Reading Tip

As you read, use other skills, such as summarizing and connecting, to help you understand comparisons and contrasts.

Target Your Reading

Use this to focus on the main ideas as you read the chapter.

① **Before you read** the chapter, respond to the statements below on your worksheet or on a numbered sheet of paper.

- Write an **A** if you **agree** with the statement.
- Write a **D** if you **disagree** with the statement.

② **After you read** the chapter, look back to this page to see if you've changed your mind about any of the statements.

- If any of your answers changed, explain why.
- Change any false statements into true statements.
- Use your revised statements as a study guide.

Before You Read A or D		Statement	After You Read A or D
	1	The Sun contains more than 99 percent of the mass of the entire solar system.	
	2	Venus is sometimes called Earth's twin because its size and mass are similar to Earth's.	
	3	Mars is the third planet from the Sun and is nicknamed the blue planet.	
	4	Earth is the most volcanically active object in the solar system.	
	5	Jupiter, Saturn, Uranus, and Neptune all have rings that orbit these planets.	
	6	Most asteroids are located in an area called the asteroid belt, which is located between the orbits of Jupiter and Saturn.	
	7	Asteroids, meteoroids, and comets do not contain water.	

Science Online
Print out a worksheet of this page at earth.msscience.com

section 1

The Solar System

as you read

What **You'll Learn**

- **Compare** models of the solar system.
- **Explain** that gravity holds planets in orbits around the Sun.

Why **It's Important**

New technology has come from exploring the solar system.

Review Vocabulary

system: a portion of the universe and all of its components, processes, and interactions

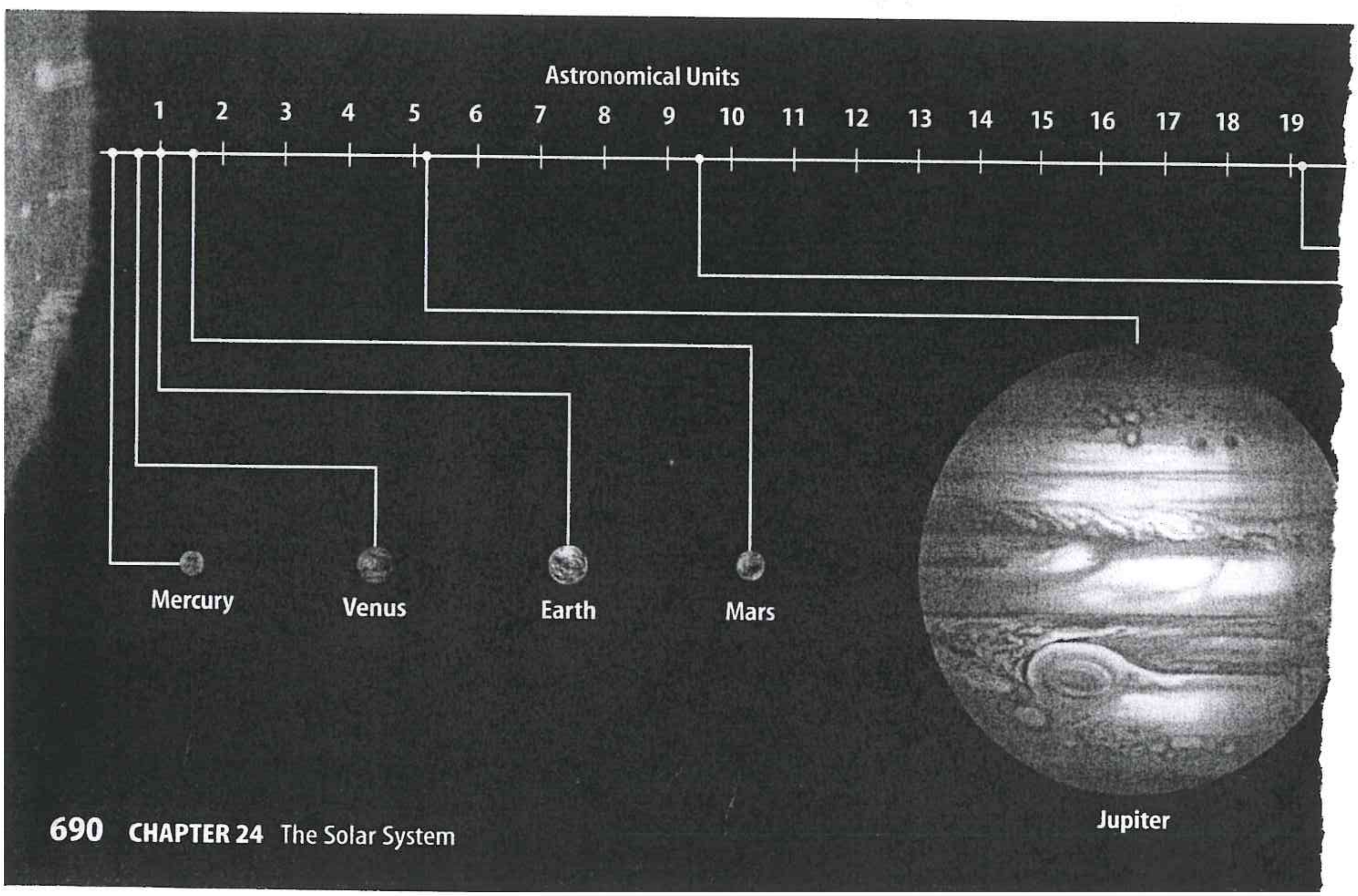
New Vocabulary

- solar system

Ideas About the Solar System

People have been looking at the night sky for thousands of years. Early observers noted the changing positions of the planets and developed ideas about the solar system based on their observations and beliefs. Today, people know that objects in the solar system orbit the Sun. People also know that the Sun's gravity holds the solar system together, just as Earth's gravity holds the Moon in its orbit around Earth. However, our understanding of the solar system changes as scientists make new observations.

Earth-Centered Model Many early Greek scientists thought the planets, the Sun, and the Moon were fixed in separate spheres that rotated around Earth. The stars were thought to be in another sphere that also rotated around Earth. This is called the Earth-centered model of the solar system. It included Earth, the Moon, the Sun, five planets—Mercury, Venus, Mars, Jupiter, and Saturn—and the sphere of stars.



Sun-Centered Model People believed the idea of an Earth-centered solar system for centuries. Then in 1543, Nicholas Copernicus published a different view. Copernicus stated that the Moon revolved around Earth and that Earth and the other planets revolved around the Sun. He also stated that the daily movement of the planets and the stars was caused by Earth's rotation. This is the Sun-centered model of the solar system.

Using his telescope, Galileo Galilei observed that Venus went through a full cycle of phases like the Moon's. He also observed that the apparent diameter of Venus was smallest when the phase was near full. This only could be explained if Venus were orbiting the Sun. Galileo concluded that the Sun is the center of the solar system.

Modern View of the Solar System As of 2006, the **solar system** is made up of eight planets, including Earth, and many smaller objects that orbit the Sun. The eight planets and the Sun are shown in **Figure 1.** Notice how small Earth is compared with some of the other planets and the Sun.

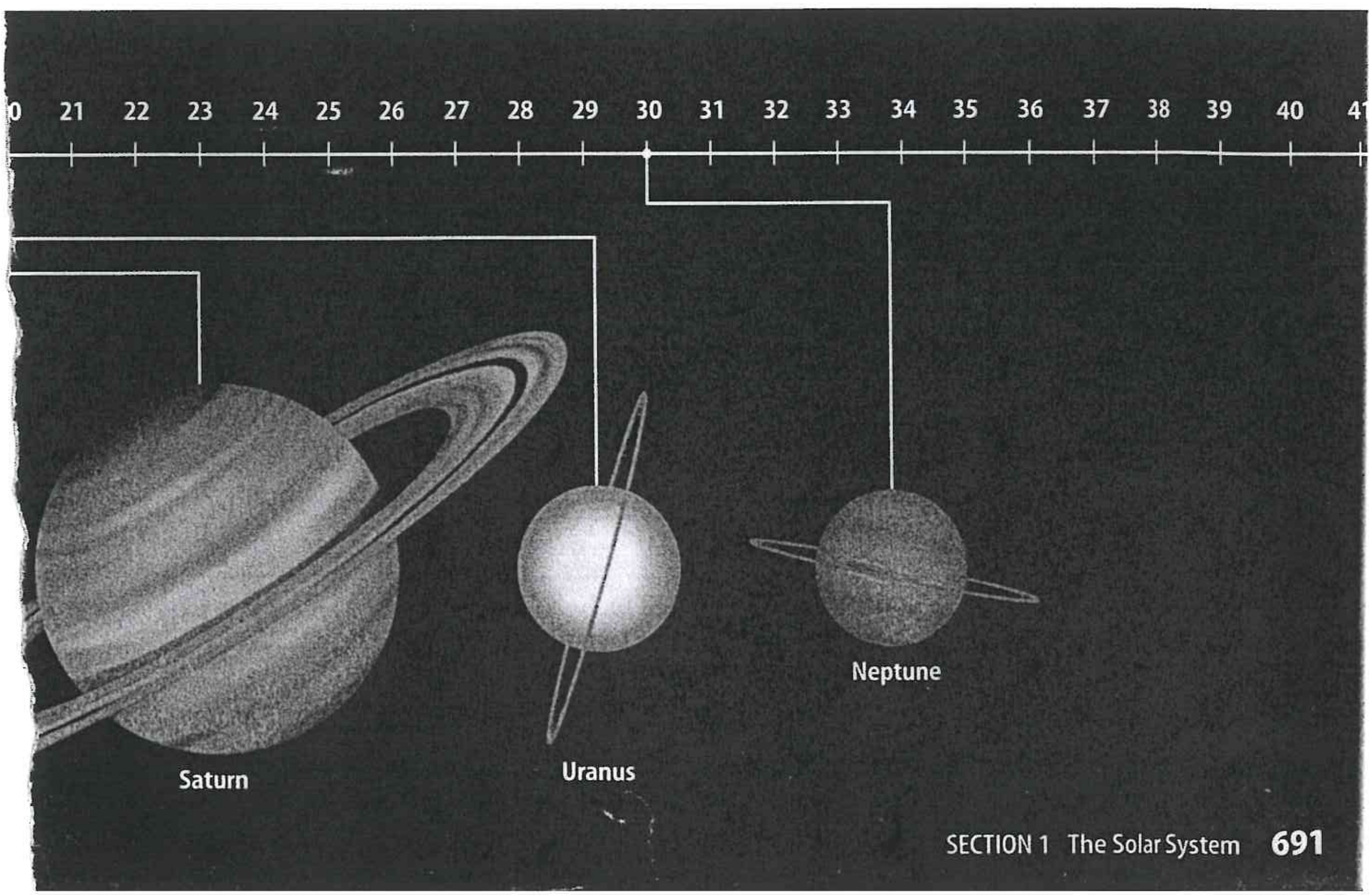
The solar system includes a huge volume of space that stretches in all directions from the Sun. Because the Sun contains 99.86 percent of the mass of the solar system, its gravity is immense. The Sun's gravity holds the planets and other objects in the solar system in their orbits.

