**Mercury**

Sun-scorched Mercury is only slightly larger than [Earth's Moon](http://solarsystem.nasa.gov/planets/profile.cfm?Object=Moon). Like the Moon, Mercury has very little atmosphere to stop impacts, and it is covered with craters. Mercury's dayside is super-heated by the [sun](http://solarsystem.nasa.gov/planets/profile.cfm?Object=Sun), but at night temperatures drop hundreds of degrees below freezing. Ice may even exist in craters.

Mercury speeds around the sun every 88 days, traveling through space at nearly 50 km (31 miles) per second -- faster than any other planet. One Mercury solar day equals 175.97 Earth days.

Mercury's elliptical orbit takes the small planet as close as 47 million km (29 million miles) and as far as 70 million km (43 million miles) from the [sun](http://solarsystem.nasa.gov/planets/profile.cfm?Object=Sun). If one could stand on the scorching surface of Mercury when it is at its closest point to the sun, our star would appear more than three times as large as it does when viewed from [Earth](http://solarsystem.nasa.gov/planets/profile.cfm?Object=Earth). Because Mercury is so close to the sun, it is hard to directly observe from Earth except during twilight.

**Temperatures** on Mercury's surface can reach 800 degrees Fahrenheit (427 degrees Celsius). Because Mercury's atmosphere is so thin, the surface cannot retain that heat so nighttime temperatures can drop to -290 degrees Fahrenheit (-179 degrees Celsius).

Mercury's thin **atmosphere**, or *exosphere*, is made up of atoms blasted off the surface by the solar wind and micrometeoroid impacts. Because of solar radiation pressure, the atoms quickly escape into space and form a tail of neutral particles. Though Mercury's magnetic field has just 1 percent the strength of Earth's, the field is very active. The magnetic field in the solar wind episodically connects to Mercury's field, creating intense magnetic tornadoes that funnel the fast, hot solar wind plasma down to the surface. When these ions strike the surface, they knock off neutral atoms and send them on a loop high into the sky where other processes may fling them back to the surface or accelerate them away from Mercury.

Mercury's surface resembles that of [Earth's Moon](http://solarsystem.nasa.gov/planets/profile.cfm?Object=Moon), scarred by many impact craters resulting from collisions with [meteoroids](http://solarsystem.nasa.gov/planets/profile.cfm?Object=Meteors) and [comets](http://solarsystem.nasa.gov/planets/profile.cfm?Object=Comets). While there are areas of smooth terrain, there are also lobe-shaped scarps or cliffs, some hundreds of miles long and soaring up to a mile high, formed by contraction of the crust. The Caloris Basin, one of the largest features on Mercury, is about 1,550 km (960 miles) in diameter. It was the result of an [asteroid](http://solarsystem.nasa.gov/planets/profile.cfm?Object=Asteroids) impact on the planet's surface early in the solar system's history. Over the next several billion years, Mercury shrank in radius about 1 to 2 km (0.6 to 1.2 miles) as the planet cooled after its formation. The outer crust contracted and grew strong enough to prevent magma from reaching the surface, ending the period of volcanic activity.

Mercury is the second densest planet after Earth, with a large metallic core having a radius of 1,800 to 1,900 km (1,100 to 1,200 miles), about 75 percent of the planet's radius. In 2007, researchers using ground-based radars to study the core found evidence that it is molten (liquid). Mercury's outer shell, comparable to Earth's outer shell (called the mantle), is only 500 to 600 km (300 to 400 miles) thick.

**Venus**

Venus is a dim world of intense heat and volcanic activity. Similar in structure and size to Earth, Venus' thick, toxic atmosphere traps heat in a runaway "greenhouse effect." The scorched world has temperatures hot enough to melt lead. Glimpses below the clouds reveal volcanoes and deformed mountains. Venus spins slowly in the opposite direction of most planets.

Venus and [Earth](http://solarsystem.nasa.gov/planets/profile.cfm?Object=Earth) are similar in size, mass, density, composition and gravity. There, however, the similarities end. Venus is covered by a thick, rapidly spinning atmosphere, creating a scorched world with temperatures hot enough to melt lead and a surface pressure 90 times that of Earth.

The Venusian year (orbital period) is about 225 Earth days long, while the planet's sidereal rotation period is 243 Earth days, making a Venus solar day (measured noon to noon) about 117 Earth days long. Resulting from this slow rotation Venus cannot generate a magnetic field similar to Earth's -- though its core iron content is similar to that of the Earth. (Venus' iron core is approximately 3,000 km [1,900 miles] in radius.) Venus rotates retrograde (east to west) compared with Earth's prograde (west to east) rotation. Seen from Venus, the sun would rise in the west and set in the east.

Venus' atmosphere consists mainly of carbon dioxide, with clouds of sulfuric acid droplets. Only trace amounts of water have been detected in the atmosphere. The thick atmosphere traps the sun's heat, resulting in surface **temperatures** higher than 880 degrees Fahrenheit (471 degrees Celsius). Probes that have landed on Venus survived only a few hours before being destroyed by the incredible temperatures. Sulfur compounds are abundant in Venus' clouds. The corrosive chemistry and dense, moving atmosphere cause significant surface weathering and erosion.

As Venus moves forward in its solar orbit while slowly rotating backwards on its axis, the top level of cloud layers zips around the planet every four Earth days, driven by hurricane-force winds traveling at about 360 km (224 miles) per hour. The wind speeds within the clouds decrease with cloud height, and winds at the surface are estimated to be just a few kilometers per hour. How this atmospheric super-rotation forms and is maintained continues to be a topic of scientific investigation.

Atmospheric lightning bursts, long suspected by scientists, were finally confirmed in 2007 by the European Venus Express orbiter. On Earth, Jupiter and Saturn, lightning is associated with water clouds, but on Venus, it is associated with clouds of sulfuric acid.

Radar images of the surface show wind streaks and sand dunes. Craters smaller than 1.5 to 2 km (0.9 to 1.2 miles) across do not exist on Venus because small meteors burn up in the dense atmosphere before they reach the surface.

