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?***

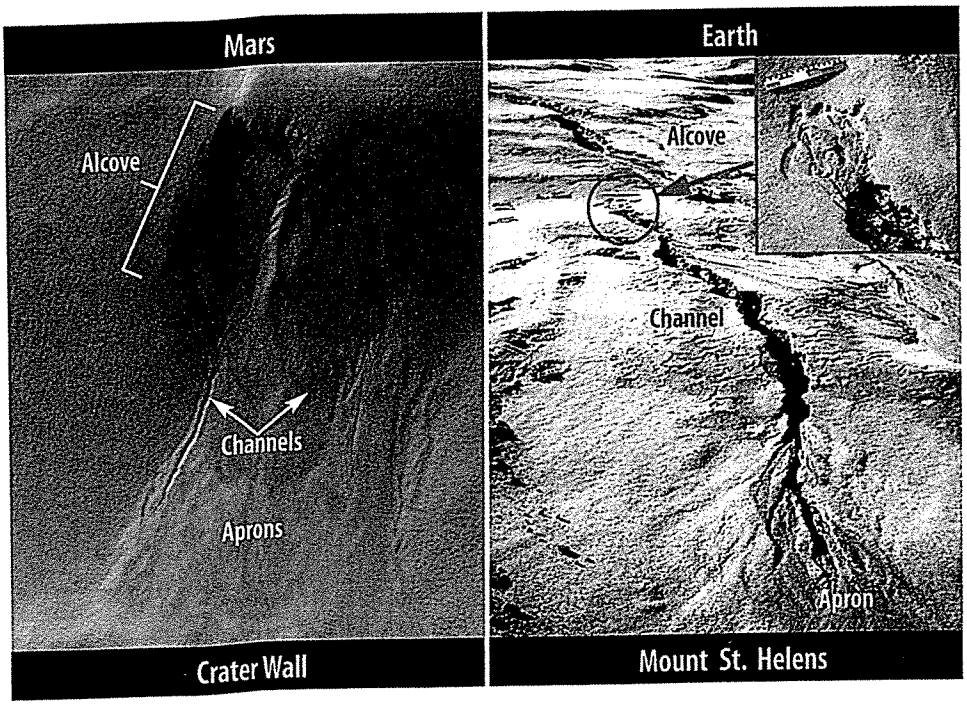


Figure 8 Compare the features found on Mars with those found on an area of Mount St. Helens in Washington state that experienced a flash flood.

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?

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 km) × (0.533) = 6,799 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.

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

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.

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.

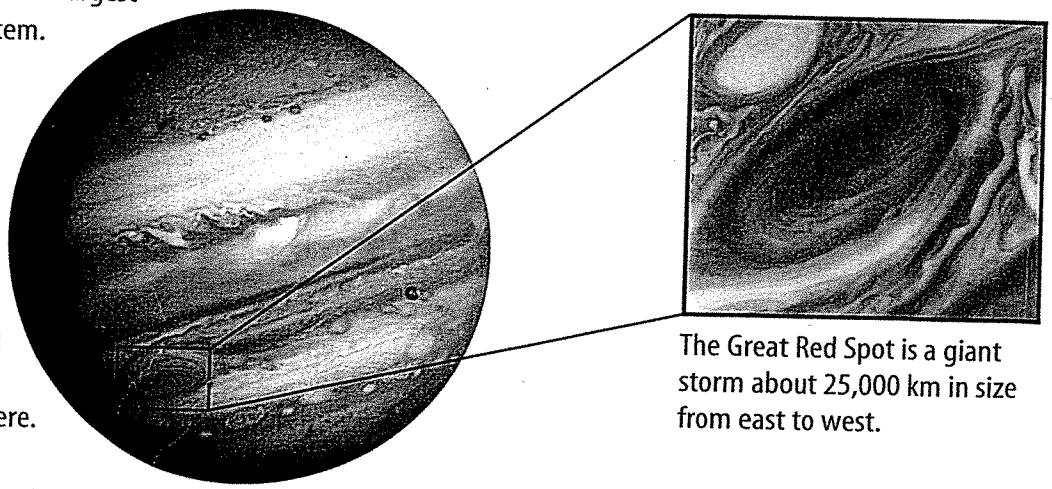
Jupiter

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.

