Section 2

The Sun

Reading Preview

Key Concepts

- What are the three layers of the sun's interior?
- What are the three layers of the sun's atmosphere?
- What features form on or above the sun's surface?

Key Terms

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

Target Reading Skill

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

The Sun
I. The sun's interior
A. The core
B.
C.
II. The sun's atmosphere
A. The photosphere

Lab zone Discover Activity

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 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 other distant objects in orbit.

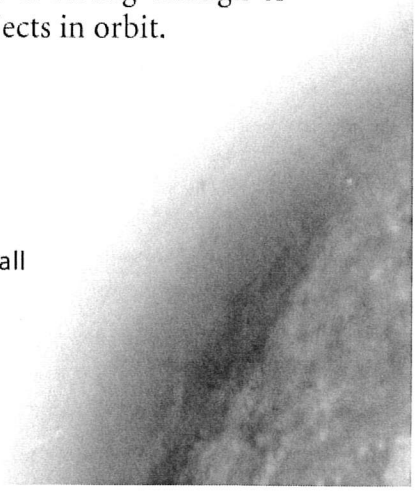


FIGURE 6
Active Sun
The sun is a huge, hot ball of glowing gas.

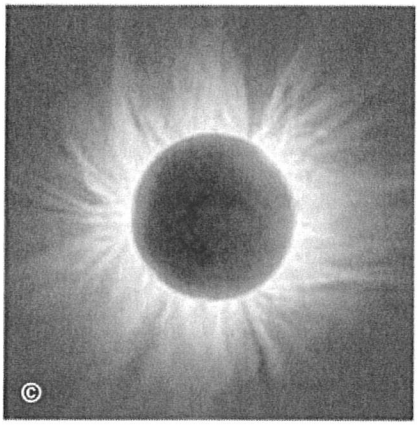


FIGURE 7
The Sun's Corona
During a total solar eclipse, you can see light from the corona, the outer layer of the sun's atmosphere around the dark disk of the moon.

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 an 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 7. 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.**

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

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?

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.**

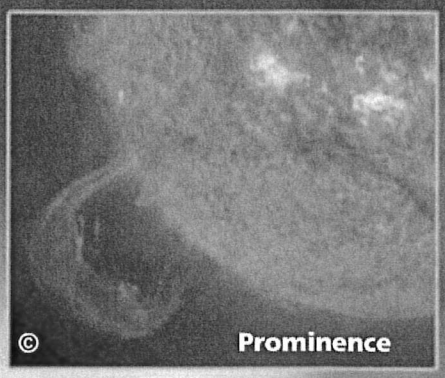
Sunspots Early observers noticed dark spots on the sun's surface. These became known as sunspots. Sunspots look small. But in fact, they can be larger than Earth. **Sunspots** are areas of gas on the sun's surface that are cooler than the gases around them. Cooler gases don't give off as much light as 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.