It is thought that Venus was completely resurfaced by volcanic activity 300 to 500 million years ago. More than 1,000 volcanoes or volcanic centers larger than 20 km (12 miles) in diameter dot the surface. Volcanic flows have produced long, sinuous channels extending for hundreds of kilometers. Venus has two large highland areas: Ishtar Terra, about the size of Australia, in the North Polar Region; and Aphrodite Terra, about the size of South America, straddling the equator and extending for almost 10,000 km (6,000 miles). Maxwell Montes, the highest mountain on Venus and comparable to Mount Everest on Earth, is at the eastern edge of Ishtar Terra.

**Earth**

Earth is an ocean planet. Our home world's abundance of water -- and life -- makes it unique in our solar system. Other planets, plus a few moons, have ice, atmospheres, seasons and even weather, but only on Earth does the whole complicated mix come together in a way that encourages life -- and lots of it.

Earth, our home planet, is the only planet in [our solar system](http://solarsystem.nasa.gov/planets/profile.cfm?Object=SolarSys) known to harbor life: life that is incredibly diverse. All the things we need to survive exist under a thin layer of atmosphere that separates us from the cold, airless void of space.

Earth is made up of complex, interactive systems that create a constantly changing world that we are striving to understand. From the vantage point of space we are able to observe our planet globally, using sensitive instruments to understand the delicate balance among its oceans, air, land and life. Satellite observations help study and predict weather, drought, pollution, climate change and many other phenomena that affect the environment, economy and society.

Earth is the third planet from the [sun](http://solarsystem.nasa.gov/planets/profile.cfm?Object=Sun) and the fifth largest in our solar system. Earth's diameter is just a few hundred kilometers larger than that of [Venus](http://solarsystem.nasa.gov/planets/profile.cfm?Object=Venus).

The four seasons are a result of Earth's axis of rotation being tilted 23.45 degrees with respect to the plane of Earth's orbit around the sun. During part of the year, the northern hemisphere is tilted toward the sun and the southern hemisphere is tilted away, producing summer in the north and winter in the south. Six months later, the situation is reversed. During March and September, when spring and fall begin in the northern hemisphere, both hemispheres receive roughly equal amounts of solar illumination.

Earth's global ocean, which covers nearly 70 percent of the planet's surface, has an average depth of about 4 km (2.5 miles). Fresh water exists in the liquid phase only within a narrow temperature span: 32 to 212 degrees Fahrenheit (0 to 100 degrees Celsius). This span is especially narrow when contrasted with the full range of temperatures found within the solar system. The presence and distribution of water vapor in the atmosphere is responsible for much of Earth's weather.

We are enveloped by an atmosphere that consists of 78 percent nitrogen, 21 percent oxygen and 1 percent other ingredients. The atmosphere affects Earth's long-term climate and short-term local weather, shields us from much of the harmful radiation coming from the sun and protects us from [meteors](http://solarsystem.nasa.gov/planets/profile.cfm?Object=Meteors) as well: most of which burn up before they can strike the surface as meteorites. Earth-orbiting satellites have revealed that the upper atmosphere actually swells by day and contracts by night due to solar heating during the day and cooling at night.

Our planet's rapid rotation and molten nickel-iron core give rise to a magnetic field, which the solar wind distorts into a teardrop shape in space. (The solar wind is a stream of charged particles continuously ejected from the sun.) The Earth's magnetic field does not fade off into space, but has definite boundaries. When charged particles from the solar wind become trapped in Earth's magnetic field, they collide with air molecules above our planet's magnetic poles. These air molecules then begin to glow, and are known as the aurorae -- the northern and southern lights.

Earth's lithosphere, which includes the crust (both continental and oceanic) and the upper mantle, is divided into huge plates that are constantly moving. For example, the North American plate moves west over the Pacific Ocean basin, roughly at a rate equal to the growth of our fingernails. Earthquakes result when plates grind past one another, ride up over one another, collide to make mountains, or split and separate. The theory of motion of the large plates of the lithosphere is known as plate tectonics. Developed within the last 40 years, this explanation has unified the results of centuries of study of our planet.

**Mars**

Mars is a cold desert world. It is half the diameter of Earth and has the same amount of dry land. Like Earth, Mars has seasons, polar ice caps, volcanoes, canyons and weather, but its atmosphere is too thin for liquid water to exist for long on the surface. There are signs of ancient floods on Mars, but evidence for water now exists mainly in icy soil and thin clouds.

Though details of Mars' surface are difficult to see from Earth, telescope observations show seasonally changing features and white patches at the poles. For decades, people speculated that bright and dark areas on Mars were patches of vegetation that Mars could be a likely place for life-forms and that water might exist in the polar caps. When the Mariner 4 spacecraft flew by Mars in 1965, many were shocked to see photographs of a bleak, cratered surface. Mars seemed to be a dead planet. Later missions, however, have shown that Mars is a complex member of the solar system and holds many mysteries yet to be solved.

Mars is a rocky body about half the size of [Earth](http://solarsystem.nasa.gov/planets/profile.cfm?Object=Earth). As with the other terrestrial planets -- [Mercury](http://solarsystem.nasa.gov/planets/profile.cfm?Object=Mercury), [Venus](http://solarsystem.nasa.gov/planets/profile.cfm?Object=Venus) and Earth -- the surface of Mars has been altered by volcanism, impacts, crustal movement, and atmospheric effects such as dust storms.

Mars often appears reddish due to a combination of the fact that its surface is comprised of iron-rich minerals that essentially rusts (or oxidizes) and that the dust made of these minerals is kicked up into the atmosphere, giving the atmosphere a reddish hue as well.

