is changed into energy. It moves slowly outward from the core, eventually escaping into space. Some of this energy reaches Earth, where you experience it as light and heat.

FIGURE 7
Nuclear Fusion
During nuclear fusion, two atomic nuclei collide and fuse.



Forces in Balance Nuclear fusion in the sun's core produces an incredible amount of energy. This energy causes gas ions within the sun to move very fast, generating a tremendous pressure pushing outward from the core. This pressure would cause the sun to explode if it weren't balanced by an equal and opposite force. This opposing force is the sun's own gravity, which pulls matter inward. The weight of matter pressing inward and the outward pushing pressure are balanced throughout the sun. As a result, the sun is stable. The sun will remain stable as long as there is a steady energy source within it. Astronomers estimate that the sun will be stable for another 5 billion years or so.

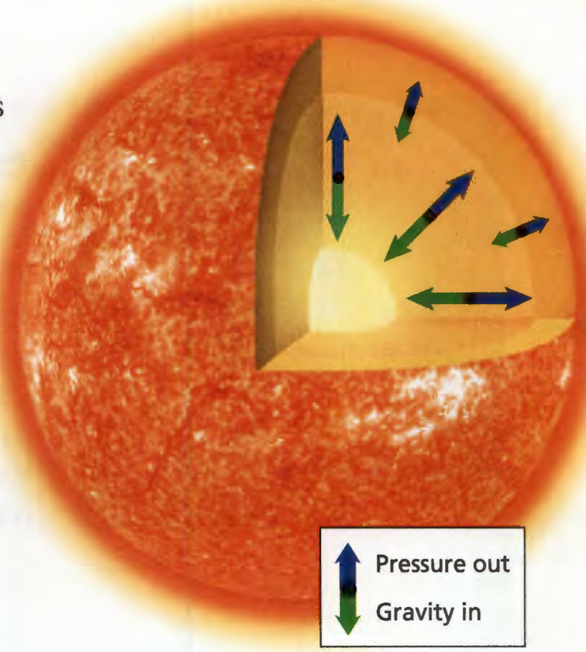


FIGURE 8
Forces Within the Sun
Gravity and outward pressure are balanced throughout the sun. These forces combine to produce the sun's spherical shape.
Interpreting Diagrams *In which region of the sun's interior is the force of gravity strongest?*

The Sun's Interior

Like Earth, the sun has an interior and an atmosphere. **The sun's interior consists of the core, the radiation zone, and the convection zone.**

The Core As you have learned, the sun's energy is produced in its central core. Here, the temperature and pressure are so high that nuclear fusion can take place. The sun's core has a diameter of about 400,000 km, more than 30 times Earth's diameter.

The Radiation Zone The energy produced in the sun's core moves outward through the middle layer of the sun's interior, the radiation zone. The **radiation zone** is a region of very tightly packed gas where energy is transferred mainly in the form of electromagnetic radiation. Because the radiation zone is so dense, energy can take more than 100,000 years to move through it.

The Convection Zone The **convection zone** is the outermost layer of the sun's interior. Hot gases rise from the bottom of the convection zone and gradually cool as they approach the top. Cooler gases sink, forming loops of gas that move energy toward the sun's surface.

Reading Checkpoint What is the convection zone?

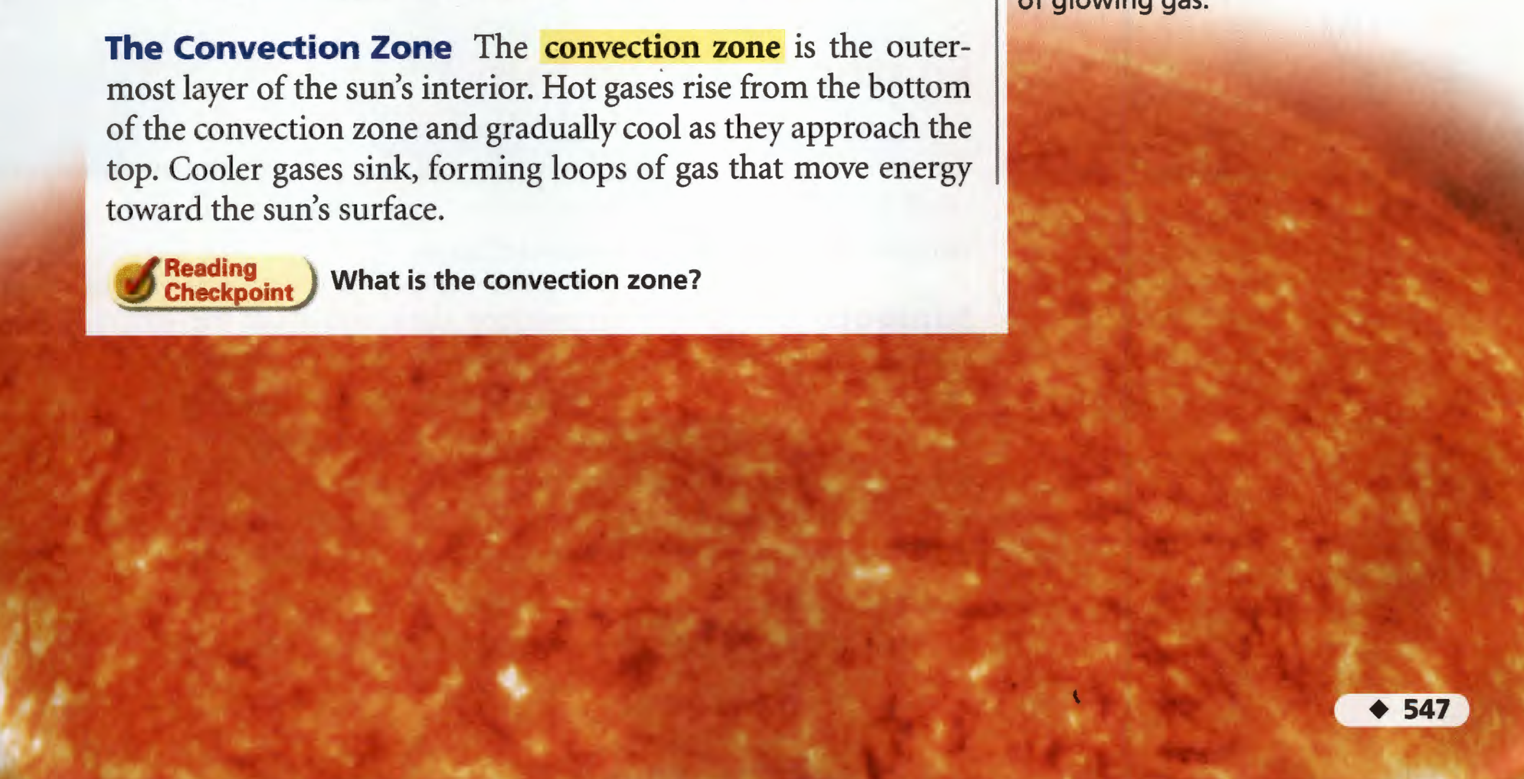


FIGURE 9
Active Sun
The sun is a huge, hot ball of glowing gas.

The Sun's Atmosphere

The sun's atmosphere includes the photosphere, the chromosphere, and the corona. Each layer has unique properties.

The Photosphere The inner layer of the sun's atmosphere is called the **photosphere** (FOH tuh sfeer). The Greek word *photos* means "light," so *photosphere* means the sphere that gives off visible light. The sun does not have a solid surface, but the gases of the photosphere are thick enough to be visible. When you look at a typical image of the sun, you are looking at the photosphere. It is considered to be the sun's surface layer.

The Chromosphere During a total solar eclipse, the moon blocks light from the photosphere. The photosphere no longer produces the glare that keeps you from seeing the sun's faint, outer layers. At the start and end of a total eclipse, a reddish glow is visible just around the photosphere. This glow comes from the middle layer of the sun's atmosphere, the **chromosphere** (KROH muh sfeer). The Greek word *chroma* means "color," so the chromosphere is the "color sphere."

The Corona During a total solar eclipse an even fainter layer of the sun becomes visible, as you can see in Figure 10. This outer layer, which looks like a white halo around the sun, is called the **corona**, which means "crown" in Latin. The corona extends into space for millions of kilometers. It gradually thins into streams of electrically charged particles called the **solar wind.**

FIGURE 10
The Sun's Corona
During a total solar eclipse, you can see light from the corona, the outer layer of the sun's atmosphere, around the dark disk of the moon.

Reading Checkpoint During what event could you see the sun's corona?

Features on the Sun

For hundreds of years, scientists have used telescopes to study the sun. They have spotted a variety of features on the sun's surface. **Features on or just above the sun's surface include sunspots, prominences, and solar flares.**

Sunspots Early observers noticed dark spots on the sun's surface. These became known as sunspots. Sunspots look small. But in fact, they can be larger than Earth. **Sunspots** are areas of gas on the sun's surface that are cooler than the gases around them. Cooler gases don't give off as much light as hotter gases, which is why sunspots look darker than the rest of the photosphere. Sunspots seem to move across the sun's surface, showing that the sun rotates on its axis, just as Earth does. The number of sunspots on the sun varies over a period of about 11 years.

Lab zone Try This **Activity**

Viewing Sunspots

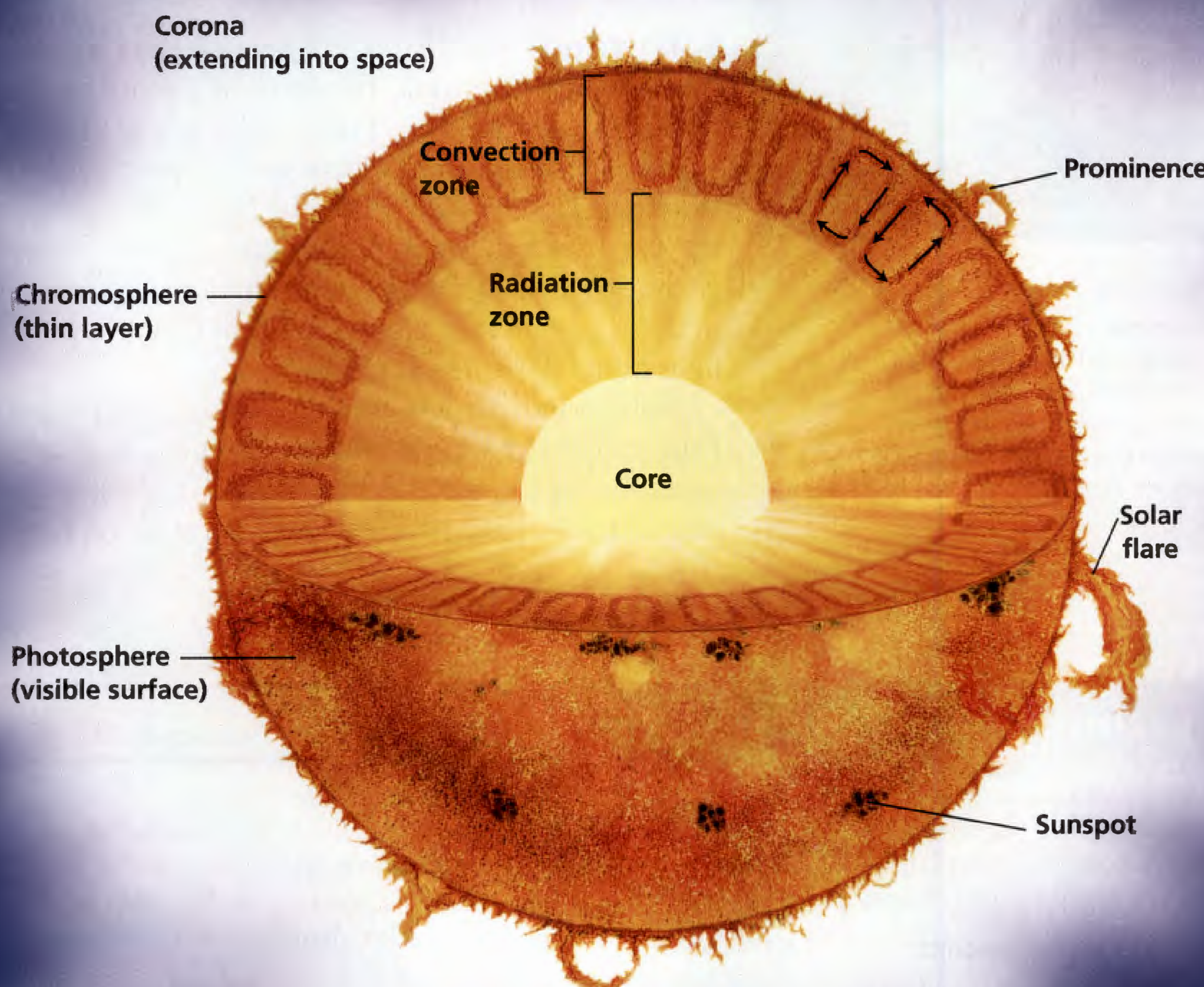
You can observe changes in the number of sunspots.

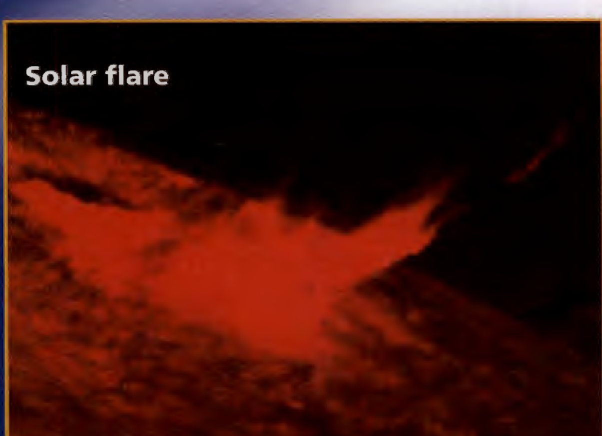
1. Make a data table to record the number of sunspots you see each day.
2. Decide on a time to study sunspots each day.
3. View the sun's image in the way described in the Discover activity in this section. **CAUTION:** *Never look directly at the sun. You will hurt your eyes if you do.*
4. Make and record your observations.

Interpreting Data How much did the number of sunspots change from day to day?

FIGURE 11
The Layers of the Sun

The sun has an interior and an atmosphere, each of which consists of several layers. The diameter of the sun (not including the chromosphere and the corona) is about 1.4 million kilometers. **Interpreting Diagrams** *Name the layers of the sun's interior, beginning at its center.*





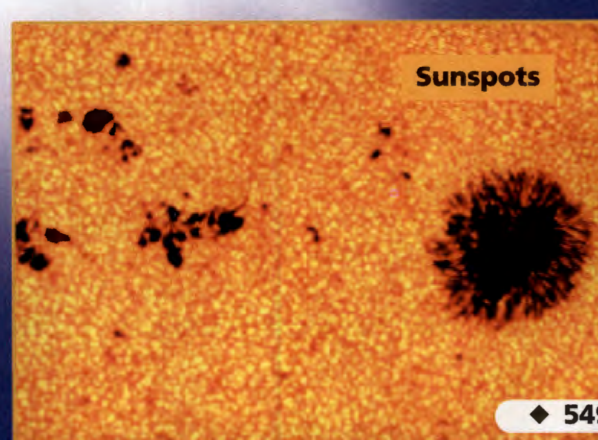


FIGURE 12
Auroras
Auroras such as this can occur near Earth's poles when particles of the solar wind strike gas molecules in Earth's upper atmosphere.

