Section 28.3

Objectives

- **Compare and contrast** the gas giant planets.
- **Identify** the major moons.
- **Explain** the formation of moons and rings.
- **Compare** the composition of the gas giant planets to the composition of the Sun.

Review Vocabulary

asteroid: metallic or silicate-rich objects that orbit the Sun in a belt between Mars and Jupiter

New Vocabulary

gas giant planet
liquid metallic hydrogen
belt
zone

The Outer Planets

MAIN Idea **Jupiter, Saturn, Uranus, and Neptune have large masses, low densities, and many moons and rings.**

Real-World Reading Link Just as the inner planets resemble a family that shares many physical characteristics, the outer planets also show strong family resemblances.

The Gas Giant Planets

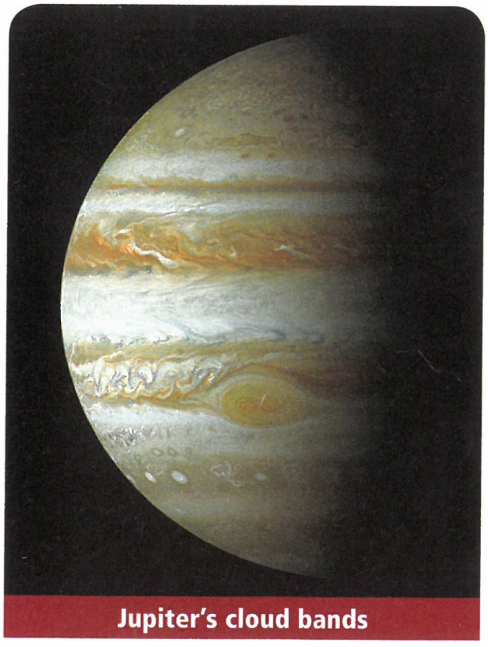
Jupiter, Saturn, Uranus, and Neptune are known as the gas giants. The **gas giant planets** are all very large, ranging from 15 to more than 300 times the mass of Earth, and from about 4 to more than 10 times Earth's diameter. Their interiors are either gases or liquids, and they might have small, solid cores. They are made primarily of lightweight elements such as hydrogen, helium, carbon, nitrogen, and oxygen, and they are very cold at their surfaces. The gas giants have many satellites as well as ring systems.

Jupiter

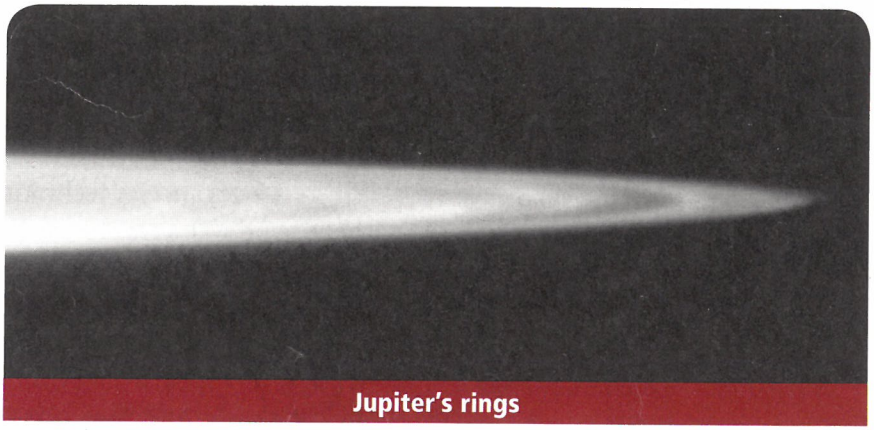
Jupiter is the largest planet, with a diameter one-tenth that of the Sun and 11 times larger than Earth's. Jupiter's mass makes up 70 percent of all planetary matter in the solar system. Jupiter appears bright because its albedo is 0.52. Telescopic views of Jupiter show a banded appearance, as a result of flow patterns in its atmosphere. Nestled among Jupiter's cloud bands is the Great Red Spot, an atmospheric storm that has raged for more than 300 years. This is shown in **Figure 28.20.**