Like Earth, Mars experiences seasons because of the tilt of its rotational axis (in relation to the plane of its orbit). Mars' orbit is slightly elliptical, so its distance to the [sun](http://solarsystem.nasa.gov/planets/profile.cfm?Object=Sun) changes, affecting the Martian seasons. Mars' seasons last longer than those of Earth. The polar ice caps on Mars grow and recede with the seasons; layered areas near the poles suggest that the planet's climate has changed more than once. Volcanism in the highlands and plains was active more than 3 billion years ago, but some of the giant shield volcanoes are younger, having formed between 1 and 2 billion years ago. Mars has the largest volcanic mountain in the solar system, Olympus Mons, as well as a spectacular equatorial canyon system, Valles Marineris.

The cold temperatures and thin atmosphere on Mars don't allow liquid water to exist at the surface for long, and the quantity of water required to carve Mars' great channels and flood plains is not evident today. Unraveling the story of water on Mars is important to unlocking its climate history, which will help us understand the evolution of all the planets. Water is believed to be an essential ingredient for life; evidence of past or present water on Mars is expected to hold clues about whether Mars could ever have been a habitat for life.

**Jupiter**

Jupiter, the most massive planet in our solar system -- with dozens of moons and an enormous magnetic field -- forms a kind of miniature solar system. Jupiter does resemble a star in composition, but it did not grow big enough to ignite. The planet's swirling cloud stripes are punctuated by massive storms such as the Great Red Spot, which has raged for hundreds of years.

Jupiter's appearance is a tapestry of beautiful colors and atmospheric features. Most visible clouds are composed of ammonia. Water vapor exists deep below and can sometimes be seen through clear spots in the clouds. The planet's "stripes" are dark belts and light zones created by strong east-west winds in Jupiter's upper atmosphere.

Most visible clouds are composed of ammonia. Water vapor exists deep below and can sometimes be seen through clear spots in the clouds. The planet's "stripes" are dark belts and light zones created by strong east-west winds in Jupiter's upper atmosphere. Dynamic storm systems rage on Jupiter. The Great Red Spot, a giant spinning storm, has been observed since the 1800s. In recent years, three storms merged to form the Little Red Spot, about half the size of the Great Red Spot.

The composition of Jupiter's atmosphere is similar to that of the [sun](http://solarsystem.nasa.gov/planets/profile.cfm?Object=Sun) -- mostly hydrogen and helium. Deep in the atmosphere, the pressure and temperature increase, compressing the hydrogen gas into a liquid. At depths of about a third of the way down, the hydrogen becomes metallic and electrically conducting. In this metallic layer, Jupiter's powerful magnetic field is generated by electrical currents driven by Jupiter's fast rotation. At the center, the immense pressure may support a solid core of rock about the size of Earth.

About 87 percent of Jupiter’s atmosphere is molecular hydrogen, H2, with helium, He, constituting most of the remaining 13 percent. The interior must have essentially the same composition as the atmosphere in order to yield the low observed density. It appears that this huge world is made mostly from the two lightest and most abundant elements in the universe, a composition similar to that of the sun and other stars. Jupiter may therefore represent a direct condensation of a portion of the primordial solar nebula—the great cloud of interstellar gas and dust from which the entire solar system formed about 4.6 billion years ago.

Jupiter radiates about twice as much energy as it receives from the sun. The source of this energy is apparently a very slow gravitational contraction of the entire planet, rather than the nuclear fusion that powers the sun. Jupiter would have to be almost 100 times larger to have enough mass to ignite a nuclear furnace.

Jupiter’s turbulent, cloud-filled atmosphere is cold, although the probe from the *Galileo* spacecraft in 1995 indicated a hotter, drier atmosphere than previously believed. With hydrogen so abundant, hydrogen-based molecules, such as methane, ammonia, and water, predominate. Periodic temperature fluctuations in Jupiter’s upper atmosphere reveal a pattern of changing winds like that in the equatorial region of earth’s stratosphere. Photographs of sequential changes in Jovian clouds suggest the birth and decay of giant cyclonic storm systems in the atmosphere; *Galileo*’s probe gave evidence of winds up to 644 km per hour (400 mph).

Ammonia freezes in the low temperature of Jupiter’s upper atmosphere (–125° C/–193° F), forming the white cirrus clouds—zones, ovals, and plumes—seen in many photographs of the planet transmitted by the *Voyager* spacecraft. At lower levels, ammonium hydrosulfide can condense. Colored by other compounds, clouds of this substance may contribute to the widespread tawny cloud layer on the planet. The temperature at the tops of these clouds is about –50° C (about –58° F), and the atmospheric pressure about twice the sea-level atmospheric pressure on earth. Through holes in this cloud layer, radiation escapes from a region where the temperature reaches 17° C (about 63° F). Still deeper, warmer layers have been detected by radio telescopes that are sensitive to cloud-penetrating radiation.

**Saturn**

Adorned with thousands of beautiful ringlets, Saturn is unique among the planets. All four gas giant planets have rings -- made of chunks of ice and rock -- but none are as spectacular or as complicated as Saturn's. Like the other gas giants, Saturn is mostly a massive ball of hydrogen and helium.

Like [Jupiter](http://solarsystem.nasa.gov/planets/profile.cfm?Object=Jupiter), Saturn is made mostly of hydrogen and helium. Its volume is 755 times greater than that of [Earth](http://solarsystem.nasa.gov/planets/profile.cfm?Object=Earth). Winds in the upper atmosphere reach 500 m (1,600 feet) per second in the equatorial region. (In contrast, the strongest hurricane-force winds on Earth top out at about 110 m, or 360 feet per second.) These super-fast winds, combined with heat rising from within the planet's interior, cause the yellow and gold bands visible in the atmosphere.

Though Saturn's magnetic field is not as huge as Jupiter's, it is still 578 times as powerful as the Earth's. Saturn, its rings and many of its satellites lie totally within Saturn's own enormous magnetosphere -- the region of space in which the behavior of electrically charged particles is influenced more by Saturn's magnetic field than by the solar wind. While the Hubble Space Telescope imaged Saturn's aurora in the ultraviolet, the Cassini spacecraft found that Saturn has a unique secondary aurora at the North Pole, imaged in the infrared in 2008. Aurorae occur when charged particles spiral into a planet's atmosphere along magnetic field lines. On Earth, these charged particles come from the solar wind. Cassini showed that at least some of Saturn's aurorae are like Jupiter's and are largely unaffected by the solar wind.

