23.2 The Terrestrial Planets

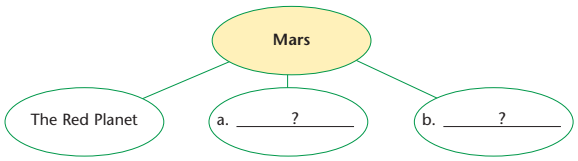
Reading Focus

Key Concepts

- What are the distinguishing characteristics of each terrestrial planet?

Reading Strategy

Using Prior Knowledge Copy the web diagram below. Before you read, add properties that you already know about Mars. Then add details about each property as you read. Make a similar web diagram for the other terrestrial planets.



In January 2004, the space rover, *Spirit,* bounced onto the rocky surface of Mars, known as the Red Planet. Shown in Figure 5, *Spirit* and its companion rover, *Opportunity,* were on the Red Planet to study minerals and geological processes, both past and present. They also searched for signs of the liquid water—such as eroded rocks or dry stream channels on Mars's surface. For the next few months, the rovers sent back to Earth numerous images and chemical analysis of Mars's surface. Much of what we learn about the planets has been gathered by rovers, such as *Spirit,* or space probes that travel to the far reaches of the solar system, such as *Voyager.* In this section, we'll explore three terrestrial planets—Mercury, Venus, and Mars—and see how they compare with Earth.

Figure 5 *Spirit* roved the surface of Mars and gathered data about the Red Planet's geologic past and present.

Mercury: The Innermost Planet

Mercury, the innermost and smallest planet, is hardly larger than Earth's moon and is smaller than three other moons in the solar system. Like our own moon, it absorbs most of the sunlight that strikes it and reflects only 6 percent of sunlight back into space. This low percentage of reflection is characteristic of terrestrial bodies that have no atmosphere. Earth, on the other hand, reflects about 30 percent of the light that strikes it. Most of this reflection is from clouds.

Section 23.2

1 FOCUS

Section Objective

23.3 **Describe** the distinguishing characteristics of each terrestrial planet.

Reading Focus

Build Vocabulary L2

Vocabulary List Encourage students to keep a list of new terms they encounter as they read this chapter. Have them use the context of each term to predict its definition. Go over the terms with the class. Some terms they may select are *rover*, *nonexistent*, *penetrate*, *veiled*, *summit*, *flank*, and *prominent*.

Reading Strategy L2

Sample answers:
a. explored by rovers
b. numerous large volcanoes

Address Misconceptions L2

Some students may think that scientific knowledge is only acquired from controlled experiments. However, a great deal of scientific knowledge is a result of fieldwork and careful observations. In fact, a great deal of what we know about the universe and our solar system, we learned strictly from observation. To help students realize this, ask these questions as you teach this section. Ask: **What did we learn about Venus from the Magellan spacecraft?** *(Venus has varied topography like Earth.)* **What did we learn about Mars from the orbiting spacecraft Mariner 9?** *(Mars has volcanoes and canyons.)* **What did we learn about Mars from the rovers Spirit and Opportunity?** *(Mars has evaporite minerals and evidence of geological processes caused by liquid water; Mars has sand dunes and impact craters.)* **What did we learn from Mars Global Surveyor?** *(Underground springs may have existed on Mars.)* **Could we have learned these things simply from controlled experiments on Earth?** *(no)* **Verbal**

2 INSTRUCT

Mercury: The Innermost Planet

Build Reading Literacy L1

Refer to **p. 362D** in **Chapter 13**, which provides guidelines for this reading strategy.

Use Prior Knowledge Have students make a web diagram for Mercury that includes information they already know about it. Have them add new information to their web as they read. Possible characteristics for web include: small, hot, closest to sun, has craters, very dense, revolves around sun quickly, rotates slowly, greatest temperature extremes of any planet. **Visual, Verbal**

Venus: The Veiled Planet

Build Science Skills L2

Comparing and Contrasting Have students write a list of the similarities between Earth and Venus. *(size, density, mass, location in solar system, clouds, plateaus and mountains, volcanoes, have few impact craters)* Then have students create a chart contrasting Venus and Earth. For example:

Venus	Earth
One year is 255 Earth-days	One year is 365 Earth-days
Covered in thick clouds	Thin atmosphere
Very hot surface temperature	Surface temperature allows liquid water
97 percent of atmosphere is carbon dioxide	Very little of the atmosphere is carbon dioxide
Very little water vapor and nitrogen	Lots of water vapor and nitrogen
Atmospheric pressure is 90 times Earth's surface pressure	

Verbal, Visual

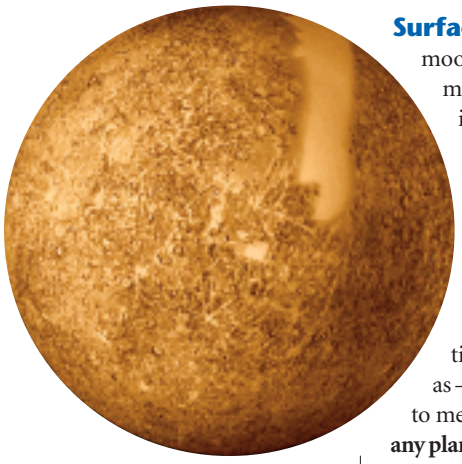


Figure 6 Mercury's surface looks somewhat similar to the far side of Earth's moon.

Surface Features Mercury has cratered highlands, much like the moon, and some smooth terrains that resemble maria. Unlike the moon, however, Mercury is a very dense planet, which implies that it contains a large iron core for its size. Also, Mercury has very long scarps (deep slopes) that cut across the plains and craters alike. These scarps may have resulted from crustal changes as the planet cooled and shrank.

Surface Temperature Mercury, shown in Figure 6, revolves around the sun quickly, but it rotates slowly. One full day-night cycle on Earth takes 24 hours. On Mercury, one rotation requires 59 Earth-days. Nighttime temperatures drop as low as –173°C, and noontime temperatures exceed 427°C—hot enough to melt lead. **Mercury has the greatest temperature extremes of any planet.** The odds of life as we know it existing on Mercury are almost nonexistent.

Reading Checkpoint *How does Mercury's period of rotation compare with Earth's?*

Venus: The Veiled Planet

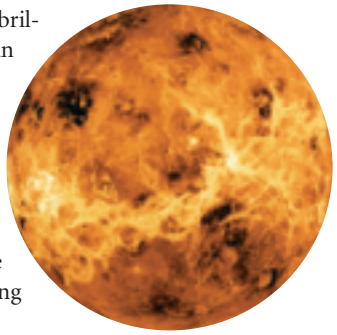


Figure 7 Venus This global view of the surface of Venus is computer generated from two years of Magellan Project radar mapping. The twisting bright features that cross the planet are highly fractured mountains and canyons of the eastern Aphrodite highland.

Venus is second only to the moon in brilliance in the night sky. It orbits the sun once every 255 Earth-days. Venus is similar to Earth in size, density, mass, and location in the solar system. Thus, it has been referred to as "Earth's twin." Because of these similarities, it is hoped that a detailed study of Venus will provide geologists with a better understanding of Earth's history.

Surface Features Venus is covered in thick clouds that hide its surface from view. Nevertheless, radar mapping by the uncrewed *Magellan* spacecraft and by instruments on Earth have revealed a varied topography with features somewhat between those of Earth and Mars, as shown in Figure 7. To map Venus, radar pulses are sent toward the planet's surface, and the heights of plateaus and mountains are measured by timing the return of the radar echo. **Data have confirmed that basaltic volcanism and tectonic activity shape Venus's surface. Based on the low density of impact craters, these forces must have been very active during the recent geologic past.**

Go Online NSTA SCI LINKS

For: Links on extraterrestrial volcanoes
Visit: www.SciLinks.org
Web Code: cjn-7232

Customize for English Language Learners

Have students use a thesaurus rather than a dictionary to look up unfamiliar words. This will help them learn the meaning of multiple words simultaneously. It is likely that at least one synonym listed is a word they know.

Go Online NSTA SCI LINKS

Download a worksheet on extraterrestrial volcanoes for students to complete, and find additional teacher support from NSTA SciLinks.

About 80 percent of Venus's surface consists of plains covered by volcanic flows. Some lava channels extend hundreds of kilometers—one is 6800 kilometers long. Scientists have identified thousands of now inactive volcanic structures. Most are small shield volcanoes, although more than 1500 volcanoes greater than 20 kilometers across have been mapped. Figure 8 shows two of these volcanoes—one is Sapas Mons, 400 kilometers across and 1.5 kilometers high. Flows from this volcano mostly erupted from its flanks rather than its summit, in the manner of Hawaiian shield volcanoes.