Rings The *Galileo* spacecraft observed Jupiter and its moons during a 5-year mission in the 1990s. It revealed two faint rings around the planet in addition to a 6400-km-wide ring around Jupiter that had been discovered by *Voyager 1*. A portion of Jupiter's faint ring system is also shown in **Figure 28.20.**

Figure 28.20 Jupiter's cloud bands contain the Great Red Spot. The planet is circled by three faint rings that are probably composed of dust particles.



Jupiter's cloud bands



Jupiter's rings

Atmosphere and interior Jupiter has a density of 1326 kg/m^3, which is low for its size, because it is composed mostly of hydrogen and helium in gaseous or liquid form. Below the liquid hydrogen is a layer of **liquid metallic hydrogen,** a form of hydrogen that has properties of both a liquid and a metal, which can exist only under conditions of very high pressure. Electric currents exist within the layer of liquid metallic hydrogen and generate Jupiter's magnetic field. Models suggest that Jupiter might have an Earth-sized solid core containing heavier elements.

Rotation Jupiter rotates very rapidly for its size; it spins once on its axis in a little less than 10 hours, giving it the shortest day in the solar system. This rapid rotation distorts the shape of the planet so that the diameter through its equatorial plane is 7 percent larger than the diameter through its poles. Jupiter's rapid rotation causes its clouds to flow rapidly as well, in bands of alternating dark and light colors called belts and zones. **Belts** are low, warm, dark-colored clouds that sink, and **zones** are high, cool, light-colored clouds that rise. These are similar to cloud patterns in Earth's atmosphere caused by Earth's rotation.

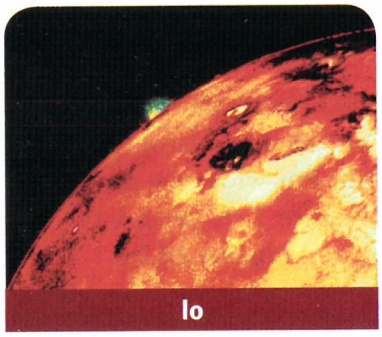
Moons Jupiter has more than 60 moons, most of which are extremely small. Jupiter's four largest moons, Io, Europa, Ganymede, and Callisto, are called Galilean satellites after their discoverer. Three of them are bigger than Earth's Moon, and all four are composed of ice and rock. The ice content is lower in Io and Europa, which are shown in **Figure 28.21,** because they have been squeezed and heated by Jupiter's gravitational force more than the outer Galilean moons. In fact, Io is almost completely molten inside and undergoes constant volcanic eruptions. Gravitational heating has melted Europa's ice in the past, and astronomers hypothesize that it still has a subsurface ocean of liquid water. Cracks and water channels mark Europa's icy surface.

Reading Check **Explain** why scientists think that Europa has an ocean of liquid water beneath its surface.

Jupiter's smaller moons were discovered by a series of space probes beginning with *Pioneer 10* and *Pioneer 11* in the 1970s followed by *Voyager 1* and *Voyager 2* that also detected Jupiter's rings. Most of the information on Jupiter and its moons came from the *Galileo* space probe that arrived at Jupiter in 1995. Jupiter's four small, inner moons are thought to be the source of Jupiter's rings. Scientists think that the rings are produced as meteoroids strike these moons and release fine dust into Jupiter's orbit.

Gravity assist A technique first used to help propel *Mariner 10* to Venus and Mars was to use the Sun's gravity to boost the speed of the satellite. Today it is common for satellites to use a planet's gravity to help propel them deeper into space. Jupiter is the most massive planet, and so any satellite passing deeper into space than Jupiter uses its gravity to give it an assist. Recent flybys on their way to Saturn and Pluto by the *Cassini* and *New Horizons* missions used that assist.