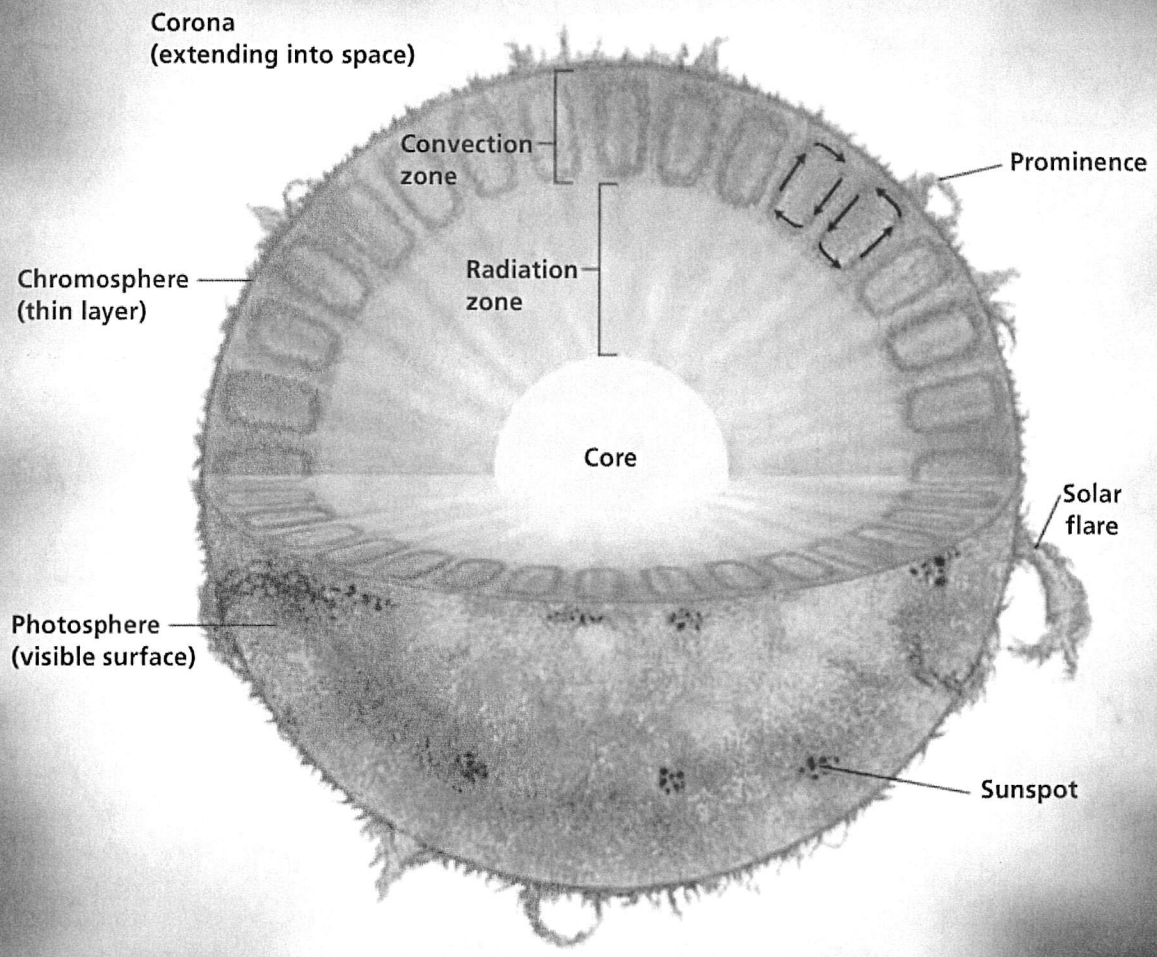
FIGURE 8

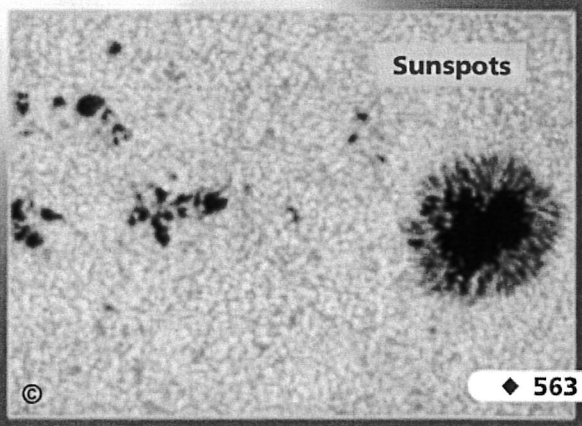
The Layers of the Sun

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.*







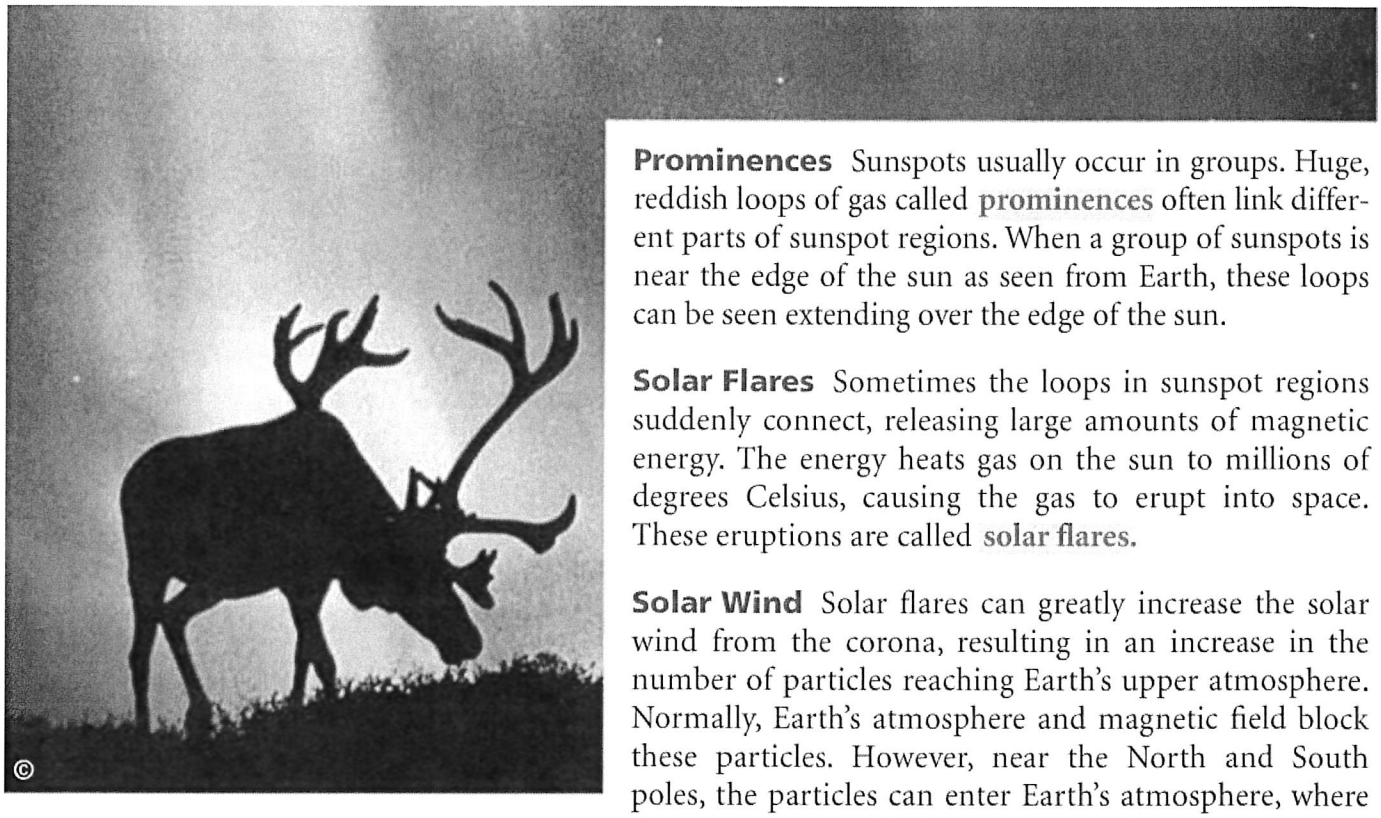


FIGURE 9
Auroras
Auroras such as this can occur near Earth's poles when particles of the solar wind strike gas molecules in Earth's upper atmosphere.

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, releasing large amounts of magnetic 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

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

Reviewing Key Concepts

HINT 1. a. Listing List the three layers of the sun's interior, starting from the center.

HINT b. Explaining Where is the sun's energy produced?

HINT c. Comparing and Contrasting Compare how energy moves through the radiation zone and the convection zone.

HINT 2. a. Listing What three layers make up the sun's atmosphere?

HINT b. Identifying Which of the sun's layers produces its visible light?

HINT 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. HINT

b. Relating Cause and Effect Why do sunspots look darker than the rest of the sun's photosphere? HINT

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

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.

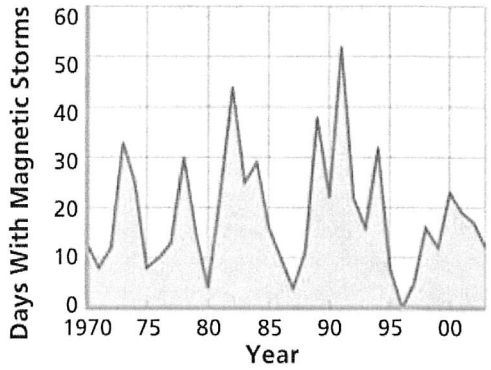
Analyze and Conclude

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.

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



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 5

Comets, Asteroids, and Meteors

Reading Preview

Key Concepts

- 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

Target Reading Skill

Comparing and Contrasting

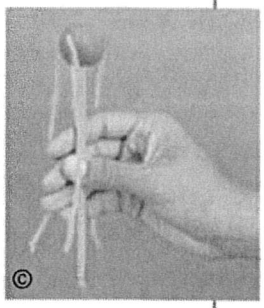
As you read, compare and contrast comets, asteroids, and meteoroids by completing a table like the one below.

Comets, Asteroids, and Meteoroids

Feature	Comets	Asteroids
Origin	Kuiper belt and Oort cloud	
Size		
Composition		

Lab zone Discover Activity

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 their 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.

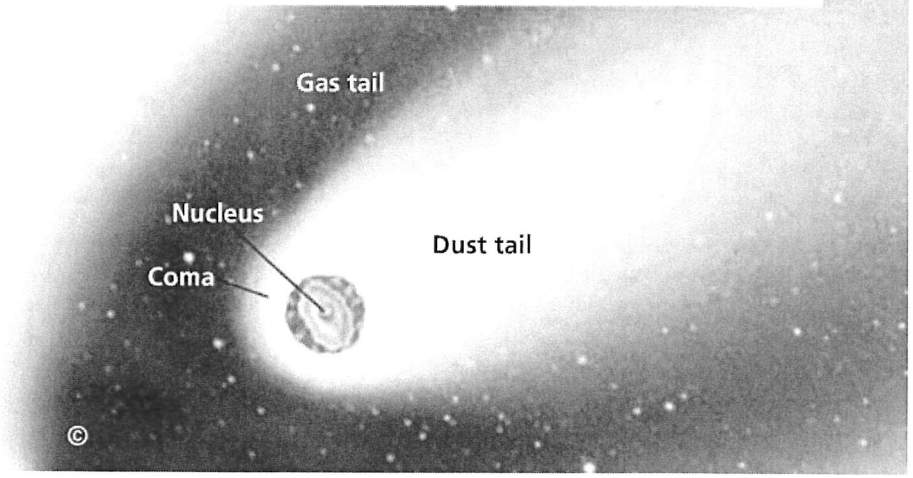


FIGURE 23
Structure of a Comet
The main parts of a comet are the nucleus, the coma, and the tail. The nucleus is deep within the coma. Most comets have two tails—a bluish gas tail and a white dust tail.

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 23 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. Most comets have two tails—a gas tail and a dust tail. Both tails usually point away from the sun, as shown in Figure 24.

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 are found in 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 out to more than 1,000 times the distance between Pluto and the sun.

