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

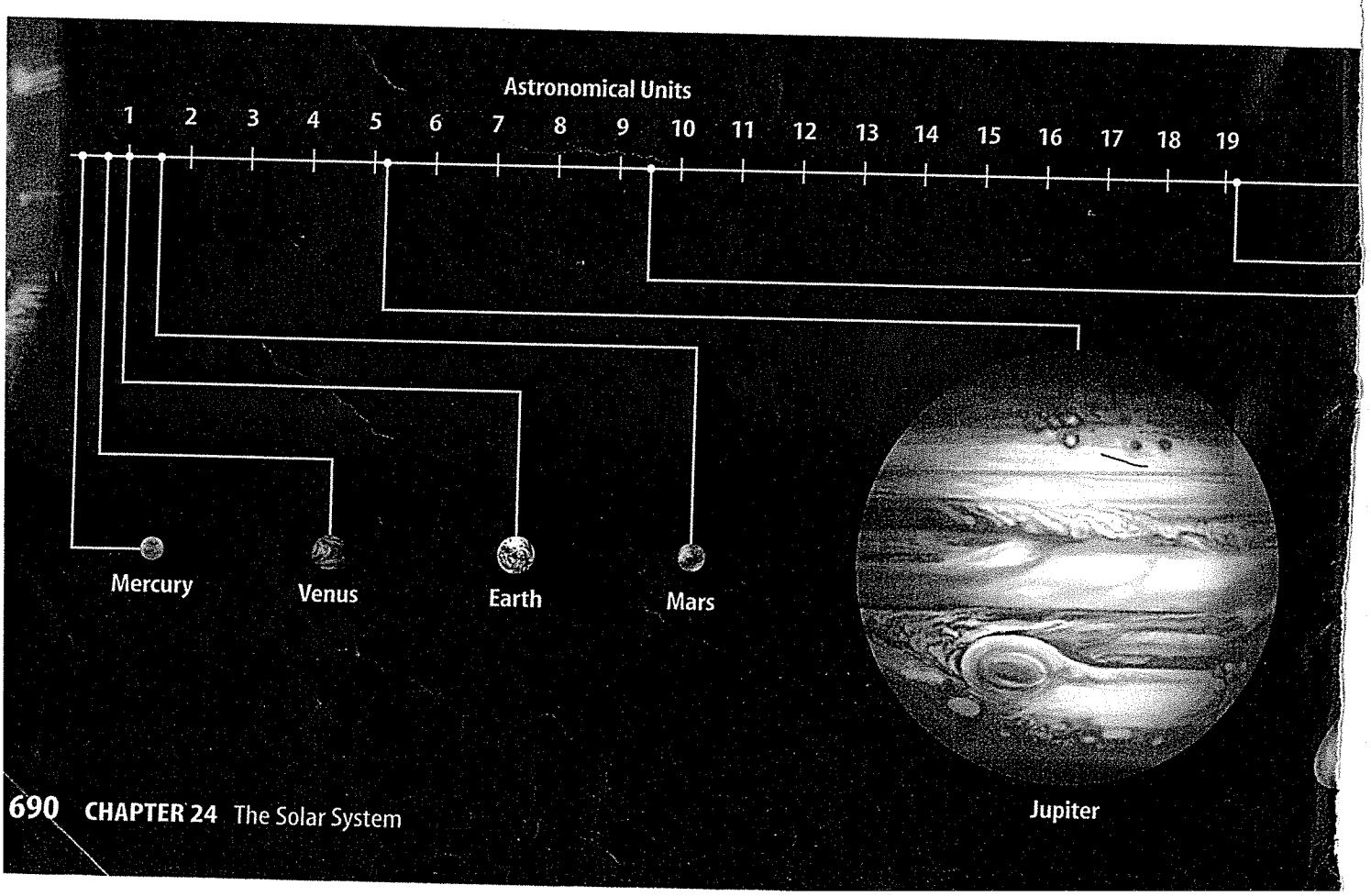
New Vocabulary

- 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.