Science Online

Topic: Solar System

Visit earth.msscience.com for Web links to information about planets.

Figure 1 Each of the eight planets in the solar system is unique. The distances between the planets and the Sun are shown on the scale. One astronomical unit (AU) is the average distance between Earth and the Sun.



INTEGRATE Physics

Rotational Motion You might have noticed that when a twirling ice skater pulls in her arms, she spins faster. The same thing occurs when a cloud of gas, ice, and dust in a nebula contracts. As mass moves toward the center of the cloud, the cloud rotates faster.

How the Solar System Formed

Scientists hypothesize that the solar system formed from part of a nebula of gas, ice, and dust, like the one shown in **Figure 2.** Follow the steps shown in **Figures 3A** through **3D** to learn how this might have happened. A nearby star might have exploded and the shock waves produced by these events could have caused the cloud to start contracting. As it contracted, the nebula likely fragmented into smaller and smaller pieces. The density in the cloud fragments became greater, and the attraction of gravity pulled more gas and dust toward several centers of contraction. This in turn caused them to flatten into disks with dense centers. As the cloud fragments continued to contract, they began to rotate faster and faster.

As each cloud fragment contracted, its temperature increased. Eventually, the temperature in the core of one of these cloud fragments reached about 10 million degrees Celsius. Nuclear fusion began when hydrogen atoms started to fuse and release energy. A star was born—the beginning of the Sun.

It is unlikely that the Sun formed alone. A cluster of stars like the Sun likely formed from parts of the original cloud. The Sun, which is one of many stars in our galaxy, probably escaped from this cluster and has since revolved around the galaxy many times.

Reading Check *What is nuclear fusion?*

Planet Formation Not all of the nearby gas, ice, and dust was drawn into the core of the cloud fragment. The matter that did not get pulled into the center collided and stuck together to form the planets and asteroids. Close to the Sun, the temperature was hot, and the easily vaporized elements could not condense into solids. This is why lighter elements are scarcer in the planets near the Sun than in planets farther out in the solar system.

The inner planets of the solar system—Mercury, Venus, Earth, and Mars—are small, rocky planets with iron cores. The outer planets are Jupiter, Saturn, Uranus, and Neptune. The outer planets are much larger and are made mostly of lighter substances such as hydrogen, helium, methane, and ammonia.

Figure 2 Systems of planets, such as the solar system, form in areas of space like this, called a nebula.

NATIONAL GEOGRAPHIC

VISUALIZING THE SOLAR SYSTEM'S FORMATION

Figure 3

Through careful observations, astronomers have found clues that help explain how the solar system may have formed. A More than 4.6 billion years ago, the solar system was a cloud fragment of gas, ice, and dust. B Gradually, this cloud fragment contracted into a large, tightly packed, spinning disk. The disk's center was so hot and dense that nuclear fusion reactions began to occur, and the Sun was born. C Eventually, the rest of the material in the disk cooled enough to clump into scattered solids. D Finally, these clumps collided and combined to become the eight planets that make up the solar system today.

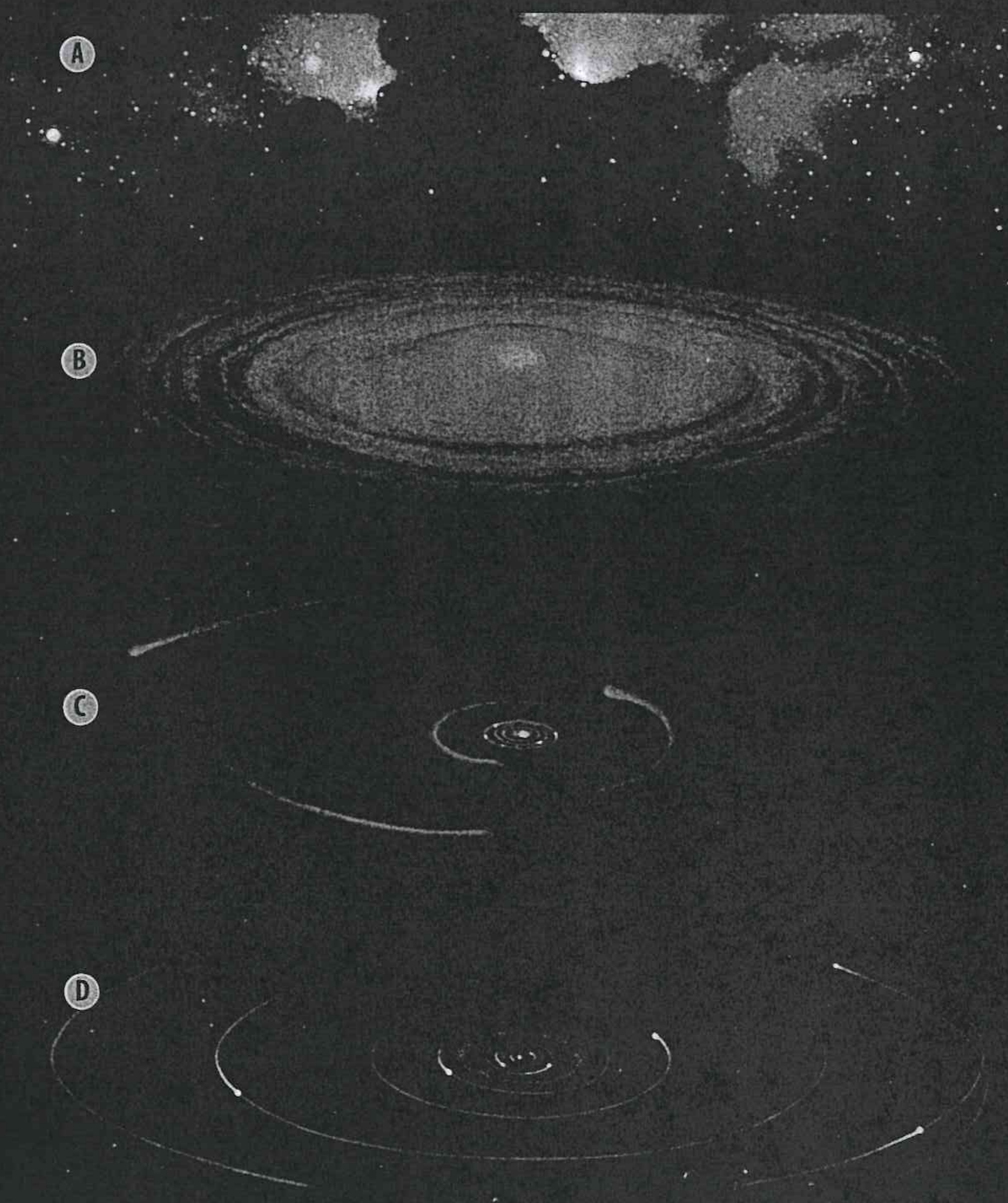


Table 1 Average Orbital Speed

Planet	Average Orbital Speed (km/s)
Mercury	48
Venus	35
Earth	30
Mars	24
Jupiter	13
Saturn	9.7
Uranus	6.8
Neptune	5.4

Johannes Kepler

Motions of the Planets

INTEGRATE Physics When Nicholas Copernicus developed his Sun-centered model of the solar system, he thought that the planets orbited the Sun in circles. In the early 1600s, German mathematician Johannes Kepler began studying the orbits of the planets. He discovered that the shapes of the orbits are not circular. They are oval shaped, or elliptical. His calculations further showed that the Sun is not at the center of the orbits but is slightly offset.

Kepler also discovered that the planets travel at different speeds in their orbits around the Sun, as shown in **Table 1.** You can see that the planets closer to the Sun travel faster than planets farther away from the Sun. Because of their slower speeds and the longer distances they must travel, the outer planets take much longer to orbit the Sun than the inner planets do.

Copernicus's ideas, considered radical at the time, led to the birth of modern astronomy. Early scientists didn't have technology such as space probes to learn about the planets. Nevertheless, they developed theories about the solar system that still are used today.

section 1 review

Summary

Ideas About the Solar System

- The planets in the solar system revolve around the Sun.
- The Sun's immense gravity holds the planets in their orbits.

How the Solar System Formed

- The solar system formed from a piece of a nebula of gas, ice, and dust.
- As the piece of nebula contracted, nuclear fusion began at its center and the Sun was born.

Motion of the Planets

- The planets' orbits are elliptical.
- Planets that are closer to the Sun revolve faster than those that are farther away from the Sun.

Self Check

1. **Describe** the Sun-centered model of the solar system. What holds the solar system together?
2. **Explain** how the planets in the solar system formed.
3. **Infer** why life is unlikely on the outer planets in spite of the presence of water, methane, and ammonia—materials needed for life to develop.
4. **List** two reasons why the outer planets take longer to orbit the Sun than the inner planets do.
5. **Think Critically** Would a year on the planet Neptune be longer or shorter than an earth year? Explain.

Applying Skills

6. **Concept Map** Make a concept map that compares and contrasts the Earth-centered model with the Sun-centered model of the solar system.

Science Online earth.msscience.com/self_check_quiz

LAB

Planetary Orbits

Planets travel around the Sun along paths called orbits. As you construct a model of a planetary orbit, you will observe that the shape of planetary orbits is an ellipse.

Real-World Question

How can you model planetary orbits?

Goals

- **Model** planetary orbits.
- **Calculate** the eccentricity of ellipses.

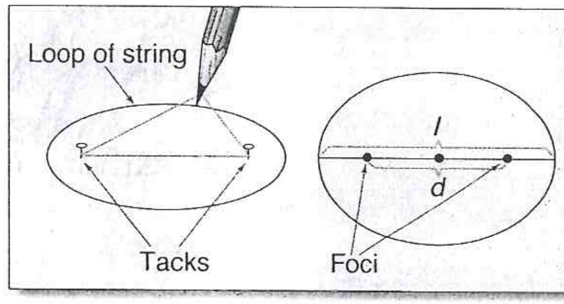
Materials

thumbtacks or pins (2)
cardboard (23 cm × 30 cm)
paper (21.5 cm × 28 cm)
metric ruler
string (25 cm)
pencil

Safety Precautions

Procedure

1. Place a blank sheet of paper on top of the cardboard and insert two thumbtacks or pins about 3 cm apart.
2. Tie the string into a circle with a circumference of 15 cm to 20 cm. Loop the string around the thumbtacks. With someone holding the tacks or pins, place your pencil inside the loop and pull it tight.
3. Moving the pencil around the tacks and keeping the string tight, mark a line until you have completed a smooth, closed curve.
4. Repeat steps 1 through 3 several times. First, vary the distance between the tacks, then vary the length of the string. However, change only one of these each time. Make a data table to record the changes in the sizes and shapes of the ellipses.
5. Eccentricity is a measure of how an orbit varies from a perfect circle. Eccentricity, *e*, is determined by dividing the distance, *d*, between the foci (fixed points—here, the tacks) by the length, *l*, of the major axis.