Reading Checkpoint **What is the Oort cloud?**

Go Online NSTA SciLinks

For: Links on comets, asteroids, and meteors
Visit: www.SciLinks.org
Web Code: scn-0635

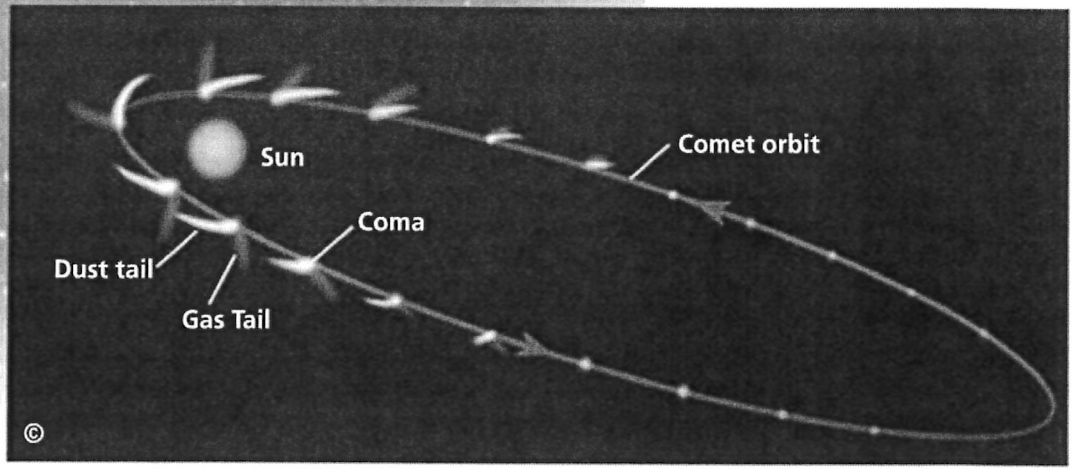


FIGURE 24
Comet Orbits
Most comets revolve around the sun in very long, narrow orbits. Gas and dust tails form as the comet approaches the sun.
Observing *What shape is a comet's orbit?*

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 between the orbits of Mars and Jupiter.** This region of the solar system, shown in Figure 25, 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.**

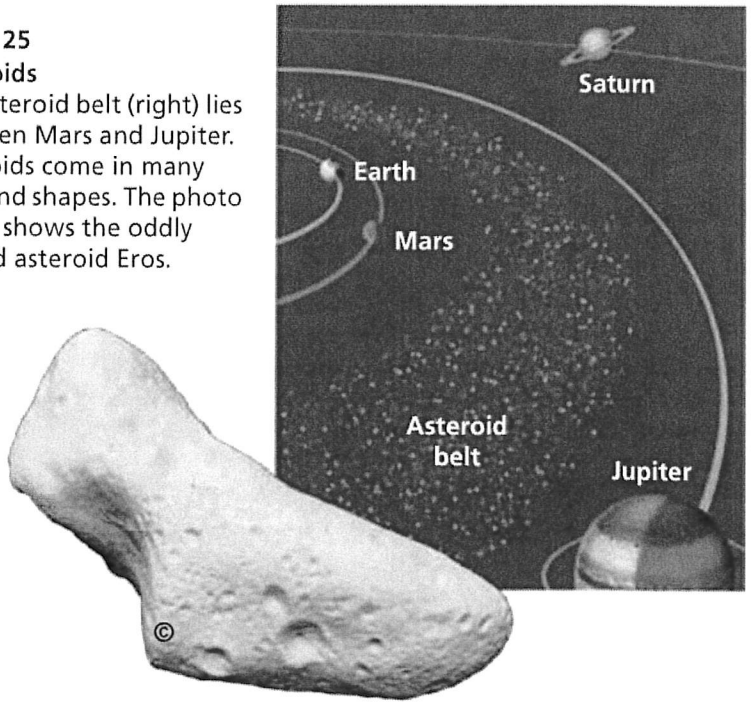


FIGURE 25
Asteroids
The asteroid belt (right) lies between Mars and Jupiter. Asteroids come in many sizes and shapes. The photo below shows the oddly shaped asteroid Eros.

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 burn up completely. Meteoroids that pass through the atmosphere and hit Earth's surface are called **meteorites.** The craters on the moon were formed by meteoroids.

FIGURE 26 Meteors
Meteoroids make streaks of light called meteors as they burn up in the atmosphere.

Section 5 Assessment

Target Reading Skill Comparing and Contrasting Use the information in your table about comets, asteroids, and meteoroids to help you answer the questions below.

Reviewing Key Concepts

HINT HINT HINT
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?

HINT HINT HINT
2. a. Describing What is an asteroid?
   b. Explaining Where are most asteroids found?
   c. Summarizing How did the asteroids form?

HINT HINT HINT
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.

Is There Life Beyond Earth?

Reading Preview

Key Concepts

- 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

Target Reading Skill

Asking Questions Before you read, preview the red headings. In a graphic organizer like the one below, ask a question for each heading. As you read, write the answers to your questions.

Is There Life Beyond Earth?

Question	Answer
What are the "Goldilocks" conditions?	The "Goldilocks" conditions are . . .

Lab zone Discover Activity

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 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.**

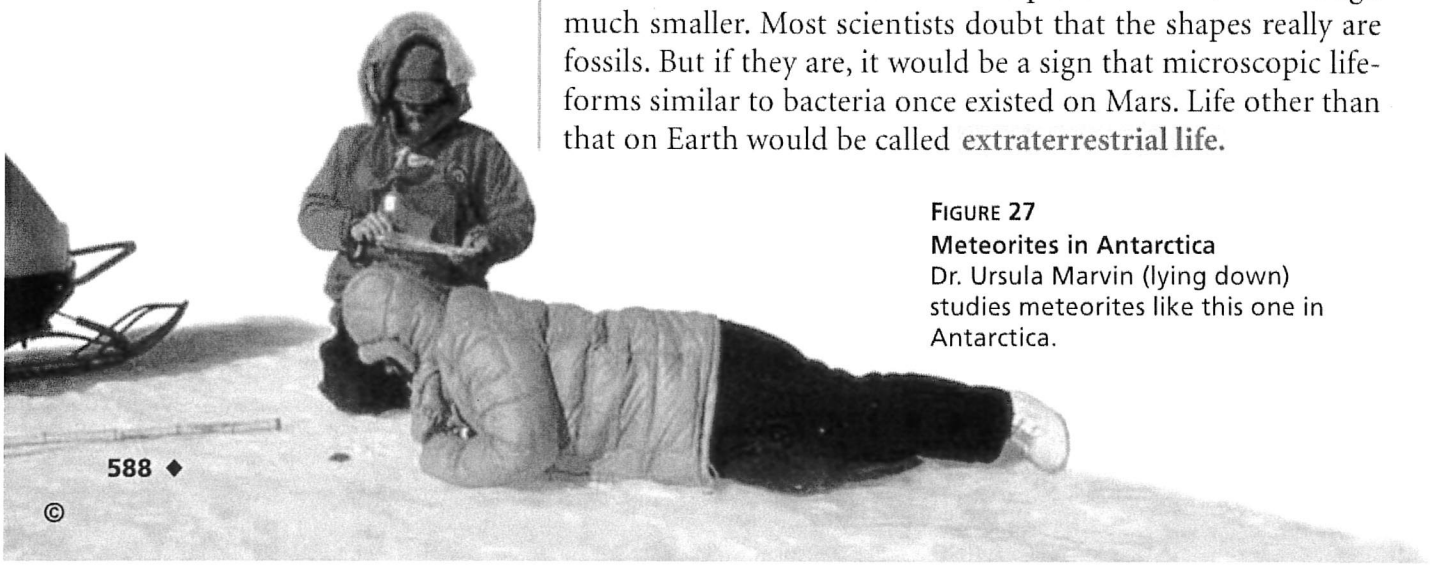
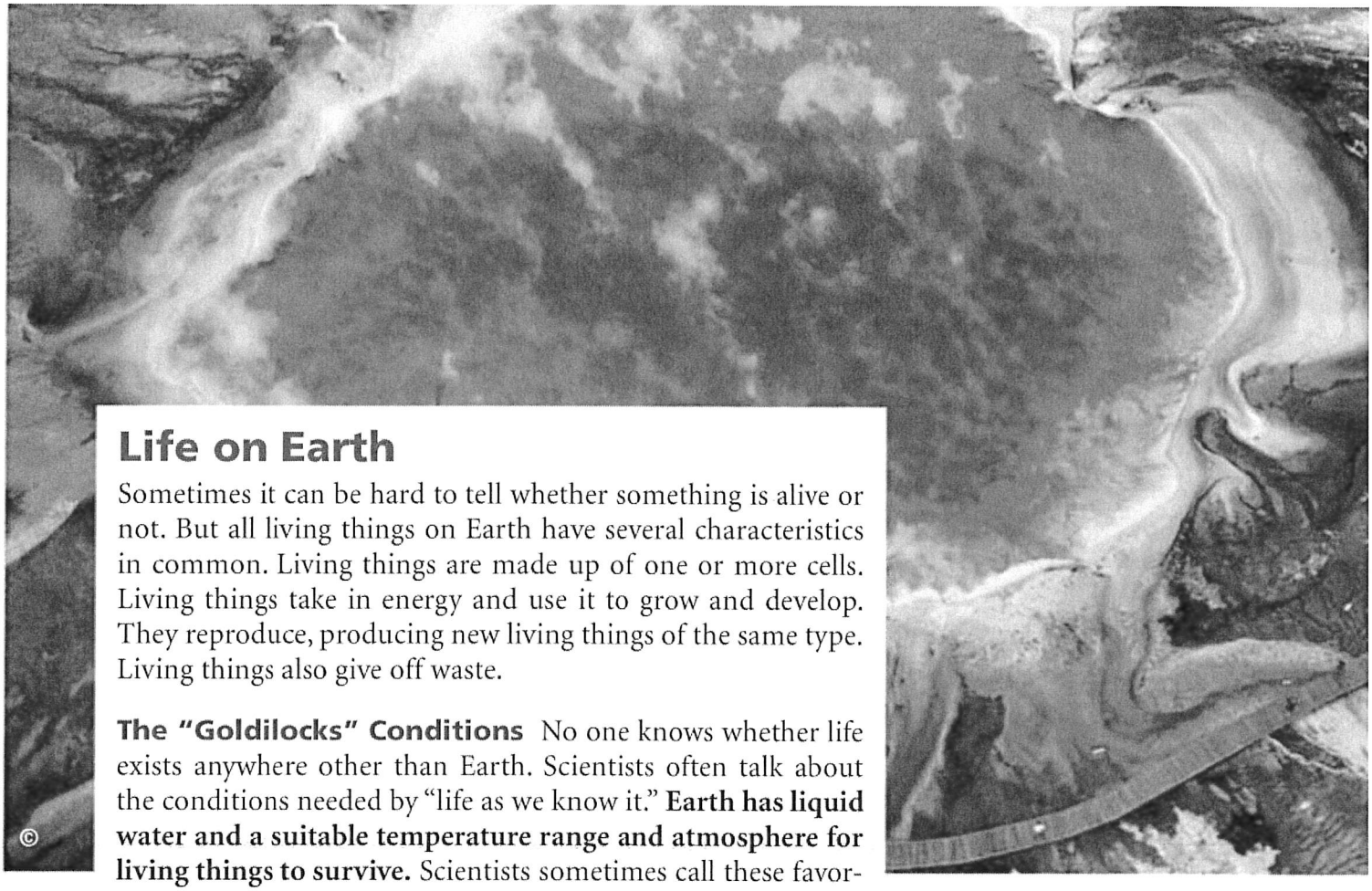