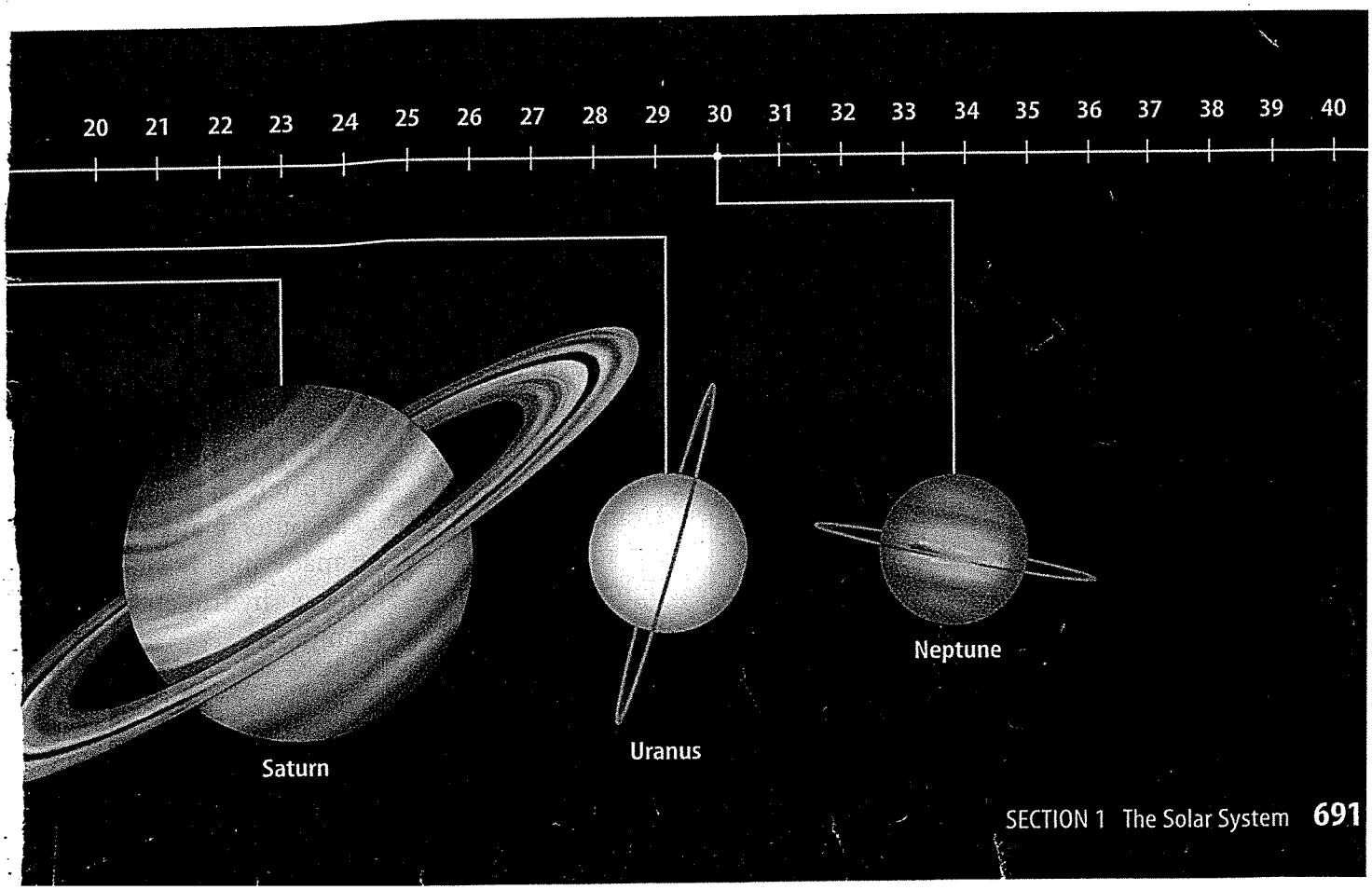


Figure 1 Each of the eight planets in the solar system is unique. The distances between the planets and the Sun are shown on the scale. One astronomical unit (AU) is the average distance between Earth and the Sun.

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.

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.

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

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.

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

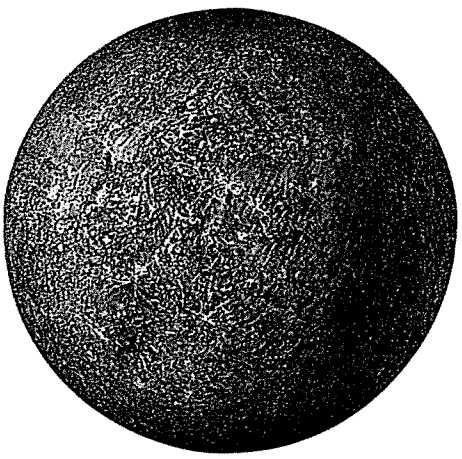
Today, people know more about the solar system than ever before. Better telescopes allow astronomers to observe the planets from Earth and space. In addition, space probes have explored much of the solar system. Prepare to take a tour of the solar system through the eyes of some space probes.

