10.4 Mars

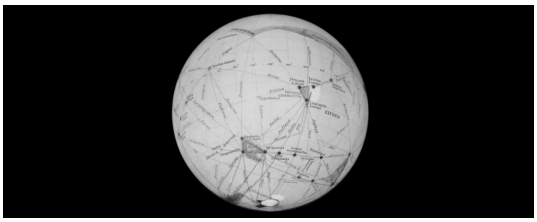
- Distance: 1.52 AU
- Rotation Period: 24.6 hrs
- Craters, volcanoes, riverbeds

Exploration
- 1960s Mariners
- 1970s Viking
- 1990s Pathfinder rover, global surveyor
- 2000s odyssey, express orbiter, reconnaissance, MAVEN, Mangalayaan, spirt & opportunity, phoenix, curiosity

Mars versus Earth

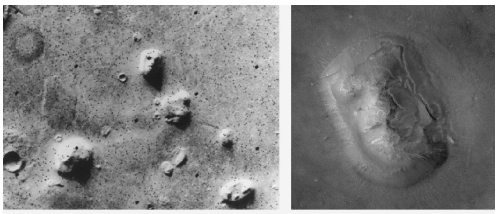
- 50% Earth's radius, 10% Earth's mass
- 1.5 AU from the Sun
- Axis tilt about the same as Earth
- Similar rotation period
- Thin CO_2 atmosphere: little greenhouse
- Main difference: Mars is SMALLER

Figure 10.4



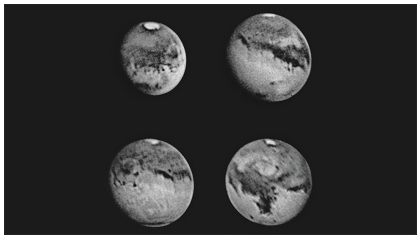
- **Lowell's Mars Globe.** One of the remarkable globes of Mars prepared by Percival Lowell, showing a network of dozens of canals, oases, and triangular water reservoirs that he claimed were visible on the red planet.

Figure 10.31



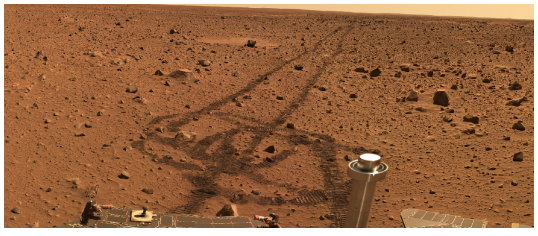
- **Face on Mars.** The so-called "Face on Mars" is seen (a) in low resolution from Viking (the "face" is in the upper part of the picture) and (b) with 20 times better resolution from the *Mars Global Surveyor*. (credit a: modification of work NASA/JPL; credit b: modification of work by NASA/JPL/MSSS)

Figure 10.3



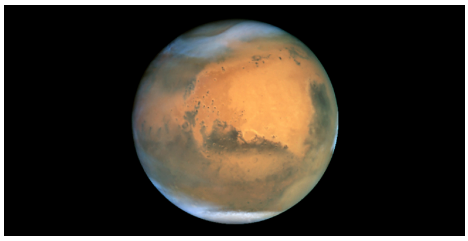
- **Mars as Seen from Earth's Surface.** These are among the best Earth-based photos of Mars, taken in 1988 when the planet was exceptionally close to Earth. The polar caps and dark surface markings are evident, but not topographic features. (credit: modification of work by Steve Larson, Lunar and Planetary Laboratory, University of Arizona)

Figure 10.1



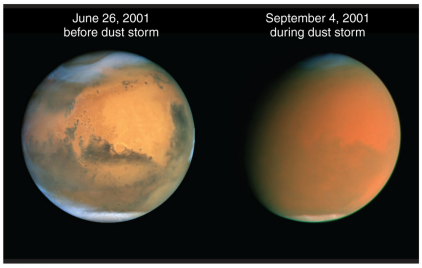
- **Spirit Rover on Mars.** This May 2004 image shows the tracks made by the Mars Exploration *Spirit* rover on the surface of the red planet. *Spirit* was active on Mars between 2004 and 2010, twenty times longer than its planners had expected. It "drove" over 7.73 kilometers in the process of examining the martian landscape. (credit: modification of work by NASA/JPL/Cornell)

