Section 28.2

Objectives

- **Compare** the characteristics of the inner planets.
- **Survey** some of the space probes used to explore the solar system.
- **Explain** the differences among the terrestrial planets.

Review Vocabulary

albedo: the amount of sunlight that reflects from the surface

New Vocabulary

terrestrial planet
scarp

The Inner Planets

MAIN Idea Mercury, Venus, Earth, and Mars have high densities and rocky surfaces.

Real-World Reading Link Just as in a family in which brothers and sisters share a strong resemblance, the inner planets share many characteristics.

Terrestrial Planets

The four inner planets are called **terrestrial planets** because they are similar in density to Earth and have solid, rocky surfaces. Their average densities, obtained by dividing the mass of a planet by its volume, range from about 3.5 to just over 5.5 g/cm^3. Average density is an important indicator of internal conditions, and densities in this range indicate that the interiors of these planets are compressed.

Mercury

Mercury is the planet closest to the Sun, and for this reason it is difficult to see from Earth. During the day it is lost in the Sun's light and it is more easily seen at sunset and sunrise. Mercury is about one-third the size of Earth and has a smaller mass. Mercury has no moons. Radio observations in the 1960s revealed that Mercury has a slow spin of 1407.6 hours. In one orbit around the Sun, Mercury rotates one and one-half times, as shown in **Figure 28.10.** As Mercury spins, the side facing the Sun at the beginning of the orbit faces away from the Sun at the end of the orbit. This means that two complete Mercury years equal three complete Mercury days.

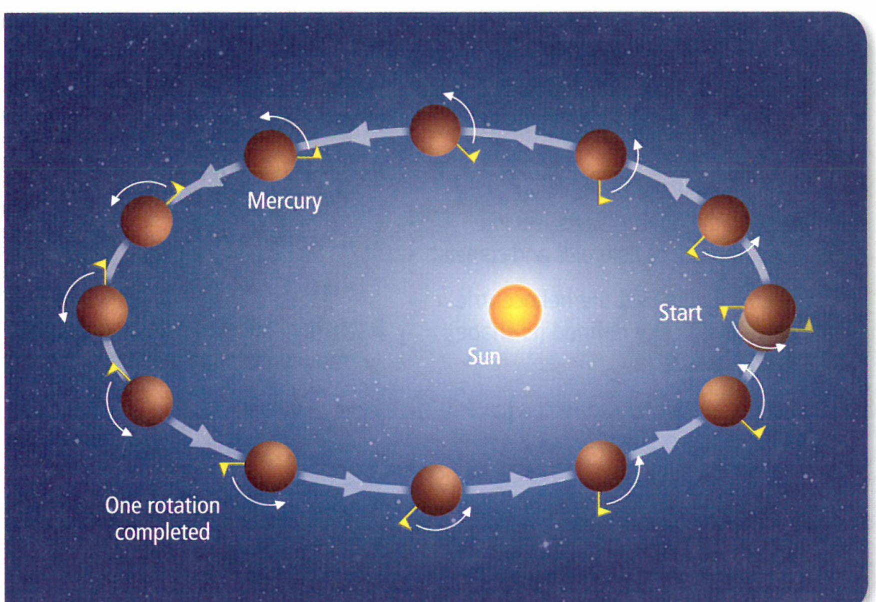
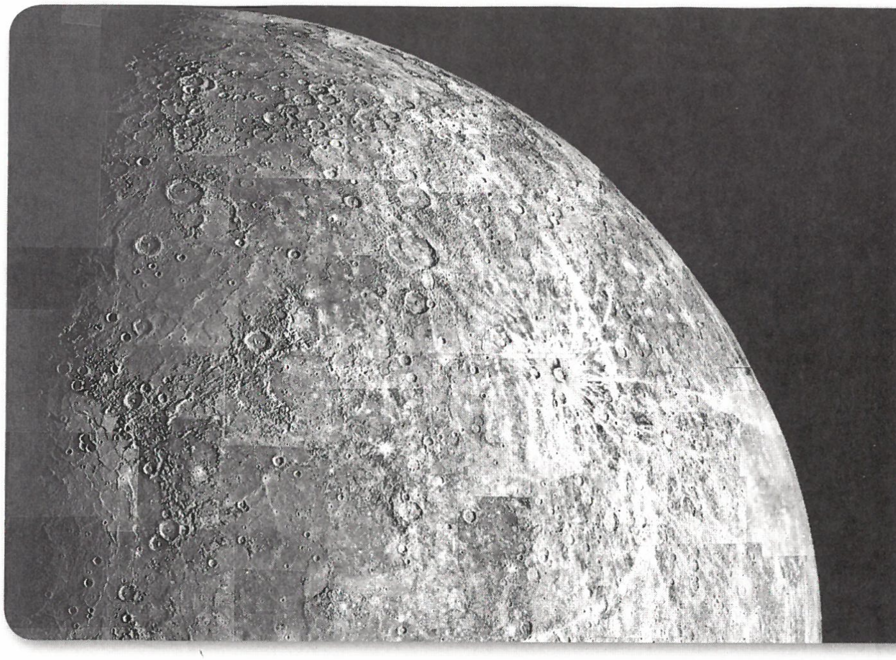