FIGURE 27
Meteorites in Antarctica
Dr. Ursula Marvin (lying down) studies meteorites like this one in Antarctica.



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?**

FIGURE 28
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?*

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 NSTA SCILINKS

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

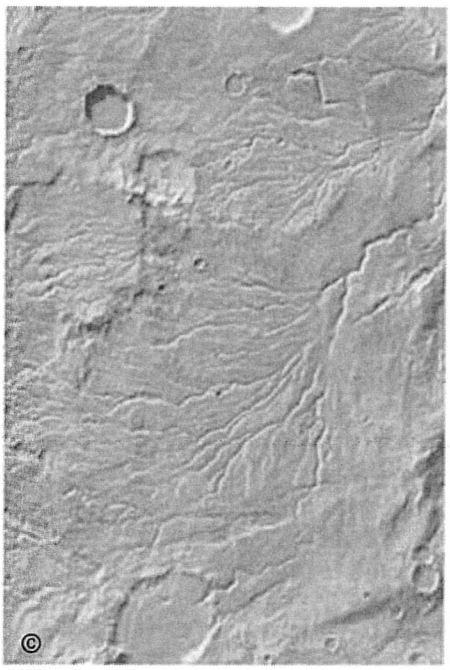


FIGURE 29
Liquid Water on Mars
The river-like patterns on the surface of Mars indicate that liquid water once flowed there.
Applying Concepts *Why does this evidence make it more likely that there may once have been life on Mars?*

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 29 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 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?**

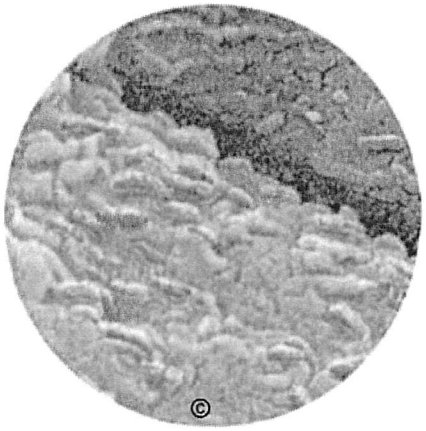


FIGURE 30
Martian Fossils?
This false-color electron microscope image shows tiny fossil-like shapes found in a meteorite from Mars. These structures are less than one-hundredth the width of a human hair.

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 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 31
Exploring Europa
Scientists have discussed sending a robotic probe to search for life in the ocean below Europa's icy crust.

Section 6 Assessment

Target Reading Skills Asking Questions Use the answers to the questions you wrote about the section headings to help answer the questions.

Reviewing Key Concepts

HINT
1. a. Relating Cause and Effect What conditions does life on Earth need to survive?

HINT
b. Summarizing Why is Earth said to have the "Goldilocks" conditions?

HINT
c. Applying Concepts Do you think there could be life as we know it on Neptune? Explain. (*Hint*: Review Section 4.)

HINT
2. a. Explaining Why do astronomers think there could be life on Europa?

HINT
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? HINT

Lab zone At-Home Activity

Making 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 16 Study Guide

The BIG Idea **Earth in space** 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

In a geocentric system, Earth is perceived to be at the center of the revolving planets and stars. In a heliocentric system, Earth and the other planets revolve around the sun.

Galileo's discoveries supported the heliocentric model. Kepler found that the orbit of each planet is an ellipse.

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

2 The Sun

Key Concepts

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

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

3 The Inner Planets

Key Concepts

The four inner planets are small and dense and have rocky surfaces.

Earth has liquid water at its surface.

Mercury is the smallest terrestrial planet.

Venus's internal structure is similar to Earth's.

Scientists think that a large amount of liquid water flowed on Mars's surface in the distant past.

Key Terms

• terrestrial planets • greenhouse effect

4 The Outer Planets

Key Concepts

Jupiter, Saturn, Uranus, and Neptune are much larger and more massive than Earth.

Jupiter is the largest and most massive planet in the solar system.

Saturn has the most spectacular rings of any planet.

Uranus's axis of rotation is tilted at an angle of about 90 degrees from the vertical.

Neptune's 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

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

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

Go Online
PHSchool.com
For: Self-Assessment
Visit: PHSchool.com
Web Code: cpa-0016

Organizing Information

Comparing and Contrasting Fill in the graphic organizer to compare and contrast the geocentric system and the heliocentric system. (For more on Comparing and Contrasting, see the Skills Handbook.)

Feature	Geocentric System	Heliocentric System
Object at center	Earth	a. ?
Objects that move around center	Planets and sun	b. ?
Proposed by	c. ?	Copernicus
Supporters	Ptolemy	d. ?

Reviewing Key Terms

Choose the letter of the best answer.

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

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

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

HINT
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.

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

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

HINT
6. The shape of the orbit of each planet is a(n) ellipse.

HINT
7. Prominences are regions of cooler gases on the sun.