Mercury

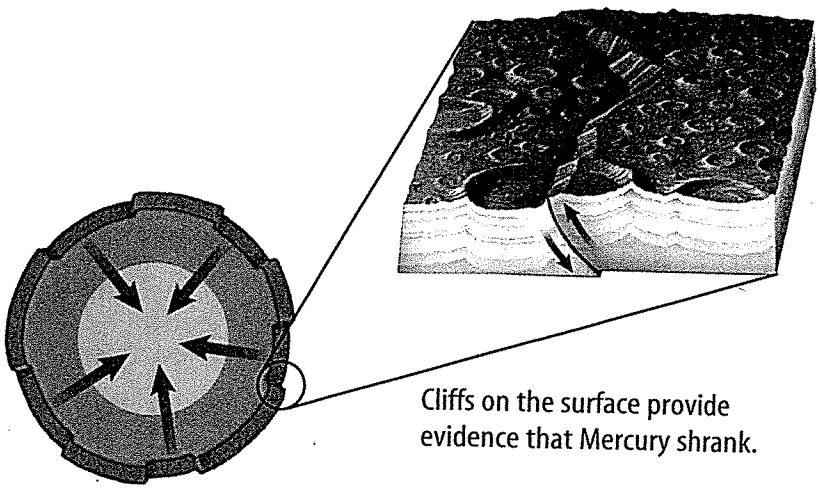
The closest planet to the Sun is **Mercury.** The first American spacecraft mission to Mercury was in 1974–1975 by *Mariner 10.* The spacecraft flew by the planet and sent pictures back to Earth. *Mariner 10* photographed only 45 percent of Mercury's surface, so scientists don't know what the other 55 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.

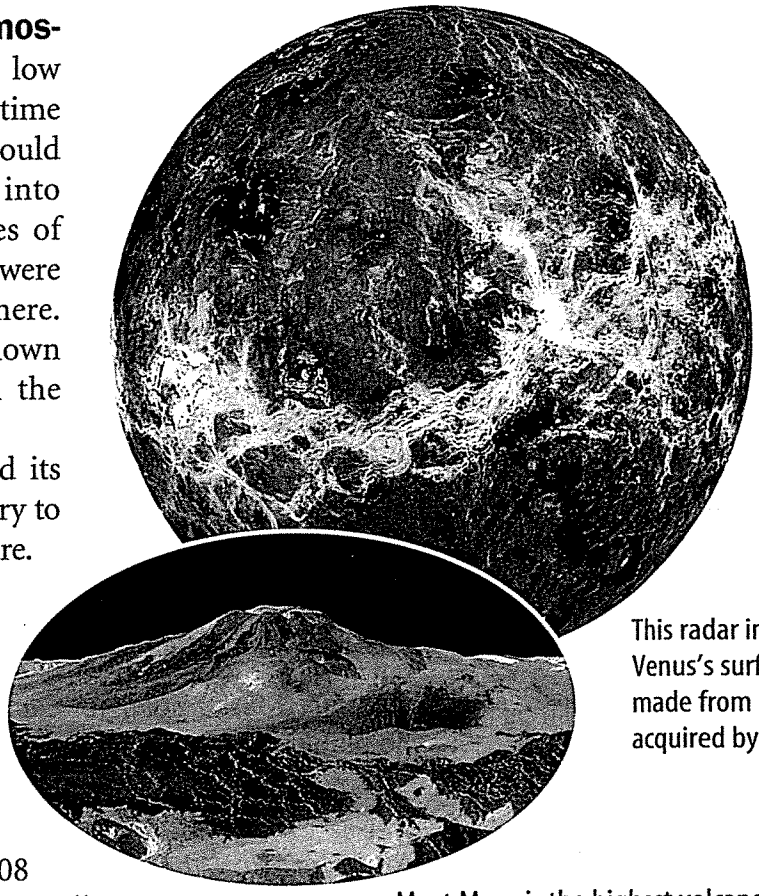


Cliffs on the surface provide evidence that Mercury shrank.

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.