In many ways, Saturn is similar to Jupiter, but it is much smaller. It is the second largest planet in our Solar System and it is a gas giant like Jupiter. Under the clouds of methane, hydrogen and helium, the sky gradually turns into liquid until it becomes a giant ocean of liquid chemicals.

Saturn is the least dense planet in our Solar System. It is made up of mostly hydrogen and helium, which are the two lightest elements in the universe and thus make Saturn the lightest planet that we know of. This is why you wouldn't weigh as much on Saturn as you think you would because of its size. And because Saturn is so light, it does not have as much gravity. Interestingly, it is believed Saturn would actually be able to float in water because the hydrogen and helium that make up the planet are so lightweight.

Because Saturn is such a lightweight planet and it spins so fast, Saturn is not perfectly round like most of the other planets. Like Jupiter, Saturn is wider in the middle and more narrow near its top and bottom.

**Uranus**

Uranus is the only giant planet whose equator is nearly at right angles to its orbit. A collision with an Earth-sized object may explain Uranus' unique tilt. Nearly a twin in size to Neptune, Uranus has more methane in its mainly hydrogen and helium atmosphere than Jupiter or Saturn. Methane gives Uranus its blue tint.

Like [Venus](http://solarsystem.nasa.gov/planets/profile.cfm?Object=Venus), Uranus rotates east to west. Uranus' rotation axis is tilted almost parallel to its orbital plane, so Uranus appears to be rotating on its side. This situation may be the result of a collision with a planet-sized body early in the planet's history, which apparently radically changed Uranus' rotation. Because of Uranus' unusual orientation, the planet experiences extreme variations in sunlight during each 20-year-long season.

[Voyager 2](http://solarsystem.nasa.gov/missions/profile.cfm?MCode=Voyager_2), the only spacecraft to visit Uranus, imaged a bland-looking sphere in 1986. When Voyager flew by, the south pole of Uranus pointed almost directly at the sun because Uranus was near its southern summer solstice, with the southern hemisphere bathed in continuous sunlight and the northern hemisphere radiating heat into the blackness of space.

Uranus reached equinox in December 2007, when it was fully illuminated as the sun passed over the planet's equator. By 2028, the North Pole will point directly at the sun, a reversal of the situation when Voyager flew by. Equinox also brings ring-plane crossing, when Uranus' rings appear to move more and more edge-on as seen from Earth.

The [Hubble](http://solarsystem.nasa.gov/missions/profile.cfm?MCode=HST) Space Telescope and the Keck Observatory in Hawaii captured detailed images of Uranus as the planet approached equinox. While Voyager 2 saw only a few discrete clouds, more recent observations reveal that Uranus exhibits dynamic clouds as it approaches equinox, including rapidly evolving bright features and a new Great Dark Spot like those seen on Neptune.

Uranus is one of the two ice giants of the outer solar system (the other is [Neptune](http://solarsystem.nasa.gov/planets/profile.cfm?Object=Neptune)). Uranus' atmosphere is mostly hydrogen and helium, with a small amount of methane and traces of water and ammonia. Uranus gets its blue-green color from methane gas in the atmosphere. Sunlight passes through the atmosphere and is reflected back out by Uranus' cloud tops. Methane gas absorbs the red portion of the light, resulting in a blue-green color. The bulk (80 percent or more) of the mass of Uranus is contained in an extended liquid core consisting mostly of icy materials (water, methane and ammonia).

For nearly a quarter of the Uranian year, the sun shines directly over each pole, plunging the other half of the planet into a long, dark winter.

While magnetic fields are typically in alignment with a planet's rotation, Uranus' magnetic field is tipped over: the magnetic axis is tilted nearly 60 degrees from the planet's axis of rotation, and is also offset from the center of the planet by one-third of the planet's radius. The magnetic fields of both Uranus and Neptune are very irregular.

**Neptune**

Dark, cold and whipped by supersonic winds, Neptune is the last of the hydrogen and helium gas giants in our solar system. More than 30 times as far from the sun as Earth, the planet takes almost 165 Earth years to orbit our sun. In 2011 Neptune completed its first orbit since its discovery in 1846.

Nearly 4.5 billion km (2.8 billion miles) from the [sun](http://solarsystem.nasa.gov/planets/profile.cfm?Object=Sun), Neptune orbits the sun once every 165 years. It is invisible to the naked eye because of its extreme distance from Earth. Interestingly, the unusual elliptical orbit of the dwarf planet [Pluto](http://solarsystem.nasa.gov/planets/profile.cfm?Object=Pluto) brings Pluto inside Neptune's orbit for a 20-year period out of every 248 Earth years. Pluto can never crash into Neptune, though, because for every three laps Neptune takes around the sun, Pluto makes two. This repeating pattern prevents close approaches of the two bodies.

The main axis of Neptune's magnetic field is tipped over by about 47 degrees compared with the planet's rotation axis. Like Uranus, whose magnetic axis is tilted about 60 degrees from the axis of rotation; Neptune's magnetosphere undergoes wild variations during each rotation because of this misalignment. The magnetic field of Neptune is about 27 times more powerful than that of Earth.

Neptune's atmosphere extends to great depths, gradually merging into water and other melted ices over a heavier, approximately Earth-size solid core. Neptune's blue color is the result of methane in the atmosphere. Uranus' blue-green color is also the result of atmospheric methane, but Neptune is a more vivid, brighter blue, so there must be an unknown component that causes the more intense color.