HINT
8. The trapping of heat by a planet's atmosphere is called nuclear fusion.

HINT
9. All the terrestrial planets are surrounded by rings.

HINT
10. The solid inner core of a comet is its coma.

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.

Discovery Channel School

The Solar System
Video Preview
Video Field Trip
▶ Video Assessment

Review and Assessment

Checking Concepts

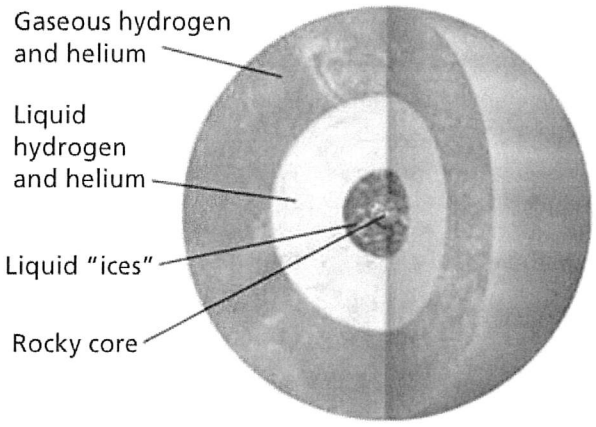
11. Describe the contributions Tycho Brahe and Johannes Kepler made to modern astronomy.
12. What is the solar wind?
13. Why does Mercury have very little atmosphere?
14. Why can astronomers see the surface of Mars clearly but not the surface of Venus?
15. What evidence do astronomers have that water 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.

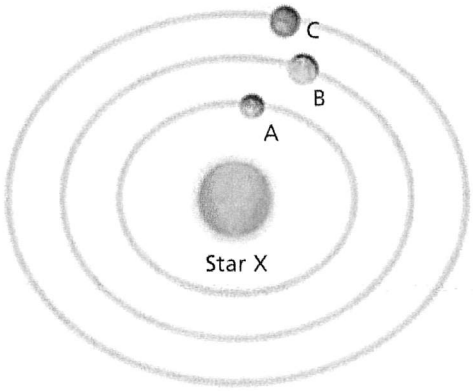


22. **Making Generalizations** Why would the discovery of liquid water on another planet be important?

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 Chapter Project

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.

GA Preparing for the CRCT

Test-Taking Tip

Interpreting a Data Table

When answering a question that is related to a data table, read the headings of the columns and rows to see how the data is organized. Think about the relationship between the columns and rows. For example, the table shown before Question 3 gives data about period of rotation, period of revolution, and average distance from the sun (column headings) for five planets (row headings). Do not spend much time trying to examine all the data, because you may not need total understanding to answer the questions.

Sample Question

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.

Answer

The correct answer is **B**. The table shows that planets' periods of revolution increase the farther they are from the sun. There is no relationship between a planet's distance from the sun and its period of rotation.

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. **S6E1.c**

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. **S6E1.c**

The table below shows data for five planets in our solar system. Use the table and your knowledge of science to answer Questions 3–5.

Planet	Period of Rotation (Earth days)	Period of Revolution (Earth years)	Average Distance From the Sun (million km)
Mars	1.03	1.9	228
Jupiter	0.41	12	779
Saturn	0.45	29	1,434
Uranus	0.72	84	2,873
Neptune	0.67	164	4,495

3. Which of these planets' orbits is farthest from Earth's orbit?
   A Mars **B** Jupiter
   C Uranus **D** Neptune **S6E1.c**

4. Which planet has a "day" that is most similar in length to a day on Earth?
   A Mars **B** Jupiter
   C Uranus **D** Neptune **S6E1.c**

5. Light takes about 8 minutes and 20 seconds to travel from the sun to Earth, 150 million kilometers 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

S6E1.c

Constructed Response

6. Describe three major differences between the terrestrial planets and the gas giants. **S6E1.c**

Section 4

Star Systems and Galaxies

Reading Preview

Key Concepts

- What is a star system?
- What are the major types of galaxies?
- How do astronomers describe the scale of the universe?

Key Terms

- binary star
- eclipsing binary
- open cluster
- globular cluster
- galaxy
- spiral galaxy
- elliptical galaxy
- irregular galaxy
- quasar
- universe
- scientific notation

Target Reading Skill

Building Vocabulary Carefully read the definition of each key term. Also read the neighboring sentences. Then write a definition of each key term in your own words.

Lab zone **Discover Activity**

Why Does the Milky Way Look Hazy?

1. Using a pencil, carefully poke at least 20 holes close together in a sheet of white paper.
2. Tape the paper to a chalkboard or dark-colored wall.
3. Go to the other side of the room and look at the paper. From the far side of the room, what do the dots look like? Can you see individual dots?

Think It Over

Making Models How is looking at the paper from the far side of the room like trying to see many very distant stars that are close together? How does your model compare to the photograph of the Milky Way below?

On a clear, dark night in the country, you can see a hazy band of light stretched across the sky. This band of stars is called the Milky Way. It looks as if the Milky Way is very far away. Actually, though, Earth is inside the Milky Way! The Milky Way looks milky or hazy from Earth because the stars are too close together for your eyes to see them individually. The dark blotches in the Milky Way are clouds of dust that block light from stars behind them.

The Milky Way

FIGURE 15
Invisible Partners
If you saw someone dancing but couldn't see a partner, you could infer that the partner was there by watching the dancer you could see. Astronomers use a similar method to detect faint stars in star systems.

Star Systems and Clusters

Our solar system has only one star, the sun. But this is not the most common situation for stars. **Most stars are members of groups of two or more stars, called star systems.** If you were on a planet in one of these star systems, at times you might see two or more suns in the sky! At other times, one or more of these suns would be below the horizon.

Multiple Star Systems Star systems that have two stars are called double stars or **binary stars.** (The prefix *bi* means "two.") Those with three stars are called triple stars. The nearby star Proxima Centauri may be part of a triple star system. The other two stars in the system, Alpha Centauri A and Alpha Centauri B, form a double star. Scientists are not sure whether Proxima Centauri is really part of the system or is just passing close to the other two stars temporarily.

Often one star in a binary star is much brighter and more massive than the other. Astronomers can sometimes detect a binary star even if only one of the stars can be seen from Earth. Astronomers can often tell that there is a dim star in a binary system by observing the effects of its gravity. As the dim companion star revolves around a bright star, the dim star's gravity causes the bright star to wobble back and forth. Imagine watching a pair of dancers who are twirling each other around. Even if one dancer were invisible, you could tell that the invisible dancer was there from watching the motion of the visible dancer.

Eclipsing Binaries A wobble is not the only clue that a star has a dim companion. A dim star in a binary star may pass in front of a brighter star and eclipse it. From Earth, the binary star would suddenly look much dimmer. A system in which one star periodically blocks the light from another is called an **eclipsing binary.** As Figure 16 shows, the star Algol is actually an eclipsing binary star system.