6. **Calculate** and record the eccentricity of the ellipses that you constructed.
7. **Research** the eccentricities of planetary orbits. Construct an ellipse with the same eccentricity as Earth's orbit.

Conclude and Apply

1. **Analyze** the effect that a change in the length of the string or the distance between the tacks has on the shape of the ellipse.
2. **Hypothesize** what must be done to the string or placement of tacks to decrease the eccentricity of a constructed ellipse.
3. **Describe** the shape of Earth's orbit. Where is the Sun located within the orbit?

Communicating Your Data

Compare your results with those of other students. **For more help, refer to the Science Skill Handbook.**

section 2

The Inner Planets

as you read

What You'll Learn

- List the inner planets in order from the Sun.
- Describe each inner planet.
- Compare and contrast Venus and Earth.

Why It's Important

The planet that you live on is uniquely capable of sustaining life.

Review Vocabulary

space probe: an instrument that is sent to space to gather information and send it back to Earth

New Vocabulary

- Mercury
- Venus
- Earth
- Mars

Inner Planets

Today, people know more about the solar system than ever before. Better telescopes allow astronomers to observe the planets from Earth and space. In addition, space probes have explored much of the solar system. Prepare to take a tour of the solar system through the eyes of some space probes.

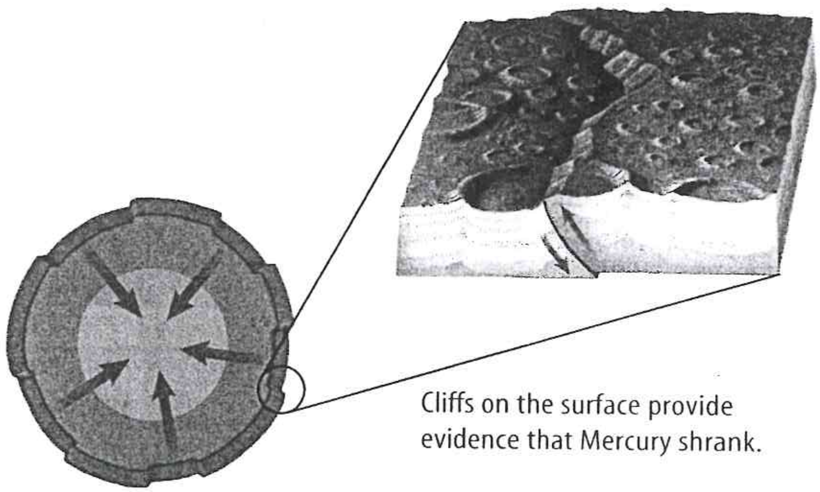
Mercury

The closest planet to the Sun is **Mercury.** The first American spacecraft mission to Mercury was in 1974–1975 by *Mariner 10.* The spacecraft flew by the planet and sent pictures back to Earth. *Mariner 10* photographed only 45 percent of Mercury's surface, so scientists don't know what the other 55 percent looks like. What they do know is that the surface of Mercury has many craters and looks much like Earth's Moon. It also has cliffs as high as 3 km on its surface. These cliffs might have formed at a time when Mercury shrank in diameter, as seen in **Figure 4.**

Why would Mercury have shrunk? *Mariner 10* detected a weak magnetic field around Mercury. This indicates that the planet has an iron core. Some scientists hypothesize that Mercury's crust solidified while the iron core was still hot and molten. As the core started to solidify, it contracted. The cliffs resulted from breaks in the crust caused by this contraction.

Figure 4 Large cliffs on Mercury might have formed when the crust of the planet broke as the planet contracted.

Mercury has many craters.

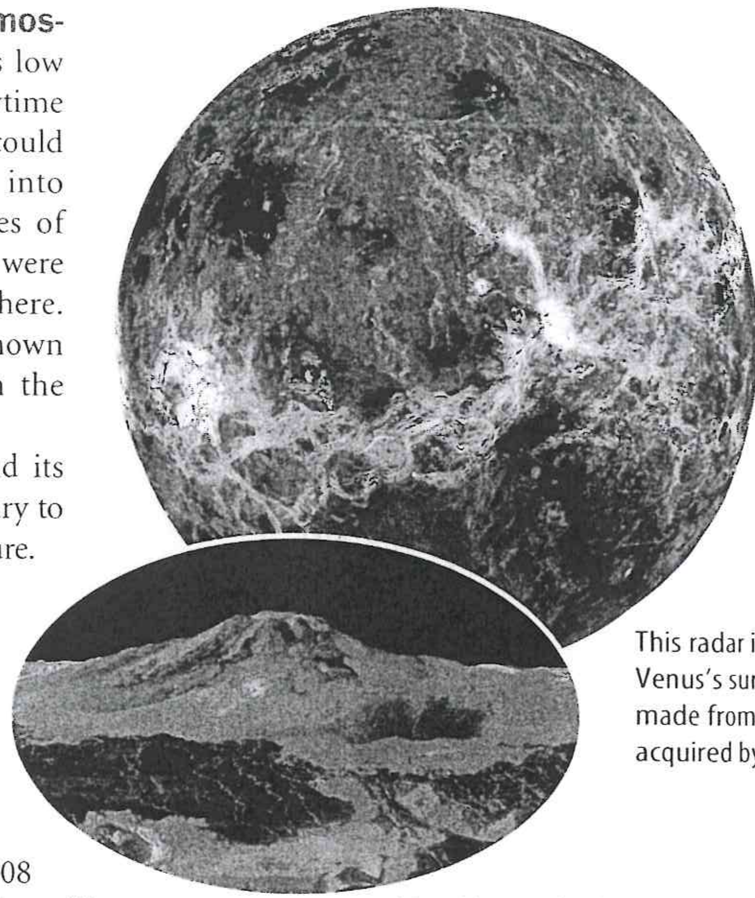


Cliffs on the surface provide evidence that Mercury shrank.

Does Mercury have an atmosphere? Because of Mercury's low gravitational pull and high daytime temperatures, most gases that could form an atmosphere escape into space. *Mariner 10* found traces of hydrogen and helium gas that were first thought to be an atmosphere. However, these gases are now known to be temporarily taken from the solar wind.

The lack of atmosphere and its nearness to the Sun cause Mercury to have great extremes in temperature. Mercury's temperature can reach 425°C during the day, and it can drop to −170°C at night.

Future Mission Launched in 2004, *Messenger* is the next mission to Mercury. This space probe will fly by the planet in 2008 and orbit it in 2011. The probe will photograph and map the entire surface.



This radar image of Venus's surface was made from data acquired by *Magellan.*

Maat Mons is the highest volcano on Venus. Lava flows extend for hundreds of kilometers across the plains.

Figure 5 Venus is the second planet from the Sun.

Venus

The second planet from the Sun is **Venus,** shown in **Figure 5.** Venus is sometimes called Earth's twin because its size and mass are similar to Earth's. In 1962, *Mariner 2* flew past Venus and sent back information about Venus's atmosphere and rotation. The former Soviet Union landed the first probe on the surface of Venus in 1970. *Venera 7,* however, stopped working in less than an hour because of the high temperature and pressure. Additional *Venera* probes photographed and mapped the surface of Venus. Between 1990 and 1994, the U.S. *Magellan* probe used its radar to make the most detailed maps yet of Venus's surface. It collected radar images of 98 percent of Venus's surface. Notice the huge volcano in **Figure 5.**

Clouds on Venus are so dense that only a small percentage of the sunlight that strikes the top of the clouds reaches the planet's surface. The sunlight that does get through warms Venus's surface, which then gives off heat to the atmosphere. Much of this heat is absorbed by carbon dioxide gas in Venus's atmosphere. This causes a greenhouse effect similar to, but more intense than, Earth's greenhouse effect. Due to this intense greenhouse effect, the temperature on the surface of Venus is between 450°C and 475°C.

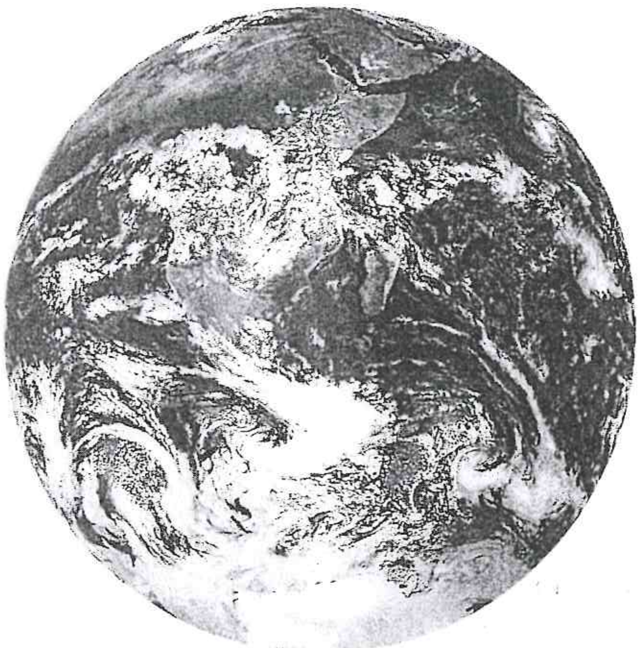


Figure 6 More than 70 percent of Earth's surface is covered by liquid water.
Explain *how Earth is unique.*

Earth

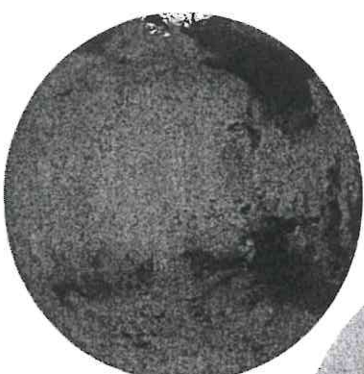
Figure 6 shows **Earth,** the third planet from the Sun. The average distance from Earth to the Sun is 150 million km, or one astronomical unit (AU). Unlike other planets, Earth has abundant liquid water and supports life. Earth's atmosphere causes most meteors to burn up before they reach the surface, and its ozone layer protects life from the effects of the Sun's intense radiation.

Mars

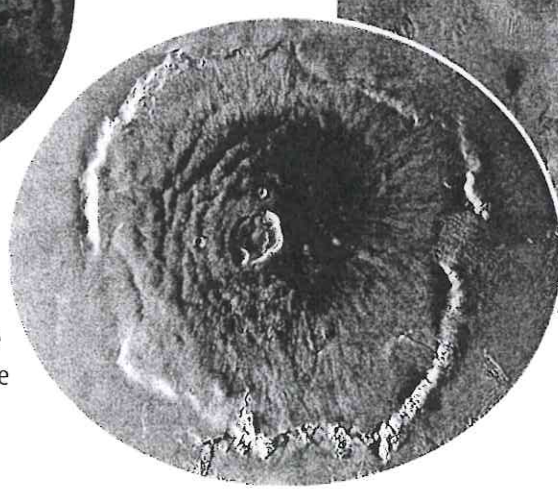
Look at **Figure 7.** Can you guess why **Mars,** the fourth planet from the Sun, is called the red planet? Iron oxide in soil on its surface gives it a reddish color. Other features visible from Earth are Mars's polar ice caps and changes in the coloring of the planet's surface. The ice caps are made of frozen water covered by a layer of frozen carbon dioxide.