Despite its great distance and low energy input from the sun, Neptune's winds can be three times stronger than [Jupiter](http://solarsystem.nasa.gov/planets/profile.cfm?Object=Jupiter)'s and nine times stronger than [Earth](http://solarsystem.nasa.gov/planets/profile.cfm?Object=Earth)'s. In 1989, Voyager 2 tracked a large, oval-shaped, dark storm in Neptune's southern hemisphere. This "Great Dark Spot," which was large enough to contain the entire Earth, spun counterclockwise, and moved westward at almost 1,200 km (750 miles) per hour. Subsequent images taken by the [Hubble](http://solarsystem.nasa.gov/missions/profile.cfm?MCode=HST) Space Telescope showed no sign of this Great Dark Spot, but did reveal the appearance and then fading of two other Great Dark Spots over the last decade. [Voyager 2](http://solarsystem.nasa.gov/missions/profile.cfm?MCode=Voyager_2) also imaged clouds casting shadows on a lower cloud deck, enabling scientists to visually measure the altitude differences between the upper and lower cloud decks.

**Jupiter (Jovian Giant)**

The most massive planet in our solar system, with four planet-size moons and many smaller satellites, Jupiter forms a kind of miniature solar system. Jupiter resembles a star in composition. In fact, if it had been about eighty times more massive, it would have become a star rather than a planet.

On January 7, 1610, using his primitive telescope, astronomer Galileo Galilei saw four small "stars" near Jupiter. He had discovered Jupiter's four largest **moons**, now called Io, Europa, Ganymede, and Callisto. Collectively, these four moons are known today as the Galilean satellites.

Galileo would be astonished at what we have learned about Jupiter and its moons in the last 30 years. Io is the most volcanically active body in our solar system. Ganymede is the largest planetary moon and is the only moon in the solar system known to have its own magnetic field. A liquid ocean may lie beneath the frozen crust of Europa. Icy oceans may also lie deep beneath the crusts of Callisto and Ganymede. In 2003 alone, astronomers discovered 23 new moons orbiting the giant planet, giving Jupiter a total moon count of 49, the most in the solar system. The numerous small outer moons may be asteroids captured by the giant planet's gravity.

Jupiter's appearance is a tapestry of beautiful colors and atmospheric features. Most visible clouds are composed of ammonia. Water exists deep below and can sometimes be seen through clear spots in the clouds. The planet's "stripes" are dark belts and light zones created by strong east-west winds in Jupiter's upper atmosphere. Within these belts and zones are storm systems that have raged for years. The **Great Red Spot**, a giant spinning storm, has been observed for more than 300 years.

**Atmosphere**

The composition of Jupiter's **atmosphere** is similar to that of the sun—mostly hydrogen and helium. Deep in the atmosphere, the pressure and temperature increase, compressing the hydrogen gas into a liquid. At depths about a third of the way down, the hydrogen becomes metallic and electrically conducting. In this metallic layer, Jupiter's powerful magnetic field is generated by electrical currents driven by Jupiter's fast rotation. At the center, the immense pressure may support a solid core of ice-rock about the size of Earth.

Jupiter's enormous magnetic field is nearly 20,000 times as powerful as Earth's. Trapped within Jupiter's **magnetosphere** (the area in which magnetic field lines encircle the planet from pole to pole) are swarms of charged particles. Jupiter's rings and moons are embedded in an intense radiation belt of electrons and ions trapped in the magnetic field. The Jovian magnetosphere, composed of these particles and fields, balloons 600,000 to 2 million miles (1 million to 3 million kilometers) toward the sun and tapers into a windsock-shaped tail extending more than 600 million miles (1 billion kilometers) behind Jupiter, as far as Saturn's orbit.

Discovered in 1979 by NASA's Voyager 1 spacecraft, Jupiter's **rings** were a surprise: a flattened main ring and an inner cloudlike ring, called the halo, are both composed of small, dark particles. A third ring, known as the gossamer ring because of its transparency, is actually three rings of microscopic debris from three small moons: Amalthea, Thebe, and Adrastea. Jupiter's ring system may be formed by dust kicked up as interplanetary meteoroids smash into the giant planet's four small inner moons. The main ring probably comes from the moon Metis. Jupiter's rings are only visible when backlit by the sun.

In December 1995, NASA's Galileo spacecraft dropped a probe into Jupiter's atmosphere, which collected the first direct measurements of the atmosphere. Following the release of the probe, the Galileo spacecraft began a multiyear study of Jupiter and its largest moons. As Galileo began its 29th orbit, the Cassini-Huygens spacecraft was nearing Jupiter for a gravity-assist maneuver on the way to Saturn. The two spacecraft made simultaneous observations of the magnetosphere, solar wind, rings, and Jupiter's auroras.

**SATURN The Ringed Planet**

Saturn was the most distant of the five planets known to the ancients. In 1610, Italian astronomer Galileo Galilei was the first to gaze at Saturn through a telescope. To his surprise, he saw a pair of objects on either side of the planet. He sketched them as separate spheres and wrote that Saturn appeared to be triple-bodied. In 1659, Dutch astronomer Christiaan Huygens, using a more powerful telescope than Galileo's, proposed that Saturn was surrounded by a thin, flat ring.

In 1675, Italian-born astronomer Jean-Dominique Cassini discovered a "division" between what are now called the A and B rings. It is now known that the gravitational influence of Saturn's moon Mimas is responsible for the **Cassini Division**, which is 3,000 miles (4,800 kilometers) wide.

Like Jupiter, Saturn is made mostly of hydrogen and helium. Its volume is 755 times greater than that of Earth. Winds in the upper atmosphere reach 1,600 feet (500 meters) per second in the equatorial region. (In contrast, the strongest hurricane-force winds on Earth top out at about 360 feet, or 110 meters, per second.) These superfast winds, combined with heat rising from within the planet's interior, cause the yellow and gold bands visible in the atmosphere.

Saturn's **ring system** is the most extensive and complex in the solar system, extending hundreds of thousands of kilometers from the planet. In the early 1980s, NASA's two Voyager spacecraft revealed that Saturn's rings are made mostly of water ice. They also found "braided" rings, ringlets, and "spokes," dark features in the rings that circle the planet at different rates from that of the surrounding ring material. Material in the rings ranges in size from a few micrometers to several tens of meters. Two of Saturn's small moons orbit within gaps in the main rings.