Prominences Sunspots usually occur in groups. Huge, reddish loops of gas called **prominences** often link different parts of sunspot regions. When a group of sunspots is near the edge of the sun as seen from Earth, these loops can be seen extending over the edge of the sun.

Solar Flares Sometimes the loops in sunspot regions suddenly connect, converting large amounts of magnetic energy into thermal energy. The energy heats gas on the sun to millions of degrees Celsius, causing the gas to erupt into space. These eruptions are called **solar flares.**

Solar Wind Solar flares can greatly increase the solar wind from the corona, resulting in an increase in the number of particles reaching Earth's upper atmosphere. Normally, Earth's atmosphere and magnetic field block these particles. However, near the North and South poles, the particles can enter Earth's atmosphere, where they create powerful electric currents that cause gas molecules in the atmosphere to glow. The result is rippling sheets of light in the sky called auroras.

Solar wind particles can also affect Earth's magnetic field, causing magnetic storms. Magnetic storms sometimes disrupt radio, telephone, and television signals. Magnetic storms can also cause electrical power problems.

Reading Checkpoint **What is a prominence?**

Section 2 Assessment

S 8.2.g, 8.4.b,
E-LA: Reading 8.1.2

Vocabulary Skill **Greek Word Origins** Use Greek word origins to explain the difference between *photosphere* and *chromosphere.*

Reviewing Key Concepts

1. a. **Defining** What is nuclear fusion?
   b. **Explaining** Where is the sun's energy produced?
   c. **Sequencing** Describe the steps involved in the process of nuclear fusion within the sun.
2. a. **Listing** List the layers of the sun's interior and atmosphere, starting from the center.
   b. **Identifying** Which of the sun's layers produces its visible light?
   c. **Relating Cause and Effect** Why is it usually impossible to see the sun's corona from Earth?
3. a. **Describing** Describe three features found on or just above the sun's surface.
   b. **Relating Cause and Effect** Why do sunspots look darker than the rest of the sun's photosphere?

Lab zone **At-Home Activity**

Sun Symbols As the source of heat and light, the sun is an important symbol in many cultures. With family members, look around your home and neighborhood for illustrations of the sun on signs, flags, clothing, and in artwork. Which parts of the sun's atmosphere do the illustrations show?

Lab zone **Skills Lab**

Stormy Sunspots

S 8.4, 8.9.e

Problem

How are magnetic storms on Earth related to sunspot activity?

Skills Focus

graphing, interpreting data

Materials

- graph paper
- ruler

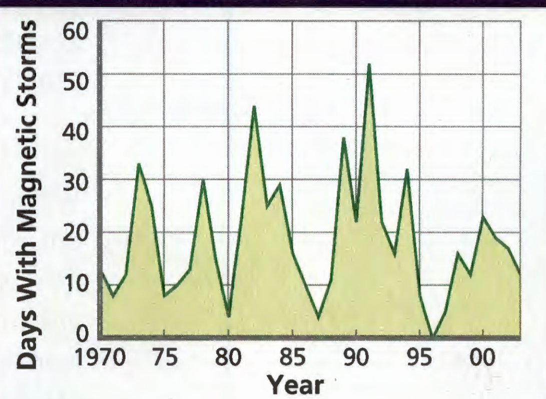
Procedure

1. Use the data in the table of Annual Sunspot Numbers to make a line graph of sunspot activity between 1972 and 2002.
2. On the graph, label the *x*-axis "Year." Use a scale with 2-year intervals, from 1972 to 2002.
3. Label the *y*-axis "Sunspot Number." Use a scale of 0 through 160 in intervals of 10.
4. Graph a point for the Sunspot Number for each year.
5. Complete your graph by drawing lines to connect the points.

Annual Sunspot Numbers

Year	Sunspot Number	Year	Sunspot Number
1972	68.9	1988	100.2
1974	34.5	1990	142.6
1976	12.6	1992	94.3
1978	92.5	1994	29.9
1980	154.6	1996	8.6
1982	115.9	1998	64.3
1984	45.9	2000	119.6
1986	13.4	2002	104.0

Magnetic Storm Days



Analyze and Conclude

1. **Graphing** Based on your graph, which years had the highest Sunspot Number? The lowest Sunspot Number?
2. **Interpreting Data** How often does the cycle of maximum and minimum activity repeat?
3. **Interpreting Data** When was the most recent maximum sunspot activity? The most recent minimum sunspot activity?
4. **Inferring** Compare your sunspot graph with the magnetic storms graph. What relationship can you infer between periods of high sunspot activity and magnetic storms? Explain.
5. **Communicating** Suppose you are an engineer working for an electric power company. Write a brief summary of your analysis of sunspot data. Explain the relationship between sunspot number and electrical disturbances on Earth.

More to Explore

Using the pattern of sunspot activity you found, predict the number of peaks you would expect in the next 30 years. Around which years would you expect the peaks to occur?

Section 3

The Inner Planets

CALIFORNIA Standards Focus

S 8.4.e Students know the appearance, general composition, relative position and size, and motion of objects in the solar system, including planets, planetary satellites, comets, and asteroids.

What characteristics do the inner planets have in common?

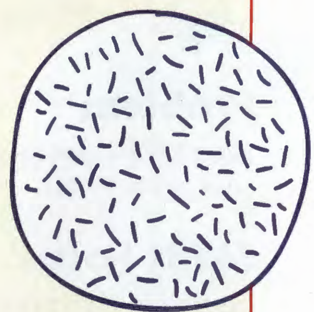
What are the main characteristics that distinguish each of the inner planets?

Key Terms

- terrestrial planets
- greenhouse effect

Lab zone **Standards Warm-Up**

How Does Mars Look From Earth?



1. Work in pairs. On a sheet of paper, draw a circle 20 cm across to represent Mars. Draw about 100 small lines, each about 1 cm long, at random places inside the circle.
2. Have your partner look at your drawing of Mars from the other side of the room. Your partner should draw what he or she sees.
3. Compare your original drawing with what your partner drew. Then look at your own drawing from across the room.

Think It Over

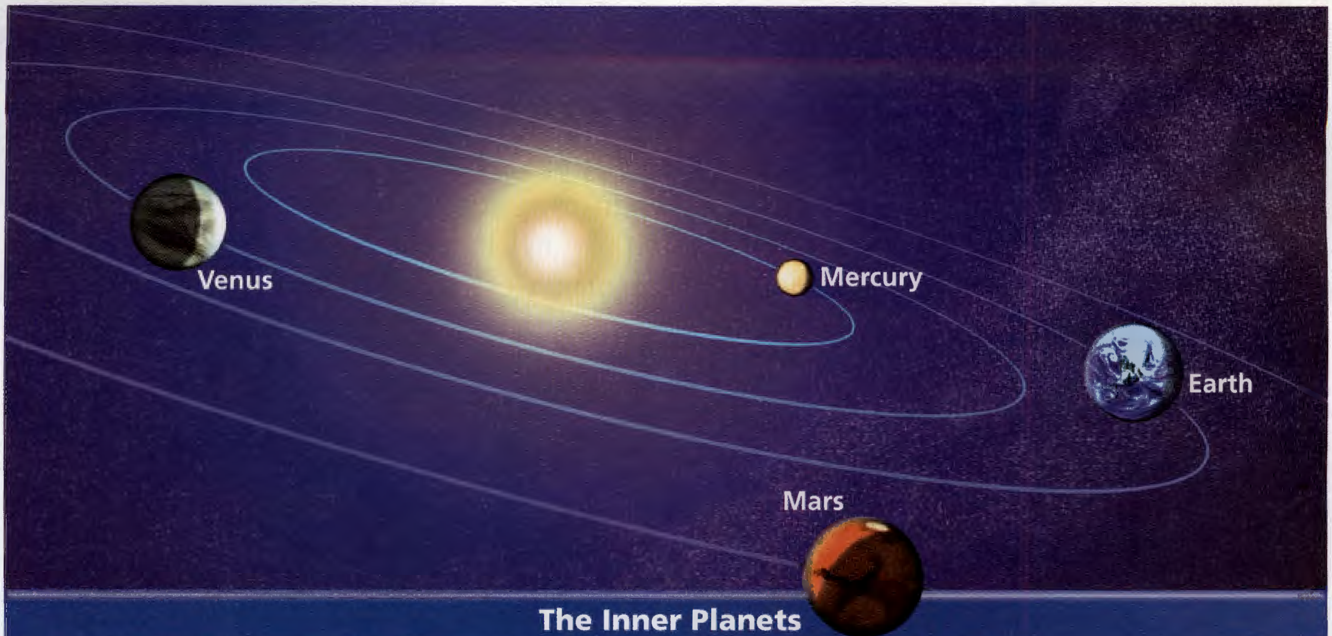
Observing Did your partner draw any connecting lines that were not actually on your drawing? What can you conclude about the accuracy of descriptions of other planets based on observations from Earth?

Where could you find a planet whose atmosphere has almost entirely leaked away into space? How about a planet whose surface is hot enough to melt lead? And how about a planet with volcanoes higher than any on Earth? Finally, where could you find a planet with oceans of water brimming with fish and other life? These are descriptions of the four planets closest to the sun, known as the inner planets.

Earth and the three other inner planets—Mercury, Venus, and Mars—are more similar to each other than they are to the five outer planets. **The four inner planets are small and dense and have rocky surfaces.** The inner planets are often called the **terrestrial planets,** from the Latin word *terra,* which means "Earth." Figure 13 summarizes data about the inner planets.

Earth

As you can see in Figure 14, Earth has three main layers—a crust, a mantle, and a core. The crust includes the solid, rocky surface. Under the crust is the mantle, a layer of hot molten rock. When volcanoes erupt, this hot material rises to the surface. Earth has a dense core made of mainly iron and nickel. The outer core is liquid, but the inner core is solid.



The Inner Planets

Planet	Size (kilometers)		Period of Rotation (Earth days)	Average Distance From Sun (AU)	Period of Revolution (Earth years)	Number of Moons
	Diameter	Radius				
Mercury	4,879	2,440	59	0.39	0.24	0
Venus	12,104	6,052	243	0.72	0.62	0
Earth	12,756	6,378	1	1.0	1	1
Mars	6,794	3,397	1.03	1.5	1.9	2

FIGURE 13
The inner planets take up only a small part of the solar system. Note that sizes and distances are not drawn to scale.

Water **Earth is unique in our solar system in having liquid water at its surface.** In fact, most of Earth's surface, about 70 percent, is covered with water. Perhaps our planet should be called "Water" instead of "Earth"! Earth has a suitable temperature range for water to exist as a liquid, gas, or solid. Water is important in shaping Earth's surface, wearing it down and changing its appearance over time.

Atmosphere Earth has enough gravity to hold on to most gases. These gases make up Earth's atmosphere, which extends more than 100 kilometers above its surface. Other planets in the solar system have atmospheres too, but only Earth has an atmosphere that is rich in oxygen. The oxygen you need to live makes up about 20 percent of Earth's atmosphere. Nearly all the rest is nitrogen, with small amounts of other gases such as argon and carbon dioxide. The atmosphere also includes varying amounts of water in the form of a gas. Water in a gaseous form is called water vapor.

Reading Checkpoint **What two gases make up most of Earth's atmosphere?**

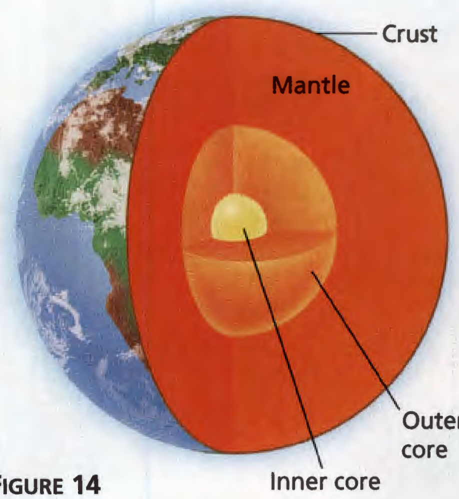
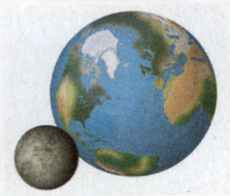


FIGURE 14
Earth's Layers
Earth has a solid, rocky surface.
Interpreting Diagrams *What are Earth's three main layers?*



Size of Mercury compared to Earth

Mercury

Mercury is the smallest terrestrial planet and the planet closest to the sun. Mercury is not much larger than Earth's moon and has no moons of its own. The interior of Mercury is probably made up mainly of the dense metal iron.

Exploring Mercury Because Mercury is so close to the sun, it is hard to see from Earth. Much of what astronomers know about Mercury's surface came from a single probe, *Mariner 10.* It flew by Mercury three times in 1974 and 1975. Two new missions to Mercury are planned. The first of these, called *MESSENGER*, is scheduled to go into orbit around Mercury in 2011.

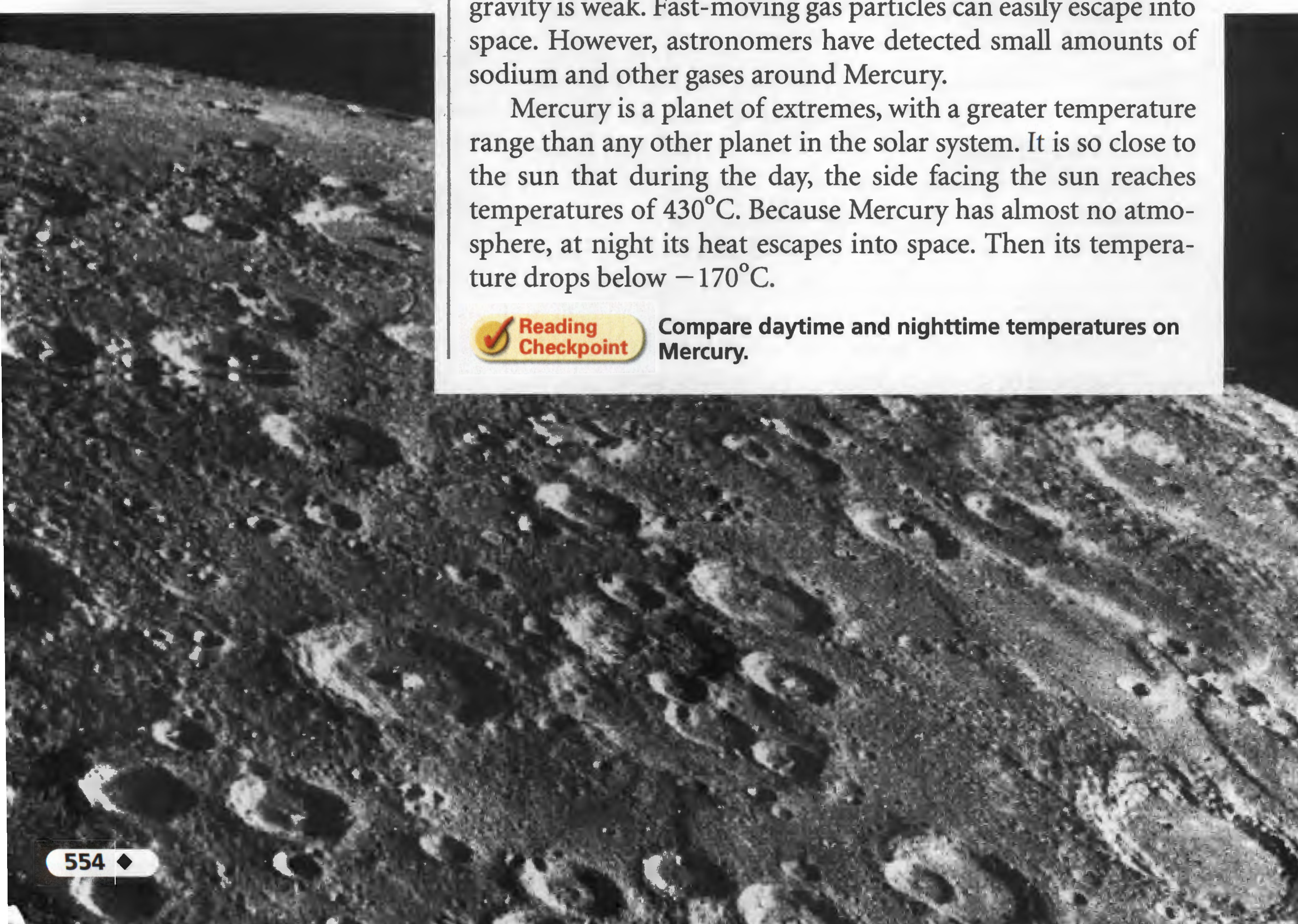
Mariner 10's photographs show that Mercury has many flat plains and craters on its surface. The large number of craters shows that Mercury's surface has changed little for billions of years. Many of Mercury's craters have been named for artists, writers, and musicians, such as the composers Bach and Mozart.