Most of the information scientists have about Mars came from *Mariner 9*, the *Viking* probes, *Mars Pathfinder, Mars Global Surveyor, Mars Odyssey,* and the Mars Exploration Rovers. *Mariner 9* orbited Mars in 1971 and 1972. It revealed long channels on the planet that might have been carved by flowing water. *Mariner 9* also discovered the largest volcano in the solar system, Olympus Mons, shown in **Figure 7.** Olympus Mons is probably extinct. Large rift valleys in the Martian crust also were discovered. One such valley, Valles Marineris, is shown in **Figure 7.**

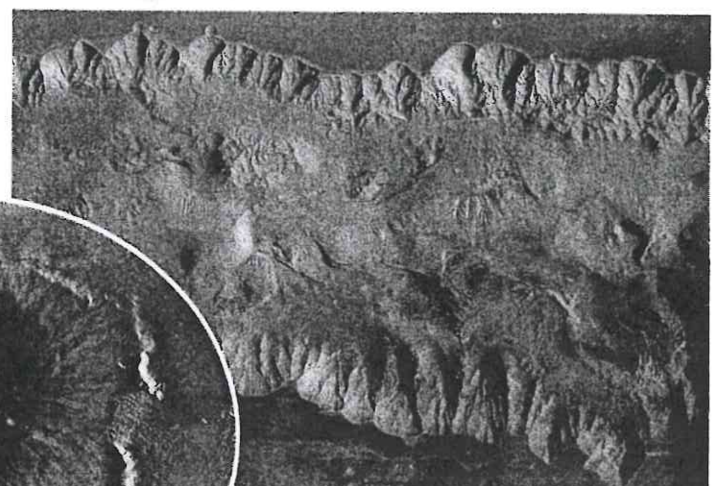
Figure 7 Many features on Mars are similar to those on Earth.



Mars is often called the "red planet."



Olympus Mons is the largest volcano in the solar system.



Valles Marineris is more than 4,000 km long, up to 200 km wide, and more than 7 km deep.

The *Viking* Probes The *Viking 1* and *2* probes arrived at Mars in 1976. Each probe consisted of an orbiter and a lander. The orbiters photographed the entire planet from their orbits, while the landers touched down on the surface. Instruments on the landers attempted to detect possible life by analyzing gases in the Martian soil. The tests found no conclusive evidence of life.

Pathfinder* and *Global Surveyor The *Mars Pathfinder* carried a robot rover named *Sojourner* to test samples of Martian rocks and soil. The data showed that iron in the crust might have been leached out by groundwater. Cameras onboard *Global Surveyor* showed features that looked like sediment gullies and deposits formed by flowing water. These features, shown in **Figure 8,** seem to indicate that groundwater might exist on Mars and that it reached the surface. The features are similar to those formed by flash floods on Earth, such as on Mount St. Helens.

***Odyssey* and Mars Exploration Rovers** In 2002, *Mars Odyssey* began orbiting Mars. It measured elements in Mars's crust and searched for signs of water. Instruments on *Odyssey* detected high levels of hematite, a mineral that forms in water, and subsurface ice near the poles.

Odyssey also relayed data to Earth from the Mars Exploration Rovers *Spirit* and *Opportunity* in 2004. These robot rovers analyzed Martian geology. Data from *Opportunity* confirmed that there were once bodies of water on Mars's surface.

Reading Check *What evidence indicates that Mars has water?*

Mini LAB

Inferring Effects of Gravity

Procedure

1. Suppose you are a crane operator who is sent to Mars to help build a colony.
2. Your crane can lift 4,500 kg on Earth, but the force due to gravity on Mars is only 40 percent as large as that on Earth.
3. Determine how much mass your crane could lift on Earth and Mars.

Analysis

1. How can what you have discovered be an advantage over construction on Earth?
2. How might construction advantages change the overall design of the Mars colony?

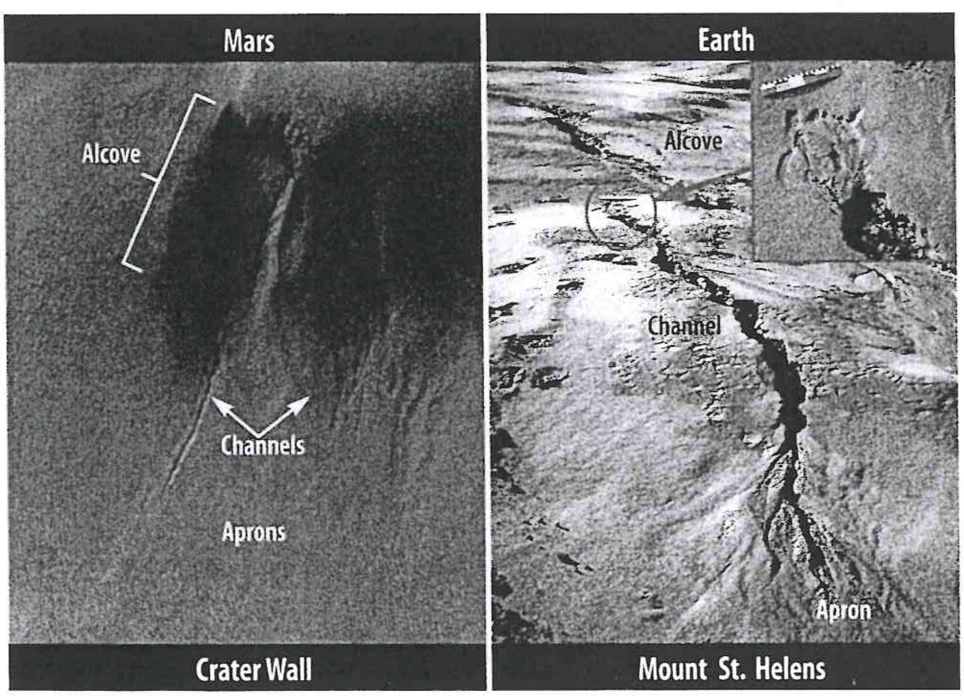


Figure 8 Compare the features found on Mars with those found on an area of Mount St. Helens in Washington state that experienced a flash flood.

Science Online

Topic: Mars Exploration

Visit earth.msscience.com for Web links to information about future missions to Mars.

Activity Make a timeline that shows when each probe is scheduled to reach Mars. Include the mission objectives for each probe on your timeline.

Mars's Atmosphere The *Viking* and *Global Surveyor* probes analyzed gases in the Martian atmosphere and determined atmospheric pressure and temperature. They found that Mars's atmosphere is much thinner than Earth's. It is composed mostly of carbon dioxide, with some nitrogen and argon. Surface temperatures range from −125°C to 35°C. The temperature difference between day and night results in strong winds on the planet, which can cause global dust storms during certain seasons. This information will help in planning possible human exploration of Mars in the future.

Martian Seasons Mars's axis of rotation is tilted 25°, which is close to Earth's tilt of 23.5°. Because of this, Mars goes through seasons as it orbits the Sun, just like Earth does. The polar ice caps on Mars change with the season. During winter, carbon dioxide ice accumulates and makes the ice cap larger. During summer, carbon dioxide ice changes to carbon dioxide gas and the ice cap shrinks. As one ice cap gets larger, the other ice cap gets smaller. The color of the ice caps and other areas on Mars also changes with the season. The movement of dust and sand during dust storms causes the changing colors.

Applying Math **Use Percentages**

DIAMETER OF MARS The diameter of Earth is 12,756 km. The diameter of Mars is 53.3 percent of the diameter of Earth. Calculate the diameter of Mars.

Solution

1 *This is what you know:*

- diameter of Earth: 12,756 km
- percent of Earth's diameter: 53.3%
- decimal equivalent: 0.533 (53.3% ÷ 100)

2 *This is what you need to find:*

diameter of Mars

3 *This is the procedure you need to use:*

Multiply the diameter of Earth by the decimal equivalent.

$(12{,}756 \text{ km}) \times (0.533) = 6{,}799 \text{ km}$

Practice Problems

1. Use the same procedure to calculate the diameter of Venus. Its diameter is 94.9 percent of the diameter of Earth.
2. Calculate the diameter of Mercury. Its diameter is 38.2 percent of the diameter of Earth.

Science Online | For more practice, visit earth.msscience.com/math_practice

Martian Moons Mars has two small, irregularly shaped moons that are heavily cratered. Phobos, shown in **Figure 9,** is about 25 km in length, and Deimos is about 13 km in length. Deimos orbits Mars once every 31 h, while Phobos speeds around Mars once every 7 h.

Phobos has many interesting surface features. Grooves and chains of smaller craters seem to radiate out from the large Stickney Crater. Some of the grooves are 700 m across and 90 m deep. These features probably are the result of the large impact that formed the Stickney Crater.

Deimos is the outer of Mars's two moons. It is among the smallest known moons in the solar system. Its surface is smoother in appearance than that of Phobos because some of its craters have partially filled with soil and rock.

As you toured the inner planets through the eyes of the space probes, you saw how each planet is unique. Refer to **Table 3** following Section 3 for a summary of the planets. Mercury, Venus, Earth, and Mars are different from the outer planets, which you'll explore in the next section.

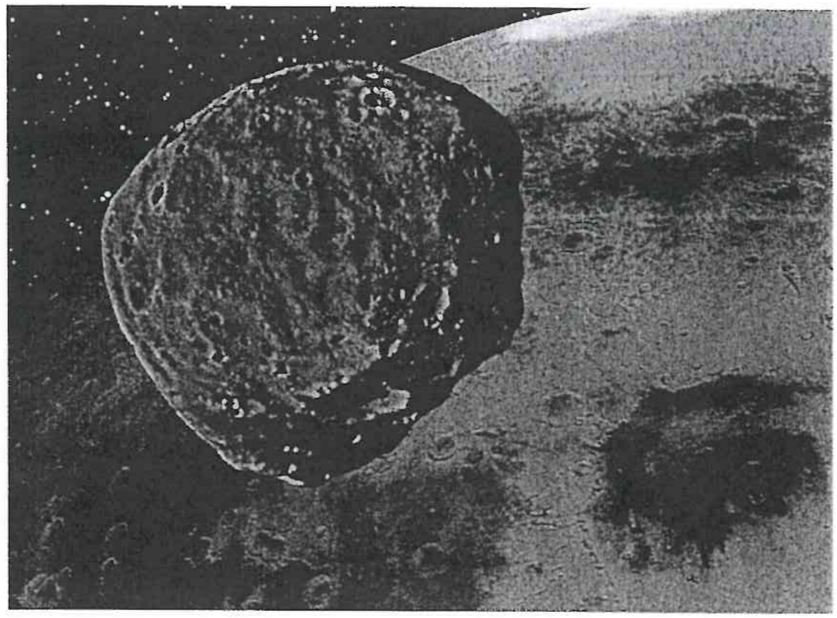


Figure 9 Phobos orbits Mars once every 7 h.
Infer *why Phobos has so many craters.*

section 2 review

Summary

Mercury

- Mercury is extremely hot during the day and extremely cold at night.
- Its surface has many craters.