**Many Moons**

Saturn has 52 known natural satellites, or **moons**, and there are probably many more waiting to be discovered. Saturn's largest satellite, **Titan**, is a bit bigger than the planet Mercury. (Titan is the second-largest moon in the solar system; only Jupiter's moon Ganymede is bigger.) Titan is shrouded in a thick, nitrogen-rich atmosphere that might be similar to what Earth's was like long ago. Further study of this moon promises to reveal much about planetary formation and, perhaps, about the early days of Earth. Saturn also has many smaller "icy" satellites. From Enceladus, which shows evidence of recent (and ongoing) surface changes, to Iapetus, with one hemisphere darker than asphalt and the other as bright as snow, each of Saturn's satellites is unique.

Though Saturn's magnetic field is not as huge as Jupiter's, it is still 578 times as powerful as Earth's. Saturn, the rings, and many of the satellites lie totally within Saturn's enormous **magnetosphere**, the region of space in which the behavior of electrically charged particles is influenced more by Saturn's magnetic field than by the solar wind. Hubble Space Telescope images show that Saturn's polar regions have aurorae similar to Earth's. Aurorae occur when charged particles spiral into a planet's atmosphere along magnetic field lines.

Voyagers 1 and 2 flew by and photographed Saturn in 1981. The next chapter in our knowledge of Saturn is under way, as the **Cassini- Huygens** spacecraft continues its exploration of the Saturn system. The Huygens probe descended through Titan's atmosphere in January 2005, collecting data on the atmosphere and surface. Cassini will orbit Saturn more than 70 times during a four-year study of the planet and its moons, rings, and magnetosphere. Cassini-Huygens is sponsored by NASA, the European Space Agency, and the Italian Space Agency.

**Unusual Uranus**

Once considered one of the blander-looking planets, Uranus has been revealed as a dynamic world with some of the brightest clouds in the outer solar system and 11 **rings**. The first planet found with the aid of a telescope, Uranus was discovered in 1781 by astronomer William Herschel. The seventh planet from the sun is so distant that it takes 84 years to complete one orbit.

Uranus, with no solid surface, is one of the **gas giant** planets. (The others are Jupiter, Saturn, and Neptune.) Its atmosphere is composed primarily of hydrogen and helium, with a small amount of methane and traces of water and ammonia. Uranus gets its blue-green color from methane gas. Sunlight is reflected from Uranus's cloud tops, which lie beneath a layer of methane gas. As the reflected sunlight passes back through this layer, the methane gas absorbs the red portion of the light, allowing the blue portion to pass through and resulting in the blue-green color that we see.

The planet's atmospheric details are very difficult to see in visible light. The bulk (80 percent or more) of the mass of Uranus is contained in an extended liquid core consisting primarily of "icy" materials (water, methane, and ammonia), with higher-density material at depth.

**Off-Kilter Planet**

Uranus's **rotation axis** is nearly horizontal, as though the planet has been knocked on its side. This unusual orientation may be the result of a collision with a planet-size body early in Uranus's history, which apparently radically changed the planet's rotation. Additionally, while magnetic fields are typically in alignment with a planet's rotation, Uranus's **magnetic field** is tipped over.

Even though Uranus is tipped on its side and experiences seasons that last over 20 years, the temperature differences on the summer and winter sides do not differ greatly because the planet is so far from the sun. Near the cloud tops, the temperature of Uranus is -357 degrees Fahrenheit (-216 degrees Celsius).

Because of the planet's unusual orientation, Uranus's rings are perpendicular to its orbital path about the sun. The ten outer rings are dark, thin, and narrow, while the 11th ring is inside the others and is broad and diffuse.

Uranus has 27 known **moons**, named mostly for characters from the works of William Shakespeare and Alexander Pope. Miranda is the strangest-looking Uranian moon, appearing as though it were made of spare parts. The high cliffs and winding valleys of the moon may indicate partial melting of the interior, with icy material occasionally drifting to the surface.

**Neptune**

**Invisible to the Naked Eye**

The eighth planet from the sun, Neptune was the first planet located through mathematical predictions rather than through regular observations of the sky. (Galileo had recorded it as a fixed star during observations with his small telescope in 1612 and 1613.)

When Uranus didn't travel exactly as astronomers expected it to, a French mathematician, Urbain Joseph Le Verrier, proposed the position and mass of another as yet unknown planet that could cause the observed changes to Uranus's orbit. After being ignored by French astronomers, Le Verrier sent his predictions to Johann Gottfried Galle at the Berlin Observatory, who found Neptune on his first night of searching in 1846. Seventeen days later, its largest moon, Triton, was also discovered.

Nearly 2.8 billion miles (4.5 billion kilometers) from the sun, Neptune orbits the sun once every 165 years. It is invisible to the naked eye because of its extreme distance from Earth.

The main axis of Neptune's **magnetic field** is "tipped over" by about 47 degrees compared with the planet's rotation axis. Like Uranus, whose magnetic axis is tilted about 60 degrees from the axis of rotation, Neptune's magnetosphere undergoes wild variations during each rotation because of this misalignment. The magnetic field of Neptune is about 27 times more powerful than that of Earth.

Neptune's **atmosphere** extends to great depths, gradually merging into water and other "melted ices" over a heavier, approximately Earth-size solid core. Neptune's blue color is the result of methane in the atmosphere. Uranus's blue-green color is also the result of atmospheric methane, but Neptune is a more vivid, brighter blue, so there must be an unknown component that causes the more intense color that we see. The cause of Neptune's bluish tinge remains a mystery.

**Mystery Storm**

Despite its great distance from the sun and lower energy input, Neptune's winds are three times stronger than Jupiter's and nine times stronger than Earth's.

In 1989, Voyager 2 tracked a large, oval, dark storm in Neptune's southern hemisphere. This hurricane-like **Great Dark Spot** was observed to be large enough to contain the entire Earth. It spun counterclockwise and moved westward at almost 750 miles (1,200 kilometers) per hour. (Subsequent images from the Hubble Space Telescope showed no sign of the Great Dark Spot photographed by Voyager. A comparable spot appeared in 1994 in Neptune's northern hemisphere but had disappeared by 1997.) Voyager 2 also photographed clouds casting shadows on a lower cloud deck, enabling scientists to visually measure the altitude differences between the upper and lower cloud decks.