Mercury's Atmosphere Mercury has virtually no atmosphere. Mercury's high daytime temperatures cause gas particles to move very fast. Because Mercury's mass is small, its gravity is weak. Fast-moving gas particles can easily escape into space. However, astronomers have detected small amounts of sodium and other gases around Mercury.

Mercury is a planet of extremes, with a greater temperature range than any other planet in the solar system. It is so close to the sun that during the day, the side facing the sun reaches temperatures of 430°C. Because Mercury has almost no atmosphere, at night its heat escapes into space. Then its temperature drops below −170°C.

Reading Checkpoint **Compare daytime and nighttime temperatures on Mercury.**

FIGURE 15
Mercury
This image of Mercury was produced by combining a series of smaller images made by the *Mariner 10* space probe.
Interpreting Photographs *How is Mercury's surface different from Earth's?*



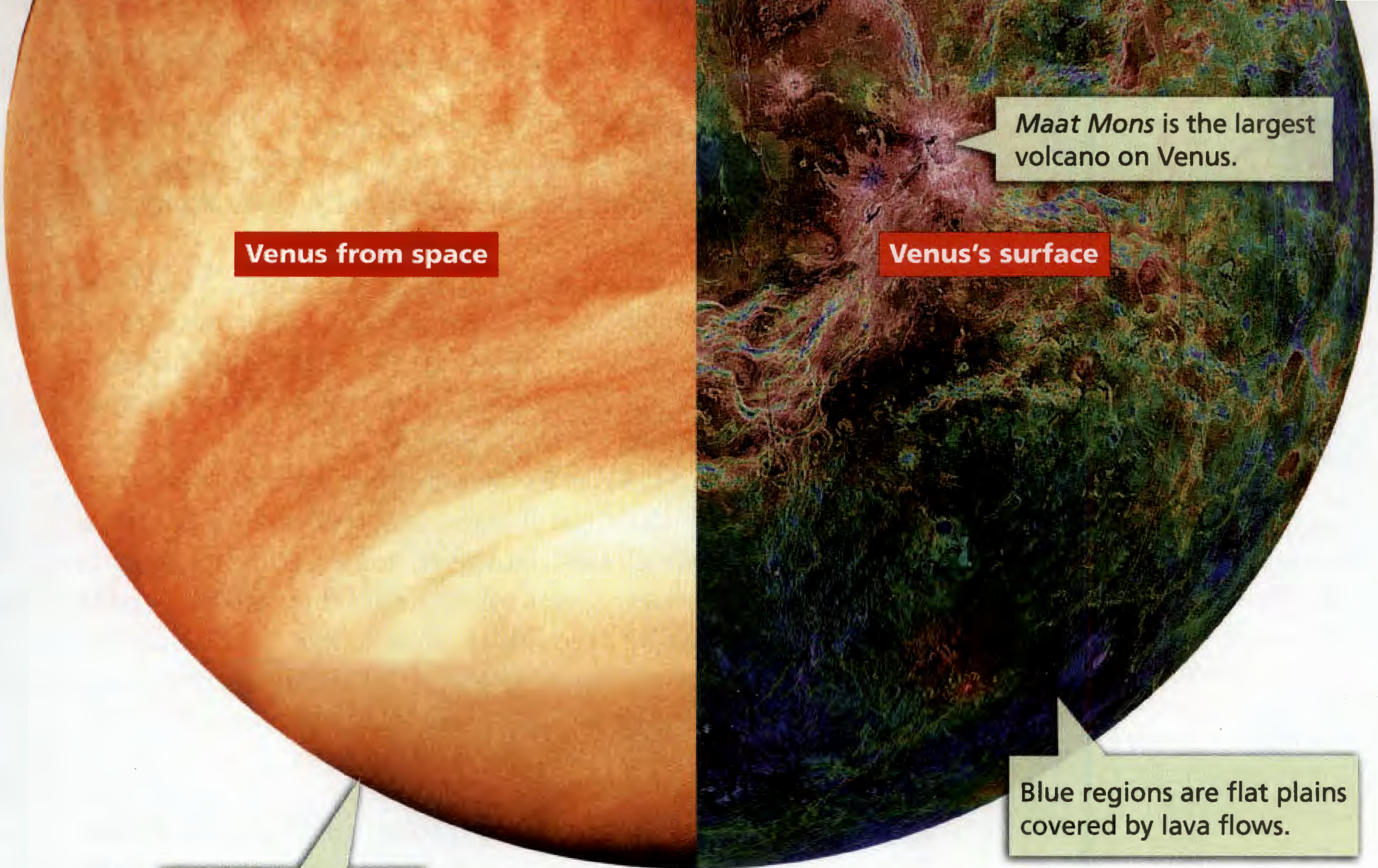


FIGURE 16
Venus
This figure combines images of Venus taken from space with a camera (left) and radar (right). The camera image shows Venus's thick atmosphere. Radar is able to penetrate Venus's clouds to reveal the surface. Both images are false color.

Venus

You can sometimes see Venus in the west just after sunset. When Venus is visible in that part of the sky, it is known as the "evening star," though of course it really isn't a star at all. At other times, Venus rises in the east before the sun in the morning. Then it is known as the "morning star."

Venus is so similar in size and mass to Earth that it is sometimes called "Earth's twin." **Venus's density and internal structure are similar to Earth's. But, in other ways, Venus and Earth are very different.**

Size of Venus compared to Earth

Venus's Rotation Venus takes about 7.5 Earth months to revolve around the sun. It takes about 8 months for Venus to rotate once on its axis. Thus, Venus rotates so slowly that its day is longer than its year! Oddly, Venus rotates from east to west, the opposite direction from most other planets and moons. Astronomers hypothesize that this unusual rotation was caused by a very large object that struck Venus billions of years ago. Such a collision could have caused Venus to change its direction of rotation. Another hypothesis is that Venus's thick atmosphere could have somehow altered its rotation.

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Lab zone Try This Activity

Greenhouse Effect

How can you measure the effect of a closed container on temperature?

1. Carefully place a thermometer into each of two glass jars. Cover one jar with cellophane. Place both jars either in direct sunlight or under a strong light source.
2. Observe the temperature of both thermometers when you start. Check the temperatures every 5 minutes for a total of 20 minutes. Record your results in a data table.

Inferring Compare how the temperature changed in the uncovered jar and the covered jar. What do you think is the reason for any difference in the temperatures of the two jars? Which jar is a better model of Venus's atmosphere?

Venus's Atmosphere Venus's atmosphere is so thick that it is always cloudy there. From Earth or space, astronomers can see only a smooth cloud cover over Venus. The clouds are made mostly of droplets of sulfuric acid.

If you could stand on Venus's surface, you would quickly be crushed by the weight of its atmosphere. The pressure of Venus's atmosphere is 90 times greater than the pressure of Earth's atmosphere. You couldn't breathe on Venus because its atmosphere is mostly carbon dioxide.

Because Venus is closer to the sun than Earth is, it receives more solar energy than Earth does. Much of this radiation is reflected by Venus's clouds. However, some radiation reaches the surface and is later given off as heat. The carbon dioxide in Venus's atmosphere traps heat so well that Venus has the hottest surface of any planet. At 460°C, its average surface temperature is hot enough to melt lead. This trapping of heat by the atmosphere is called the **greenhouse effect**.

Exploring Venus Many space probes have visited Venus. The first probe to land on the surface and send back data, *Venera 7*, landed in 1970. It survived for only a few minutes because of the high temperature and pressure. Later probes were more durable and sent images and data back to Earth.

The *Magellan* probe reached Venus in 1990, carrying radar instruments. Radar works through clouds, so *Magellan* was able to map nearly the entire surface. The *Magellan* data confirmed that Venus is covered with rock. Venus's surface has many volcanoes and broad plains formed by lava flows.

Reading Checkpoint **What are Venus's clouds made of?**

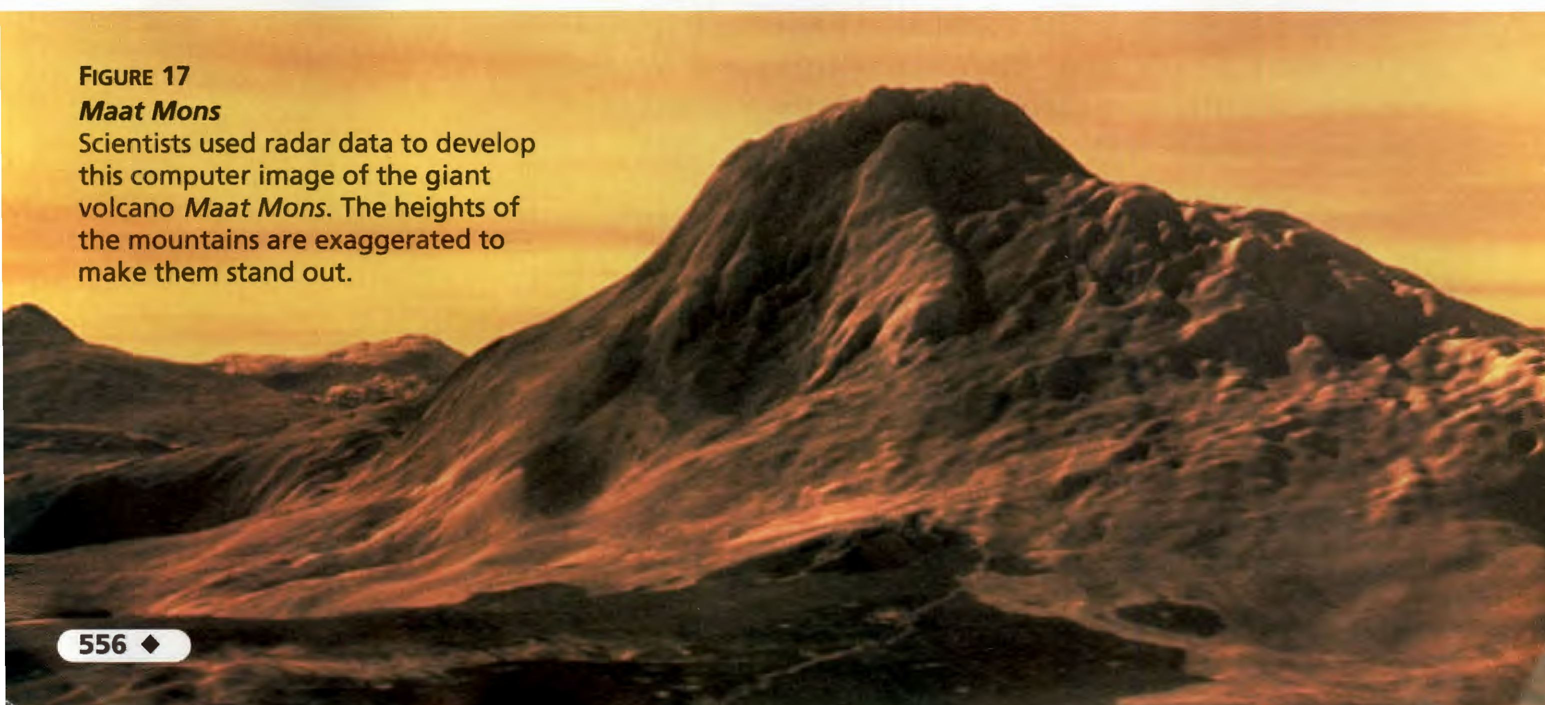


FIGURE 17
Maat Mons
Scientists used radar data to develop this computer image of the giant volcano *Maat Mons*. The heights of the mountains are exaggerated to make them stand out.

Mars

Mars is called the "red planet." When you see it in the sky, it has a slightly reddish tinge. This reddish color is due to the breakdown of iron-rich rocks, which creates a rusty dust that covers much of Mars's surface.

Size of Mars compared to Earth

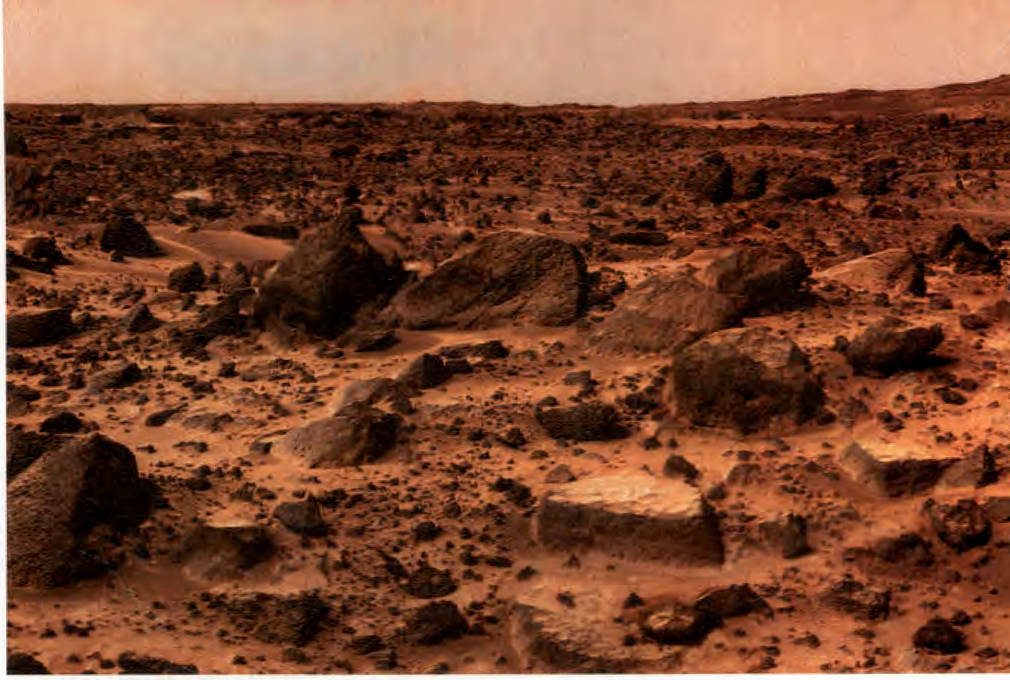
Mars's Atmosphere The atmosphere of Mars is more than 95 percent carbon dioxide. It is similar in composition to Venus's atmosphere, but much thinner. You could walk around on Mars, but you would have to wear an airtight suit and carry your own oxygen, like a scuba diver. Mars has few clouds, and they are very thin compared to clouds on Earth. Mars's transparent atmosphere allows people on Earth to view its surface with a telescope. Temperatures on the surface range from –140°C to 20°C.