Figure 28.10 Because of Mercury's odd rotation, its day lasts for two-thirds of its year. **Compare** *Mercury's orbital motion with that of Earth's Moon.*



■ **Figure 28.11** This mosaic of Mercury's heavily cratered surface was made by *Mariner 10.* Craters range in size from 100 to 1300 km in diameter.

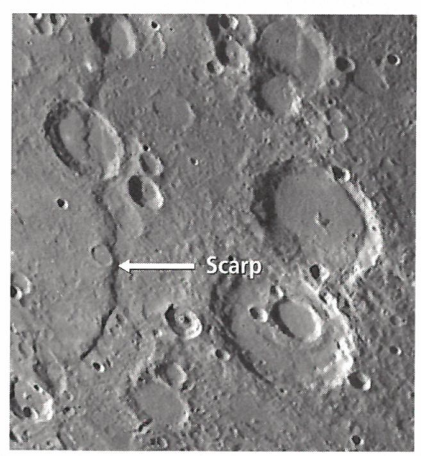
Atmosphere Unlike Earth and the other planets, Mercury's atmosphere is constantly being replenished by the solar wind. What little atmosphere does exist is composed primarily of oxygen and sodium atoms deposited by the Sun. The daytime surface temperature on Mercury is 700 K (427°C), while temperatures at night fall to 100 K (−173°C). This is the largest day-night temperature difference among the planets.

Surface Most knowledge about Mercury is based on the radio observations from Earth, and images from U.S. space probe *Mariner 10,* which passed close to Mercury three times in 1974 and 1975. Images from *Mariner 10* show that Mercury's surface, like that of the Moon, is covered with craters and plains, as shown in **Figure 28.11.** The plains on Mercury's surface are smooth and relatively crater free. Scientists think that the plains formed from lava flows that covered cratered terrain, much like the maria formed on the Moon. The surface gravity of Mercury is much greater than that of the Moon, resulting in smaller crater diameters and shorter lengths of ejecta.

Mercury has a planetwide system of cliffs called **scarps,** such as the one shown in **Figure 28.12.** Though similar to those on Earth, Mercury's scarps are much higher. Scientists hypothesize that the scarps developed as Mercury's crust shrank and fractured early in the planet's geologic history. Scientists will learn more about the surface of Mercury with the arrival of the Japanese-European *Messenger* mission in 2011.

Reading Check **Compare** the surfaces of the Moon and Mercury.

■ **Figure 28.12** Discovery, the largest scarp on Mercury, is 550 km long and 1.5 km high.



Interior Without seismic data, scientists have no way to analyze the interior of Mercury. However, its high density suggests that Mercury has a large nickel-iron core. Mercury's small magnetic field indicates that some of its core is molten.