The planet has six **rings** of varying thicknesses, confirmed by Voyager 2's observations in 1989. Neptune's rings are believed to be relatively young and relatively short-lived.

Neptune has 13 known **moons**, six of which were discovered by Voyager 2. The largest, Triton, orbits Neptune in a direction opposite to the direction of the planet's rotation. Triton is the coldest body yet visited in our solar system—temperatures on its surface are about -391 degrees Fahrenheit (-235 degrees Celsius). Despite this deep freeze, Voyager 2 discovered geysers spewing icy material upward more than five miles (eight kilometers). Triton's thin atmosphere, also discovered by Voyager, has been seen from Earth several times since, and is growing warmer—although scientists do not yet know why.

**PLUTO (About Dwarf Planets)**

The world was introduced to dwarf planets in 2006, when petite Pluto was stripped of its planet status and reclassified as a dwarf planet. The International Astronomical Union (IAU) currently recognizes two other dwarf planets, Eris and Ceres.

What differentiates a dwarf planet from a planet? For the most part, they are identical, but there's one key difference: A dwarf planet hasn't "cleared the neighborhood" around its orbit, which means it has not become gravitationally dominant and it shares its orbital space with other bodies of a similar size. (Astronomers and other experts are debating this definition.)

Because it has not cleared the neighborhood around its orbit, **Pluto** is considered a dwarf planet. It orbits in a disc-like zone beyond the orbit of Neptune called the Kuiper belt, a distant region populated with frozen bodies left over from the solar system's formation. The dwarf planet is a whopping 3.7 billion miles (5.9 billion kilometers) from the sun, and its average temperature hovers around -356 degrees Fahrenheit (-215 degrees Celsius).

Pluto's surface is composed of a mixture of frozen nitrogen, methane, and carbon monoxide ices. The dwarf planet also has polar caps and regions of frozen methane and nitrogen.

Pluto has three known **moons**, Hydra, Nix, and Charon. With a diameter of about 737 miles (1,186 kilometers), Charon is the largest of Pluto's moons. The duo's gravity puts them in a synchronous orbit, which means they face each other with the same side all the time.

In January 2006, NASA launched its New Horizons spacecraft en route to Pluto and Charon. It is expected to arrive in 2015 and will be the first spacecraft to visit the distant dwarf planet.

**Dual Identity**

Also considered by many to be an asteroid, **Ceres**, like Pluto, was also renamed as a dwarf planet in 2006. Ceres was discovered by Italian astronomer Giuseppe Piazzi in 1801.

Ceres's shape resembles a flattened sphere with a diameter of about 590 miles (950 kilometers). It is by far the largest and most massive known body in the asteroid belt, and it contains about one-third of the estimated total mass of all asteroids in the belt.

Ceres is made up of a rocky inner core surrounded by a mantle of water-ice. A thin, dusty, outer crust covers the dwarf planet named after the Roman goddess of grain.

**Mercury's** elliptical orbit takes the small planet as close as 29 million miles (47 million kilometers) and as far as 43 million miles (70 million kilometers) from the sun. If one could stand on the scorching surface of Mercury when it is at its closest point to the sun, the sun would appear almost three times as large as it does when viewed from Earth.

Temperatures on Mercury's surface can reach 800 degrees Fahrenheit (430 degrees Celsius). Because the planet has no atmosphere to retain that heat, nighttime temperatures on the surface can drop to -280 degrees Fahrenheit (-170 degrees Celsius).

Because Mercury is so close to the sun, it is hard to directly observe from Earth except during twilight. Mercury makes an appearance indirectly, however, 13 times each century. Earth observers can watch Mercury pass across the face of the sun, an event called a **transit**. These rare transits fall within several days of May 8 and November 10.

Scientists used to think that the same side of Mercury always faces the sun, but in 1965 astronomers discovered that the planet rotates three times during every two orbits. Mercury speeds around the sun every 88 days, traveling through space at nearly 31 miles (50 kilometers) per second faster than any other planet. The length of one Mercury day (**sidereal rotation**) is equal to 58.646 Earth days.

**No Atmosphere**
Rather than an atmosphere, Mercury possesses a thin **exosphere** made up of atoms blasted off its surface by solar wind and striking micrometeoroids. Because of the planet's extreme surface temperature, the atoms quickly escape into space. With the thin exosphere, there has been no wind erosion of the surface and meteorites do not burn up due to friction as they do in other planetary atmospheres.

Mercury's surface resembles that of Earth's moon, scarred by many impact craters resulting from collisions with **meteoroids** and **comets**. While there are areas of smooth terrain, there are also lobe-shaped scarps or cliffs, some hundreds of miles long and soaring up to a mile (1.6 kilometers) high, formed by early contraction of the crust. The Caloris Basin, one of the largest features on Mercury, is about 800 miles (1,300 kilometers) in diameter. It was the result of an asteroid impact on the planet's surface early in the solar system's history. Over the next half-billion years, Mercury shrank in radius about 0.6 to 1.2 miles (1 to 2 kilometers) as the planet cooled after its formation. The outer crust contracted and grew strong enough to prevent magma from reaching the surface, ending the period of geologic activity.

Mercury is the second smallest planet in the solar system, larger only than previously measured planets, such as Pluto. Mercury is the second densest planet after Earth, with a large iron core having a radius of 1,100 to 1,200 miles (1,800 to 1,900 kilometers), about 75 percent of the planet's radius. Mercury's outer shell, comparable to Earth's outer shell (called the mantle), is only 300 to 400 miles (500 to 600 kilometers) thick. Mercury's **magnetic field** is thought to be a miniature version of Earth's, but scientists are uncertain of the strength of the field.

**Missions to Mercury**

Only one spacecraft has ever visited Mercury: Mariner 10, which imaged about 45 percent of the surface. In 1991, astronomers using radar observations showed that Mercury may have water ice at its north and south poles inside deep craters that are perpetually cold. Falling comets or meteorites might have brought ice to these regions of Mercury, or water vapor might have outgassed from the interior and frozen out at the poles.