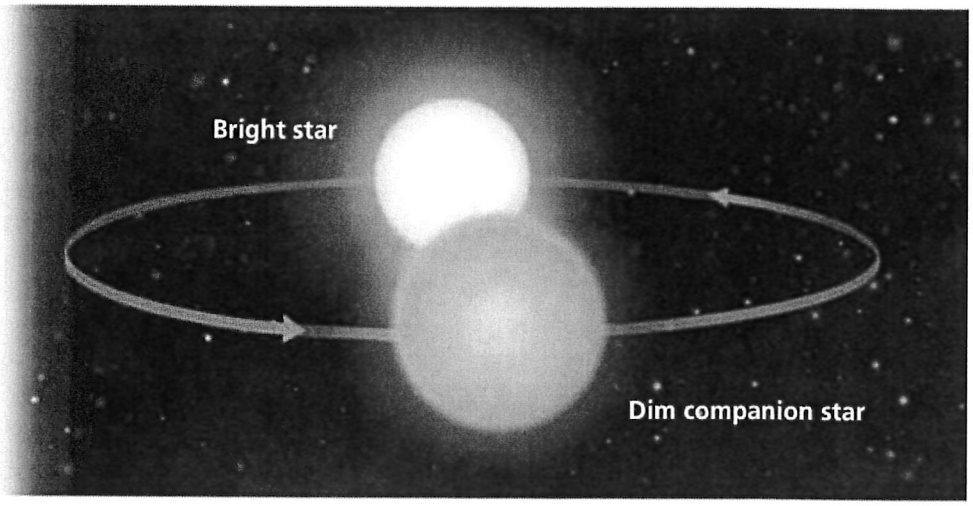


FIGURE 16
Eclipsing Binary
Algol is an eclipsing binary star system consisting of a bright star and a dim companion. Each time the dimmer star passes in front of the brighter one, Algol appears less bright.
Interpreting Diagrams *When does Algol appear brighter?*

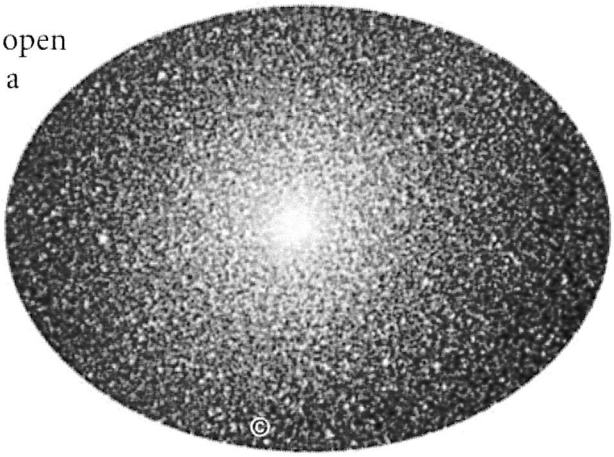
Planets Around Other Stars In 1995, astronomers first discovered a planet revolving around another ordinary star. They used a method similar to the one used in studying binary stars. The astronomers observed that a star was moving slightly toward and away from us. They knew that the invisible object causing the movement didn't have enough mass to be a star. They inferred that it must be a planet.

Since then, astronomers have discovered more than 100 planets around other stars, and new ones are being discovered all of the time. Most of these new planets are very large, with at least half of the mass of Jupiter. A small planet would be hard to detect because it would have little gravitational effect on the star it orbited.

Could there be life on planets in other solar systems? Some scientists think it is possible. A few astronomers are using radio telescopes to search for signals that could not have come from natural sources. Such a signal might be evidence that an extra-terrestrial civilization was sending out radio waves.

Star Clusters Many stars belong to larger groupings called star clusters. All of the stars in a particular cluster formed from the same nebula at about the same time and are about the same distance from Earth.

There are two major types of star clusters: open clusters and globular clusters. **Open clusters** have a loose, disorganized appearance and contain no more than a few thousand stars. They often contain many bright supergiants and much gas and dust. In contrast, **globular clusters** are large groupings of older stars. Globular clusters are round and densely packed with stars—some may contain more than a million stars.



Reading Checkpoint **What is a globular cluster?**

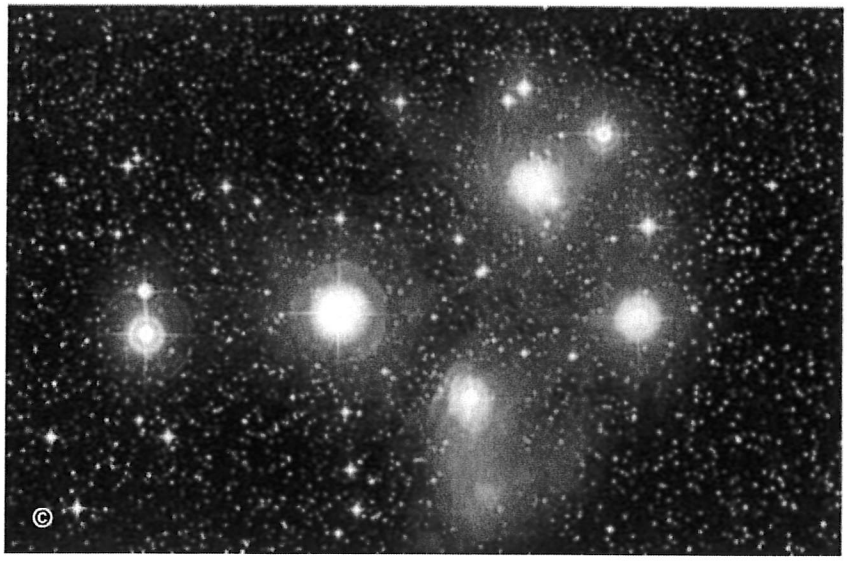
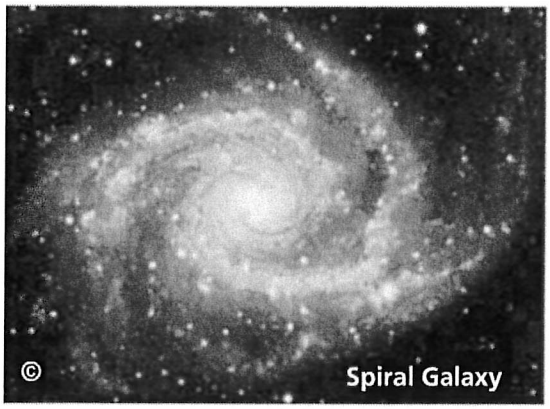
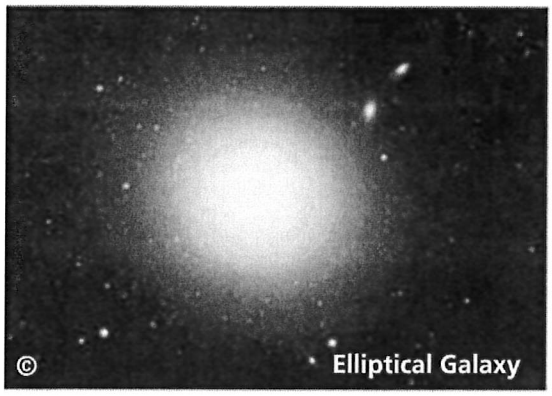


FIGURE 17
Star Clusters
The stars in a globular cluster (above) are all about the same age and the same distance from Earth. The Pleiades (left), also called the *Seven Sisters*, is an open cluster.





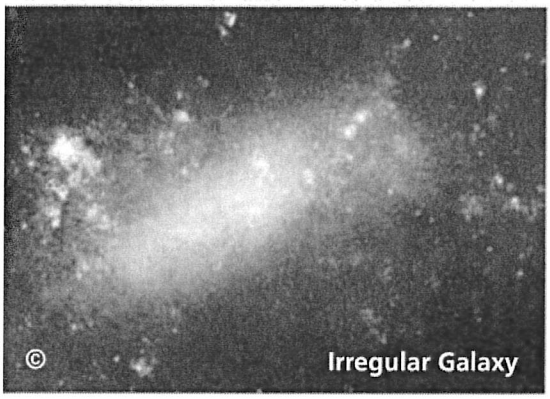


FIGURE 18
Types of Galaxies
There are three major types of galaxies: spiral, elliptical, and irregular.

Galaxies

A **galaxy** is a huge group of single stars, star systems, star clusters, dust, and gas bound together by gravity. There are billions of galaxies in the universe. The largest galaxies have more than a trillion stars. **Astronomers classify most galaxies into the following types: spiral, elliptical, and irregular.** Figure 18 shows examples of these three.

Spiral Galaxies Some galaxies appear to have a bulge in the middle and arms that spiral outward, like pinwheels. Such galaxies are called **spiral galaxies.** The spiral arms contain many bright, young stars as well as gas and dust. Most new stars in spiral galaxies form in these spiral arms. Relatively few new stars are forming in the central bulge. Some spiral galaxies, called barred-spiral galaxies, have a huge bar-shaped region of stars and gas that passes through their center.