Venus

- Venus's size and mass are similar to Earth's.
- Temperatures on Venus are between 450°C and 475°C.

Earth

- Earth is the only planet known to support life.

Mars

- Mars has polar ice caps, channels that might have been carved by water, and the largest volcano in the solar system, Olympus Mons.

Self Check

1. **Explain** why Mercury's surface temperature varies so much from day to night.
2. **List** important characteristics for each inner planet.
3. **Infer** why life is unlikely on Venus.
4. **Identify** the inner planet that is farthest from the Sun. Identify the one that is closest to the Sun.
5. **Think Critically** Aside from Earth, which inner planet could humans visit most easily? Explain.

Applying Math

6. **Use Statistics** The inner planets have the following average densities: Mercury, 5.43 g/cm^3; Venus, 5.24 g/cm^3; Earth, 5.52 g/cm^3; and Mars, 3.94 g/cm^3. Which planet has the highest density? Which has the lowest? Calculate the range of these data.

section 3

The Outer Planets

as you read

What You'll Learn

- **Describe** the characteristics of Jupiter, Saturn, Uranus, and Neptune.
- **Describe** the largest moons of each of the outer planets.

Why It's Important

Studying the outer planets will help scientists understand Earth.

Review Vocabulary

moon: a natural satellite of a planet that is held in its orbit around the planet by the planet's gravitational pull

New Vocabulary

- Jupiter
- Great Red Spot
- Saturn
- Uranus
- Neptune
- Pluto

Outer Planets

You might have heard about *Voyager*, *Galileo*, and *Cassini*. They were not the first probes to the outer planets, but they gathered a lot of new information about them. Follow the spacecrafts as you read about their journeys to the outer planets.

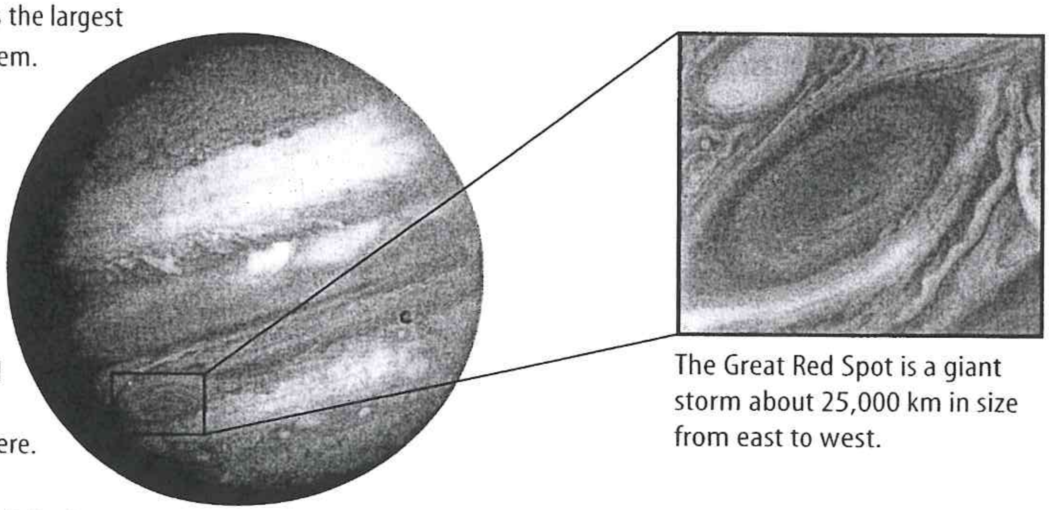
Jupiter

In 1979, *Voyager 1* and *Voyager 2* flew past **Jupiter,** the fifth planet from the Sun. *Galileo* reached Jupiter in 1995, and *Cassini* flew past Jupiter on its way to Saturn in 2000. The spacecrafts gathered new information about Jupiter. The *Voyager* probes revealed that Jupiter has faint dust rings around it and that one of its moons has active volcanoes on it.

Jupiter's Atmosphere Jupiter is composed mostly of hydrogen and helium, with some ammonia, methane, and water vapor. Scientists hypothesize that the atmosphere of hydrogen and helium changes to an ocean of liquid hydrogen and helium toward the middle of the planet. Below this liquid layer might be a rocky core. The extreme pressure and temperature, however, would make the core different from any rock on Earth.

You've probably seen pictures from the probes of Jupiter's colorful clouds. In **Figure 10,** you can see bands of white, red, tan, and brown clouds in its atmosphere. Continuous storms of swirling, high-pressure gas have been observed on Jupiter. The **Great Red Spot** is the most spectacular of these storms.

Figure 10 Jupiter is the largest planet in the solar system.

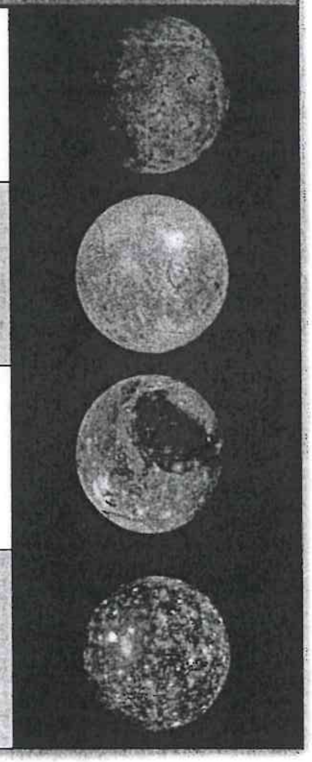


Notice the colorful bands of clouds in Jupiter's atmosphere.

The Great Red Spot is a giant storm about 25,000 km in size from east to west.

Table 2 Large Moons of Jupiter

Io The most volcanically active object in the solar system; sulfurous compounds give it its distinctive reddish and orange colors; has a thin atmosphere of sulfur dioxide .
Europa Rocky interior is covered by a smooth 5-km-thick crust of ice, which has a network of cracks; a 50-km-deep ocean might exist under the ice crust; has a thin oxygen atmosphere.
Ganymede Has a heavily cratered crust of ice covered with grooves; has a rocky interior surrounding a molten iron core and a thin oxygen atmosphere.
Callisto Has a heavily cratered crust with a mixture of ice and rock throughout the interior; has a rock core and a thin atmosphere of carbon dioxide.



Moons of Jupiter At least 63 moons orbit Jupiter. In 1610, the astronomer Galileo Galilei was the first person to see Jupiter's four largest moons, shown in **Table 2.** Io (I oh) is the closest large moon to Jupiter. Jupiter's tremendous gravitational force and the gravity of Europa, Jupiter's next large moon, pull on Io. This force heats up Io, causing it to be the most volcanically active object in the solar system. You can see a volcano erupting on Io in **Figure 11.** Europa is composed mostly of rock with a thick, smooth crust of ice. Under the ice might be an ocean as deep as 50 km. If this ocean of water exists, it will be the only place in the solar system, other than Earth, where liquid water exists in large quantities. Next is Ganymede, the largest moon in the solar system—larger even than the planet Mercury. Callisto, the last of Jupiter's large moons, is composed mostly of ice and rock. Studying these moons adds to knowledge about the origin of Earth and the rest of the solar system.

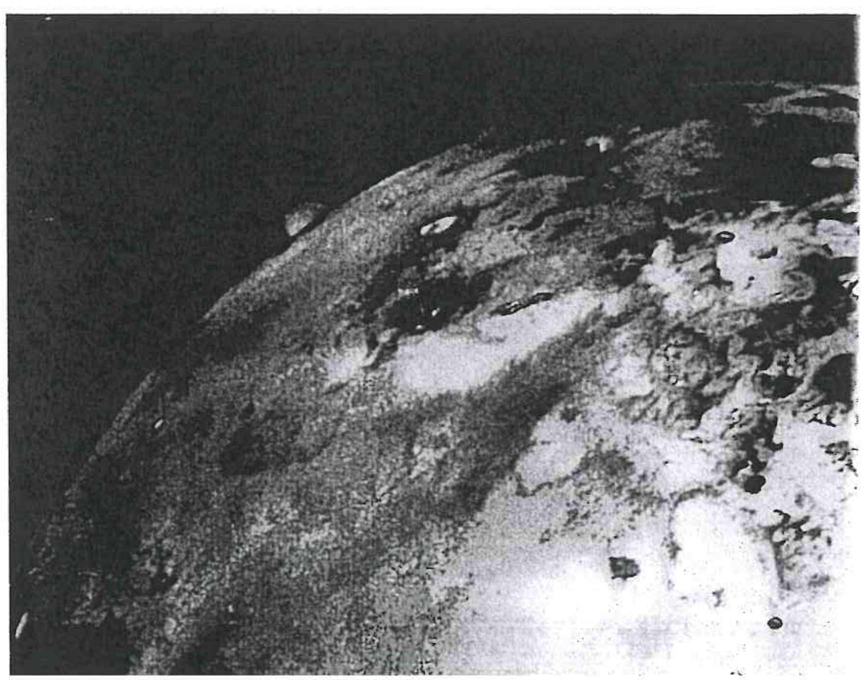


Figure 11 *Voyager 2* photographed the eruption of this volcano on Io in July 1979.