A new NASA mission to Mercury called MErcury Surface, Space ENvironment, Geochemistry, and Ranging (MESSENGER) will begin orbiting Mercury in March 2011 to investigate key scientific areas such as the planet's composition, the structure of the core, the magnetic field, and the materials at the poles.

**Venus** and Earth are similar in size, mass, density, composition, and distance from the sun. There, however, is where the similarities end.

Venus is covered by a thick, rapidly spinning atmosphere, creating a scorched world with temperatures hot enough to melt lead and a surface pressure 90 times that of Earth. Because of its proximity to Earth and the way its clouds reflect sunlight, Venus appears to be the brightest planet in the sky.

Like Mercury, Venus can be seen periodically passing across the face of the sun. These **transits** occur in pairs, with more than a century separating each pair. Since the telescope was invented, transits have been observed in 1631, 1639; 1761, 1769; and 1874, 1882. On June 8, 2004, astronomers worldwide saw the tiny dot of Venus crawl across the sun; the second in this pair of early 21st-century transits will occur June 6, 2012.

**Toxic Atmosphere**

Venus's **atmosphere** consists mainly of carbon dioxide, with clouds of sulfuric acid droplets. Only trace amounts of water have been detected in the atmosphere. The thick atmosphere traps the sun's heat, resulting in surface temperatures over 880 degrees Fahrenheit (470 degrees Celsius). Probes that have landed on Venus have not survived more than a few hours before being destroyed by the incredibly high temperatures.

The Venusian year (**orbital period**) is about 225 Earth days long, while the planet's rotation period is 243 Earth days, making a Venus day about 117 Earth days long. Venus rotates retrograde (east to west) compared with Earth's prograde (west to east) rotation. Seen from Venus, the sun would rise in the west and set in the east. As Venus moves forward in its solar orbit while slowly rotating "backwards" on its axis, the cloud-level atmosphere zips around the planet in the opposite direction from the rotation every four Earth days, driven by constant hurricane-force winds. How this atmospheric "super rotation" forms and is maintained continues to be a topic of scientific investigation.

About 90 percent of the surface of Venus appears to be recently solidified basalt lava; it is thought that the planet was completely resurfaced by volcanic activity 300 million to 500 million years ago.

Sulfur compounds, possibly attributable to volcanic activity, are abundant in Venus's clouds. The corrosive chemistry and dense, moving atmosphere cause significant surface weathering and erosion. Radar images of the surface show wind streaks and sand dunes. Craters smaller than 0.9 to 1.2 miles (1.5 to 2 kilometers) across do not exist on Venus, because small meteors burn up in the dense atmosphere before they can reach the surface.

**Geological Features**

More than a thousand volcanoes or volcanic centers larger than 12 miles (20 kilometers) in diameter dot the surface of Venus. Volcanic flows have produced long, sinuous channels extending for hundreds of kilometers.

Venus has two large highland areas: **Ishtar Terra**, about the size of Australia, in the north polar region, and **Aphrodite Terra**, about the size of South America, straddling the equator and extending for almost 6,000 miles (10,000 kilometers). Maxwell Montes, the highest mountain on Venus and comparable to Mount Everest on Earth, is at the eastern edge of Ishtar Terra.

Venus has an iron core about 1,200 miles (3,000 kilometers) in radius. Venus has no global magnetic field; though its core iron content is similar to that of Earth, Venus rotates too slowly to generate the type of magnetic field that Earth has.

**The Red Planet**

**Mars** is a small rocky body once thought to be very Earthlike. Like the other **terrestrial planets**—Mercury, Venus, and Earth—its surface has been changed by volcanism, impacts from other bodies, movements of its crust, and atmospheric effects such as dust storms. It has polar ice caps that grow and recede with the change of seasons; areas of layered soils near the Martian poles suggest that the planet's climate has changed more than once, perhaps caused by a regular change in the planet's orbit.

Martian tectonism, the formation and change of a planet's crust, differs from Earth's. Where Earth tectonics involve sliding plates that grind against each other or spread apart in the seafloors, Martian tectonics seem to be vertical, with hot lava pushing upwards through the crust to the surface.

Periodically, great dust storms engulf the entire planet. The effects of these storms are dramatic, including giant dunes, wind streaks, and wind-carved features.

**Water on Mars?**

Scientists believe that 3.5 billion years ago, Mars experienced the largest known floods in the solar system. This water may even have pooled into lakes or shallow oceans. But where did the ancient floodwater come from, how long did it last, and where did it go?

At present, Mars is too cold and its atmosphere is too thin to allow liquid water to exist at the surface for long. There's water ice close to the surface and more water frozen in the polar ice caps, but the quantity of water required to carve Mars's great channels and flood plains is not evident on—or near—the surface today. Images from NASA's Mars Global Surveyor spacecraft suggest that underground reserves of water may break through the surface as springs. The answers may lie deep beneath Mars's red soil.

Unraveling the story of water on Mars is important to unlocking its past climate history, which will help us understand the evolution of all planets, including our own. Water is also believed to be a central ingredient for the initiation of life; the evidence of past or present water on Mars is expected to hold clues about past or present life on Mars, as well as the potential for life elsewhere in the universe. And, before humans can safely go to Mars, we need to know much more about the planet's environment, including the availability of resources such as water.

**Mountains, Moons, and More**

Mars has some remarkable geological characteristics, including the largest volcanic mountain in the solar system, **Olympus Mons**; volcanoes in the northern Tharsis region that are so huge they deform the planet's roundness; and a gigantic equatorial rift valley, the **Valles Marineris**. This canyon system stretches a distance equivalent to the distance from New York to Los Angeles; Arizona's Grand Canyon could easily fit into one of the side canyons of this great chasm.

Mars also has two small moons, **Phobos** and **Deimos**. Although no one knows how they formed, they may be asteroids snared by Mars's gravity.