Elliptical Galaxies Not all galaxies have spiral arms. **Elliptical galaxies** look like round or flattened balls. These galaxies contain billions of stars but have little gas and dust between the stars. Because there is little gas or dust, stars are no longer forming. Most elliptical galaxies contain only old stars.

Irregular Galaxies Some galaxies do not have regular shapes. These are known as **irregular galaxies.** Irregular galaxies are typically smaller than other types of galaxies. They generally have many bright, young stars and lots of gas and dust to form new stars.

Quasars In the 1960s, astronomers discovered objects that are very bright, but also very far away. Many of these objects are 10 billion light-years or more away, making them among the most distant objects in the universe. These distant, enormously bright objects looked almost like stars. Since *quasi* means "something like" in Latin, these objects were given the name quasi-stellar objects, or **quasars.**

What could be so bright at such a great distance from Earth? Astronomers have concluded that quasars are active young galaxies with giant black holes at their centers. Each of these black holes has a mass a billion times or more as great as that of the sun. As enormous amounts of gas revolve around the black hole, the gas heats up and shines brightly.

Reading Checkpoint **What is a quasar?**

Go Online NSTA SCILINKS
For: Links on galaxies
Visit: www.SciLinks.org
Web Code: scn-0644

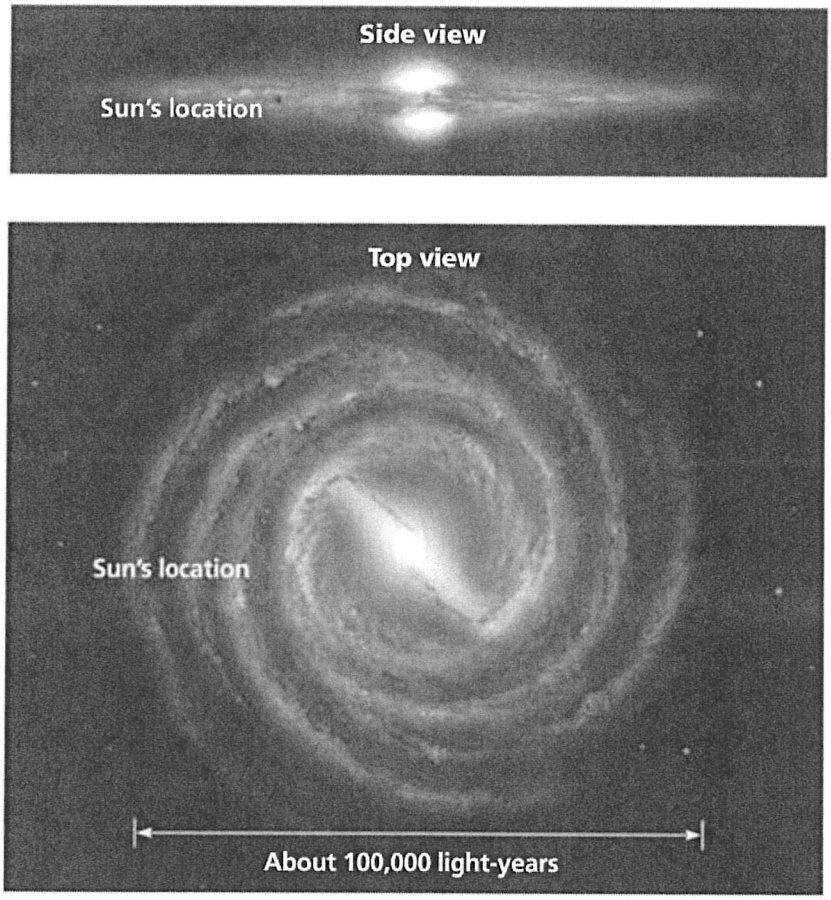


FIGURE 19
Structure of the Milky Way
From the side, the Milky Way appears to be a narrow disk with a bulge in the middle. The galaxy's spiral structure is visible only from above or below the galaxy.
Interpreting Diagrams *Where in the galaxy is the sun located?*

The Milky Way

Our solar system is located in a spiral galaxy called the Milky Way. As Figure 19 shows, the shape of the Milky Way varies depending on your vantage point. From the side, the Milky Way would look like a narrow disk with a large bulge in the middle. But from the top or bottom, the Milky Way would have a spiral, pinwheel shape. You can't see the spiral shape of the Milky Way from Earth because our solar system is inside the galaxy in one of the spiral arms.

The Milky Way is usually thought of as a standard spiral galaxy. However, recent evidence suggests that the Milky Way is a barred-spiral galaxy instead.

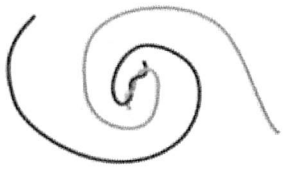
When you see the Milky Way at night during the summer, you are looking toward the center of our galaxy. The center of the galaxy is about 25,000 light-years away, but it is hidden from view by large clouds of dust and gas. However, astronomers can study the center using X-rays, infrared radiation, and radio waves.

Reading Checkpoint **How far away is the center of the galaxy?**

Lab zone Try This Activity

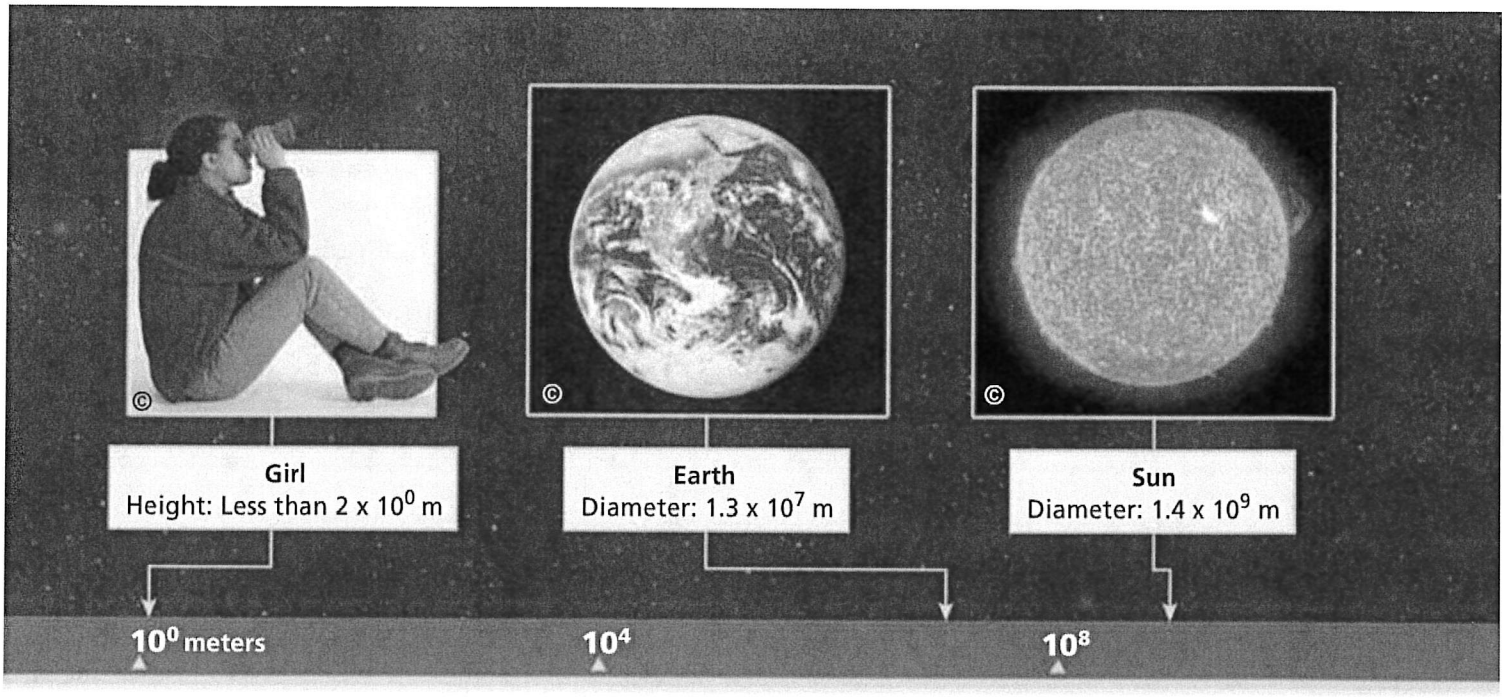
A Spiral Galaxy

You can make a model of our galaxy.