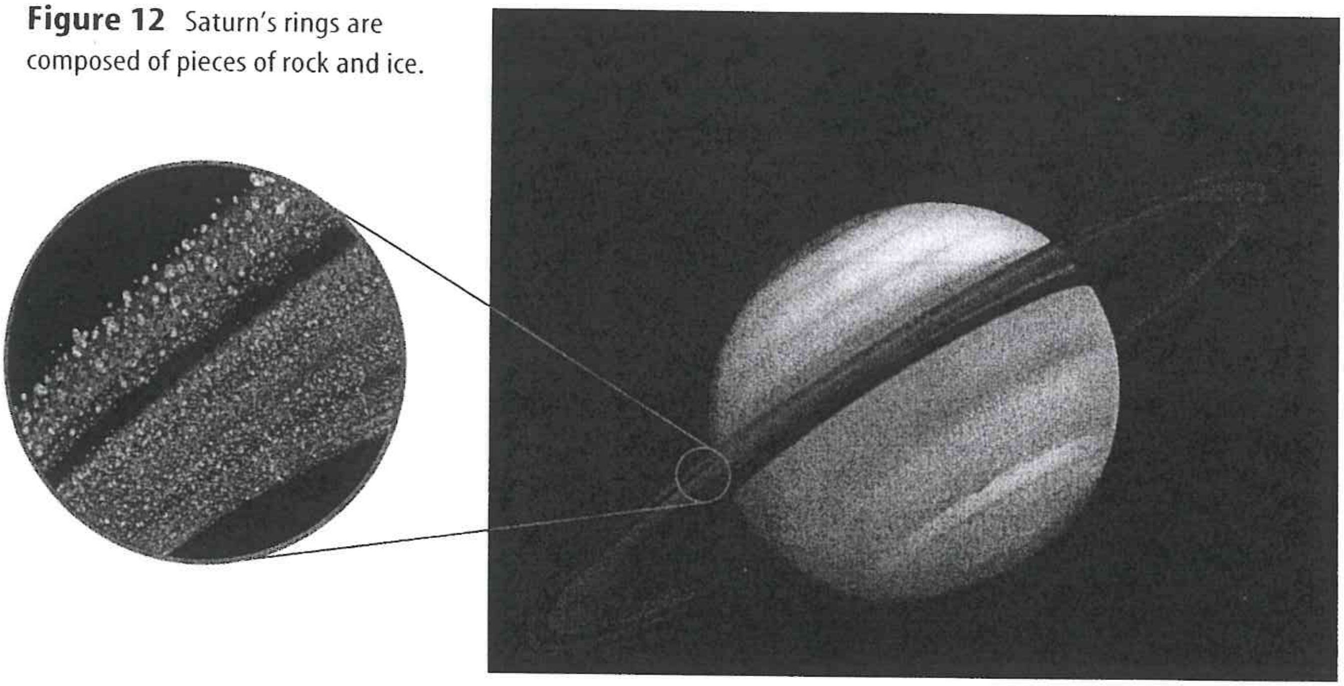


Figure 12 Saturn's rings are composed of pieces of rock and ice.

Saturn

The *Voyager* probes next surveyed Saturn in 1980 and 1981. *Cassini* reached Saturn on July 1, 2004. **Saturn** is the sixth planet from the Sun. It is the second-largest planet in the solar system, but it has the lowest density.

Saturn's Atmosphere Similar to Jupiter, Saturn is a large, gaseous planet. It has a thick outer atmosphere composed mostly of hydrogen and helium. Saturn's atmosphere also contains ammonia, methane, and water vapor. As you go deeper into Saturn's atmosphere, the gases gradually change to liquid hydrogen and helium. Below its atmosphere and liquid layer, Saturn might have a small, rocky core.

Rings and Moons The *Voyager* and *Cassini* probes gathered information about Saturn's ring system. The probes showed that there are several broad rings. Each large ring is composed of thousands of thin ringlets. **Figure 12** shows that Saturn's rings are composed of countless ice and rock particles. These particles range in size from a speck of dust to tens of meters across. Saturn's ring system is the most complex one in the solar system.

At least 47 moons orbit Saturn. Saturn's gravity holds these moons in their orbits around Saturn, just like the Sun's gravity holds the planets in their orbits around the Sun. The largest moon, Titan, is larger than the planet Mercury. It has a thick atmosphere of nitrogen, argon, and methane. *Cassini* delivered the *Huygens* probe to analyze Titan's atmosphere in 2005.

Mini LAB

Modeling Planets

Procedure

1. Research the planets to determine how the sizes of the planets in the solar system compare with Earth's size.
2. Select a scale for the diameter of Earth.
3. Make a model by drawing a circle with this diameter on **paper.**
4. Using Earth's diameter as 1.0 unit, draw each of the other planets to scale.

Analysis

1. Which planet is largest? Which is smallest?
2. Which scale diameter did you select for Earth? Was this a good choice? Why or why not?

Try at Home

Uranus

Beyond Saturn, *Voyager 2* flew by Uranus in 1986. **Uranus** (YOOR uh nus) is the seventh planet from the Sun and was discovered in 1781. It is a large, gaseous planet with at least 27 moons and a system of thin, dark rings. Uranus's largest moon, Titania, has many craters and deep valleys. The valleys on this moon indicate that some process reshaped its surface after it formed. Uranus's 11 rings surround the planet's equator.

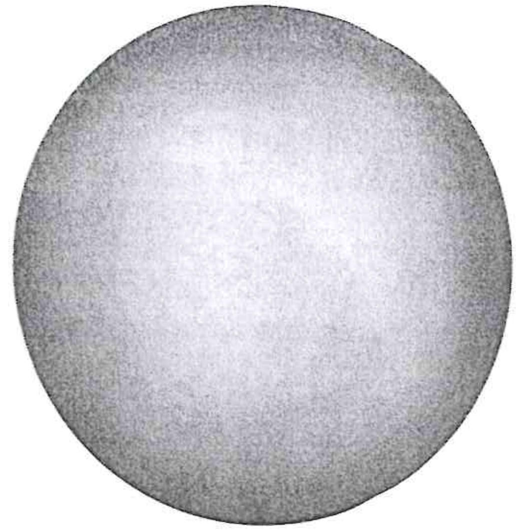


Figure 13 The atmosphere of Uranus gives the planet its distinct bluish-green color.

Uranus's Characteristics The atmosphere of Uranus is composed of hydrogen, helium, and some methane. Methane gives the planet the bluish-green color that you see in **Figure 13.** Methane absorbs the red and yellow light, and the clouds reflect the green and blue. Few cloud bands and storm systems can be seen on Uranus. Evidence suggests that under its atmosphere, Uranus is composed primarily of rock and various ices. There is no separate core.

Figure 14 shows one of the most unusual features of Uranus. Its axis of rotation is tilted on its side compared with the other planets. The axes of rotation of the other planets are nearly perpendicular to the planes of their orbits. However, Uranus's axis of rotation is nearly parallel to the plane of its orbit. Some scientists believe a collision with another object tipped Uranus on its side.

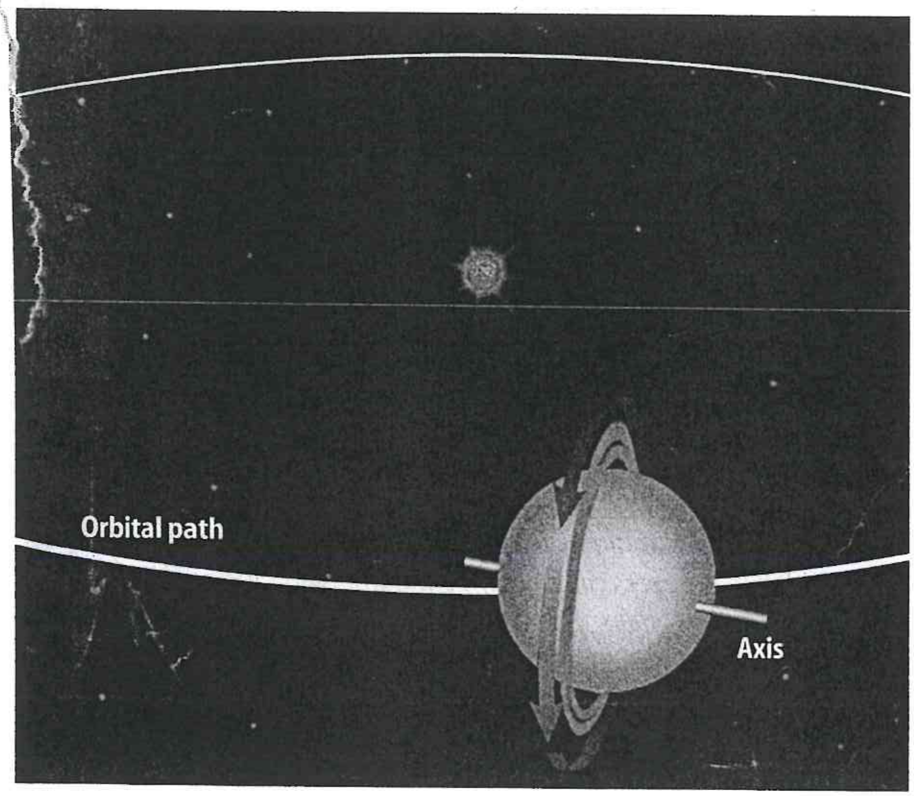
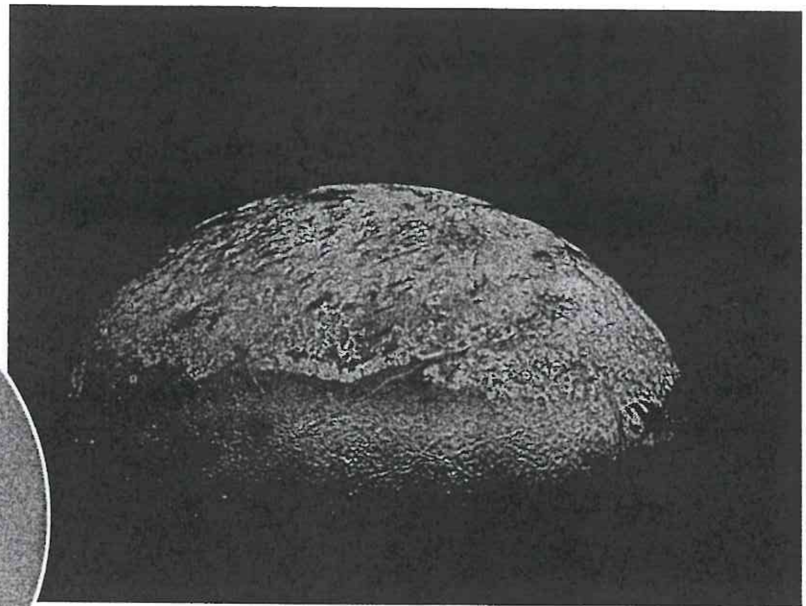


Figure 14 Uranus's axis of rotation is nearly parallel to the plane of its orbit. During its revolution around the Sun, each pole, at different times, points almost directly at the Sun.

Neptune has a distinctive bluish-green color.



The pinkish hue of Neptune's largest moon, Triton, is thought to come from an evaporating layer of nitrogen and methane ice.

Figure 15 Neptune is the eighth planet from the Sun.

Neptune

Passing Uranus, *Voyager 2* traveled to Neptune, another large, gaseous planet. Discovered in 1846, **Neptune** is the eighth planet from the Sun.

Neptune's Characteristics Like Uranus's atmosphere, Neptune's atmosphere is made up of hydrogen and helium, with smaller amounts of methane. The methane content gives Neptune, shown in **Figure 15,** its distinctive bluish-green color, just as it does for Uranus.

Reading Check *What gives Neptune its bluish-green color?*

Neptune has dark-colored storms in its atmosphere that are similar to the Great Red Spot on Jupiter. One discovered by *Voyager 2* in 1989 was called the Great Dark Spot. It was about the size of Earth with windspeeds higher than any other planet. Observations by the *Hubble Space Telescope* in 1994 showed that the Great Dark Spot disappeared and then reappeared. Bright clouds also form and then disappear. Scientists don't know what causes these changes, but they show that Neptune's atmosphere is active and changes rapidly.

Under its atmosphere, Neptune has a mixture of rock and various types of ices made from methane and ammonia. Neptune probably has a rocky core.

Neptune has at least 13 moons and several rings. Triton, shown in **Figure 15,** is Neptune's largest moon. It has a thin atmosphere composed mostly of nitrogen. Neptune's dark rings are young and probably won't last very long.