Only 8 percent of Venus's surface consists of highlands that may be similar to continental areas on Earth. Tectonic activity on Venus seems to be driven by upwelling and downwelling of material in the planet's interior.

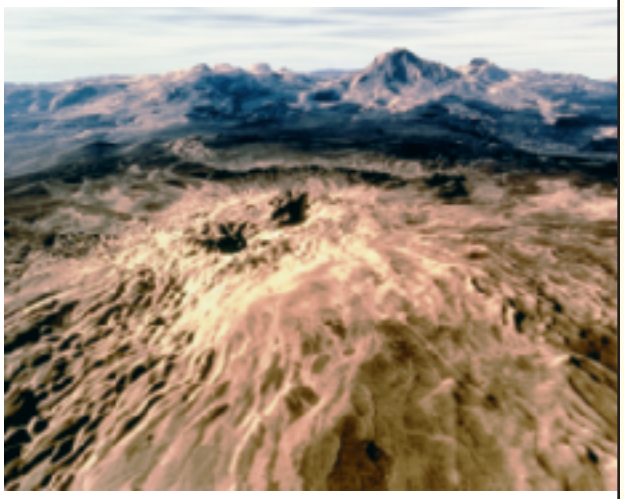


Figure 8 Sapas Mons and Maat Mons In this computer-generated image from Venus, Maat Mons, a large volcano, is near the horizon. Sapas Mons is the bright feature in the foreground.
Comparing and Contrasting ***What features on Venus are similar to those on Earth? What features are different?***

Surface Temperature On Venus, the greenhouse effect has heated the planet's atmosphere to 475°C. That's hot enough to melt lead! Several factors contribute to what scientists have called Venus's *runaway* greenhouse effect.

The main reason for the runaway greenhouse effect on Venus is that its atmosphere is 97 percent carbon dioxide, a greenhouse gas. Venus lacks oceans in which carbon dioxide gas could dissolve, thus removing it from the atmosphere. Scientists think that oceans on Venus may have evaporated early in its history. Water vapor in the atmosphere then accelerated the greenhouse effect. But the atmosphere eventually lost most of its water vapor. The sun's ultraviolet radiation broke down water molecules into hydrogen and oxygen. These gases then escaped into space.

Reading Checkpoint *Describe the composition of Venus's atmosphere.*

Mars: The Red Planet

Mars has evoked great interest throughout history. Mars is easy to observe, which may explain why so many people are fascinated by it. Mars is known as the Red Planet because it appears as a reddish ball when viewed through a telescope. Mars also has some dark regions that change intensity during the Martian year. The most prominent telescopic features of Mars are its brilliant white polar caps.

Facts and Figures

Mars has two natural satellites (moons), Phobos and Deimos. Although Mars is easy to observe from Earth, these moons were not discovered until 1977. Perhaps this is because they are only 24 and 15 km in diameter. Phobos is closer to Mars than any other natural satellite in the solar system, and it requires just 7 hours and 39 minutes for one revolution. *Mariner 9* found that both moons are irregularly shaped and have numerous impact craters.

Mars: The Red Planet

Use Community Resources L2

If possible, invite an astronomer or geologist in your community to talk to students about the findings of the rovers *Spirit* and *Opportunity* on Mars. Encourage students to list questions they have about Mars before the speaker comes to visit.
Verbal, Interpersonal

Integrate Chemistry L3

Polar Ice Caps Inform students that Mars has polar ice caps that are made mostly of frozen carbon dioxide, with some frozen water. Have advanced students brainstorm how these ice caps could be used to help make Mars habitable for humans.
Verbal, Logical

Answer to . . .

Figure 8 *Features on Venus that are similar to those on Earth include plains, highlands, mountains, and volcanoes. Features on Venus that are different than those on Earth include thick clouds, volcanic flows covering most plains, thousands of volcanoes, no process of plate tectonics, and an atmosphere that can't sustain life.*

Reading Checkpoint *One full day-night cycle on Earth takes 24 hours. On Mercury, it requires 59 Earth-days.*

Reading Checkpoint *Venus's atmosphere is mainly made of carbon dioxide with traces of water vapor and nitrogen.*

Build Reading Literacy

L1

Refer to **p. 1D** in **Chapter 1**, which provides guidelines for this reading strategy.