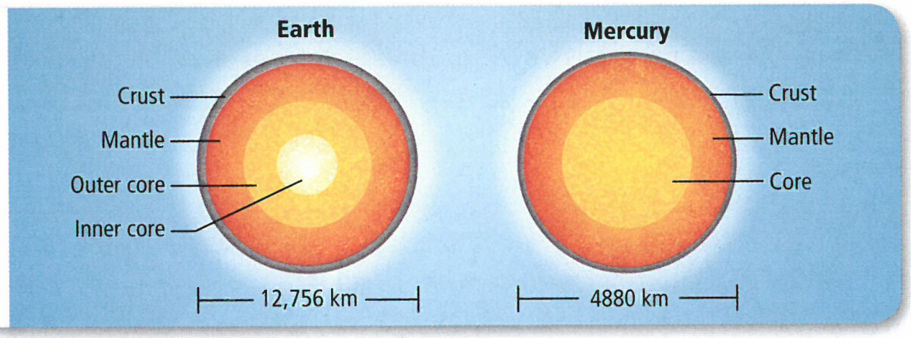


Figure 28.13 The structure of Mercury's interior, which contains a proportionally larger core than Earth, suggests that Mercury was once much larger.

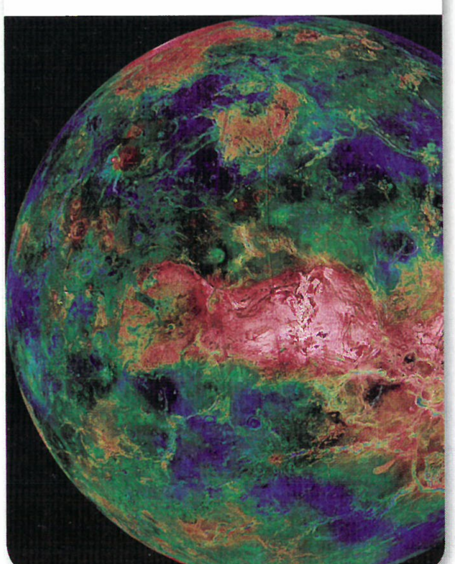
Early Mercury Mercury's small size, high density, and probable molten interior resemble what Earth might be like if its crust and mantle were removed, as shown in **Figure 28.13.** These observations suggest that Mercury was originally much larger, with a mantle and crust similar to Earth's, and that the outer layers might have been lost in a collision with another celestial body early in its history.

Venus

Venus and Mercury are the only two planets closer to the Sun than Earth. Like Mercury, Venus has no moons. Venus is the brightest planet in the sky because it is close to Earth and because its albedo is 0.75—the highest of any planet. Venus is the first bright "star" to be seen after sunset in the western sky, or the last "star" to be seen before sunrise in the morning, depending on which side of the Sun it is on. For these reasons it is often called either the evening or morning star.

Thick clouds around Venus prevent astronomers from observing the surface directly. However, astronomers learned much about Venus from spacecraft launched by the United States and the Soviet Union. Some probes landed on the surface of the planet, and others flew by. Then, the 1978 *Pioneer-Venus* and 1989 *Magellan* missions of the United States used radar to map 98 percent of the surface of Venus. A view of the surface was obtained using a type of radar imaging and combining images from *Magellan* spacecraft with those produced by the radio telescope in Arecibo, Puerto Rico. This view, shown in **Figure 28.14,** uses false colors to outline the major landmasses. In 2006, a European space probe, called *Venus Express*, went into orbit around Venus. Its mission was to gather atmospheric data for about one and one-half years.

Figure 28.14 Radar imaging revealed the surface of Venus. Highlands are shown in red, and valleys are shown in blue. Large highland regions are like continents on Earth.
Infer *What do green areas represent?*



Retrograde rotation Radar measurements show that Venus rotates slowly—a day on Venus is equivalent to 243 Earth days. Also, Venus rotates clockwise, unlike most planets that spin counterclockwise. This backward spin, called retrograde rotation, means that an observer on Venus would see the Sun rise in the west and set in the east. Astronomers theorize that this retrograde rotation might be the result of a collision between Venus and another body early in the solar system's history.

Atmosphere Venus is the planet most similar to Earth in physical properties, such as diameter, mass, and density, but its surface conditions and atmosphere are vastly different from those on Earth. The atmospheric pressure on Venus is 92 atmospheres (atm), compared to 1 atm at sea level on Earth. If you were on Venus, the pressure of the atmosphere would make you feel like you were under 915 m of water.

The atmosphere of Venus is composed primarily of carbon dioxide and nitrogen, somewhat similar to Earth's atmosphere. Venus also has clouds, as shown in **Figure 28.15,** an image taken of the night side of Venus by *Venus Express.* Instead of being composed of water vapor and ice, as on Earth, clouds on Venus consist of sulfuric acid.