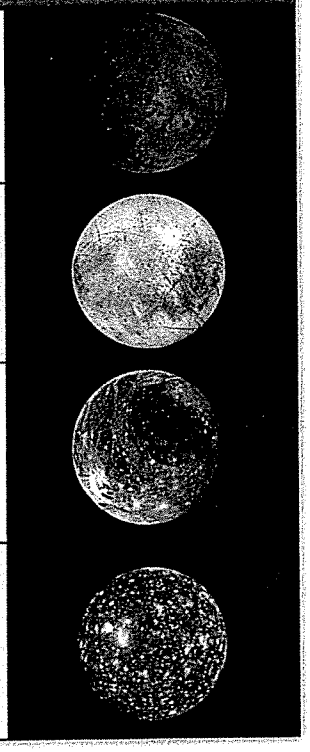
Figure 10 Jupiter is the largest planet in the solar system.



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.

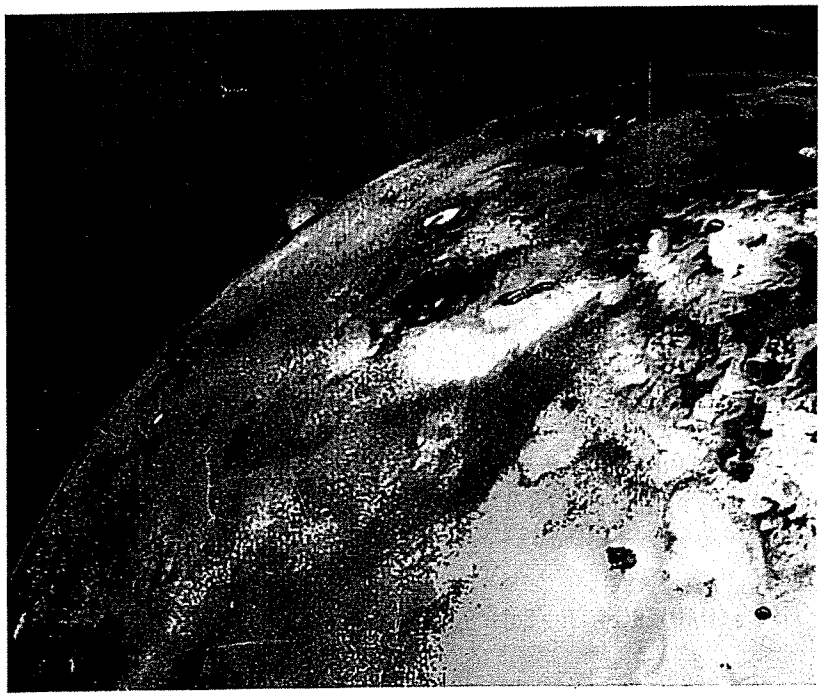
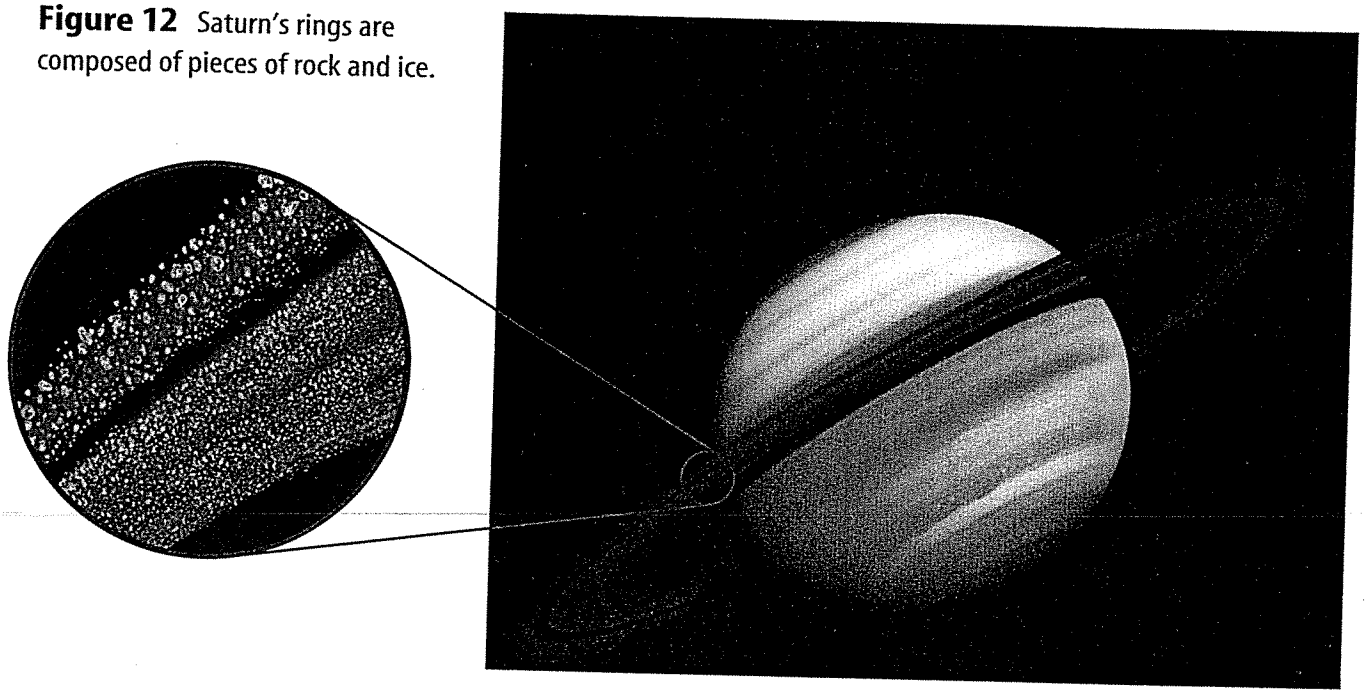