Water on Mars In 1877, an Italian astronomer named Giovanni Schiaparelli (sky ah puh REL ee) announced that he had seen long, straight lines on Mars. He called them *canale*, or channels. In the 1890s and early 1900s, Percival Lowell, an American astronomer, convinced many people that these lines were canals that had been built by intelligent Martians to carry water. Astronomers now know that Lowell was mistaken. There are no canals on Mars.

Images of Mars taken from space do show a variety of features that look as if they were made by ancient streams, lakes, or floods. There are huge canyons and features that look like the remains of ancient coastlines. **Scientists think that a large amount of liquid water flowed on Mars's surface in the distant past.** Scientists infer that Mars must have been much warmer and had a thicker atmosphere at that time.

At present, liquid water cannot exist for long on Mars's surface. Mars's atmosphere is so thin that any liquid water would quickly turn into a gas. So where is Mars's water now? Some of it is located in the planet's two polar ice caps, which contain frozen water and carbon dioxide. A small amount also exists as water vapor in Mars's atmosphere. Some water vapor has probably escaped into space. But scientists think that a large amount of water may still be frozen underground.

FIGURE 18
Mars
Because of its thin atmosphere and its distance from the sun, Mars is quite cold. Mars has ice caps at both poles. **Inferring** *Why is it easy to see Mars's surface from space?*



Video Field Trip
Discovery Channel School
The Solar System

Lab zone Try This **Activity**

Remote Control

How hard is it to explore another planet by remote control?

1. Tape a piece of paper over the front of a pair of goggles. Have your partner put them on.
2. Walk behind your partner and direct him or her to another part of the room. **CAUTION:** *Do not give directions that would cause your partner to walk into a wall or a corner, trip on an obstacle, or bump into anything.*
3. Trade places and repeat Steps 1 and 2.

Drawing Conclusions Which verbal directions worked best? How quickly could you move? How is this activity similar to the way engineers have moved rovers on Mars? How fast do you think such a rover could move?

Seasons on Mars Because Mars has a tilted axis, it has seasons just as Earth does. During the Martian winter, an ice cap grows larger as a layer of frozen carbon dioxide covers it. Because the northern and southern hemispheres have opposite seasons, one ice cap grows while the other one shrinks.

As the seasons change on the dusty surface of Mars, windstorms arise and blow the dust around. Since the dust is blown off some regions, these regions look darker. A hundred years ago, some people thought these regions looked darker because plants were growing there. Astronomers now realize that the darker color is often just the result of windstorms.

Exploring Mars Many space probes have visited Mars. The first ones seemed to show that Mars is barren and covered with craters like the moon. Recently, two new probes landed on Mars's surface. NASA's *Spirit* and *Opportunity* rovers explored opposite sides of the planet. They examined a variety of rocks and soil samples. At both locations, the rovers found strong evidence that liquid water was once present. The European Space Agency's *Mars Express* probe orbited overhead, finding clear evidence of frozen water (ice). However, the *Mars Express* lander failed.

Volcanoes on Mars Some regions of Mars have giant volcanoes. Astronomers see signs that lava flowed from the volcanoes in the past, but the volcanoes are not currently active. However, volcanic eruptions may have occurred in some areas within the past few million years. *Olympus Mons* on Mars is the largest volcano in the solar system. It covers a region as large as the state of Missouri and is nearly three times as tall as Mount Everest, the tallest mountain on Earth!

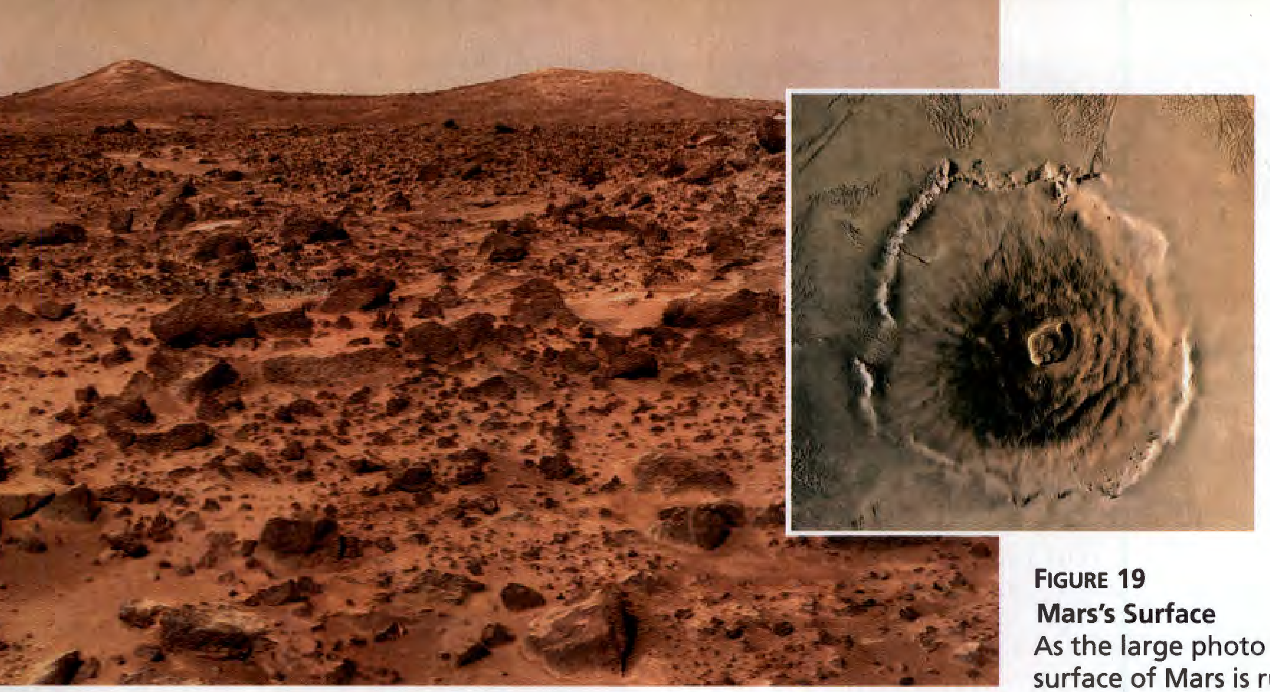


FIGURE 19
Mars's Surface
As the large photo shows, the surface of Mars is rugged and rocky. Mars has many large volcanoes. The volcano *Olympus Mons* (inset) rises about 27 km from the surface. It is the largest volcano in the solar system.

Mars's Moons Mars has two very small, oddly-shaped moons. Phobos, the larger moon, is only 27 kilometers in diameter, about the distance a car can travel on the highway in 20 minutes. Deimos is even smaller, only 15 kilometers in diameter. Like Earth's moon, Phobos and Deimos are covered with craters. Phobos, which is much closer to Mars than Deimos is, is slowly spiraling down toward Mars. Astronomers predict that Phobos will smash into Mars in about 40 million years.

Reading Checkpoint How many moons does Mars have? What are their names?

Section 3 Assessment

S 8.4.e, ELA: Writing 8.2.0, Reading 8.2.0

Target Reading Skill **Create Outlines** Use your outline of this section to help answer the following questions.

Reviewing Key Concepts

1. a. **Listing** List the four inner planets in order of size, from smallest to largest.
   b. **Comparing and Contrasting** How are the four inner planets similar to one another?
2. a. **Describing** Describe an important characteristic of each inner planet.
   b. **Comparing and Contrasting** Compare the atmospheres of the four inner planets.
   c. **Relating Cause and Effect** Venus is much farther from the sun than Mercury is. Yet average temperatures on Venus's surface are much higher than those on Mercury. Explain why.

Writing in Science

Travel Brochure Select one of the inner planets other than Earth. Design a travel brochure for your selected planet, including basic facts and descriptions of places of interest. Also include a few sketches or photos to go along with your text.

Science and
Society

S 8.4.d, 8.4.e

Space Exploration—Is It Worth the Cost?

Imagine that your spacecraft has just landed on the moon or on Mars. You've spent years planning for this moment. Canyons, craters, plains, and distant mountains stretch out before you. Perhaps a group of scientists has already begun construction of a permanent outpost. You check your spacesuit and prepare to step out onto the rocky surface.

Is such a trip likely? Would it be worthwhile? How much is space flight really worth to human society? Scientists and public officials have already started to debate such questions. Space exploration can help us learn more about the universe. But exploration can be risky and expensive. Sending people into space costs billions of dollars and risks the lives of astronauts. How can we balance the costs and benefits of space exploration?

Moon Landing
A rocket is preparing to dock with a lander on the moon's surface in this imaginative artwork.

The Issues

Should Humans Travel Into Space?

Many Americans think that Neil Armstrong's walk on the moon in 1969 was one of the great moments in history. Learning how to keep people alive in space has led to improvements in everyday life. Safer equipment for firefighters, easier ways to package frozen food, and effective heart monitors have all come from space program research.

What Are the Alternatives?

Space exploration can involve a project to establish a colony on the moon or Mars. It also can involve a more limited use of scientific instruments near Earth, such as the Hubble Space Telescope. Instead of sending people, we could send space probes like *Cassini* to other planets.

◀ **Lunar Outpost**
A mining operation on the moon is shown in this imaginative artwork. Such a facility may someday harvest oxygen from the moon's soil.

◀ **Lunar Module**
This artwork shows a futuristic vehicle that may one day be used to explore the moon and Mars. The vehicle serves as a combination lander, rover, and habitat for astronauts.

Is Human Space Exploration Worth the Cost?

Scientists who favor human travel into space say that only people can collect certain kinds of information. They argue that the technologies developed for human space exploration will have many applications on Earth. But no one knows if research in space really provides information more quickly than research that can be done on Earth. Many critics of human space exploration think that other needs are more important. One United States senator said, "Every time you put money into the space station, there is a dime that won't be available for our children's education or for medical research."

You Decide

1. Identify the Problem
In your own words, list the various costs and benefits of space exploration.

2. Analyze the Options
Make a chart of three different approaches to space exploration: sending humans to the moon or another planet, doing only Earth-based research, and one other option. What are the benefits and drawbacks of each of these approaches?

3. Find a Solution
Imagine that you are a member of Congress who has to vote on a new budget. There is a fixed amount of money to spend, so you have to decide which needs are most important. Make a list of your top ten priorities. Explain your decisions.

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Section 4

The Outer Planets

CALIFORNIA Standards Focus

S 8.4.e Students know the appearance, general composition, relative position and size, and motion of objects in the solar system, including planets, planetary satellites, comets, and asteroids.

- What characteristics do the gas giants have in common?
- What characteristics distinguish each of the outer planets?

Key Terms

- gas giant
- ring

Lab zone **Standards Warm-Up**

How Big Are the Planets?

The table shows the diameters of the outer planets compared to Earth. For example, Jupiter's diameter is about 11 times Earth's diameter.

Planet	Diameter (Earth = 1)
Earth	1.0
Jupiter	11.2
Saturn	9.4
Uranus	4.0
Neptune	3.9

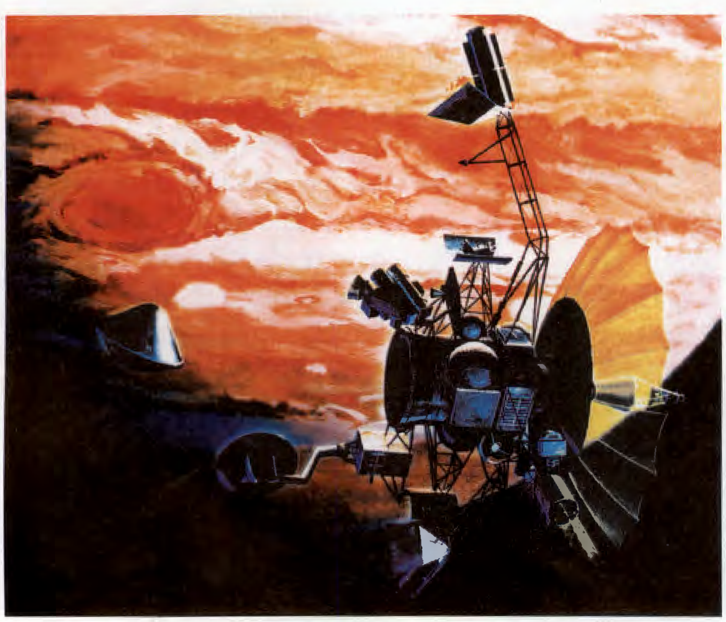
1. Measure the diameter of a quarter in millimeters. Trace the quarter to represent Earth.
2. If Earth were the size of a quarter, calculate how large Jupiter would be. Now draw a circle to represent Jupiter.
3. Repeat Step 2 for each of the other planets in the table.

Think It Over

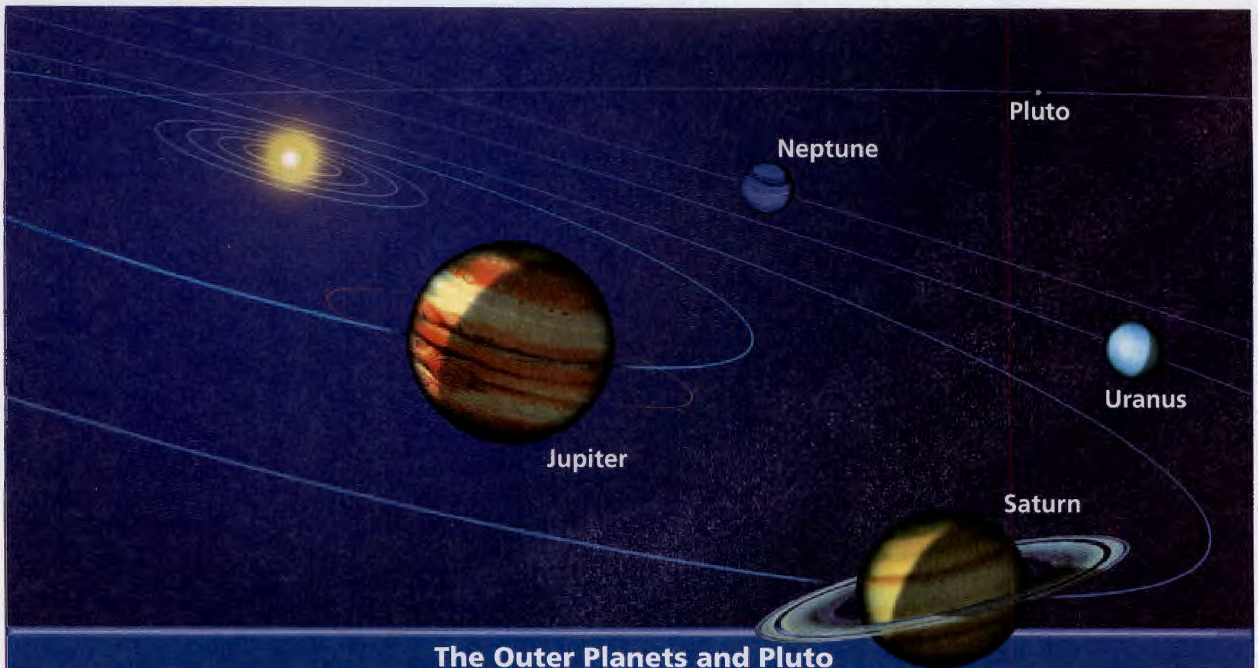
Classifying List the outer planets in order from largest to smallest. What is the largest outer planet?