Anticipation Guide

Ask students to respond to the following questions in writing before they read the section on Mars. Have the students check over their answers and make changes as needed after they finish reading the section. Students should answer True or False to the following series of statements: **Mars's polar ice caps are mostly made of water.** *(False)* **There are active volcanoes on Mars.** *(False)* **Mars often has dust storms with hurricane force winds.** *(True)* **Mars has canyons that are much larger than Earth's Grand Canyon.** *(True)* **There is evidence that liquid water once flowed on Mars.** *(True)* **Liquid water currently flows on the Martian surface.** *(False)*

Verbal

Figure 9 Many parts of Mars's landscape resemble desert areas on Earth.

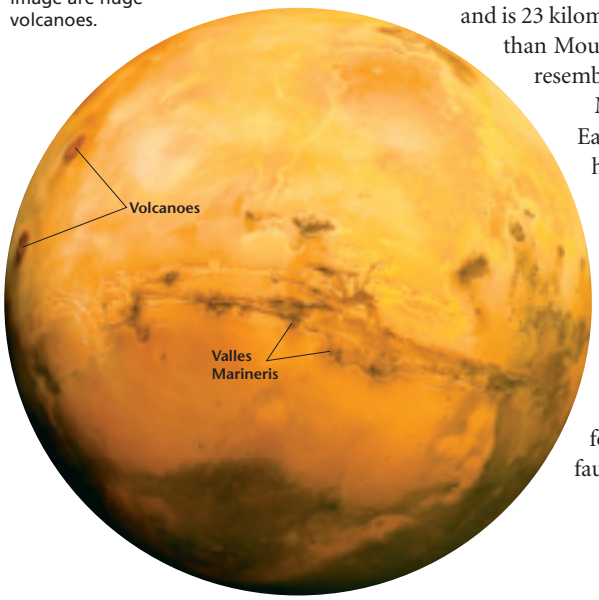
The Martian Atmosphere The Martian atmosphere has only 1 percent the density of Earth's. It is made up primarily of carbon dioxide with tiny amounts of water vapor. Data from Mars probes confirm that the polar caps of Mars are made of water ice, covered by a thin layer of frozen carbon dioxide. As winter nears in either hemisphere, temperatures drop to −125°C, and additional carbon dioxide is deposited. **Although the atmosphere of Mars is very thin, extensive dust storms occur and may cause the color changes observed from Earth. Hurricane-force winds up to 270 kilometers per hour can persist for weeks.** The composition of Mars's atmosphere is similar to that of Venus. But Mars is very cold. Why doesn't the greenhouse effect warm Mars's atmosphere? The reason is that Mars's atmosphere is extremely thin compared with the atmosphere of Venus (or Earth). Scientists think that, early in its history, Mars had a thick atmosphere warmed by the greenhouse effect. But Mars's gravity was too low for the planet to keep its atmosphere. Most of the gases escaped into space, and the planet cooled.

Surface Features *Mariner 9,* the first spacecraft to orbit another planet, reached Mars in 1971 amid a raging dust storm. When the dust cleared, images of Mars' northern hemisphere revealed numerous large inactive volcanoes. The biggest, Olympus Mons, is the size of Ohio and is 23 kilometers high—over two and a half times higher than Mount Everest. This gigantic volcano and others resemble Hawaiian shield volcanoes on Earth.

Most Martian surface features are old by Earth standards. The highly cratered southern hemisphere is probably 3.5 billion to 4.5 billion years old. Even the relatively "fresh" volcanic features of the northern hemisphere may be older than 1 billion years.

Another surprising find made by *Mariner 9* was the existence of several canyons that are much larger than Earth's Grand Canyon. The largest, Valles Marineris, is shown in Figure 10. It is thought to have formed by slippage of material along huge faults in the crustal layer.

Figure 10 Valles Marineris Mars's Valles Marineris canyon system is more than 5000 kilometers long and up to 8 kilometers deep. The dark spots on the left edge of the image are huge volcanoes.