1. Using pipe cleaners, make a pinwheel with two spirals.
2. View the spirals along the surface of the table. Sketch what you see.
3. Next, view the spirals from above the table and sketch them.

Observing The sun is inside a flat spiral galaxy. From Earth's position on the flat surface, is it possible to get a good view of stars in the spiral arms? Why or why not?



The Scale of the Universe

Astronomers define the **universe** as all of space and everything in it. The universe is enormous, almost beyond imagination. Astronomers study objects as close as the moon and as far away as quasars. They study incredibly large objects, such as galaxies that are millions of light-years across. They also study the behavior of tiny particles, such as the atoms within stars. **Since the numbers astronomers use are often very large or very small, they frequently use scientific notation to describe sizes and distances in the universe.**

Scientific Notation Scientific notation uses powers of ten to write very large or very small numbers in shorter form. Each number is written as the product of a number between 1 and 10 and a power of 10. For example: 1,200 is written as 1.2×10^3. One light-year is about 9,500,000,000,000,000 meters. Since there are 15 digits after the first digit, in scientific notation this number is written as 9.5×10^{15} meters.

The Immensity of Space The structures in the universe vary greatly in scale. To understand the scale of these structures, imagine that you are going on a journey through the universe. Refer to Figure 20 as you take your imaginary trip. Start at the left with something familiar—a girl looking through binoculars. She is about 1.5 meters tall. Now shift to the right and change the scale by 10,000,000 or 10^7. You're now close to the diameter of Earth, 1.28×10^7 meters. As you move from left to right across Figure 20, the scale increases. The diameter of the sun is about 100 times that of Earth.

Math Skills

Scientific Notation

The bright star Deneb is about 3,230 light-years from Earth. To express this number in scientific notation, first insert a decimal point in the original number so that you have a number between one and ten. In this case, the number is 3.23.

To determine the power of 10, count the number of places that the decimal point moved. Here the decimal point moved three places.

3,230 light-years = 3.23×10^3 light-years

Practice Problem The sun takes about 220,000,000 years to revolve once around the center of the galaxy. Express this length of time in scientific notation.

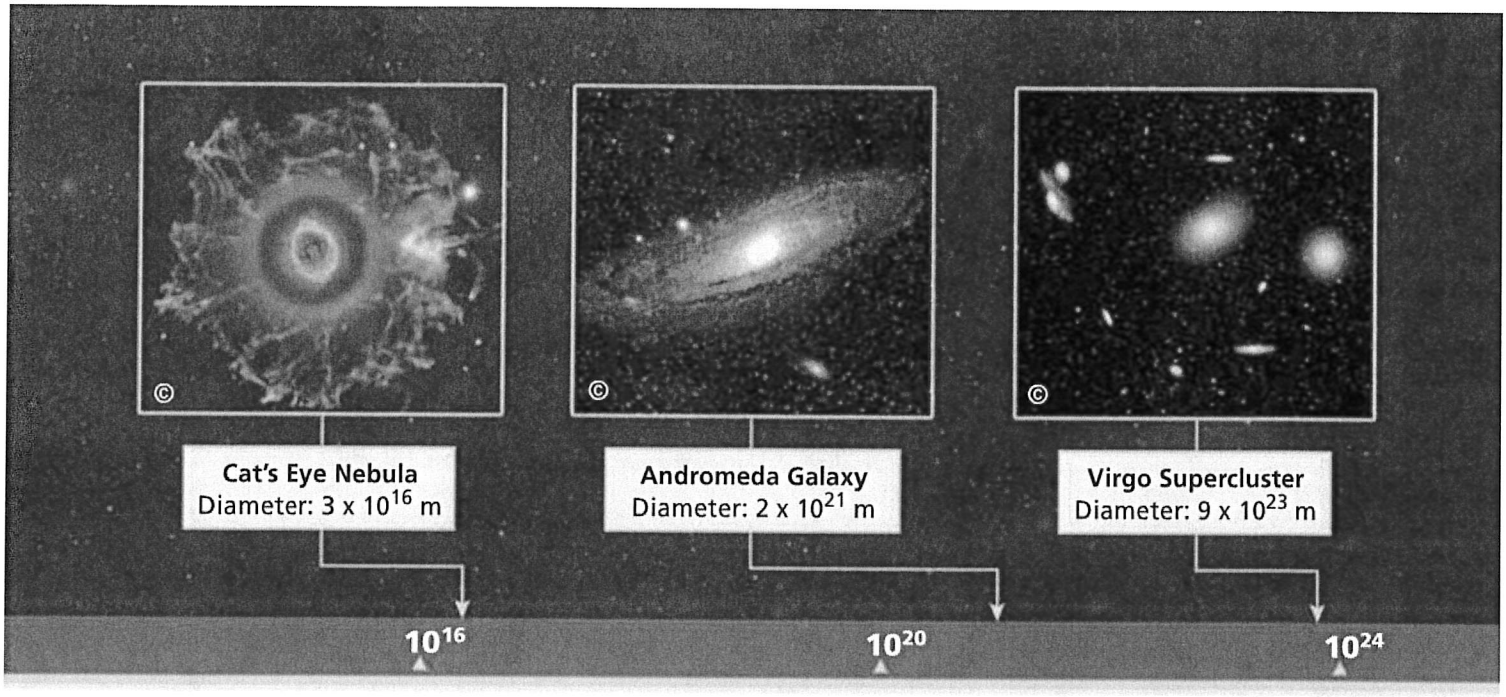


FIGURE 20
Scientific Notation
Scientists often use scientific notation to help describe the vast sizes and distances in space.
Calculating *About how many times larger is the Cat's Eye Nebula than Earth?*

Beyond the solar system, the sizes of observable objects become much larger. For example, within our galaxy, the beautiful Cat's Eye Nebula is about 3×10^{16} meters across.

Beyond our galaxy are billions of other galaxies, many of which contain billions of stars. For example, the nearby spiral galaxy Andromeda is about 2×10^{21} meters across. The Milky Way is part of a cluster of 50 or so galaxies called the Local Group. The Local Group is part of the Virgo Supercluster, which contains hundreds of galaxies. The size of the observable universe is about 10^{10} light years, or 10^{26} meters.

Section 4 Assessment

Vocabulary Skill **Suffixes** What suffixes do you see in the words *elliptical* and *scientific*? What parts of speech do they indicate? Use the term *elliptical galaxy* in a sentence.

Reviewing Key Concepts

HINT
1. a. **Defining** What is a binary star?

HINT
b. **Classifying** Are all binary stars part of star systems? Explain.

HINT
c. **Applying Concepts** Some binary stars are called eclipsing binaries. Explain why this term is appropriate. (*Hint:* Think about Algol as you write your answer.)

HINT
2. a. **Listing** Name the main types of galaxies.

HINT
b. **Classifying** What type of galaxy is the Milky Way?

HINT
c. **Classifying** Suppose astronomers discover a galaxy that contains only old stars. What type of galaxy is it likely to be?

HINT
3. a. **Reviewing** What is scientific notation?

HINT
b. **Explaining** How is scientific notation useful to astronomers?

HINT
c. **Calculating** How large is the Cat's Eye Nebula in light-years? (*Hint:* Refer to Figure 20.)

Math Practice

4. **Scientific Notation** The star Betelgeuse has a diameter of 940,000,000 km. Betelgeuse is 427 light-years from Earth. Write each of these figures in scientific notation.