Imagine you are in a spaceship approaching Jupiter. You'll quickly discover that Jupiter is very different from the terrestrial planets. The most obvious difference is Jupiter's great size. Jupiter is so large that more than 1,300 Earths could fit within it!

As your spaceship enters Jupiter's atmosphere, you encounter thick, colorful bands of clouds. Next, you sink into a denser and denser mixture of hydrogen and helium gas. Eventually, if the enormous pressure of the atmosphere does not crush your ship, you'll reach an incredibly deep "ocean" of liquid hydrogen and helium. But where exactly is Jupiter's surface? Surprisingly, there isn't a solid surface. Like the other giant planets, Jupiter has no real surface, just a core buried deep within the planet.



◀ An illustration of the space probe *Galileo* approaching the cloud-covered atmosphere of Jupiter.



The Outer Planets and Pluto

Planet or Dwarf Planet	Size (kilometers)		Period of Rotation (Earth days)	Average Distance From Sun (AU)	Period of Revolution (Earth years)	Number of Moons
	Diameter	Radius				
Jupiter	143,000	71,490	0.41	5.2	12	63+
Saturn	120,500	60,270	0.45	9.6	29	47+
Uranus	51,120	25,560	0.72	19.2	84	27+
Neptune	49,530	24,760	0.67	30.0	164	13+
Pluto	2,390	1,200	6.4	39.2	248	3

FIGURE 20
The outer planets are much farther apart than the inner planets. Pluto is now considered to be a dwarf planet. Note that planet sizes and distances are not drawn to scale. **Observing** *Which outer planet has the most moons?*

Gas Giants and Pluto

Jupiter and the other planets farthest from the sun are called the outer planets. **The four outer planets—Jupiter, Saturn, Uranus, and Neptune—are much larger and more massive than Earth, and they do not have solid surfaces.** Because these four planets are all so large, they are often called the **gas giants.** Figure 20 provides information about these planets. It also includes Pluto, which is now classified as a dwarf planet.

Like the sun, the gas giants have atmospheres composed mainly of hydrogen and helium. Because they are so massive, the gas giants exert a much stronger gravitational force than the terrestrial planets. Gravity keeps the giant planets' gases from escaping, so they have thick atmospheres. Despite the name "gas giant," much of the hydrogen and helium is actually in liquid form because of the enormous pressure inside the planets. The outer layers are extremely cold because of their great distance from the sun. Temperatures increase greatly within the planets.

All the gas giants have many moons. In addition, each of the gas giants is surrounded by a set of rings. A **ring** is a thin disk of small particles of ice and rock.

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Jupiter

Jupiter is the largest and most massive planet. Jupiter's enormous mass dwarfs the other planets. In fact, its mass is about $2\frac{1}{2}$ times that of all the other planets combined!

Jupiter's Atmosphere Like all of the gas giants, Jupiter has a thick atmosphere made up mainly of hydrogen and helium. An especially interesting feature of Jupiter's atmosphere is its Great Red Spot, a storm that is larger than Earth! The storm's swirling winds blow hundreds of kilometers per hour, similar to a hurricane. But hurricanes on Earth weaken quickly as they pass over land. On Jupiter, there is no land to weaken the huge storm. The Great Red Spot, which was first observed in the mid-1600s, shows no signs of going away soon.

Jupiter's Structure Astronomers think that Jupiter, like the other giant planets, may have a dense core of rock and iron at its center. As shown in Figure 21, a thick mantle of liquid hydrogen and helium surrounds this core. Because of the crushing weight of Jupiter's atmosphere, the pressure at Jupiter's core is estimated to be about 30 million times greater than the pressure at Earth's surface.

Jupiter's Moons Recall that Galileo discovered Jupiter's four largest moons. These moons, which are highlighted in Figure 22, are named Io (EYE oh), Europa, Ganymede, and Callisto. All four are larger than Earth's own moon. However, they are very different from one another. Since Galileo's time, astronomers have discovered dozens of additional moons orbiting Jupiter. Many of these are small moons that have been found in the last few years thanks to improved technology.

Reading Checkpoint What is Jupiter's atmosphere composed of?

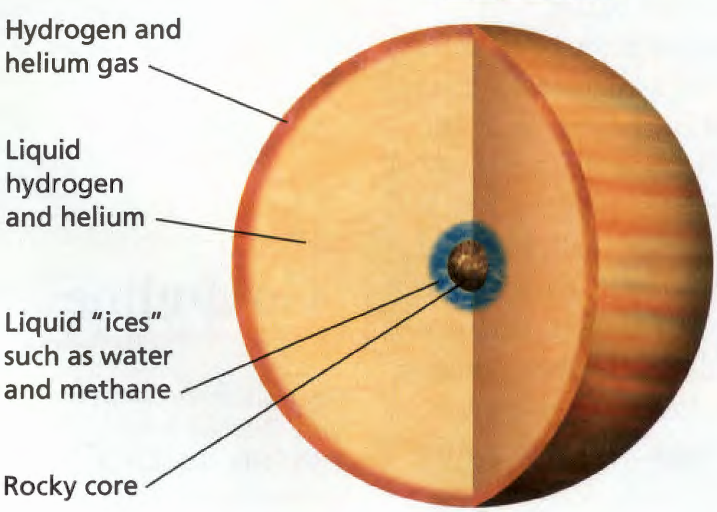


FIGURE 21
Jupiter's Structure
Jupiter is composed mainly of the elements hydrogen and helium. Although Jupiter is often called a "gas giant," much of it is actually liquid.
Comparing and Contrasting *How does the structure of Jupiter differ from that of a terrestrial planet?*

FIGURE 22

Jupiter's Moons

The astronomer Galileo discovered Jupiter's four largest moons. These images are not shown to scale.

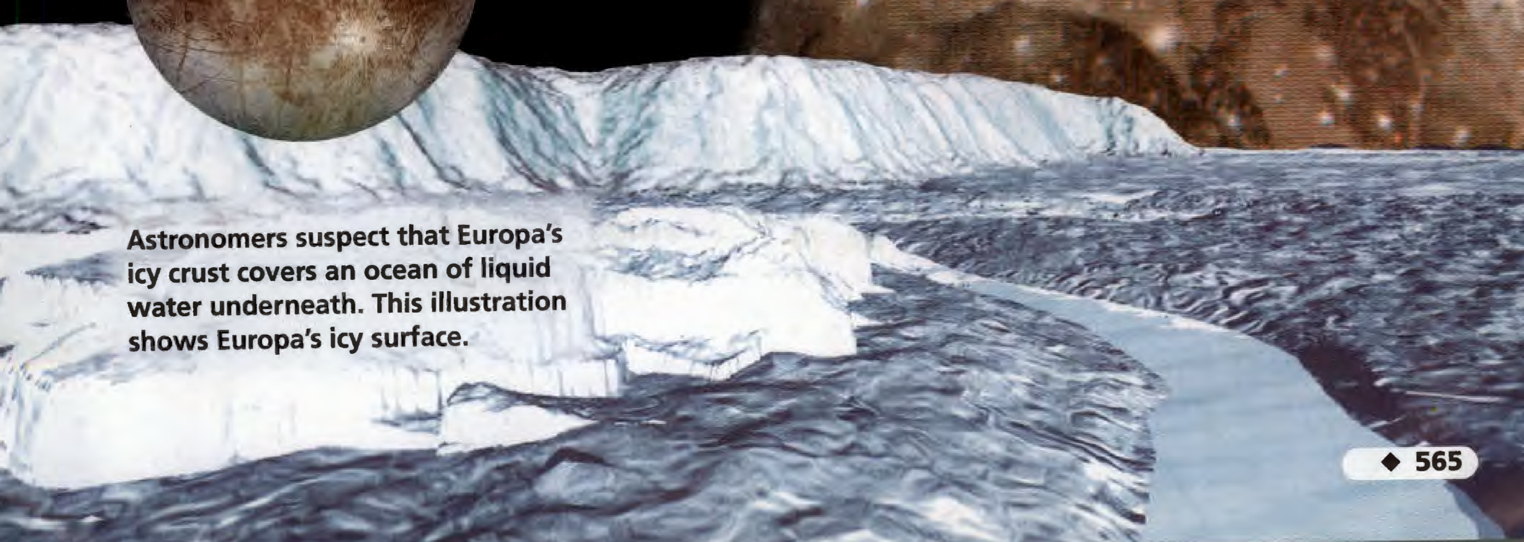
Interpreting Photographs *Which is the largest of Jupiter's moons?*

▲ Io's surface is covered with large, active volcanoes. An eruption of sulfur lava can be seen near the bottom of this photo. Sulfur gives Io its unusual colors.

Callisto's surface is icy and covered with craters. ▼

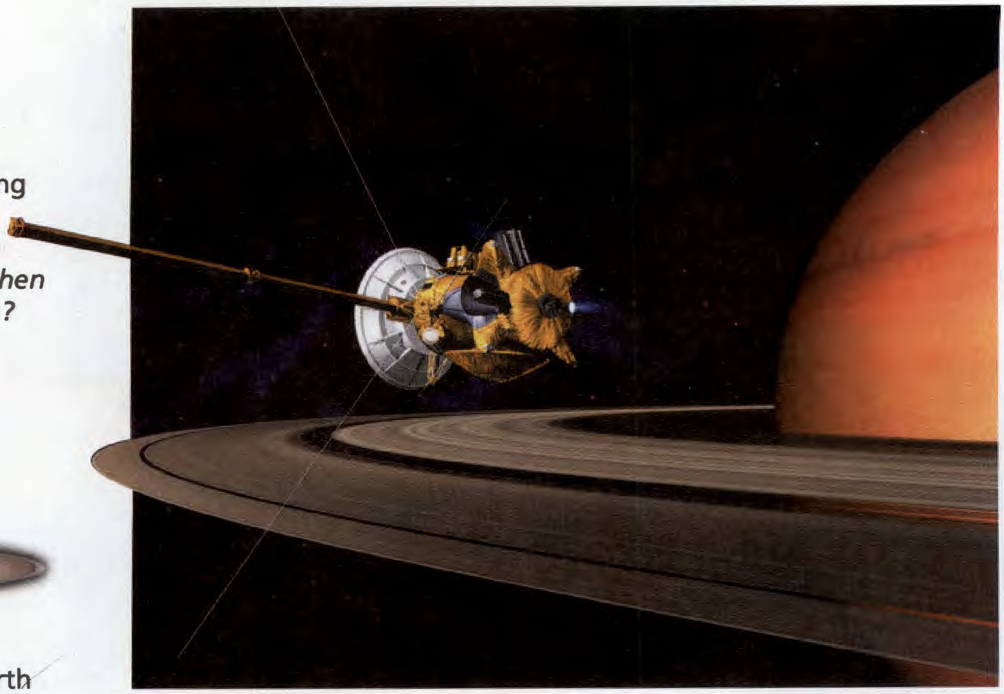
Ganymede is the largest moon in the solar system. It is larger than either Mercury or Pluto. ▼

Europa ▼



Astronomers suspect that Europa's icy crust covers an ocean of liquid water underneath. This illustration shows Europa's icy surface.

FIGURE 23
Exploring Saturn
The *Cassini* probe is exploring Saturn and its moons.
Observing *Why might it be hard to see Saturn's rings when their edges are facing Earth?*



Saturn

The second-largest planet in the solar system is Saturn. The *Voyager* probes showed that Saturn, like Jupiter, has a thick atmosphere made up mainly of hydrogen and helium. Saturn's atmosphere also contains clouds and storms, but they are less dramatic than those on Jupiter. Saturn is the only planet whose average density is less than that of water.

Saturn's Rings When Galileo first looked at Saturn with a telescope, he could see something sticking out on the sides. But he didn't know what it was. A few decades later, an astronomer using a better telescope discovered that Saturn had rings around it. These rings are not solid. They are made of chunks of ice and rock, each traveling in its own orbit around Saturn.

Saturn has the most spectacular rings of any planet. From Earth, it looks as though Saturn has only a few rings and that they are divided from each other by narrow, dark regions. The *Voyager* spacecraft discovered that each of these obvious rings is divided into many thinner rings. Saturn's rings are broad and thin, like a compact disc.

Saturn's Moons Saturn's largest moon, Titan, is larger than the planet Mercury. Titan was discovered in 1665 but was known only as a point of light until the *Voyager* probes flew by. The probes showed that Titan has an atmosphere so thick that little light can pass through it. Four other moons of Saturn are each over 1,000 kilometers in diameter.

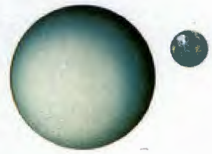
Reading Checkpoint **What are Saturn's rings made of?**

Lab zone Skills Activity

Making Models

1. Use a plastic foam sphere 8 cm in diameter to represent Saturn.
2. Use an overhead transparency to represent Saturn's rings. Cut a circle 18 cm in diameter out of the transparency. Cut a hole 9 cm in diameter out of the center of the circle.
3. Stick five toothpicks into Saturn, spaced equally around its equator. Put the transparency on the toothpicks and tape it to them. Sprinkle baking soda on the transparency.
4. Use a peppercorn to represent Titan. Place the peppercorn 72 cm away from Saturn on the same plane as the rings.
5. What do the particles of baking soda represent?

Size of Uranus compared to Earth



Uranus

Although the gas giant Uranus (YOOR uh nus) is about four times the diameter of Earth, it is still much smaller than Jupiter and Saturn. Uranus is twice as far from the sun as Saturn, so it is much colder. Uranus looks blue-green because of traces of methane in its atmosphere. Like the other gas giants, Uranus is surrounded by a group of thin, flat rings, although they are much darker than Saturn's rings.

Discovery of Uranus In 1781, Uranus became the first new planet discovered since ancient times. Astronomer William Herschel, in England, found a fuzzy object in the sky that did not look like a star. At first he thought it might be a comet, but it soon proved to be a planet beyond Saturn. The discovery made Herschel famous and started an era of active solar system study.

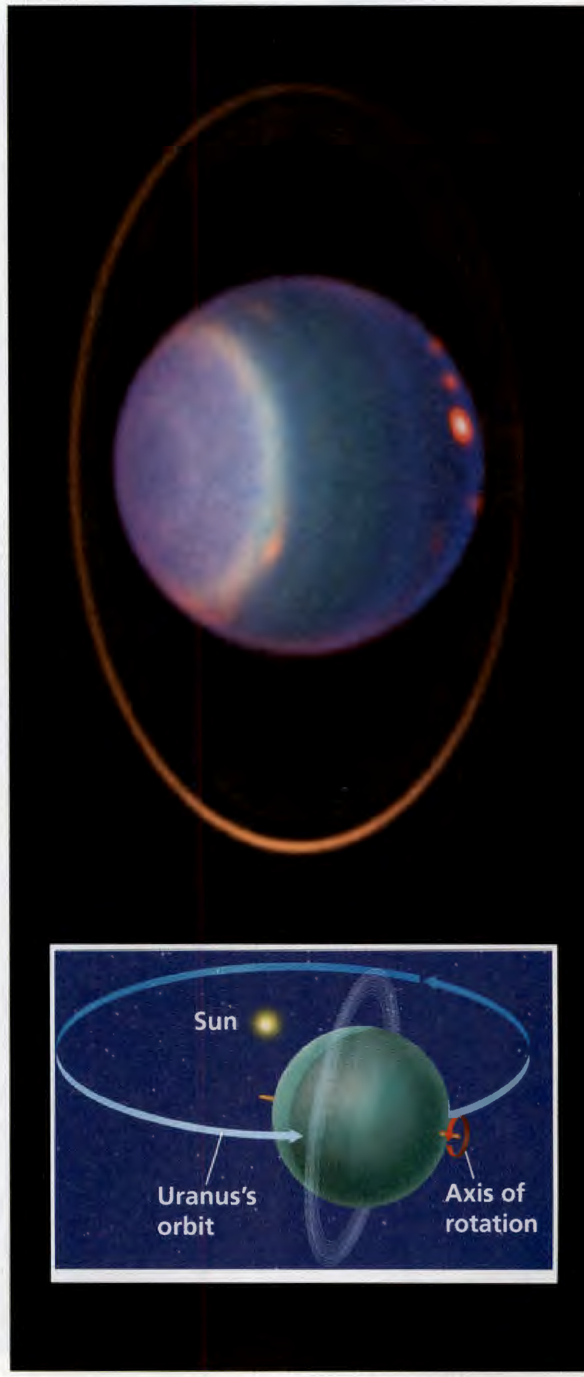
Exploring Uranus About 200 years after Herschel's discovery, *Voyager 2* arrived at Uranus and sent back close-up views of that planet. Images from *Voyager 2* show only a few clouds on Uranus's surface. But even these few clouds allowed astronomers to calculate that Uranus rotates in about 17 hours.