Figure 10.13



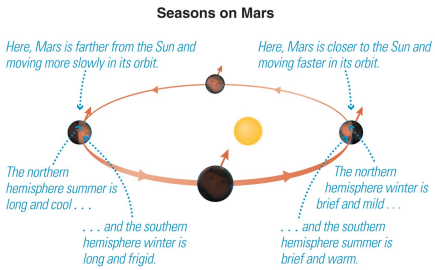
- **Mars Photographed by the Hubble Space Telescope.** This is one of the best photos of Mars taken from our planet, obtained in June 2001 when Mars was only 68 million kilometers away. The resolution is about 20 kilometers—much better than can be obtained with ground-based telescopes but still insufficient to reveal the underlying geology of Mars. (credit: modification of work by NASA and the Hubble Heritage Team (STScI/AURA))

Storms on Mars



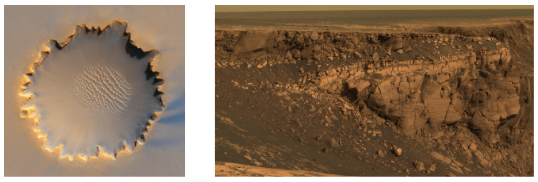
- Seasonal winds on Mars can drive huge dust storms.

Seasons on Mars



- Seasons on Mars are more extreme in the southern hemisphere because of its elliptical orbit.

Figure 10.15



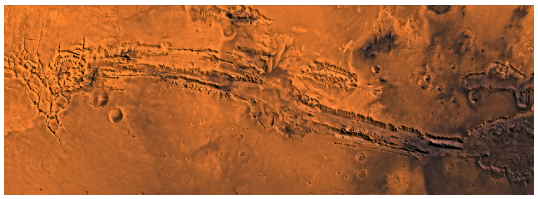
(a) (b)

- **Victoria Crater.**
  - (a) This crater in Meridiani Planum is 800 meters wide, making it slightly smaller than Meteor crater on Earth. Note the dune field in the interior.
  - (b) This image shows the view from the *Opportunity* rover as it scouted the rim of Victoria crater looking for a safe route down into the interior.

Figure 10.18

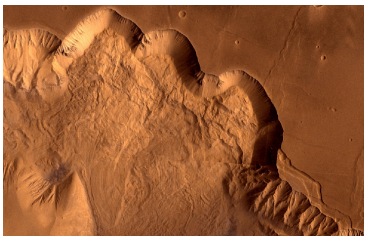
- **Olympus Mons.** The largest volcano on Mars, and probably the largest in the solar system, is Olympus Mons, illustrated in this computer-generated rendering based on data from the *Mars Global Surveyor's* laser altimeter. Placed on Earth, the base of Olympus Mons would completely cover the state of Missouri; the caldera, the circular opening at the top, is 65 kilometers across, about the size of Los Angeles. (credit: NASA/Corbis)

Figure 10.19



- **Heavily Eroded Canyonlands on Mars.** This image shows the Valles Marineris canyon complex, which is 3000 kilometers wide and 8 kilometers deep. (credit: NASA/JPL/USGS)

Figure 10.20

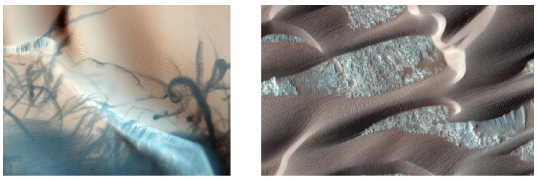


- **Martian Landslides.** This Viking orbiter image shows Ophir Chasma, one of the connected valleys of the Valles Marineris canyon system. Look carefully and you can see enormous landslides whose debris is piled up underneath the cliff wall, which tower up to 10 kilometers above the canyon floor. (credit: modification of work by NASA/JPL/USGS)

Figure 10.21

- **Three Martian Landing Sites.** The Mars landers Viking 1 in Chryse, Pathfinder in Ares Valley, and Viking 2 in Utopia, all photographed their immediate surroundings. It is apparent from the similarity of these three photos that each spacecraft touched down on a flat, windswept plain littered with rocks ranging from tiny pebbles up to meter-size boulders. It is probable that most of Mars looks like this on the surface.