INTEGRATE Language Arts

Names of Planets The names of most of the planets in the solar system come from Roman or Greek mythology. For example, Neptune was the Roman god of the sea. Research to learn about the names of the other planets. Write a paragraph in your Science Journal that summarizes what you learn.

Dwarf Planets

From the time of its discovery in 1930 until 2006 Pluto was considered the ninth planet in the solar system. But with the discovery of Eris (EE rihs), which is larger than Pluto, the International Astronomical Union decided to define the term *planet*. Now, scientists call Pluto a dwarf planet.

Ceres Ceres was discovered in 1801. It has an average diameter of about 940 km and is located within the asteroid belt at an average distance of about 2.7 AU from the Sun. Ceres orbits the Sun about once every 4.6 years.

Pluto 1930 Pluto has a diameter of 2,300 km. It is an average distance of 39.2 AU from the Sun and takes 248 years to complete one orbit. It is surrounded by only a thin atmosphere and it has a solid, icy-rock surface. Pluto has three moons: Charon, Hydra, and Nix. The largest moon, Charon, has a diameter of about 1,200 km and orbits Pluto at a distance of about 19,500 km.

Eris Astronomers discovered Eris in 2005, originally calling it UB313. With a diameter of about 2,400 km, Eris is slightly larger than Pluto. Eris has an elliptical orbit that varies from between about 38 AU to 98 AU from the Sun. Eris orbits the Sun once every 557 years and has one moon, named Dysnomia (dihs NOH mee uh).

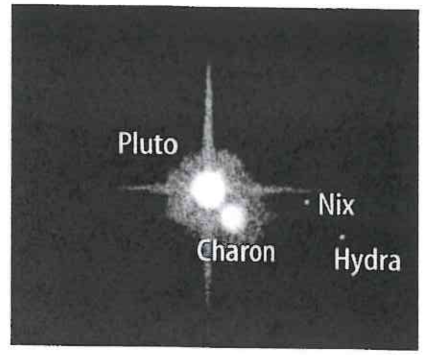


Figure 16 Hydra and Nix are about three times farther from Pluto than Charon is.

section 3 review

Summary

Jupiter

- Jupiter is the largest planet in the solar system.
- The Great Red Spot is a huge storm on Jupiter.

Saturn

- Saturn has a complex system of rings.

Uranus

- Uranus has a bluish-green color caused by methane in its atmosphere.

Neptune

- Like Uranus, Neptune has a bluish-green color.
- Neptune's atmosphere can change rapidly.

Dwarf Planets

- Pluto is made of ice and rock.
- Ceres is a dwarf planet within the asteroid belt.

Self Check

1. **Describe** the differences between the outer planets and the inner planets.
2. **Describe** what Saturn's rings are made from.
3. **Compare** Pluto to the eight planets.
4. **Explain** how Uranus's axis of rotation differs from those of most other planets.
5. **Think Critically** What would seasons be like on Uranus? Explain.

Applying Skills

6. **Identify a Question** When a probe lands on Pluto, so many questions will be answered. Think of a question about Pluto that you'd like to have answered. Then, explain why the answer is important to you.

Table 3 Planets

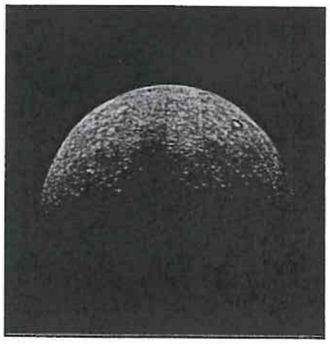
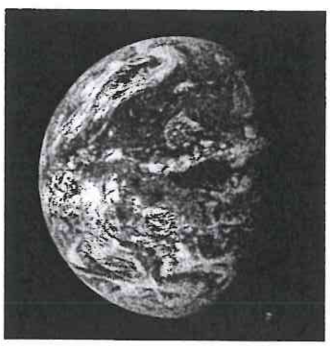
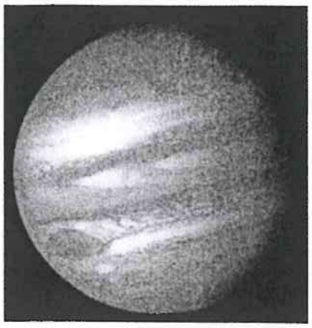
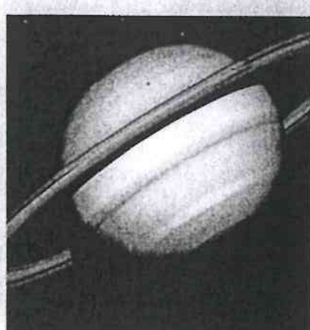
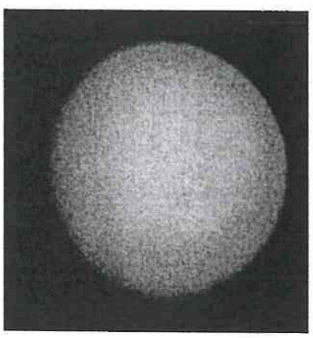
Mercury		■ closest to the Sun ■ second-smallest planet ■ surface has many craters and high cliffs ■ no atmosphere ■ temperatures range from 425°C during the day to −170°C at night ■ has no moons
Venus		■ similar to Earth in size and mass ■ thick atmosphere made mostly of carbon dioxide ■ droplets of sulfuric acid in atmosphere give clouds a yellowish color ■ surface has craters, faultlike cracks, and volcanoes ■ greenhouse effect causes surface temperatures of 450°C to 475°C ■ has no moons
Earth		■ atmosphere protects life ■ surface temperatures allow water to exist as solid, liquid, and gas ■ only planet where life is known to exist ■ has one large moon
Mars		■ surface appears reddish-yellow because of iron oxide in soil ■ ice caps are made of frozen carbon dioxide and water ■ channels indicate that water had flowed on the surface; has large volcanoes and valleys ■ has a thin atmosphere composed mostly of carbon dioxide ■ surface temperatures range from −125°C to 35°C ■ huge dust storms often blanket the planet ■ has two small moons

Table 3 Planets

Jupiter		■ largest planet ■ has faint rings ■ atmosphere is mostly hydrogen and helium; continuous storms swirl on the planet—the largest is the Great Red Spot ■ has four large moons and at least 59 smaller moons; one of its moons, Io, has active volcanoes
Saturn		■ second-largest planet ■ thick atmosphere is mostly hydrogen and helium ■ has a complex ring system ■ has at least 47 moons—the largest, Titan, is larger than Mercury
Uranus		■ large, gaseous planet with thin, dark rings ■ atmosphere is hydrogen, helium, and methane ■ axis of rotation is nearly parallel to plane of orbit ■ has at least 27 moons
Neptune		■ large, gaseous planet with rings that vary in thickness ■ is sometimes farther from the Sun than Pluto is ■ methane atmosphere causes its bluish-green color ■ has dark-colored storms in atmosphere ■ has at least 13 moons

section 4

Other Objects in the Solar System

as you read

What You'll Learn

- **Describe** how comets change when they approach the Sun.
- **Distinguish** among comets, meteoroids, and asteroids.
- **Explain** that objects from space sometimes impact Earth.

Why It's Important

Comets, asteroids, and most meteorites are very old. Scientists can learn about the early solar system by studying them.

Review Vocabulary
crater: a nearly circular depression in a planet, moon, or asteroid that formed when an object from space hit its surface

New Vocabulary
- comet
- meteor
- meteorite
- asteroid

Comets

The planets and their moons are the most noticeable members of the Sun's family, but many other objects also orbit the Sun. Comets, meteoroids, and asteroids are other important objects in the solar system.

You might have heard of Halley's comet. A **comet** is composed of dust and rock particles mixed with frozen water, methane, and ammonia. Halley's comet was last seen from Earth in 1986. English astronomer Edmund Halley realized that comet sightings that had taken place about every 76 years were really sightings of the same comet. This comet, which takes about 76 years to orbit the Sun, was named after him.

Oort Cloud Astronomer Jan Oort proposed the idea that billions of comets surround the solar system. This cloud of comets, called the Oort Cloud, is located beyond the orbit of Pluto. Oort suggested that the gravities of the Sun and nearby stars interact with comets in the Oort Cloud. Comets either escape from the solar system or get captured into smaller orbits.

Comet Hale-Bopp On July 23, 1995, two amateur astronomers made an exciting discovery. A new comet, Comet Hale-Bopp, was headed toward the Sun. Larger than most that approach the Sun, it was the brightest comet visible from Earth in 20 years. Shown in **Figure 17,** Comet Hale-Bopp was at its brightest in March and April 1997.

Figure 17 Comet Hale-Bopp was most visible in March and April 1997.

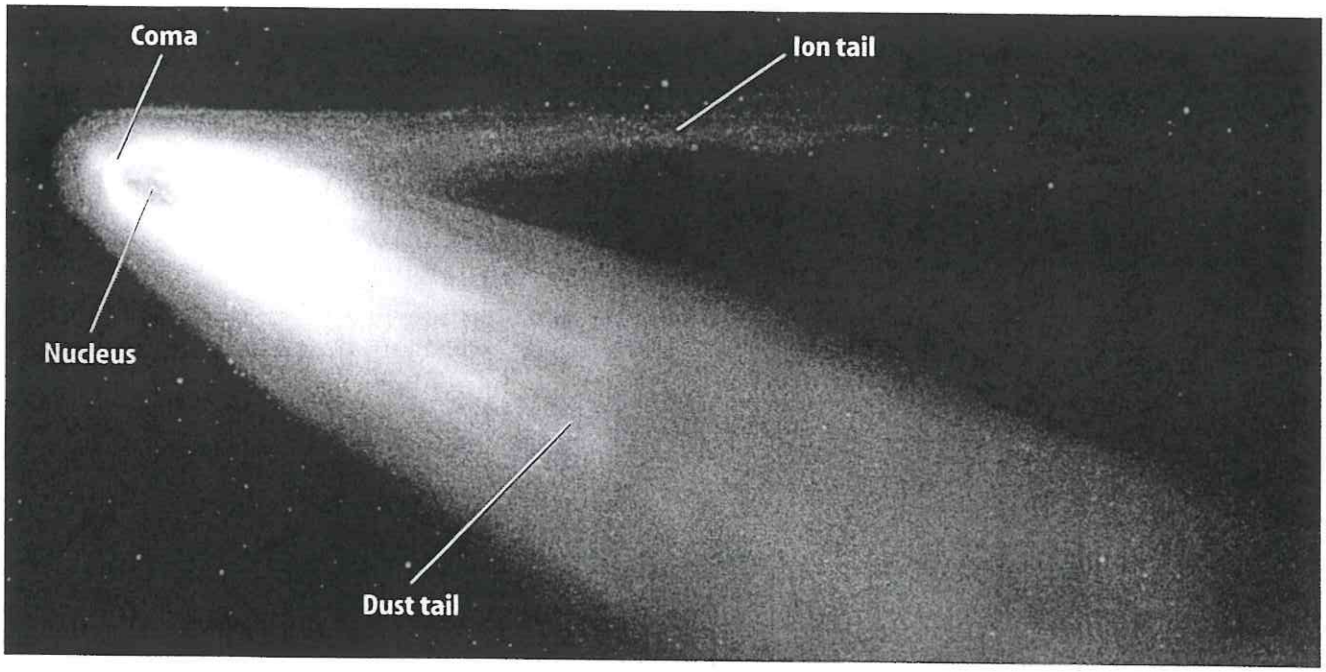


Figure 18 A comet consists of a nucleus, a coma, a dust tail, and an ion tail. Pictures of the comet Wild 2 from *Stardust* show that the comet has a rocky, cratered surface.