Figure 11 *Voyager 2* photographed the eruption of this volcano on Io in July 1979.

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.

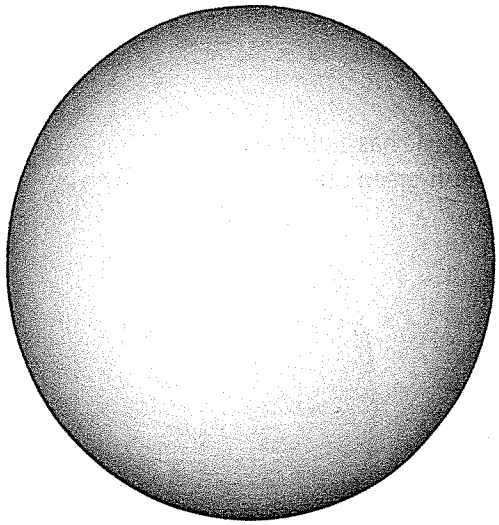


Figure 13 The atmosphere of Uranus gives the planet its distinct bluish-green color.

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.

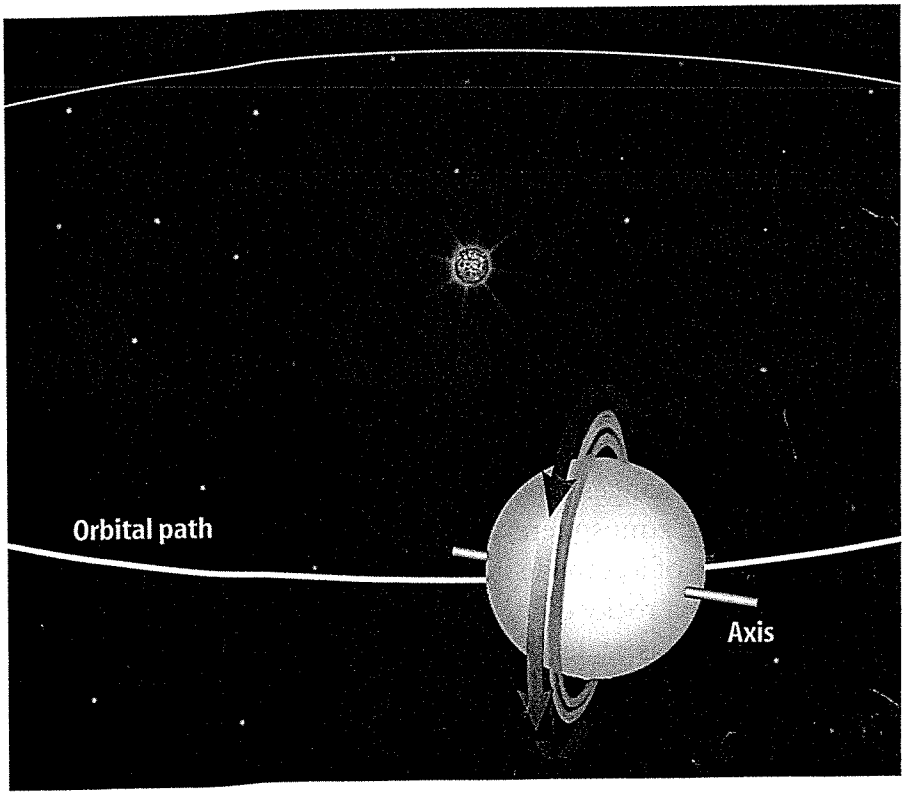