Figure 10.23



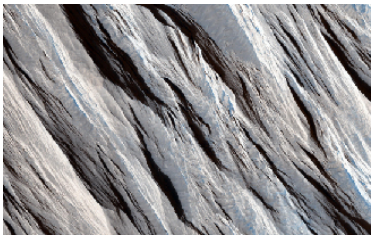
(a) (b)

- **Dust Devil Tracks and Sand Dunes.**

(a) This high-resolution photo from the *Mars Global Surveyor* shows the dark tracks of several dust devils that have stripped away a thin coating of light-colored dust. This view is of an area about 3 kilometers across. Dust devils are one of the most important ways that dust gets redistributed by the martian winds. They may also help keep the solar panels of our rovers free of dust.

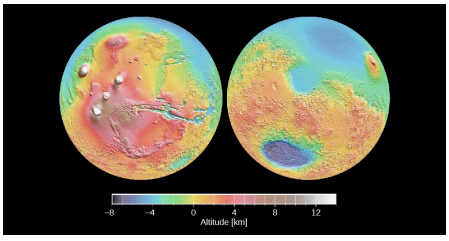
(b) These windblown sand dunes on Mars overlay a lighter sandy surface. Each dune in this high-resolution view is about 1 kilometer across.

Figure 10.24

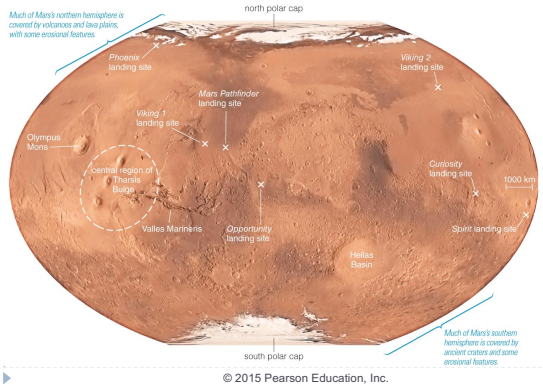


- **Wind Erosion on Mars.** These long straight ridges, called yardangs, are aligned with the dominant wind direction. This is a high-resolution image from the *Mars Reconnaissance Orbiter* and is about 1 kilometer wide. (credit: NASA/JPL-Caltech/University of Arizona)

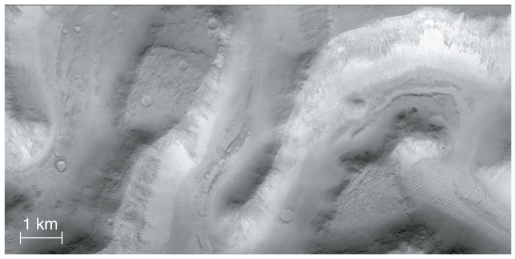
Figure 10.17



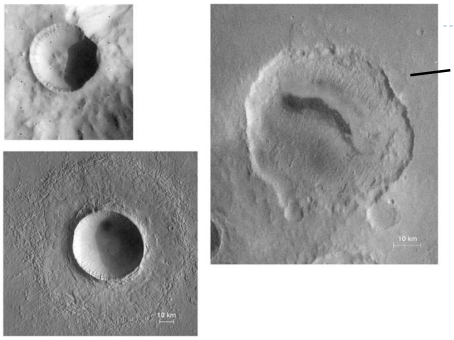
- **Mars Map from Laser Ranging.** These globes are highly precise topographic maps, reconstructed from millions of individual elevation measurements made with the *Mars Global Surveyor*. Color is used to indicate elevation. The hemisphere on the left includes the Tharsis bulge and Olympus Mons, the highest mountain on Mars; the hemisphere on the right includes the Hellas basin, which has the lowest elevation on Mars. (credit: modification of work by NASA/JPL)