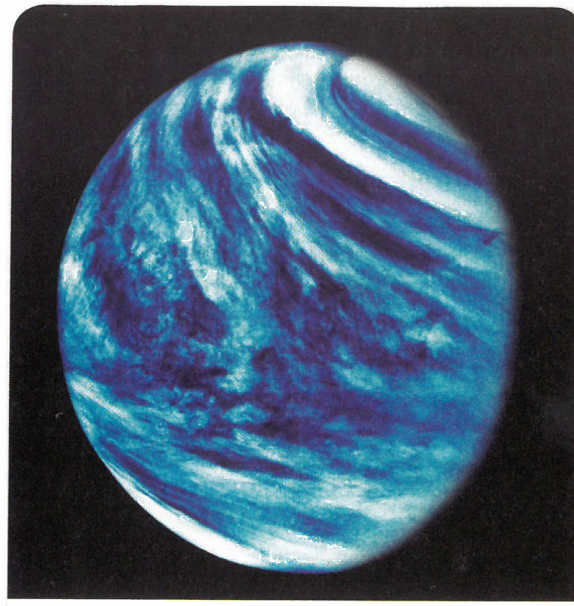


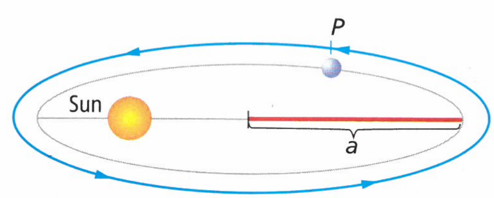
Figure 28.15 Clouds swirl around Venus in this image taken using ultraviolet wavelengths.

Greenhouse effect Venus also experiences a greenhouse effect similar to Earth's, but Venus's is more efficient. As you learned in Chapter 14, greenhouse gases in Earth's atmosphere trap infrared radiation and keep Earth much warmer than it would be if it had no atmosphere. The concentration of carbon dioxide is so high in Venus's atmosphere that it keeps the surface extremely hot—hot enough to melt lead. In fact, Venus is the hottest planet, with an average surface temperature of about 737 K (464°C), compared with Earth's average surface temperature of 288 K (15°C). It is so hot on the surface of Venus that no liquid water can exist.

PROBLEM-SOLVING LAB

Apply Kepler's Third Law

How well do the orbits of the planets conform to Kepler's third law? For the six planets closest to the Sun, Kepler observed that $P^2 = a^3$, where P is the orbital period in years and a is the semimajor axis in AU.



Analysis

1. Use this typical planet orbit diagram and the data from the *Reference Handbook* to confirm the relationship between P^2 and a^3 for each of the planets.

Think Critically

2. **Prepare** a table showing your results and how much they deviate from predicted values.
3. **Determine** which planets conform most closely to Kepler's law and which do not seem to follow it.
4. **Consider** Would Kepler have formulated this law if he had been able to study Uranus and Neptune? Explain.
5. **Predict** the orbital period of an asteroid orbiting the Sun at 2.5 AU.
6. **Solve** Find the semimajor axis of Halley's comet, which has an orbital period of 76 years.

Surface The *Magellan* orbiter used radar reflection measurements to map the surface of Venus. This revealed that Venus has a surface smoothed by volcanic lava flows and with few impact craters. The most recent volcanic activity took place about 500 mya. Unlike Earth, there is little evidence of current tectonic activity on Venus, and there is no well-defined system of crustal plates.

Interior Because the size and density of Venus are similar to Earth's, it is probable that the internal structure is similar also. Astronomers theorize that Venus has a liquid metal core that extends halfway to the surface. Despite this core, Venus has no measurable magnetic field, probably because of its slow rotation.