Uranus's axis of rotation is tilted at an angle of about 90 degrees from the vertical. Viewed from Earth, Uranus is rotating from top to bottom instead of from side to side, the way most of the other planets do. Uranus's rings and moons rotate around this tilted axis. Astronomers think that billions of years ago Uranus was hit by an object that knocked it on its side.

Uranus's Moons Photographs from *Voyager 2* show that Uranus's five largest moons have icy, cratered surfaces. The craters show that rocks from space have hit the moons. Uranus's moons also have lava flows on their surfaces, suggesting that material has erupted from inside each moon. *Voyager 2* images revealed 10 moons that had never been seen before. Recently, astronomers discovered several more moons, for a total of at least 27.

Reading Checkpoint Who discovered Uranus?

FIGURE 24
Uranus
The false color image of Uranus below was taken by the Hubble Space Telescope. Unlike most other planets, Uranus rotates from top to bottom rather than side to side.
Inferring *How must Uranus's seasons be unusual?*



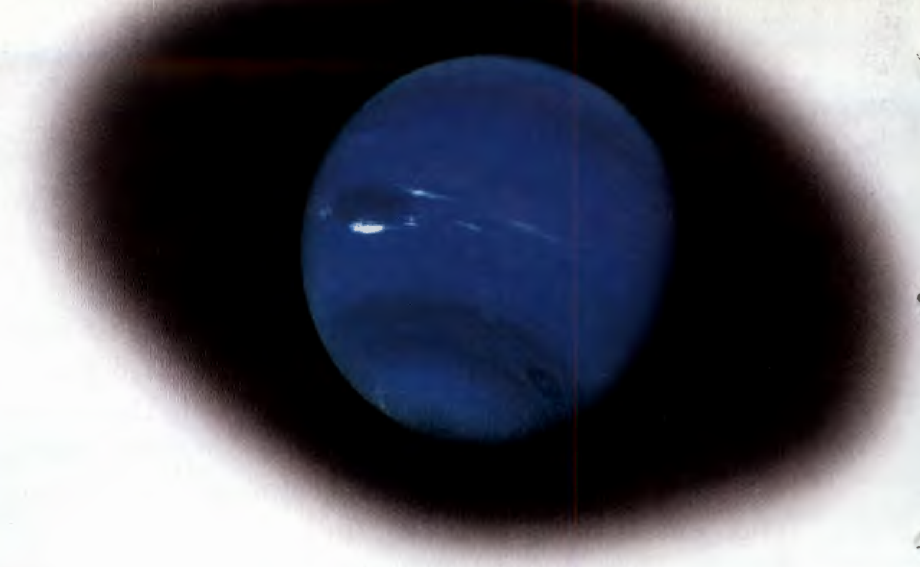


FIGURE 25
Neptune
The Great Dark Spot was a giant storm in Neptune's atmosphere. White clouds, probably made of methane ice crystals, can also be seen in the photo.

Size of Neptune compared to Earth

Neptune

Neptune is even farther from the sun than Uranus. In some ways, the two planets look like twins. They are similar in size and color. **Neptune is a cold, blue planet. Its atmosphere contains visible clouds.** Scientists think that Neptune, shown in Figure 25, is slowly shrinking, causing its interior to heat up. As this energy rises toward Neptune's surface, it produces clouds and storms in the planet's atmosphere.

Discovery of Neptune Neptune was discovered as a result of a mathematical prediction. Astronomers noted that Uranus was not quite following the orbit predicted for it. They hypothesized that the gravity of an unseen planet was affecting Uranus's orbit. By 1846, mathematicians in England and France had calculated the orbit of this unseen planet. Shortly thereafter, an observer saw an unknown object in the predicted area of the sky. It was the new planet, now called Neptune.

Exploring Neptune In 1989, *Voyager 2* flew by Neptune and photographed a Great Dark Spot about the size of Earth. Like the Great Red Spot on Jupiter, the Great Dark Spot was probably a giant storm. But the storm didn't last long. Images taken five years later showed that the Great Dark Spot was gone. Other, smaller spots and regions of clouds on Neptune also seem to come and go.

Neptune's Moons Astronomers have discovered at least 13 moons orbiting Neptune. The largest moon is Triton, which has a thin atmosphere. The *Voyager* images show that the region near Triton's south pole is covered by nitrogen ice.

Reading Checkpoint **Before they could see Neptune, what evidence led scientists to conclude that it existed?**

Math Skills

Circumference

To calculate the circumference of a circle, use this formula:

$$C = 2\pi r$$

In the formula, $\pi \approx 3.14$, and r is the circle's radius, which is the distance from the center of the circle to its edge. The same formula can be used to calculate the circumference of planets, which are nearly spherical.

Neptune's radius at its equator is about 24,760 km. Calculate its circumference.

$$C = 2\pi r$$
$$= 2.00 \times 3.14 \times 24{,}760 \text{ km}$$
$$= 156{,}000 \text{ km}$$

Practice Problem Saturn's radius is about 60,270 km. What is its circumference?

Size of Pluto compared to Earth

Pluto

Pluto is very different from the gas giants. **Pluto has a solid surface and is much smaller and denser than the outer planets.** In fact, Pluto is smaller than Earth's moon. Pluto is probably made of a mixture of rock and ice.

Pluto has three known moons. The largest of these, Charon, is more than half of Pluto's size.

Pluto's Orbit Pluto is so far from the sun that it revolves around the sun only once every 248 Earth years. Pluto's orbit is very elliptical, bringing it closer to the sun than Neptune on part of its orbit.

Dwarf Planets Until recently, Pluto was considered to be the ninth planet in our solar system. Pluto was always thought to be something of an oddball because of its small size and unusual orbit. Then, in recent years, astronomers discovered many icy objects beyond Neptune's orbit. Some of these were fairly similar to Pluto in size and makeup. Following the discovery of a body that is even larger and farther from the sun than Pluto, astronomers decided to create a new class of objects called "dwarf planets." A dwarf planet, like a planet, is round and orbits the sun. But unlike a planet, a dwarf planet has not cleared out the neighborhood around its orbit. Astronomers classified Pluto and two other bodies as dwarf planets.

FIGURE 26
Pluto and Charon
The illustration above shows Pluto (lower right) and its moon Charon. Charon is more than half the size of Pluto.

Section 4 Assessment

S 8.4.e, E-LA: Reading 8.2.0, Reviewing Math: 6MG1.1

Target Reading Skill **Create Outlines** Review your outline for this section. What three details did you include under *Gas Giants and Pluto*?

Reviewing Key Concepts

1. a. **Describing** How are the gas giants similar to one another?
   b. **Explaining** Why do all of the gas giants have thick atmospheres?
   c. **Listing** List the outer planets in order of size, from smallest to largest.
   d. **Comparing and Contrasting** Compare the structure of a typical terrestrial planet with that of a gas giant.
2. a. **Describing** Describe an important characteristic of each outer planet that helps to distinguish it from the other outer planets.
   b. **Comparing and Contrasting** How is Pluto different from the gas giants?
   c. **Classifying** Why did astronomers reclassify Pluto as a dwarf planet?

Math Practice

3. **Circumference** Jupiter's radius is about 71,490 km. What is its circumference?

Lab zone

Design Your Own Lab

Speeding Around the Sun

S 8.4.e, 8.9.a

Problem

How does a planet's distance from the sun affect its period of revolution?

Skills Focus

making models, developing hypotheses, designing experiments

Materials

- string, 1.5 m
- plastic tube, 6 cm
- meter stick
- weight or several washers
- one-hole rubber stopper
- stopwatch or watch with second hand

Procedure

PART 1 Modeling Planetary Revolution

1. Copy the data table onto a sheet of paper.

Data Table				
Distance (cm)	Period of Revolution			
	Trial 1	Trial 2	Trial 3	Average
20				
40				
60				

2. Make a model of a planet orbiting the sun by threading the string through the rubber stopper hole. Tie the end of the string to the main part of the string. Pull tightly to make sure that the knot will not become untied.
3. Thread the other end of the string through the plastic tube and tie a weight to that end. Have your teacher check both knots.
4. Pull the string so the stopper is 20 cm away from the plastic tube. Hold the plastic tube in your hand above your head. Keeping the length of string constant, swing the rubber stopper in a circle above your head just fast enough to keep the stopper moving. The circle represents a planet's orbit, and the length of string from the rubber stopper to the plastic tube represents the distance from the sun. **CAUTION:** *Stand away from other students. Make sure the swinging stopper will not hit students or objects. Do not let go of the string.*
5. Have your lab partner time how long it takes for the rubber stopper to make ten complete revolutions. Determine the period for one revolution by dividing the measured time by ten. Record the time in the data table.
6. Repeat Step 5 two more times. Be sure to record each trial in a data table. After the third trial, calculate and record the average period of revolution.

PART 2 Designing an Experiment

7. Write your hypothesis for how a planet's period of revolution would be affected by changing its distance from the sun.
8. Design an experiment that will enable you to test your hypothesis. Write the steps you plan to follow to carry out your experiment. As you design your experiment, consider the following factors:
   - What different distances will you test?
   - What variables are involved in your experiment and how will you control them?
   - How many trials will you run for each distance?
9. Have your teacher review your step-by-step plan. After your teacher approves your plan, carry out your experiment.

Analyze and Conclude

1. **Making Models** In your experiment, what represents the planet and what represents the sun?
2. **Making Models** What force does the pull on the string represent?
3. **Interpreting Data** What happened to the period of revolution when you changed the distance in Part 2? Did your experiment prove or disprove your hypothesis?
4. **Drawing Conclusions** Which planets take less time to revolve around the sun—those closer to the sun or those farther away? Use the model to support your answer.
5. **Designing Experiments** As you were designing your experiment, which variable was the most difficult to control? How did you design your procedure to control that variable?
6. **Drawing Conclusions** Did you obtain the same results in all three trials? What do your results indicate about the accuracy of your data?
7. **Communicating** Write a brief summary of your experiment for a science magazine. Describe your hypothesis, procedure, and results in one or two paragraphs.

More to Explore

Develop a hypothesis for how a planet's mass might affect its period of revolution. Then, using a stopper with a different mass, modify the activity to test your hypothesis. Before you swing your stopper, have your teacher check your knots.

Section 5

Comets, Asteroids, and Meteors

CALIFORNIA **Standards Focus**

S 8.4.e Students know the appearance, general composition, relative position and size, and motion of objects in the solar system, including planets, planetary satellites, comets, and asteroids.

- What are the characteristics of comets?
- Where are most asteroids found?
- What are meteoroids and how do they form?

Key Terms

- comet
- coma
- nucleus
- Kuiper belt
- Oort cloud
- asteroid
- asteroid belt
- meteoroid
- meteor
- meteorite

Lab zone **Standards Warm-Up**

Which Way Do Comet Tails Point?

1. Form a small ball out of modeling clay to represent a comet.
2. Using a pencil point, push three 10-cm lengths of string into the ball. The strings represent the comet's tail. Stick the ball onto the pencil point, as shown.
3. Hold the ball about 1 m in front of a fan. The air from the fan represents the solar wind. Move the ball toward the fan, away from the fan, and from side to side. **CAUTION:** *Keep your fingers away from the fan blades.*

Think It Over

Inferring How does moving the ball affect the direction in which the strings point? What determines which way the tail of a comet points?

Imagine watching a cosmic collision! That's exactly what happened in July 1994. The year before, Eugene and Carolyn Shoemaker and David Levy discovered a comet that had previously broken into pieces near Jupiter. When the comet's orbit passed near Jupiter again, the fragments crashed into Jupiter. On Earth, many people were fascinated to view images of the huge explosions—some were as large as Earth!

As this example shows, the sun, planets, and moons aren't the only objects in the solar system. There are also many smaller objects moving through the solar system. These objects are classified as comets, asteroids, or meteoroids.

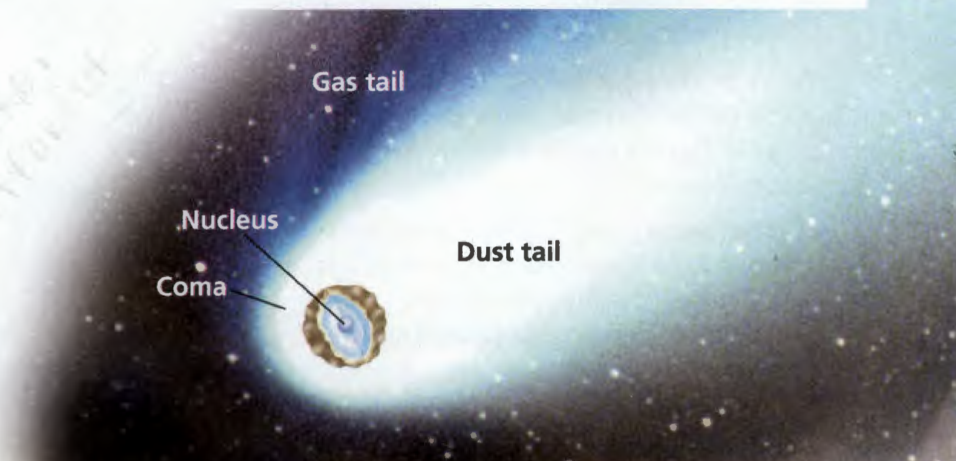


FIGURE 27
Structure of a Comet
The main parts of a comet are the nucleus, the coma, and the tail. The nucleus is deep within the coma. Most comets have two tails—a bluish gas tail and a white dust tail.

Comets

One of the most glorious things you can see in the night sky is a comet. But what exactly is a comet? You can think of a **comet** as a "dirty snowball" about the size of a mountain. **Comets are loose collections of ice, dust, and small rocky particles whose orbits are usually very long, narrow ellipses.**

A Comet's Head When a comet gets close enough to the sun, the energy in the sunlight turns the ice into gas, releasing gas and dust. Clouds of gas and dust form a fuzzy outer layer called a **coma.** Figure 27 shows the coma and the **nucleus**, the solid inner core of a comet. The brightest part of a comet, the comet's head, is made up of the nucleus and coma.

A Comet's Tail As a comet approaches the sun and heats up, some of its gas and dust stream outward, forming a tail. The name *comet* means "long-haired star" in Greek. Comets often have two tails—a gas tail and a dust tail. The gas tail always points directly away from the sun, as shown in Figure 28.