10.5 WATER AND LIFE ON MARS



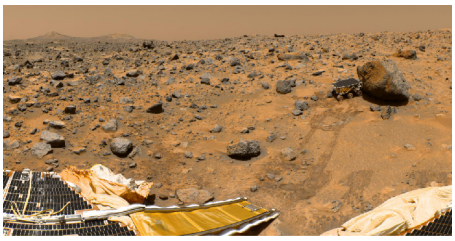
The surface of Mars appears to have ancient riverbeds.



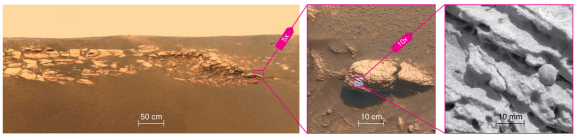
The condition of craters indicates surface history.

Figure 10.14

openstax™



Surface View from Mars Pathfinder. The scene from the Pathfinder lander shows a windswept plain, sculpted long ago when water flowed out of the martian highlands and into the depression where the spacecraft landed. The *Sojourner* rover, the first wheeled vehicle on Mars, is about the size of a microwave oven. Its flat top contains solar cells that provided electricity to run the vehicle. You can see the ramp from the lander and the path the rover took to the larger rock that the mission team nicknamed "Yogi." (credit: NASA/JPL)



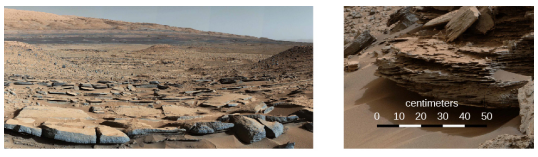
- 2004 *Opportunity* rover provided strong evidence for abundant liquid water on Mars in the distant past.
- How could Mars have been warmer and wetter in the past?

Mars Earth

Clumps of rounded pebbles discovered by the *Curiosity* rover compared with similar formations in Earth streambeds

Figure 10.30

openstax™



(a) (b)

Gale Crater.

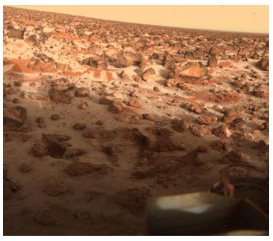
(a) This scene, photographed by the *Curiosity* rover, shows an ancient lakebed of cracked mudstones.

(b) Geologists working with the *Curiosity* rover interpret this image of cross-bedded sandstone in Gale crater as evidence of liquid water passing over a loose bed of sediment at the time this rock formed. (credit a: modification of work by NASA/JPL-Caltech/MSSS; credit b: modification of work by NASA/JPL-Caltech/MSSS)

Figure 10.16

- **Martian Meteorite.** This fragment of basalt, ejected from Mars in a crater-forming impact, eventually arrived on Earth's surface. (credit: NASA)

Figure 10.22



- **Water Frost in Utopia.** This image of surface frost was photographed at the Viking 2 landing site during late winter. (credit: NASA/JPL)

Today, most water lies frozen underground (blue regions).

Some scientists believe accumulated snowpack melts carve gullies even today.

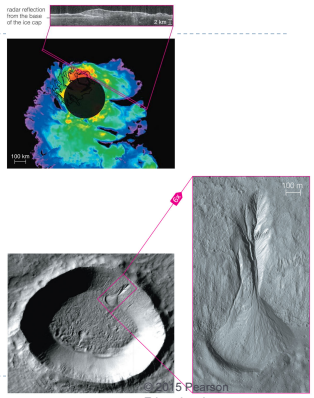
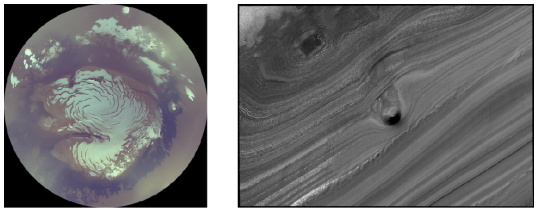
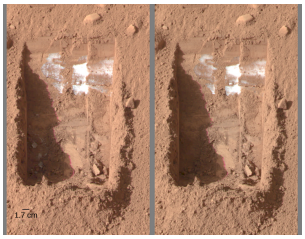


