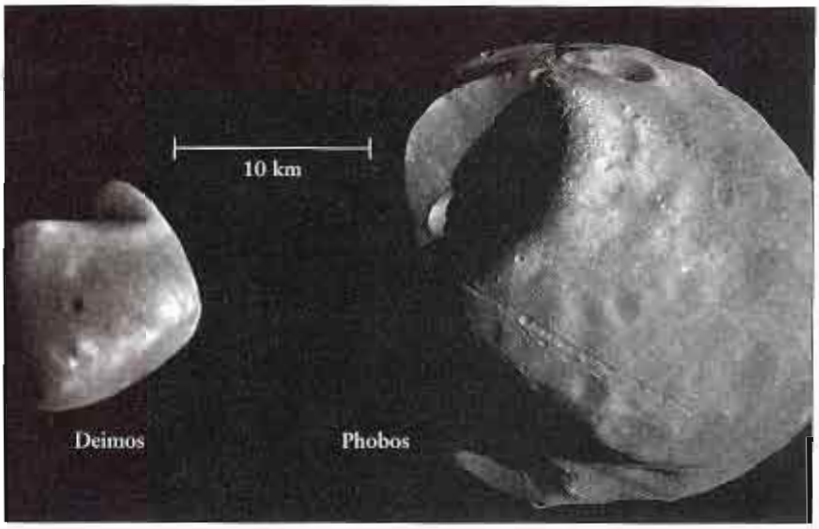

R I V U X G

FIGURE 7-36 Phobos and Deimos Phobos, the larger of Mars's two moons, is potato-shaped and measures approximately 28 × 23 × 20 km. It is dominated by crater Stickney, named for discoverer Asaph Hall's wife (Angeline Stickney). Deimos is less cratered than Phobos and measures roughly 16 × 12 × 10 km. (left: European Space Agency); right: Dr. Edwin V. Bell/NSSDC/Raytheon ITSS)

Phobos rises in the west, races across the sky in only five and a half hours as seen from Mars's equator, and sets in the east. As seen from Mars, Deimos rises in the east and takes about three Earth days to creep from one horizon to the other.

Phobos and Deimos were not formed like our Moon, by splashing off Mars. Rather, they are captured planetesimals. Both moons are in synchronous rotation as they orbit the red planet.

Would our Moon have to be closer or farther away to orbit in the same direction, but rise in the west?

INSIGHT INTO SCIENCE

Imagine the Moon The definitions we use for words based on our everyday experience often fail us in astronomy. For example, the word *moon* usually creates an image of a spherical body, like our Moon. In reality, most of the moons in the solar system are unsymmetrical, like Phobos and Deimos.

7-15 Comparisons of planetary features provide new insights

Now that we have examined the terrestrial plauets individually, it can be useful to see how their various features compare to each other and to Earth. Table 7-1 (The Inner Planets: A Comparison) summarizes much of this material.

Size and Mass Earth is the largest and most massive of all four terrestrial planets. In this regard, Venus is almost the sister planet to Earth, with nearly 95% of Earth's diameter and 82% of Earth's mass. Although Mars is most similar to Earth in other ways, such as its history of surface water and rotation rate, it is only half (53%) of Earth's diameter and 11% of Earth's mass. Mercnry, with 38% of Earth's diameter and a scant 5.5% of Earth's mass, is much more similar to Earth's Moon in dimensions. Mercury is only 1.4 times bigger than the Moon.

Surface Features Although all fonr terrestrial planets have craters, only Mercury has them in large numbers, similar to what we saw on our Moon. Venus has erased most of its craters by covering them with magma. Mars has removed many of its craters as a result of erosion and weather. Earth has removed most craters by tectonic plate motion and weathering. Like Earth, Venus has continent-like plateaus and ocean-bottom-like lowlands. Mars has a lower northern cap than the rest of the planet, but no real continent-like regions. Mercury has relatively uniform height. While Venus, Mars, and Earth all have volcanoes, those of Mars are extinct. Water erosion occurred just on Mars and Earth.

Interior The iuterior chemistries of the four terrestrial planets are similar, with cores consisting primarily of iron surrounded by rock. Venus, Earth, and Mars are known to have partially molten cores, and it remains to be seen if Mercury's core is also molten. Although Mercury is the smallest terrestrial planet, it has the highest densiry, meaning that it has the highest percentage of iron of these (and, in fact, of any) planets. This is true probably because Mercury lost more of its outer, rocky layer as a result of impacrs than did any other terrestrial planet.