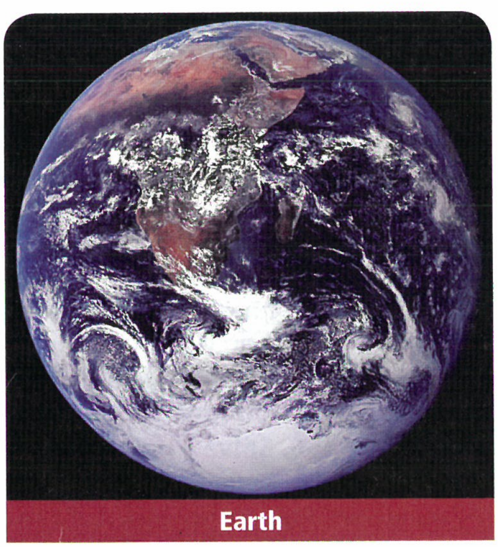
Earth

Earth, shown in **Figure 28.16,** has many unique properties when compared with other planets. Its distance from the Sun and its nearly circular orbit allow water to exist on its surface in all three states—solid, liquid, and gas. Liquid water is required for life, and Earth's abundance of water has been important for the development and existence of life on Earth. In addition, Earth's mild greenhouse effect and moderately dense atmosphere of nitrogen and oxygen provide conditions suitable for life.

Earth is the most dense and the most tectonically active of the terrestrial planets. It is the only planet where plate tectonics occurs. Unlike Venus and Mercury, Earth has a moon, probably acquired by an impact, as you learned in Chapter 27.

Mars

Mars is often referred to as the red planet because of its reddish surface color, as shown in **Figure 28.16.** Mars is smaller and less dense than Earth and has two irregularly shaped moons—Phobos and Deimos. Mars has been the target of a lot of recent exploration —*Mars Odyssey* and *Global Surveyor* in 2001, *Exploration Rovers, Reconnaissance Orbiter*, and *Mars Express* in 2003.



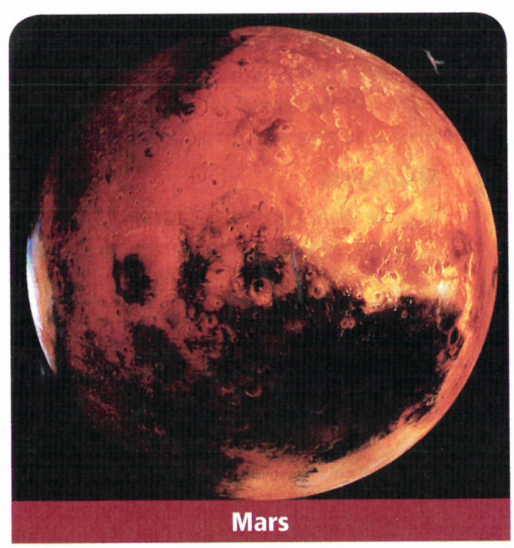


Figure 28.16 Earth's blue seas and white clouds contrast sharply with the reddish, barren Mars.

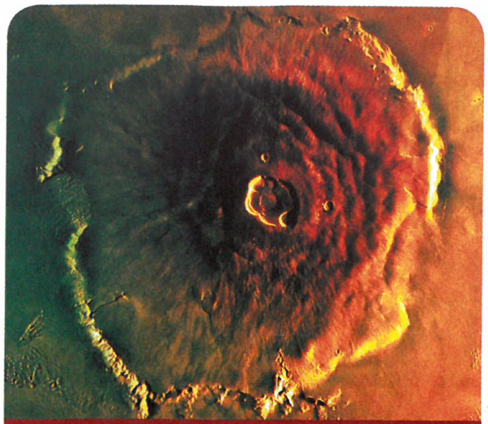


Figure 28.17 Orbital probes and landers have provided photographic details of the Martian features and surface, such as Olympus Mons and Gusev crater.

Atmosphere Both Mars and Venus have atmospheres of similar composition. The density and pressure of the atmosphere on Mars are much lower; therefore Mars does not have a strong greenhouse effect like Venus does. Although the atmosphere is thin, it is turbulent—there is constant wind, and dust storms can last for weeks at a time.

Surface The southern and northern hemispheres of Mars vary greatly, as shown in **Figure 28.17.** The southern hemisphere is a heavily cratered, highland region resembling the highlands of the Moon. The northern hemisphere has sparsely cratered plains. Scientists theorize that great lava flows covered the once-cratered terrain of the northern hemisphere. Four gigantic shield volcanoes are located near the equator, near a region called the Tharsis Plateau. The largest volcano on Mars is Olympus Mons. The base of Olympus Mons is larger than the state of Colorado, and the volcano rises 3 times higher than Mount Everest in the Himalayas.