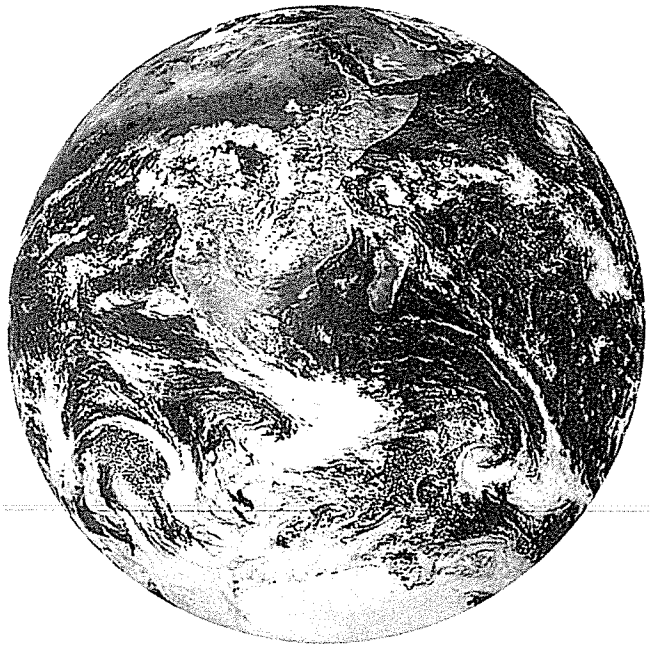


Figure 6 More than 70 percent of Earth's surface is covered by liquid water.
Explain *how Earth is unique.*

Earth

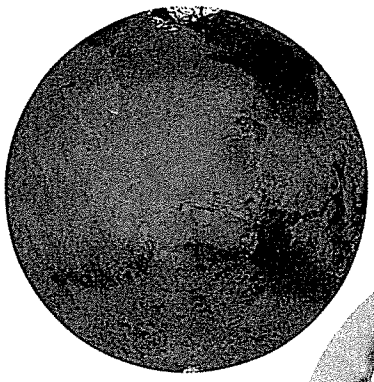
Figure 6 shows **Earth,** the third planet from the Sun. The average distance from Earth to the Sun is 150 million km, or one astronomical unit (AU). Unlike other planets, Earth has abundant liquid water and supports life. Earth's atmosphere causes most meteors to burn up before they reach the surface,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

Mars

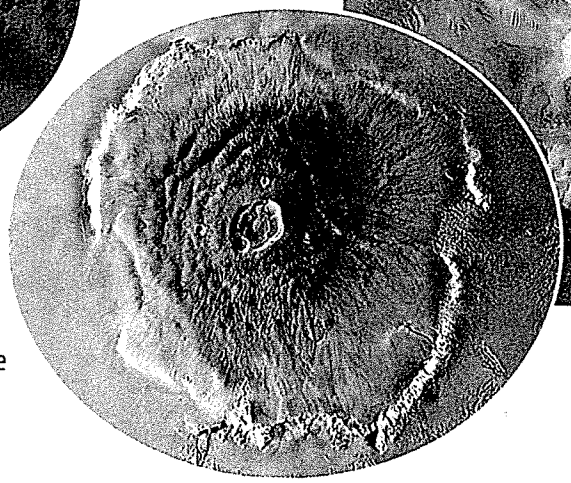
Look at **Figure 7.** Can you guess why **Mars,** the fourth planet from the Sun, is called the red planet? Iron oxide in soil on its surface gives it a reddish color. Other features visible from Earth are Mars's polar ice caps and changes in the coloring of the planet's surface. The ice caps are made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

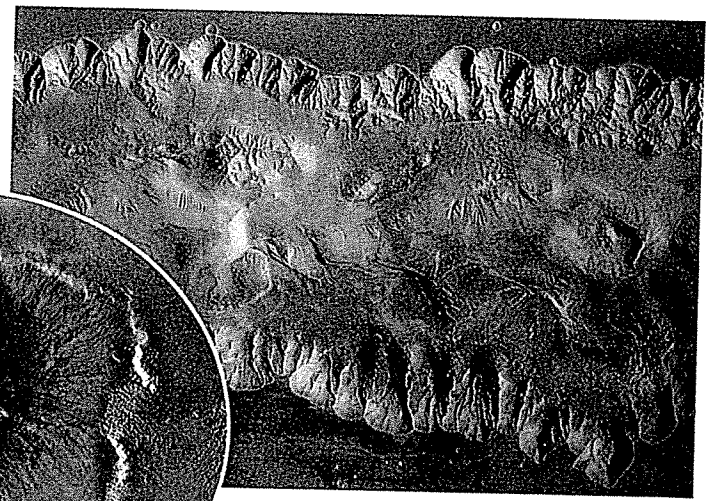
Figure 7 Many features on Mars are similar to those on Earth.



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.