A comet's tail can be more than 100 million kilometers long and stretch across most of the sky. The material is stretched out very thinly, however, so there is little mass in a comet's tail.

Origin of Comets Most comets originate from one of two distant regions of the solar system: the Kuiper belt and the Oort cloud. The **Kuiper belt** is a doughnut-shaped region that extends from beyond Neptune's orbit to about 100 times Earth's distance from the sun. The **Oort cloud** is a spherical region of comets that surrounds the solar system from about 1,000 to 10,000 times the distance between Pluto and the sun.

Reading Checkpoint What is the Oort cloud?

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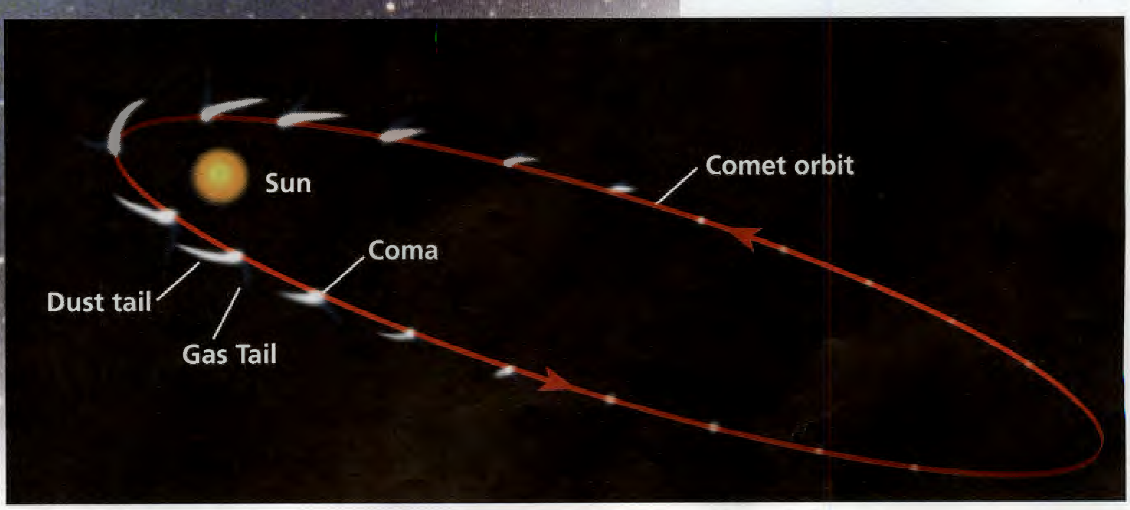

FIGURE 28
Comet Orbits
Most comets revolve around the sun in very long, narrow orbits. Gas and dust tails form as the comet approaches the sun. **Observing** *What shape is a comet's orbit?*

Lab zone Try This Activity

Micrometeorites

An estimated 300 tons of material from space fall on Earth each day. Much of this is micrometeorites, tiny, dust-sized meteorites.

1. To gather magnetic micrometeorites, tie a string to a small, round magnet and place the magnet in a plastic freezer bag. Lower the magnet close to the ground as you walk along sidewalk cracks, drain spouts, or a parking lot.
2. To gather nonmagnetic and magnetic micrometeorites, cover one side of a few microscope slides with petroleum jelly. Leave the slides outside for several days in a place where they won't be disturbed.
3. Use a microscope to examine the materials you have gathered. Any small round spheres you see are micrometeorites.

Estimating Which technique allows you to gather a more complete sample of micrometeorites? Were all the particles that were gathered in Step 2 micrometeorites? How could you use the method described in Step 2 to estimate the total number of micrometeorites that land on Earth each day?

Asteroids

Between 1801 and 1807, astronomers discovered four small objects between the orbits of Mars and Jupiter. They named the objects Ceres, Pallas, Juno, and Vesta. Over the next 80 years, astronomers found 300 more. These rocky objects, called **asteroids**, are too small and too numerous to be considered full-fledged planets. **Most asteroids revolve around the sun in fairly circular orbits between the orbits of Mars and Jupiter.** This region of the solar system, shown in Figure 29, is called the **asteroid belt.**

Astronomers have discovered more than 100,000 asteroids, and they are constantly finding more. Most asteroids are small—less than a kilometer in diameter. Only Ceres, Pallas, Vesta, and Hygiea are more than 300 kilometers across. The largest asteroid, Ceres, was recently classified as a dwarf planet. At one time, scientists thought that asteroids were the remains of a shattered planet. However, the combined mass of all the asteroids is too small to support this idea. Scientists now hypothesize that the asteroids are leftover pieces of the early solar system that never came together to form a planet.

Some asteroids have very elliptical orbits that bring them closer to the sun than Earth's orbit. Someday, one of these asteroids could hit Earth. One or more large asteroids did hit Earth about 65 million years ago, filling the atmosphere with dust and smoke and blocking out sunlight around the world. Scientists hypothesize that many species of organisms, including the dinosaurs, became extinct as a result.

Reading Checkpoint **Name the four largest asteroids.**

FIGURE 29
Asteroids
The asteroid belt (right) lies between Mars and Jupiter. Asteroids come in many sizes and shapes. The photo below shows the oddly shaped asteroid Eros.

Meteors

It's a perfect night for stargazing—dark and clear. Suddenly, a streak of light flashes across the sky. For an hour or so, you see a streak at least once a minute. You are watching a meteor shower. Meteor showers happen regularly, several times a year.

Even when there is no meteor shower, you often can see meteors if you are far from city lights and the sky is not cloudy. On average, a meteor streaks overhead every 10 minutes.

A **meteoroid** is a chunk of rock or dust in space. **Meteoroids come from comets or asteroids.** Some meteoroids form when asteroids collide in space. Others form when a comet breaks up and creates a cloud of dust that continues to move through the solar system. When Earth passes through one of these dust clouds, bits of dust enter Earth's atmosphere.

When a meteoroid enters Earth's atmosphere, friction with the air creates heat and produces a streak of light in the sky—a **meteor.** If the meteoroid is large enough, it may not disintegrate completely. Meteoroids that pass through the atmosphere and strike Earth's surface are called **meteorites.** The craters on the moon were formed by meteoroids.

FIGURE 30
Meteors
Meteoroids make streaks of light called meteors, like the one above, as they enter the atmosphere.

Reading Checkpoint **What is a meteorite?**

Section 5 Assessment

S 8.4.e, E-LA: Reading 8.2.0

Target Reading Skill **Create Outlines** Use your outline of this section to help answer the following questions.

Reviewing Key Concepts

1. a. **Defining** What is a comet?
   b. **Listing** What are the different parts of a comet?
   c. **Relating Cause and Effect** How does a comet's appearance change as it approaches the sun? Why do these changes occur?
2. a. **Describing** What is an asteroid?
   b. **Explaining** Where are most asteroids found?
   c. **Summarizing** How did the asteroids form?
3. a. **Describing** What is a meteoroid?
   b. **Explaining** What are the main sources of meteoroids?
   c. **Comparing and Contrasting** What are the differences between meteoroids, meteors, and meteorites?

Lab zone At-Home Activity

Observing Meteors Meteor showers occur regularly on specific dates. (The Perseid meteor shower, for example, occurs around August 12 each year.) Look in the newspaper, on the Internet, or in an almanac for information about the next meteor shower. With adult family members, go outside on that night and look for meteors. Explain to your family what causes the display.

Section 6

Is There Life Beyond Earth?

CALIFORNIA Standards Focus

S 8.4.e Students know the appearance, general composition, relative position and size, and motion of objects in the solar system, including planets, planetary satellites, comets, and asteroids.

S 8.6.c Students know that living organisms have many different kinds of molecules, including small ones, such as water and salt, and very large ones, such as carbohydrates, fats, proteins, and DNA.

- What conditions do living things need to exist on Earth?
- Why do scientists think Mars and Europa are good places to look for signs of life?

Key Term

- extraterrestrial life

Lab zone Standards Warm-Up

Is Yeast Alive or Not?

1. Open a package of yeast and pour it into a bowl.
2. Look at the yeast carefully. Make a list of your observations.
3. Fill the bowl about halfway with warm water (about 20°C). Add a spoonful of sugar. Stir the mixture with the spoon. Wait 5 minutes.
4. Now look at the yeast again and make a list of your observations.

Think It Over

Forming Operational Definitions Which of your observations suggest that yeast is not alive? Which observations suggest that yeast is alive? How can you tell if something is alive?

Most of Antarctica is covered with snow and ice. You would not expect to see rocks lying on top of the whiteness. But surprisingly, people have found rocks lying on Antarctica's ice. When scientists examined the rocks, they found that many were meteorites. A few of these meteorites came from Mars. Astronomers think that meteoroids hitting the surface of Mars blasted chunks of rock into space. Some of these rocks eventually entered Earth's atmosphere and landed on its surface.

In 1996, a team of scientists announced that a meteorite from Mars found in Antarctica has tiny shapes that look like fossils—the remains of ancient life preserved in rock—though much smaller. Most scientists now doubt that the shapes really are fossils. But if they are, it would be a sign that microscopic lifeforms similar to bacteria once existed on Mars. Life other than that on Earth would be called **extraterrestrial life.**

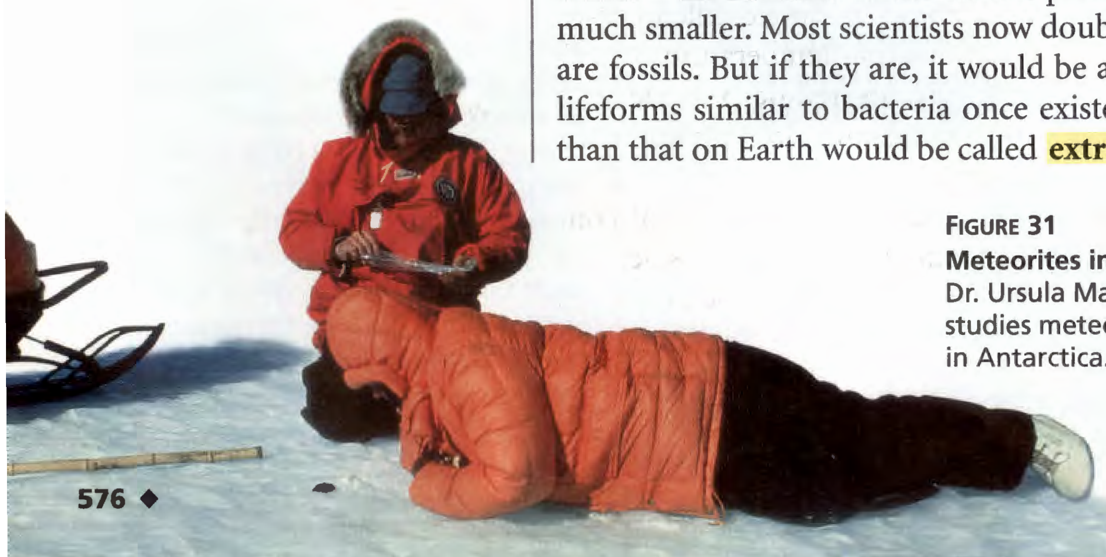

FIGURE 31
Meteorites in Antarctica
Dr. Ursula Marvin (lying down) studies meteorites like this one in Antarctica.

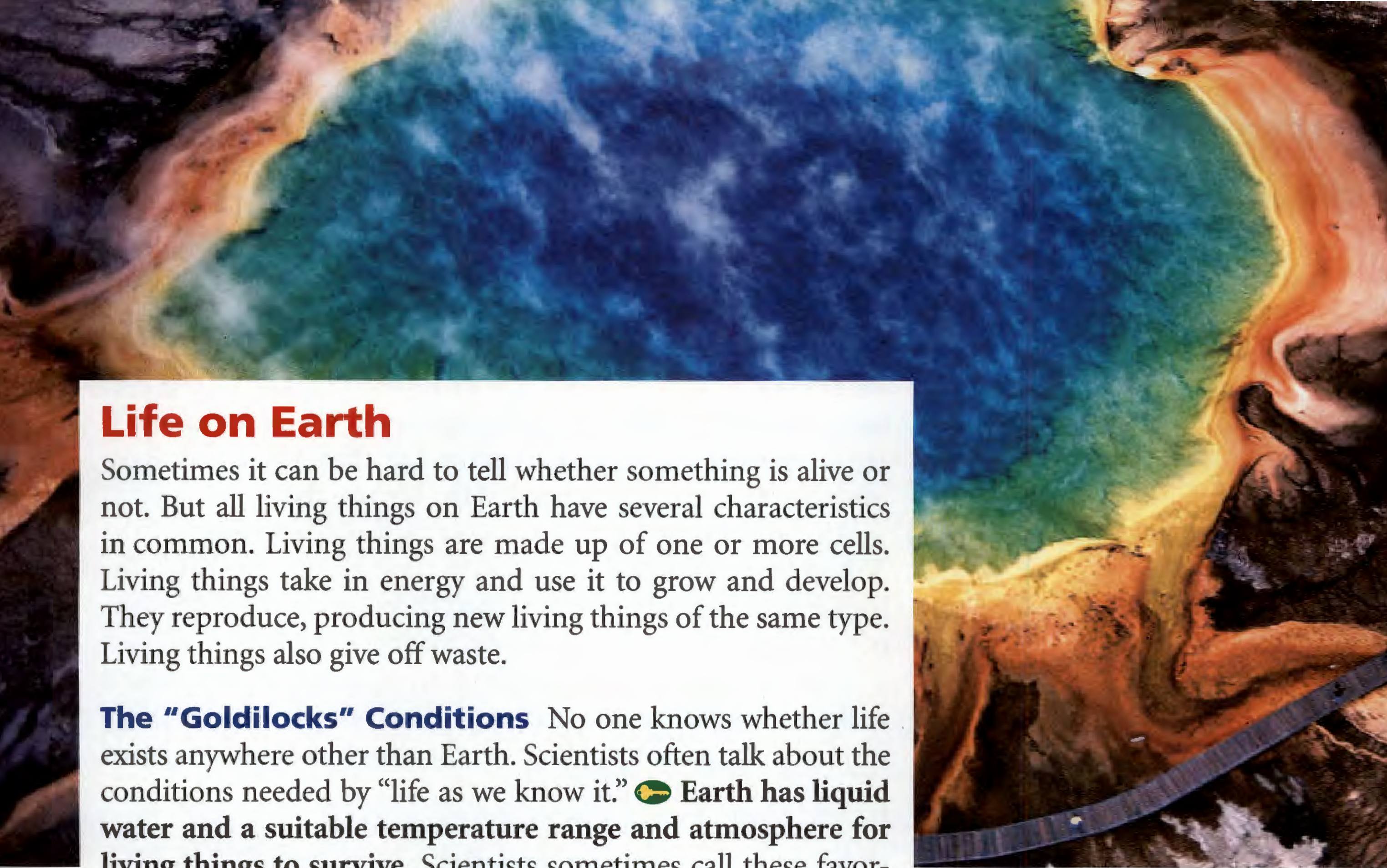

FIGURE 32
Hot Spring
Bacteria that thrive in near-boiling water help to produce the striking colors of Grand Prismatic Spring in Wyoming. **Inferring** *How does studying unusual organisms on Earth help scientists predict what extraterrestrial life might be like?*

Life on Earth

Sometimes it can be hard to tell whether something is alive or not. But all living things on Earth have several characteristics in common. Living things are made up of one or more cells. Living things take in energy and use it to grow and develop. They reproduce, producing new living things of the same type. Living things also give off waste.