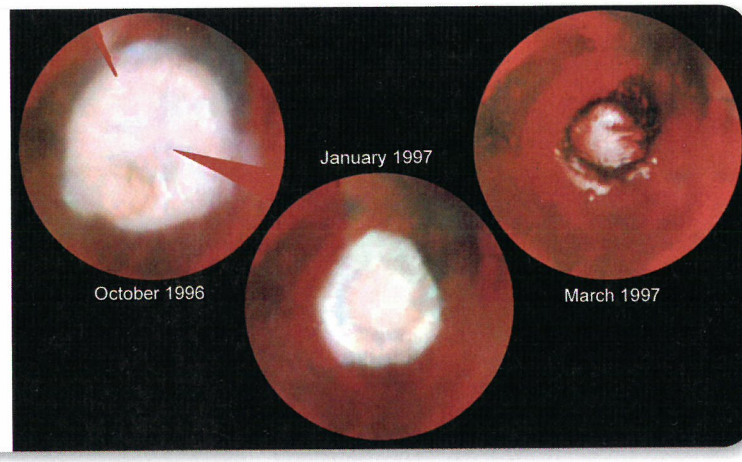
Tectonics An enormous canyon, Valles Marineris, shown in **Figure 28.18,** lies on the Martian equator, splitting the Tharsis Plateau. This canyon is 4000 km long—almost 10 times the length of the Grand Canyon on Earth and more than 3 times its depth. It probably formed as a fracture during a period of tectonic activity 3 bya, when the Tharsis Plateau was uplifted. The gigantic volcanoes were caused during the same period by upwelling of magma at a hot spot, much like the Hawaiian Island chain was formed. However, with no plate movement on Mars, magma accumulated in one area.

Erosional features Other Martian surface features include dried river and lake beds, outflow channels, and runoff channels. These erosional features suggest that liquid water once existed on the surface of Mars. Astronomers think that the atmosphere was once much warmer, thicker, and richer in carbon dioxide, allowing liquid water to flow on Mars. Although there is a relatively small amount of ice at the poles, astronomers continue to search for water at other locations on the Martian surface.

Figure 28.18 Valles Marineris is a 4000-km-long canyon on Mars.

■ **Figure 28.19** These images of Mars's northern ice cap were taken three months apart by the *Hubble Space Telescope* in 1997.

Interpret ***What do these images indicate about the orientation of Mars's axis?***



Ice caps Ice caps cover both poles on Mars. The caps grow and shrink with the seasons. Martian seasons are caused by a combination of a tilted axis and a slightly eccentric orbit. Both caps are made of carbon dioxide ice, sometimes called dry ice. Water ice lies beneath the carbon dioxide ice in the northern cap, shown in **Figure 28.19,** and is exposed during the northern hemisphere's summer when the carbon dioxide ice evaporates. There might also be water ice beneath the southern cap, but the carbon dioxide ice does not completely evaporate to expose it.

Interior The internal structure of Mars remains unknown. Astronomers hypothesize that there is a core of iron, nickel, and possibly sulfur that extends somewhere between 1200 km and 2400 km from the center of the planet. Because Mars has no magnetic field, astronomers think that the core is probably solid. Above the solid core is a mantle. There is no evidence of current tectonic activity or tectonic plates on the surface of the crust.

Section 28.2 Assessment

Section Summary

- Mercury is heavily cratered and has high cliffs. It has a hot surface and no real atmosphere.
- Venus has clouds containing sulfuric acid and an atmosphere of carbon dioxide that produces a strong greenhouse effect.
- Earth is the only planet that has all three forms of water on its surface.
- Mars has a thin atmosphere. Surface features include four volcanoes and channels that suggest that liquid water once existed on the surface.

Understand Main Ideas

1. MAIN Idea **Identify** the reason that the inner planets are called terrestrial planets.
2. **Summarize** the characteristics of each of the terrestrial planets.
3. **Compare** the average surface temperatures of Earth and Venus, and describe what causes them.
4. **Describe** the evidence that indicates there was once tectonic activity on Mercury, Venus, and Mars.

Think Critically

5. **Consider** what the inner planets would be like if impacts had not shaped their formation and evolution.

MATH in Earth Science

6. Using the *Reference Handbook,* create a graph showing the distance from the Sun for each terrestrial planet on the *x*-axis and their orbital periods in Earth days on the *y*-axis. For more help, refer to the *Skillbuilder Handbook*.

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