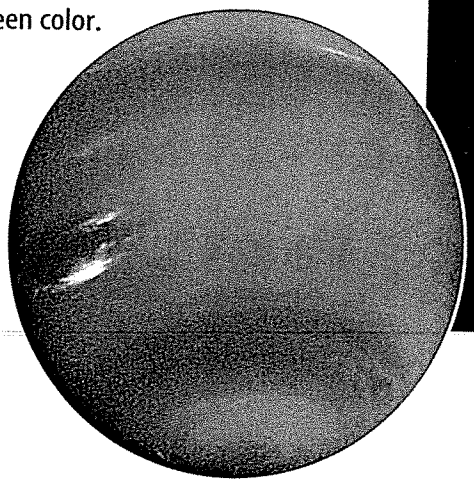
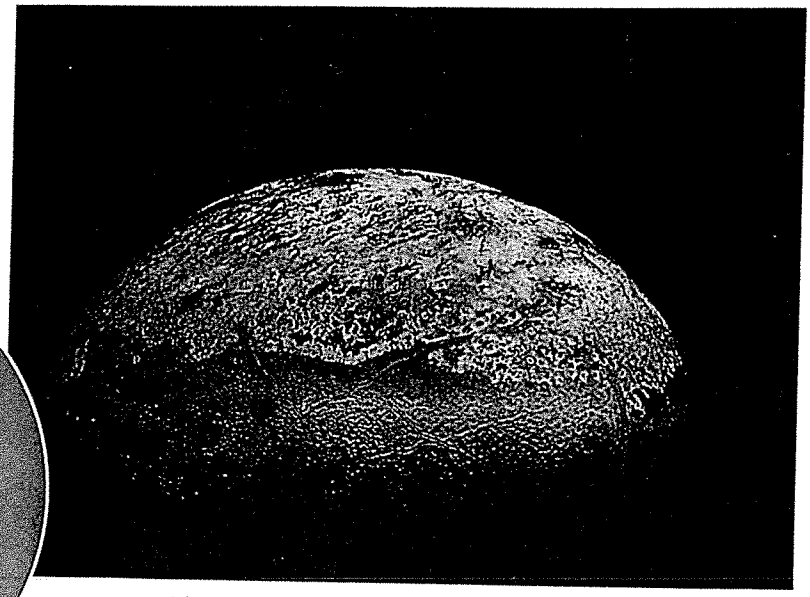


Figure 14 Uranus's axis of rotation is nearly parallel to the plane of its orbit. During its revolution around the Sun, each pole, at different times, points almost directly at the Sun.



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.