Figure 28.21 Jupiter's gravity heats Europa and Io, causing some visible effects: volcanic eruptions on Io and melting and refreezing of Europa's icy surface causing it to be crisscrossed by cracks and water channels.


Io


Europa

Saturn

Saturn, shown in **Figure 28.22,** is the second-largest planet in the solar system. Five space probes have visited Saturn, including *Pioneer 10, Pioneer 11,* and *Voyagers 1* and *2.* In 2004, the United States' *Cassini* mission arrived at Saturn and began to orbit the planet.

Atmosphere and interior Saturn is slightly smaller than Jupiter and its average density is lower than that of water. Like Jupiter, Saturn rotates rapidly for its size and has a layered cloud system. Saturn's atmosphere is mostly hydrogen and helium with ammonia ice near the cloud tops. The internal structure of Saturn is probably similar to Jupiter's—fluid throughout, except for a small, solid core. Saturn's magnetic field is 1000 times stronger than Earth's and is aligned with its rotational axis. This is highly unusual among the planets.

Rings Saturn's most striking feature is its rings, which are shown in **Figure 28.22.** Saturn's rings are much broader and brighter than those of the other gas giant planets. They are composed of pieces of ice that range from microscopic particles to house-sized chunks. There are seven major rings, and each ring is made up of narrower rings, called ringlets. The rings contain many open gaps.

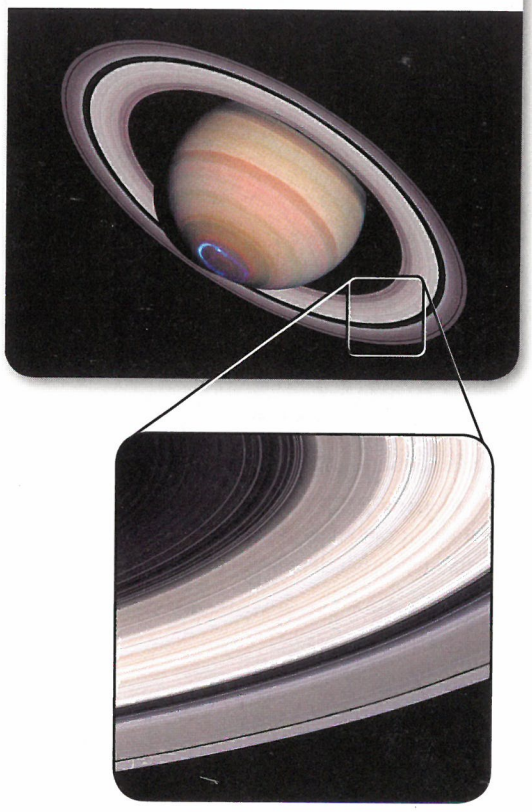
These ringlets and gaps are caused by the gravitational effects of Saturn's many moons. The rings are thin—less than 200 m thick—because rotational forces keep the orbits of all the particles confined to Saturn's equatorial plane. The ring particles have not combined to form a large satellite because Saturn's gravity prevents particles located close to the planet from sticking together. This is why the major moons of the gas giant planets are always beyond the rings.

Origin of the rings Until recently, astronomers thought that the ring particles were left over from the formation of Saturn and its moons. Now, many astronomers think it is more likely that the ring particles are debris left over from collisions of asteroids and other objects, or from moons broken apart by Saturn's gravity.

Moons Saturn has more than 55 satellites, including the giant Titan, which is larger than the planet Mercury. Titan is unique among planetary satellites because it has a dense atmosphere made of nitrogen and methane. Methane can exist as a gas, a liquid, and a solid on Titan's surface. In 2005, *Cassini* released the *Huygens* (HOY gens) probe into Titan's atmosphere. *Cassini* detected plumes of ice and water vapor ejected from Saturn's moon Enceladus, suggesting geologic activity.