Water Earth contains by far the highest percentage of water of rhe terrestrial planets. Mars contains water frozen on or near its surface, and we have yet to determiue whether it has any liquid water deep inside. Venus contaius very little water compared to either Earth or Mars because Venus is so hot that it has evaporated surface water iuto its atmosphere, and water in its interior has probably been mostly ejected through volcanoes or when the surface periodically melts. Mercury apparently has some water (very little compared to Earth or Mars) frozen at its poles, the result of collisions with water-rich comets. Because its interior is so iron-rich, the water-bearing layers were probably blasted into space by impacts early in Mercury's existence.

(NASA/USGS)

Atmosphere Venus has by far the densest atmosphere of the terrestrial planets, with about 90 times as much gas as the air we breathe. Furthermore, Venus's atmosphere is composed primarily of carbon dioxide, with a minor component of nitrogen. The thick atmosphere has protected Venus's surface from all but the most massive infalling space debris. This, and because Venus's surface may periodically melt, explains why Venus has few impact craters. Venus's atmospbere is most similar in composition to the air around Mars, although the density of Mars's air is only 0.6% as dense as the air we breathe. Although Mars's thin atmosphere has enabled many pieces of space debris to strike the planet and form craters, these craters are continually being eroded, primarily by wind.

Earth's atmosphere, once very similar ro that of Venus, was transformed by water and life into the

nitrogen-oxygen atmosphere we have today. As with Venus, Earth's atmosphere protects the surface from most impacts. Many craters have been removed by our planet's plate tectonic motion, which apparently does nor occur today on any other planet. Mercury's gravity is too low to hold any gases as a permanent atmosphere. It is surrounded by a very thin atmosphere of transient gases from the Sun and from the planet's interior. As these drift into space, they are replaced by fresh gas. Because its atmosphere is so thin and its surface unchanged by internal activity for billions of years, Mercury is the most heavily cratered of the terrestrial planets.

Temperature Some of the temperatures on the terresttial worlds are surprising at first glance. While Mercury, closest to the Sun, has a bot daytime surface of about 700 K (800°F), its lack of atmosphere allows a lot of this heat to escape at night, bringing its nighttime temperature down to a frigid 100 K (−280°F), much colder than on any other terrestrial planet. Venus's thick atmosphere creates a greenhouse effect that keeps that planet at 750 K (890°F), even hotter than Mercury. Earth's surface temperatnre ranges from about 330 K (140°F) to 180 K (−130°F), aud Mars is only slightly colder, with temperatures ranging from 280 K (45°F) down to 160 K (−170°F).

Rotation and Magnetic Field All of the terrestrial planets rotate, with Earth's solar day beiug shortest at 24 h. This motion, combined with its liquid iron core, creates a strong magnetic field that surrounds our planet. Mars has virtually the same solar day of 24 h 39 min, but its molren iron core is much smaller than ours and it has no global magnetic field, only local magnetic fields. The solar days of Venus (117 Earth days) and Mercury (176 Earth days) are both extremely long by Earth standards, and, indeed, a solar day on Mercnry is two Mercurian years loug! No magnetic field has been detected around Venus. Mercury has a weak global field tbat may result from the extremely high amount of iron it contains.

7-16 Frontiers yet to be discovered

All three terrestrial planets other than Earth have much to reveal. We have yet to see all of Mercury's surface. What is the chemical composition of its surface rocks? What is Mercury's cooling history, and how much of irs core is molten? Is there really ice at its poles? If so, how did it get there? What will its internal structure reveal?

Does Venus have active volcanoes? If not, what supplies its atmosphere with sulfur compounds? Can we find observational evidence of what caused Venus's rotation axis to flip over? Likewise, can we find further evidence that its surface periodically undergoes siguificant re-covering?

Some of the most significant questions about our solar system that could be answered are whether life ever existed on Mars, whether there is actually liquid water under the red planet's surface, and whether there is still life there. If so, how far did that life evolve? What are the similarities and differences between such life and life on Earth? Significant similarities might imply a common origin. Furthermore, what is the surface water hisrory of Mars? What causes its local magnetic fields? What does its interior look like? How did its axis get tilted? Where did its moons come from? It is likely that we will have answers to many of these questions in the coming few decades.

What does the surface of Venus lack, without which its atmosphere cannot transform into one like ours?

SUMMARY OF KEY IDEAS

All four inner planets are composed primarily of rock and metal, and tbus they are classified as *terrestrial.*

Mercury

- Even at its greatest orbital elongations, Mercury can be seen from Earth only briefly after sunset or before sunrise.
- The Mercurian surface is pocked with craters like the Moon's, but extensive, smooth plaius lie between these craters. Long cliffs meander across the surface of Mercury. These scarps probably formed as the planet cooled, solidified, aud shrank.
- The long-ago impact of a large object formed the huge Caloris Basin on Mercury and shoved up jumbled hills on the opposite side of the planet.
- Mercury has an iron core, which fills more of its interior than Earth's core fills Earth.