Figure 10.25



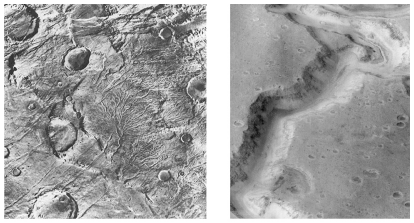
- **Martian North Polar Cap.**
  - (a) This is a composite image of the north pole in summer, obtained in October 2006 by the *Mars Reconnaissance Orbiter*. It shows the mostly water-ice residual cap sitting atop light, tan-colored, layered sediments. Note that although the border of this photo is circular, it shows only a small part of the planet.
  - (b) Here we see a small section of the layered terrain near the martian north pole. There is a mound about 40 meters high that is sticking out of a trough in the center of the picture. (credit a: modification of work by NASA/JPL/MSSS;

Figure 10.26



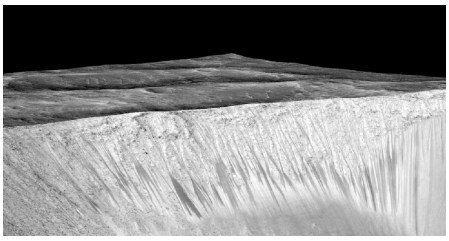
- **Evaporating Ice on Mars.** We see a trench dug by the *Phoenix* lander in the north polar region four martian days apart in June 2008. If you look at the shadowed region in the bottom left of the trench, you can see three spots of ice in the left image which have sublimated away in the right image. (credit: modification of work by NASA/JPL-Caltech/University of Arizona/Texas A&M University)

Figure 10.27



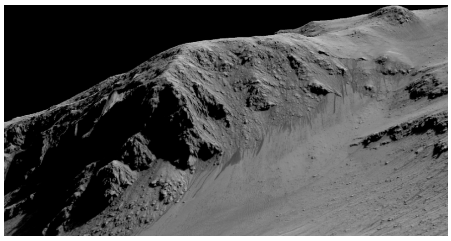
- **Runoff and Outflow Channels.**
  - (a) These runoff channels in the old martian highlands are interpreted as the valleys of ancient rivers fed by either rain or underground springs. The width of this image is about 200 kilometers.
  - (b) This intriguing channel, called Nanedi Valles, resembles Earth riverbeds in some (but not all) ways. The tight curves and terraces seen in the channel certainly suggest the sustained flow of a fluid like water. The channel is about 2.5 kilometers across. (credit a: modification of work by Jim Secosky/NASA; credit b: modification of work by Jim Secosky/NASA)

Figure 10.28



- **Gullies on the Wall of Garni Crater.** This high-resolution image is from the *Mars Reconnaissance Orbiter*. The dark streaks, which are each several hundred meters long, change in a seasonal pattern that suggests they are caused by the temporary flow of surface water. (credit: NASA/JPL-Caltech/University of Arizona)

Figure 10.29



- **Evidence for Liquid Water on Mars.** The dark streaks in Horowitz crater, which move downslope, have been called recurring slope lineae. The streaks in the center of the image go down the wall of the crater for about a distance of 100 meters. Spectra taken of this region indicate that these are locations where salty liquid water flows on or just below the surface of Mars. (The vertical dimension is exaggerated by a factor of 1.5 compared to horizontal dimensions.) (credit: NASA/JPL-Caltech/University of Arizona)

Videos

- Video msars 5 min

Reading

- 10.1 (optional)
- 10.2
- 10.3
- 10.4
- 10.5