Structure of Comets The *Hubble Space Telescope* and spacecrafts such as the *International Cometary Explorer* have gathered information about comets. In 2006, a spacecraft called *Stardust* will return a capsule to Earth containing samples of dust from a comet's tail. Notice the structure of a comet shown in **Figure 18.** It is a mass of frozen ice and rock.

As a comet approaches the Sun, it changes. Ices of water, methane, and ammonia vaporize because of the heat from the Sun. This releases dust and jets of gas. The gases and released dust form a bright cloud called a coma around the nucleus, or solid part, of the comet. The solar wind pushes on the gases and dust in the coma, causing the particles to form separate tails that point away from the Sun.

After many trips around the Sun, most of the ice in a comet's nucleus has vaporized. All that's left are dust and rock, which are spread throughout the orbit of the original comet.

Meteoroids, Meteors, and Meteorites

You learned that comets vaporize and break up after they have passed close to the Sun many times. The small pieces from the comet's nucleus spread out into a loose group within the original orbit of the comet. These pieces of dust and rock, along with those derived from other sources, are called meteoroids.

Sometimes the path of a meteoroid crosses the position of Earth, and it enters Earth's atmosphere at speeds of 15 km/s to 70 km/s. Most meteoroids are so small that they completely burn up in Earth's atmosphere. A meteoroid that burns up in Earth's atmosphere is called a **meteor,** shown in **Figure 19.**

Figure 19 A meteoroid that burns up in Earth's atmosphere is called a meteor.

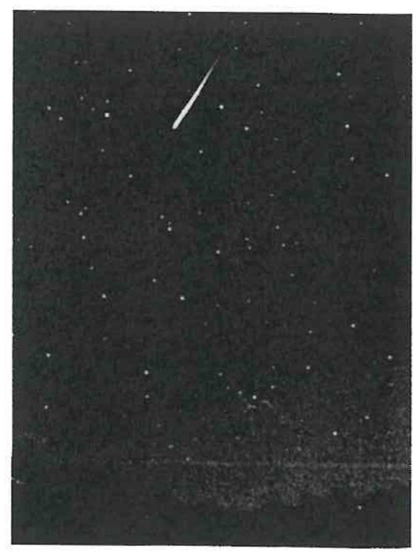


Figure 20 Meteorites occasionally strike Earth's surface. A large meteorite struck Arizona, forming a crater about 1.2 km in diameter and about 200 m deep.

Meteor Showers Each time Earth passes through the loose group of particles within the old orbit of a comet, many small particles of rock and dust enter the atmosphere. Because more meteors than usual are seen, the event is called a meteor shower.

When a meteoroid is large enough, it might not burn up completely in the atmosphere. If it strikes Earth, it is called a **meteorite.** Barringer Crater in Arizona, shown in **Figure 20,** was formed when a large meteorite struck Earth about 50,000 years ago. Most meteorites are probably debris from asteroid collisions or broken-up comets, but some originate from the Moon and Mars.

Reading Check *What is a meteorite?*

Asteroids

An **asteroid** is a piece of rock similar to the material that formed into the planets. Most asteroids are located in an area between the orbits of Mars and Jupiter called the asteroid belt. Find the asteroid belt in **Figure 21.** Why are they located there? The gravity of Jupiter might have kept a planet from forming in the area where the asteroid belt is located now.

Other asteroids are scattered throughout the solar system. They might have been thrown out of the belt by Jupiter's gravity. Some of these asteroids have orbits that cross Earth's orbit. Scientists monitor the positions of these asteroids. However, it is unlikely that an asteroid will hit Earth in the near future.

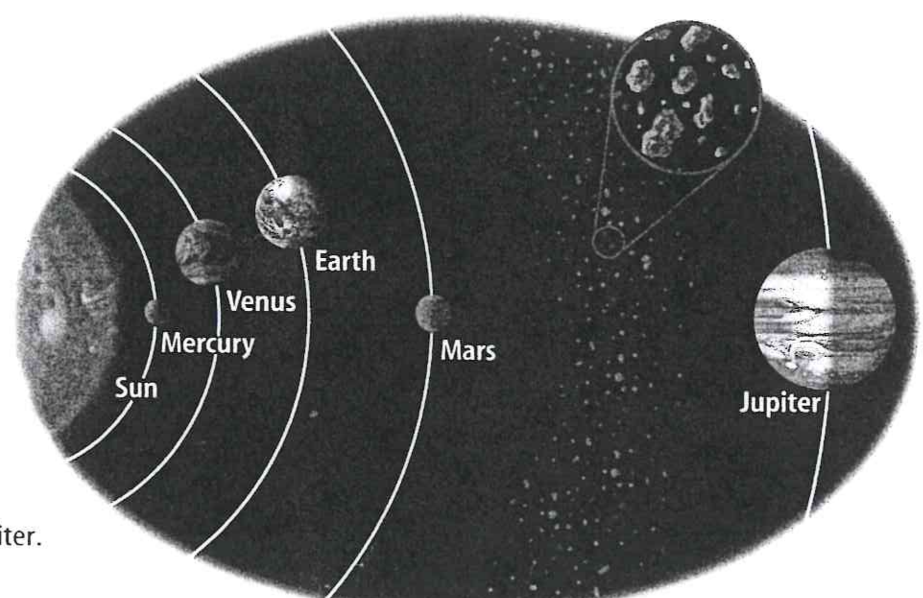


Figure 21 The asteroid belt lies between the orbits of Mars and Jupiter.

Asteroid Sizes The sizes of the asteroids in the asteroid belt range from tiny particles to objects 940 km in diameter. Ceres is the largest and the first one discovered. The next three in order of size are Vesta (530 km), Pallas (522 km), and 10 Hygiea (430 km). The asteroid Gaspra, shown in **Figure 22,** was photographed by *Galileo* on its way to Jupiter.

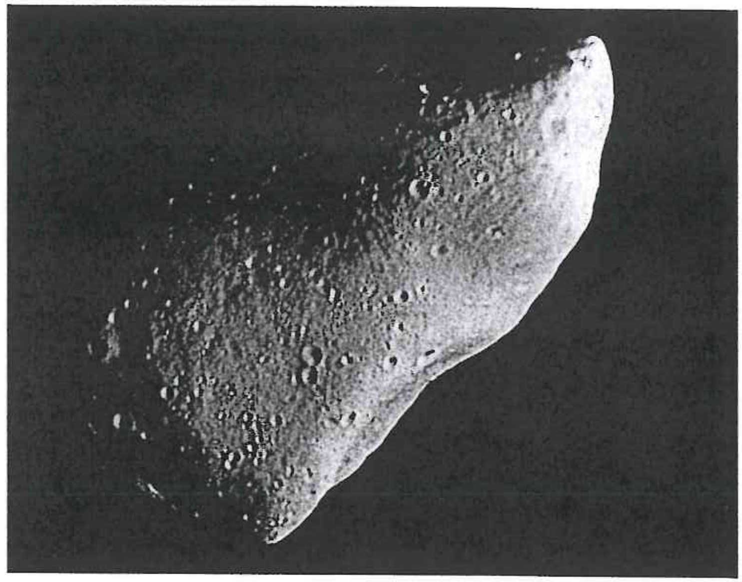


Figure 22 The asteroid Gaspra is about 20 km long.

Exploring Asteroids On February 14, 2000, the *Near Earth Asteroid Rendezvous (NEAR)* spacecraft went into orbit around the asteroid 433 Eros and later completed its one-year mission of gathering data. Data from the probe show that Eros has many craters and is similar to meteorites on Earth. The Japanese space probe *Hayabusa* arrived at the asteroid Itokawa in November 2005. Its mission is to collect samples and return them to Earth in a capsule in June 2010.

Comets, asteroids, and most meteorites formed early in the history of the solar system. Scientists study these space objects to learn what the solar system might have been like long ago. Understanding this could help scientists better understand how Earth formed.

section 4 review

Summary

Comets

- Comets consist of dust, rock, and different types of ice.
- The Oort Cloud was proposed as a source of comets in the solar system.

Meteoroids, Meteors, Meteorites

- When meteoroids burn up in the atmosphere, they are called meteors.
- Meteor showers occur when Earth crosses the orbital path of a comet.

Asteroids

- Many asteroids occur between the orbits of Mars and Jupiter. This region is called the asteroid belt.

Self Check

1. **Describe** how a comet changes when it comes close to the Sun.
2. **Explain** how craters form.
3. **Summarize** the differences between comets and asteroids.
4. **Describe** the mission of the *NEAR* space probe.
5. **Think Critically** A meteorite found in Antarctica is thought to have come from Mars. How could a rock from Mars get to Earth?

Applying Math

6. **Use Proportions** During the 2001 Leonid Meteor Shower, some people saw 20 meteors each minute. Assuming a constant rate, how many meteors did these people see in one hour?

LAB

Model and Invent

Solar System Distance Model

Goals

- **Design** a table of scale distances and model the distances between and among the Sun and the planets.

Possible Materials

meterstick
scissors
pencil
colored markers
string (several meters)
notebook paper (several sheets)

Safety Precautions

Use care when handling scissors.

Real-World Question

Distances between the Sun and the planets of the solar system are large. These large distances can be difficult to visualize. Can you design and create a model that will demonstrate the distances in the solar system?

Make a Model

1. **List** the steps that you need to take to make your model. Describe exactly what you will do at each step.
2. **List** the materials that you will need to complete your model.
3. **Describe** the calculations that you will use to get scale distances from the Sun for all nine planets.
4. **Make** a table of scale distances that you will use in your model. Show your calculations in your table.
5. **Write** a description of how you will build your model. Explain how it will demonstrate relative distances between and among the Sun and planets of the solar system.

Planetary Distances

Planet	Distance to Sun (km)	Distance to Sun (AU)	Scale Distance (1 AU = 10 cm)	Scale Distance (1 AU = 2 cm)
Mercury	5.97×10^7	0.39		
Venus	1.08×10^8	0.72		
Earth	1.50×10^8	1.00		
Mars	2.28×10^8	1.52		
Jupiter	7.78×10^8	5.20		Do not write in this book.
Saturn	1.43×10^9	9.54		
Uranus	2.87×10^9	19.19		
Neptune	4.50×10^9	30.07		