Venus

- Venus is similar to Earth in size, mass, and average density, but it is covered by unbroken, highly reflective clouds that conceal its other features from observers using visible-light telescopes.
- Although most of Venus's atmosphere is carbon dioxide, its dense clouds contain droplets of concentrated sulfuric acid mixed with yellowish sulfur dust. Active volcanoes on Venus may be a constant source of this sulfurous veil.
- Venus's exceptionally high temperature is caused by the greenhouse effect, as the dense carbon dioxide atmosphere traps and retains heat emitted by the planet. The surface pressure on Venus is 90 atm, and the surface temperature is 750 K. Both temperature and pressure decrease as altitude increases.
- The surface of Venus is surprisingly flat and mostly covered with gently rolling hills. There are two major "continents" and several large volcanoes. The surface of

Venus shows evidence of local tectonic activity but not the large-scale motions that play a major role in continually reshaping Earth's surface.

Mars

- Earth-based observers found that the Martian solar day is nearly the same as that of Earth, that Mars has polar ice caps that expand and shrink with the seasons, and that the Martian surface undergoes seasonal color changes.
- A century ago, observers reported networks of linear features that many perceived as canals. These observations led to speculation about self-aware life on Mars.
- The Martian surface has many flat-bottomed craters, several huge volcanoes, a vast equatorial canyon, and dried-up riverbeds—but no canals formed by intelligent life. River deltas and dry riverbeds on the Martian surface indicate that large amounts of water once flowed there.
- Liquid water would quickly boil away in Mars's thin present-day atmosphere, but the planet's polar ice caps contain significant quantities of frozen water, and a layer of permafrost exists beneath parts of the regolith.
- The Martian atmosphere is composed mostly of carbon dioxide. The surface pressure is less than 0.01 atm.
- Chemical reactions in the regolith, together with ultraviolet radiation from the Sun, apparently act to sterilize the Martian surface.
- Mars has no global magnetic fields, but local fields pierce its surface in at least nine places.
- Mars has two potato-shaped moons, the captured planetesimals Phobos and Deimos. Both are in synchronous rotation with Mars.

WHAT DID YOU THINK?

1. *Which terrestrial planet—Mercury, Venus, Earth, or Mars—has the coolest surface temperature?* The nighttime side of Mercury, closest planet to the Sun, is the coldest surface of any terrestrial-planet.

2. *Which planet is most similar in size to Earth?* Venus is most similar to Earth in size.

3. *Which terrestrial planet—Mercury, Venus, Earth, or Mars—has the highest surface temperature?* Venus is hottest, its temperature raised above that of Mercury by the greenhouse effect in its atmosphere.

4. *What is the composition of the clouds that surround Venus?* The clouds are made primarily of sulfuric acid.

5. *Does Mars have liquid water on its surface today? Did it have liquid surface water in the past?* Mars has no liquid surface water today, but there are very strong indications that it had liquid water on its surface in the past.

6. *Is life known to exist on Mars today?* No current life has yet been discovered on Mars, but it may exist in underground water oceans.

Key Terms for Review

3-to-2 spin-orbit coupling, 186
caldera, 198
dust devil, 200
greenhouse effect, 189
hot-spot volcanism, 198
northern vastness (northern lowlands), 194
retrograde rotation, 192
scarp, 184
southern highlands, 194

Review Questions

1. Which pair of planets have atmospheres with the most similar chemical compositions? a. Earth and Venus, b. Earth and Mars, c. Venus and Mars, d. Mercury and Mars, e. Mercury and Venus

2. Which planet is least likely to have water ice on or just under its surface? a. Earth, b. Mercury, c. Mars, d. Venus

3. Which object is most similar to Venus in mass and diameter? a. Earth b. Mars c. Mercury d. our Moon

4. Why is Mercury so difficult to observe? When is the best time to see the planet? (*Hint: Guided Discovery: The Inner Solar System,* on page 188, can help.)

5. Compare the surfaces of Mercury and our Moon. How are they similar? How are they different?

6. Compare the interiors of Mercury and Earth. How are they similar? How are they different?

7. To better understand the interiors of Mercury and Earth, do Interactive Exercise 7-1 on the Web. You can print out the result, if requested.

8. What are the longest features found on Mercury? Why are the examples of this feature probably much older than tectonic features on Earth?

9. Briefly describe a scientific theory explaining why Mercury has such a large iron core.

10. Astronomers often refer to Venus as Earth's twin. What physical properties do the two planets have in common? In what ways are the two planets dissimilar?

11. Why is it hotter on Venus than on Mercury?

12. What evidence exists for active volcanoes on Venus?

13. Describe the Venusian surface. What kinds of geologic features would you see if you could travel around the planet?