Facts and Figures

Students may ask why the volcanoes on Earth are so much smaller than volcanoes on Mars. The reason is that Earth's crust is tectonically active, so the crust over a mantle plume is constantly moving. This motion creates a series of smaller volcanoes. Since Mars does not have plates that move, a volcano was able to grow larger and larger each time it erupted. Also, the lower gravity and surface air pressure on Mars allowed the volcanoes to grow taller than they do on Earth.

Water on Mars Some areas of Mars exhibit drainage patterns similar to those created by streams on Earth. The rover *Opportunity,* for example, found evidence of evaporite minerals and geologic formations associated with liquid water, as shown in Figure 11. In addition, *Viking* images have revealed ancient islands in what is now a dry streambed. When these streamlike channels were first discovered, some observers speculated that a thick water-laden atmosphere capable of generating torrential downpours once existed on Mars. If so, what happened to this water? The present Martian atmosphere contains only traces of water.

Images from the *Mars Global Surveyor* indicate that groundwater has recently migrated to the surface. These spring-like seeps have created gullies where they emerge from valley and crater walls. Some of the escaping water may have initially frozen due to the average Martian temperatures that range between −70°C and −100°C. Eventually, however, it seeped out as a slurry of sediment, ice, and liquid that formed the gullies.

Many scientists do not accept the theory that Mars once had an active water cycle similar to Earth's. Rather, they believe that most of the large stream-like valleys were created by the collapse of surface material caused by the slow melting of subsurface ice. Data from *Opportunity,* however, indicate that some areas were "drenched" in water. It will take scientists many months, if not years, to analyze the data gathered by the latest Mars mission. Because water is an essential ingredient for life, scientists and nonscientists alike are enthusiastic about exploring this phenomenon.

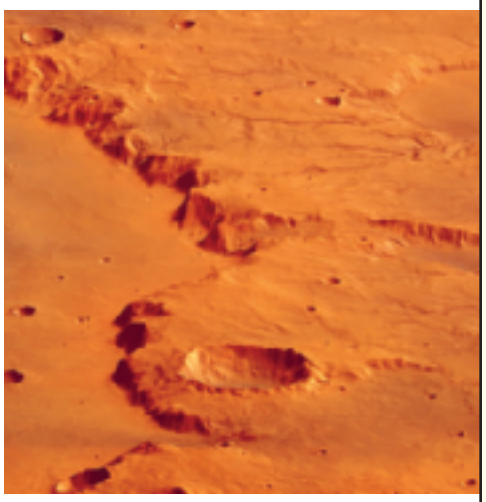


Figure 11 These channels show that liquid water once flowed on the surface of Mars.

Section 23.2 Assessment

Reviewing Concepts

1. Which inner planet is smallest?
2. How does Venus compare with Earth?
3. Identify one distinguishing characteristic of each inner planet.
4. What surface features does Mars have that are also common on Earth?

Critical Thinking

5. **Making Judgments** Besides Earth, which inner planet may have been most able to support life? Explain your answer.
6. **Relating Cause and Effect** Why are surface temperatures so high on Venus?

Writing in Science

Editorial A space mission to the moon or Mars often costs millions of dollars. Yet, it is hoped that space exploration can give us valuable knowledge about the solar system. Consider the pros and cons of space exploration. Then write an editorial stating whether or not you believe the costs are worth the potential benefits.

3 ASSESS

Evaluate Understanding L2

Review with the class by stating a characteristic of one of the planets. Have students respond with the name of the planet having that characteristic.

Reteach L1

Have students make a colored sketch of each planet. They should list each planet's characteristics next to their sketch. Then have students put their sketches in order (Mercury out to Neptune) and display their work.

Writing in Science

Remind students that writing an editorial means stating a position and backing up that statement with factual evidence.

Student editorials should discuss both the costs and benefits of space exploration. Student opinions should be supported by facts.

Section 23.2 Assessment

1. Mercury
2. Venus is similar to Earth in size, density, mass, and location in the solar system. But it is covered in thick clouds and its surface temperature is much higher.
3. Sample answer: Mercury has the greatest temperature extremes of any planet. Venus shows evidence of recent volcanic and tectonic activity. Earth is the only place where water exists in all three states at the planet's surface. Mars experiences extensive dust storms and high winds.
4. volcanoes, sand dunes, and large canyons
5. Sample answer: Mars may have been the most able to support life because it may have had liquid water on its surface.
6. Venus's atmosphere is very dense and mainly made up of carbon dioxide, which traps radiation so the heat cannot escape.