The "Goldilocks" Conditions No one knows whether life exists anywhere other than Earth. Scientists often talk about the conditions needed by "life as we know it." **Earth has liquid water and a suitable temperature range and atmosphere for living things to survive.** Scientists sometimes call these favorable conditions the "Goldilocks" conditions. That is, the temperature is not too hot and not too cold. It is just right. If Earth were much hotter, water would always be a gas—water vapor. If Earth were much colder, water would always be solid ice.

Are these the conditions necessary for life? Or are they just the conditions that Earth's living things happen to need? Scientists have only one example to study: life on Earth. Unless scientists find evidence of life somewhere else, there is no way to answer these questions for certain.

Extreme Conditions Recently, scientists have discovered living things in places where it was once believed that life could not exist. Giant tubeworms have been found under the extremely high pressures at the bottom of the ocean. Single-celled organisms have been found in the near-boiling temperatures of hot springs. Tiny life-forms have been discovered deep inside solid rock. Scientists have even found animals that do not require the energy of sunlight, but instead get their energy from chemicals.

These astounding discoveries show that the range of conditions in which life can exist is much greater than scientists once thought. Could there be life-forms in the solar system that do not need the "Goldilocks" conditions?

Reading Checkpoint **What are some characteristics of all living things?**

Lab zone Skills Activity

Communicating You are writing a letter to a friend who lives on another planet. Your friend has never been to Earth and has no idea what the planet is like. Explain in your letter why the conditions on Earth make it an ideal place for living things.

Go Online SCILINKS NSTA

For: Links on extraterrestrial life
Visit: www.SciLinks.org
Web Code: scn-0636

FIGURE 33
Liquid Water on Mars
The river-like patterns on the surface of Mars indicate that liquid water once flowed there.
Applying Concepts *Why does this evidence make it more likely that there may once have been life on Mars?*

Life Elsewhere in the Solar System?

Recall that Mars is the planet most similar to Earth. That makes Mars the most obvious place to look for living things.

Life on Mars? Spacecraft have found regions on the surface of Mars that look like streambeds with crisscrossing paths of water. Shapes like those shown in Figure 33 were almost certainly formed by flowing water. **Since life as we know it requires water, scientists hypothesize that Mars may have once had the conditions needed for life to exist.**

In 1976 twin *Viking* spacecraft reached Mars. Each of the *Viking* landers carried a small laboratory meant to search for life forms. These laboratories tested Mars's air and soil for signs of life. None of these tests showed evidence of life.

More recently, the *Spirit* and *Opportunity* rovers found rocks and other surface features on Mars that were certainly formed by liquid water. However, the rovers were not equipped to search for past or present life.

Interest in life on Mars was increased by a report in 1996 about a meteorite from Mars that may contain fossils. The scientists' report started a huge debate. What were the tube-shaped things in the meteorite? Some scientists have suggested that the tiny shapes found in the meteorite are too small to be the remains of life forms. The shapes may have come from natural processes on Mars.

The most effective way to answer these questions is to send more probes to Mars. Future Mars missions should be able to bring samples of rocks and soil back to Earth for detailed analysis. Scientists may not yet have evidence of life on Mars, but hope is growing that we can soon learn the truth.

Reading Checkpoint **What did the *Spirit* and *Opportunity* rovers discover on Mars?**

FIGURE 34
Martian Fossils?
This false-color electron microscope image shows tiny fossil-like shapes found in a meteorite from Mars. These structures are less than one-hundredth the width of a human hair.

Life on Europa? Many scientists think that Europa, one of Jupiter's moons, may have the conditions necessary for life to develop. Europa has a smooth, icy crust with giant cracks. Close-up views from the *Galileo* space probe show that Europa's ice has broken up and re-formed, resulting in large twisted blocks of ice. Similar patterns occur in the ice crust over Earth's Arctic Ocean. Scientists hypothesize that there is a liquid ocean under Europa's ice. The water in the ocean could be kept liquid by heat coming from inside Europa. **If there is liquid water on Europa, there might also be life.**

How could scientists study conditions under Europa's ice sheet? Perhaps a future space probe might be able to use radar to "see" through Europa's icy crust. After that, robotic probes could be sent to drill through the ice to search for life in the water below.

FIGURE 35
Exploring Europa
Scientists have discussed sending a robotic probe to search for life in the ocean below Europa's icy crust.

Section 6 Assessment

S 8.4.e, 8.6.c,
E-LA: Reading 8.2.0

Target Reading Skill **Create Outlines** Review your outline. What are two of the main ideas being discussed in this section?

Reviewing Key Concepts

1. a. **Relating Cause and Effect** What conditions does life on Earth need to survive?
   b. **Summarizing** Why is Earth said to have the "Goldilocks" conditions?
   c. **Applying Concepts** Do you think there could be life as we know it on Neptune? Explain. (*Hint*: Review Section 4.)
2. a. **Explaining** Why do astronomers think there could be life on Europa?
   b. **Identifying** Scientists think that in the past Mars may have had the conditions needed for life to exist. What are these conditions? Do they still exist?
   c. **Making Generalizations** What characteristic do Mars and Europa share with Earth that makes them candidates to support extraterrestrial life?

Lab zone At-Home Activity

Make a Message Imagine that scientists have found intelligent extraterrestrial life. With family members, make up a message to send to the extraterrestrials. Remember that they will not understand English, so you should use only symbols and drawings in your message.

Chapter 14

Study Guide

Apply the BIG Idea The solar system includes the sun, the planets and their moons, and smaller objects such as comets, asteroids, and meteoroids.

1 Observing the Solar System

Key Concepts S 8.4.c, 8.4.d

- In a geocentric system, Earth is at the center. In a heliocentric system, Earth and the other planets revolve around the sun.
- Galileo's discoveries supported the heliocentric model. Kepler developed three laws that describe the motions of the planets.
- The solar system consists of the sun, the planets and their moons, and a series of smaller objects that revolve around the sun.

Key Terms

• geocentric • heliocentric • ellipse
• moon • astronomical unit

2 The Sun

Key Concepts S 8.2.g, 8.4.b

- The sun produces energy through fusion.
- The sun's interior consists of the core, radiation zone, and convection zone. The sun's atmosphere consists of the photosphere, chromosphere, and corona.
- Features on or just above the sun's surface include sunspots, prominences, and solar flares.

Key Terms

• nuclear fusion • core • radiation zone
• convection zone • photosphere
• chromosphere • corona • solar wind
• sunspot • prominence • solar flare

3 The Inner Planets

Key Concepts S 8.4.e

- The four inner planets are small and dense.
- Earth is unique in our solar system in having liquid water at its surface.
- Mercury is the smallest terrestrial planet.
- Venus's internal structure is similar to Earth's.
- Liquid water flowed on Mars in the distant past.

Key Terms

• terrestrial planets • greenhouse effect

4 The Outer Planets

Key Concepts S 8.4.e

- Jupiter, Saturn, Uranus, and Neptune are much larger and more massive than Earth, and they do not have solid surfaces.
- Jupiter is the largest and most massive planet in the solar system.
- Saturn has spectacular rings.
- Uranus's axis of rotation is tilted at an angle of about 90 degrees from the vertical.
- Neptune is a cold, blue planet. Its atmosphere contains visible clouds.
- Pluto has a solid surface and is much smaller and denser than the outer planets.

Key Terms

• gas giant • ring

5 Comets, Asteroids, and Meteors

Key Concepts S 8.4.e

- Comets are loose collections of ice, dust, and small rocky particles whose orbits are usually very long, narrow ellipses.
- Most asteroids revolve around the sun between the orbits of Mars and Jupiter.
- Meteoroids come from comets or asteroids.

Key Terms

• comet • coma • nucleus • Kuiper belt
• Oort cloud • asteroid • asteroid belt
• meteoroid • meteor • meteorite

6 Is There Life Beyond Earth?

Key Concepts S 8.4.e, 8.6.c

- Earth has liquid water and a suitable temperature range and atmosphere for life.
- Scientists hypothesize that Mars may have once had the conditions for life to exist.
- If there is liquid water on Europa, there might also be life.

Key Term

• extraterrestrial life

Review and Assessment

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Target Reading Skill

Create Outlines In your notebook, complete your outline for Section 1 on *Observing the Solar System.*

Observing the Solar System

I. Earth at the Center
  A. Greek Observations
    1. Geocentric—Earth-centered
    2. Geocentric system—Earth at the center of revolving planets and stars
  B. Ptolemy's Model
    1. Planets on small circles that move on bigger circles
    2. Model was incorrect, but accepted for 1,500 years
II. Sun at the Center
  A.

Reviewing Key Terms

Choose the letter of the best answer.

1. Copernicus thought that the solar system was
  a. an ellipse.
  b. a constellation.
  c. geocentric.
  d. heliocentric.

2. The part of the sun where nuclear fusion occurs is the
  a. photosphere.
  b. core.
  c. chromosphere.
  d. corona.

3. Pluto is a(n)
  a. inner planet.
  b. terrestrial planet.
  c. dwarf planet.
  d. gas giant.

4. The region between Mars and Jupiter where many rocky objects are found is the
  a. asteroid belt.
  b. Oort cloud.
  c. convection zone.
  d. Kuiper belt.

5. A meteoroid that reaches Earth's surface is called a(n)
  a. comet.
  b. meteorite.
  c. meteor.
  d. asteroid.

Complete the following sentences so that your answers clearly explain the key terms.

6. Each planet moves around the sun in an **ellipse,** which is __________ .

7. The **photosphere** is the layer of the sun that __________ .

8. Venus has the hottest surface of any planet because of the **greenhouse effect,** which is __________ .

9. Like the other **gas giants,** Jupiter's characteristics include __________ .

10. Mars and Europa are possible locations where **extraterrestrial life,** which is __________ , might be found.

Writing in Science

News Report Imagine you are on a mission to explore the solar system. Write a brief news report telling the story of your trip from Earth to another terrestrial planet and to a gas giant. Include a description of each planet.

Video Assessment
Discovery Channel School
The Solar System

Review and Assessment

Checking Concepts

11. Describe the contributions Tycho Brahe and Johannes Kepler made to modern astronomy.

12. What is the solar wind?

13. Why does Mercury have very little atmosphere?

14. Why can astronomers see the surface of Mars clearly but not the surface of Venus?

15. What evidence do astronomers have that water once flowed on Mars?

Math Practice

16. Circumference Mars has a radius of 3,397 km at its equator. Find its circumference.

17. Circumference Jupiter has a circumference of about 449,000 km at its equator. Calculate its radius.

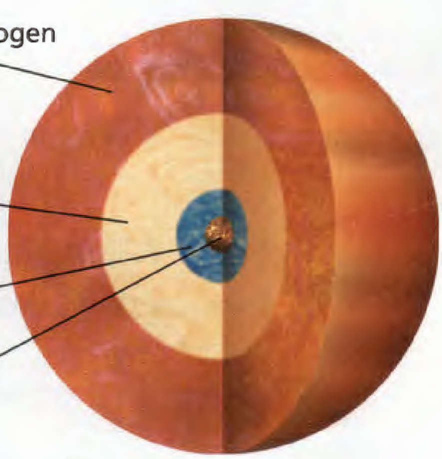
Thinking Critically

18. Applying Concepts Explain why Venus is hotter than it would be if it had no atmosphere.

19. Predicting Do you think astronomers have found all of the moons of the outer planets? Explain.

20. Comparing and Contrasting Compare and contrast comets, asteroids, and meteoroids.

21. Classifying Look at the diagram below. Do you think it represents the structure of a terrestrial planet or a gas giant? Explain.

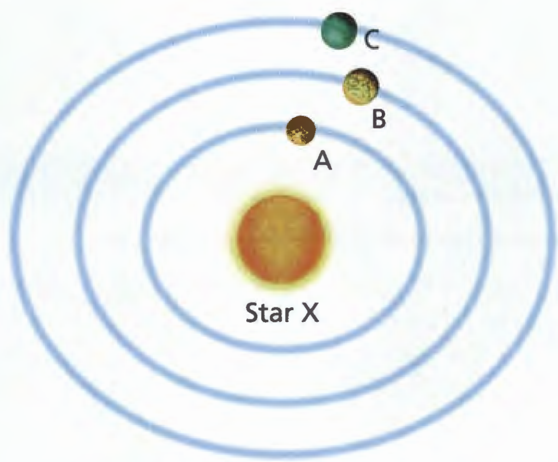


22. Making Generalizations Why would the discovery of liquid water on another planet be important?

Applying Skills

Use the diagram of an imaginary, newly discovered planetary system around Star X to answer Questions 23–25.

The periods of revolution of planets A, B, and C are 75 Earth days, 200 Earth days, and 300 Earth days.



23. Interpreting Data Which planet in this new planetary system revolves around Star X in the shortest amount of time?

24. Making Models In 150 days, how far will each planet have revolved around Star X? Copy the diagram and sketch the positions of the three planets to find out. How far will each planet have revolved around Star X in 400 days? Sketch their positions.

25. Drawing Conclusions Can Planet C ever be closer to Planet A than to Planet B? Study your drawings to figure this out.

Lab zone Standards Investigation

Performance Assessment Present your scale models of the solar system. Display your data tables showing how you did the calculations and how you checked them for accuracy.

Standards Practice

Choose the letter of the best answer.

1. What characteristic do all of the inner planets share?

A They are larger and more massive than the sun.
B They have thick atmospheres of hydrogen and helium.
C They have rocky surfaces.
D They each have many moons. **S 8.4.e**

2. Mercury has a daytime temperature of about 430°C and a nighttime temperature below –170°C. What is the best explanation?

A Mercury has a greenhouse effect.
B Global warming is occurring on Mercury.
C Mercury is the closest planet to the sun.
D Mercury has no real atmosphere. **S 8.4.e**

3. The process by which the sun produces energy is called

A combustion.
B a chemical reaction.
C nuclear fusion.
D nuclear fission. **S 8.4.b**

4. You can see the planets at night because

A they produce their own light.
B sunlight reflects from their surfaces.
C nuclear fusion takes place in their cores.
D their surfaces are brighter than those of the stars. **S 8.4.d**

5. The sun remains stable as a result of a balance between the

A outward pressure of nuclear fission and the inward pull of nuclear fusion.
B outward pressure of nuclear fusion and the inward pull of gravity.
C outward pressure of gravity and the inward pull of nuclear fusion.
D outward pressure of the greenhouse effect and the inward pull of gravity. **S 8.2.g**

The table below shows data for five planets in our solar system. Use the table and your knowledge of science to answer Questions 6–8.

Planet	Period of Rotation (Earth days)	Period of Revolution (Earth years)	Average Distance From the Sun (AU)
Mars	1.03	1.9	1.5
Jupiter	0.41	12	5.2
Saturn	0.45	29	9.6
Uranus	0.72	84	19.2
Neptune	0.67	164	30.0

6. Which planet has a "day" that is most similar in length to a day on Earth?

A Mars **B** Jupiter
C Uranus **D** Neptune **S 8.4.e**

7. Light takes about 8 minutes and 20 seconds to travel from the sun to Earth, 1 AU away. About how long does it take light to travel from the sun to Jupiter?

A 10 minutes **B** 25 minutes
C 43 minutes **D** 112 minutes **S 8.4.c**

8. Which of the following conclusions about planets is supported by information in the table?

A As distance from the sun increases, period of rotation increases.
B As distance from the sun increases, period of revolution increases.
C As distance from the sun increases, period of revolution decreases.
D There is no relationship between distance from the sun and period of revolution. **S 8.4.e**

Apply the BIG Idea

9. Describe three major differences between the terrestrial planets and the gas giants. **S 8.4.b**