Figure 28.22 Saturn's rings are made of chunks of rock and ice that can be as small as dust particles or as large as a house. A close-up view reveals ringlets and gaps.

Explain *why the ring particles orbit Saturn in the same plane.*



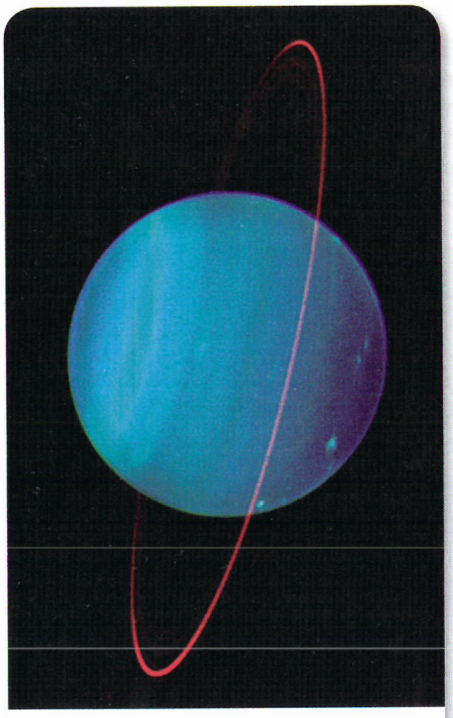


Figure 28.23 The blue color of Uranus is caused by methane in its atmosphere, which reflects blue light.

Uranus

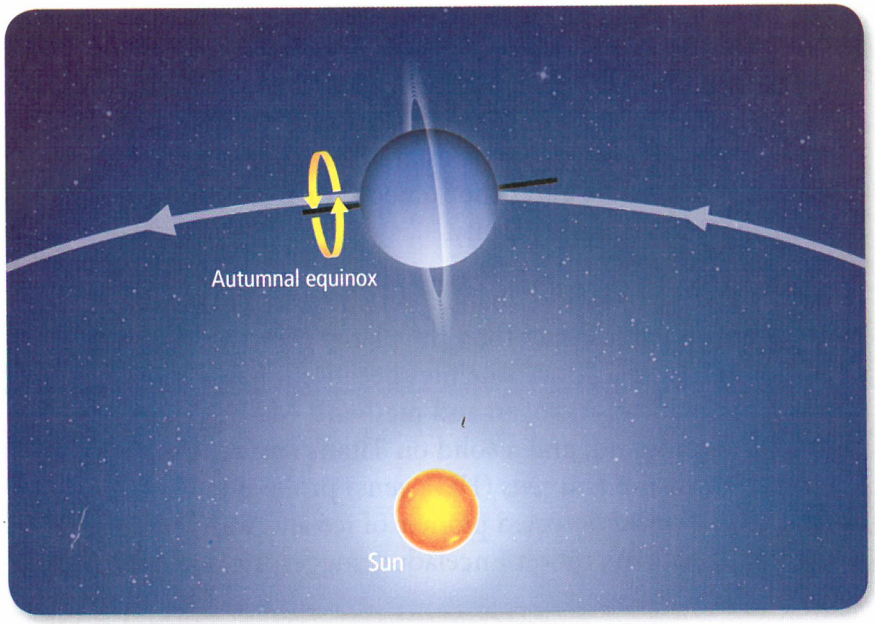
Uranus was discovered accidentally in 1781, when a bluish object was observed moving relative to the stars. In 1986, *Voyager 2* flew by Uranus and provided detailed information about the planet, including the existence of new moons and rings. Uranus's average temperature is 58 K (−215°C).

Atmosphere Uranus is 4 times larger and 15 times more massive than Earth. It has a blue, velvety appearance, shown in **Figure 28.23,** which is caused by methane gas in Uranus's atmosphere. Most of Uranus's atmosphere is composed of helium and hydrogen, which are colorless. There are few clouds, and they differ little in brightness and color from the surrounding atmosphere contributing to Uranus's featureless appearance. The internal structure of Uranus is similar to that of Jupiter and Saturn; it is completely fluid except for a small, solid core. Uranus also has a strong magnetic field.

Moons and rings Uranus has at least 27 moons and a faint ring system. Many of Uranus's rings are dark—almost black and almost invisible. They were discovered only when the brightness of a star behind the rings dimmed as Uranus moved in its orbit and the rings blocked the starlight.

Rotation The rotational axis of Uranus is tipped so far that its north pole almost lies in its orbital plane, as shown in **Figure 28.24.** Astronomers hypothesize that Uranus was knocked sideways by a massive collision with a passing object, such as a large asteroid, early in the solar system's history. Each pole on Uranus spends 42 Earth years in darkness and 42 Earth years in sunlight due to this tilt.

Figure 28.24 The axis or rotation of Uranus is tipped 98 degrees. This view shows its position at an equinox.
Draw *a diagram showing its position at the other equinox and solstices.*



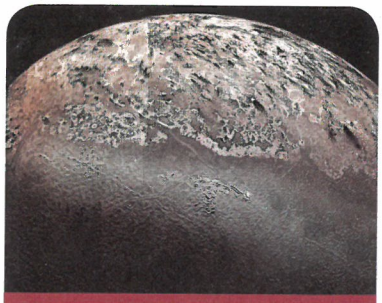
Neptune

The existence of Neptune was predicted before it was discovered, based on small deviations in the motion of Uranus and the application of Newton's universal law of gravitation. In 1846, Neptune was discovered where astronomers had predicted it to be. Few details can be observed on Neptune with an Earth-based telescope, but *Voyager 2* flew past Neptune in 1989 and took the image of its cloud-streaked atmosphere, shown in **Figure 28.25.** Neptune is the last of the gas giant planets and orbits the Sun almost 4.5 billion km away.

Atmosphere Neptune is slightly smaller and denser than Uranus, but its radius is about 4 times as large as Earth's. Other similarities between Neptune and Uranus include their bluish color caused by methane in the atmosphere, their atmospheric compositions, temperatures, magnetic fields, interiors, and particle belts or rings. Unlike Uranus, however, Neptune has distinctive clouds and atmospheric belts and zones similar to those of Jupiter and Saturn. In fact, Neptune once had a persistent storm, the Great Dark Spot, similar to Jupiter's Great Red Spot, but the storm disappeared in 1994.

Moons and rings Neptune has 13 moons, the largest of which is Triton. Triton has a retrograde orbit, which means that it orbits backward, unlike other large satellites in the solar system. Triton, as shown in **Figure 28.25,** has a thin atmosphere and nitrogen geysers. The geysers are caused by nitrogen gas below Triton's south polar ice, which expands and erupts when heated by the Sun. Neptune's six rings are composed of microscopic dust particles, which do not reflect light well. Therefore, Neptune's rings are not as visible from Earth as Saturn's rings.

Neptune cloud streaks



Triton

Figure 28.25 *Voyager 2* took the image of Neptune above showing its cloud streaks, as well as this close-up view of Neptune's largest moon, Triton. Dark streaks indicate the sites of nitrogen geysers on Triton.

Section 28.3 Assessment

Section Summary

- The gas giant planets are composed mostly of hydrogen and helium.
- The gas giant planets have ring systems and many moons.
- Some moons of Jupiter and Saturn have water and experience volcanic activity.
- All four gas giant planets have been visited by space probes.

Understand Main Ideas

1. MAIN Idea **Create** a table that lists the gas giant planets and their characteristics.
2. **Compare** the composition of the gas giant planets to the Sun.
3. **Compare** Earth's Moon with the moons of the gas giant planets.

Think Critically

4. **Evaluate** Where do you think are the most likely sites on which to find extraterrestrial life? Explain.

WRITING in Earth Science

5. Research and describe one of the *Voyager* missions to interstellar space.