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Moon

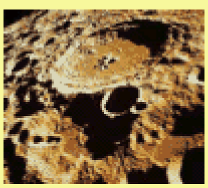
Encyclopedia Britannica

moon

The most prominent feature in the night sky is the Earth's natural satellite, the moon. Because of its nearness to Earth, the moon is second only to the sun in apparent size and brilliance. In astronomical terms, however, it is a common, small, and insignificant body. Its light is merely reflected sunlight. At least 57 additional satellites orbit other planets in the solar system, and a number of these are larger than the moon. Only one of these satellites, however, is larger compared to its primary planet than is the moon. Charon, a satellite of the planet Pluto, is about half the size of Pluto; the moon is about a quarter the size of Earth. The moon's large comparative size means that it affects the Earth to an unusual degree. The moon's influence is most evident in the ocean tides, which are caused by the pull of the moon (see Ocean Waves and Tides).

Earth-Based Observations of the Moon

Astronomy, religion, and timekeeping were once closely linked. Priests or astrologers recorded the moon's changes of phase. Some religions tried to reconcile the **lunar** calendar with the solar calendar so the months would always fall in the same seasons.



The far side of the moon was photographed by Ap...

The far side of the moon was photographed by Apollo 11 in July 1969. The large central crater is called International Astronomical Union-308. It has a diameter of about 50 miles (80 kilometers). The cratered surface of the far side differs from that of the near side which is covered with smooth, dark maria.

The study of **lunar** geography began with the invention of the telescope. Galileo examined the moon through a telescope in 1609. Later astronomers made maps of its physical features. They discovered mountains and plains, some large craters, and long valleys. Galileo's successors thought the plains on the moon were covered with water and called them maria (Latin for 'seas'). This name has persisted, even though it is now known that no water exists on the moon's surface.

In the 20th century astronomers mounted cameras on telescopes and took pictures of the moon. Such photographs were often combined to form maps of the moon. Photographic maps, though completely accurate, are often difficult to interpret because the airless moon has deceptively dark and sharp shadows. The changes in their length are accompanied by marked changes in the appearance of **lunar** features.

Earth-Based Moon Research

Scientific curiosity has not been satisfied with the information that can be obtained by looking at the moon. Calculations based on natural occurrences have provided some additional information. The tides on Earth have been used to compute the moon's gravity and mass. The moon's profile is studied during eclipses of the sun. The lengths of **lunar** shadows aid in measuring the heights of **lunar** mountains.

One important tool used to study the moon is the spectroscope, which separates light into its individual wavelengths, or spectrum. The spectrum indicates what elements are present in the light source (see Spectrum and Spectroscope). Since the moon reflects the sun's light, its spectrum includes the wavelengths in the sun's spectrum. Any differences are due to conditions on the moon. From these differences, scientists have been able to identify some of the elements on the moon's surface.

Moon Research with Unmanned Space Flights

In the 1960s spacecraft began to supply new **lunar** data. Flights that bypassed, crashed into, and orbited the moon sent closeup photographs back to Earth. The orbital flights provided pictures of the moon's far side, which is always turned away from the Earth. These pictures revealed that the far side, unlike the side visible from the Earth, has very few maria.

Spacecraft that orbited the moon exhibited a slight but unexpected variation in speed. Their speed increased over the moon's seas. Scientists concluded that the increase was caused by gravity. This means that the material under the maria is denser, or more concentrated, than the material under other portions of the moon's surface. These concentrations of mass, named mascons, occur under at least five of the circular **lunar** seas. When scientists can explain the structure and origin of mascons, they will perhaps also have learned much about the origin of the maria.

Manned Space Flights and Moon Research

On July 20, 1969, United States astronauts Neil A. Armstrong and Edwin E. Aldrin, Jr., of the space flight Apollo 11, landed in the Mare Tranquillitatis, or Sea of Tranquillity. They were the first men to set foot on the surface of the moon. They placed experimental equipment on the moon's surface and returned to Earth with 48 pounds of rock and soil samples. Apollo 12 made the second manned **lunar** landing on Nov. 19, 1969, in the Oceanus Procellarum (Ocean of Storms). The Apollo 12 astronauts also set up experiments and brought back rock and soil samples.

Equipment used in the Apollo 11 experiments included a laser-beam reflector, a seismometer, and a solar-wind-particle detector. Several Earth-based laboratories aimed lasers at the reflector to determine the distance from the Earth to the moon. The initial measurements were accurate to within about 14 feet. The seismometer recorded several events interpreted to be moonquakes, landslides, or meteor impacts. The solar-wind-particle detector was placed on the moon's surface so that it faced the sun. It was brought back to Earth and analyzed for rare gases. The results showed that it had trapped helium, neon, and argon in amounts corresponding to their abundance on the sun rather than to their abundance on Earth.

The Apollo 12 experiments employed a solar-wind spectrometer and a magnetometer. The magnetometer recorded a magnetic field some ten times stronger than scientists had expected. Another surprising discovery was made when the Apollo 12 astronauts crashed part of the **lunar** module onto the **lunar** surface to give the seismometer a reading from an impact of known force and mass. The moon vibrated for nearly an hour afterward.

Moon Rocks on Earth

About half of the rock samples brought back to Earth by Apollo 11 had been formed 312 billion years ago by an event that melted the material they contained and reorganized it as igneous rocks. The other rock samples were breccias-hardened cementlike masses composed of rock fragments of various sizes. The breccias and the loose surface soil samples were 412 billion years old. The younger age of the igneous rocks indicated that major geologic activity had taken place on the moon.

Rocks obtained by Apollo 12 from the Oceanus Procellarum were younger than the Apollo 11 samples. Most of the Apollo 12 samples had crystallized from a molten state. These crystalline igneous rocks varied widely in texture and chemical composition. The soil samples and breccias brought back by Apollo 12 were uniform in composition and about a billion years older than the crystalline rocks.

The Moon's Position in the Sky

The moon has no fixed place in the sky. It is always moving. Its path, or orbit, can be considered only in relation to other heavenly bodies. The illustration shows the moon's apparent orbit in relation to the Earth. The orbit is quite different in relation to the sun. This still represents an apparent and not the actual path, for the sun is moving at great speed through space, carrying the entire solar system along (see Star).

Several balls will help you visualize the path of the moon. Place them on a table in the relative positions of the sun, Earth, and moon. Move them to correspond with the illustrations in this article.

The Orbit of the Moon

The moon does not follow a perfect circle in its path around the Earth. Its orbit is an ellipse, with the Earth nearer one end than the other. At the point called the perigee, when the moon is nearest the Earth, its distance from the Earth's center is about 222,000 miles. When it reaches the opposite point, the apogee, the moon is about 253,000 miles from the Earth's center. The exact distances of the perigee and apogee vary from month to month.

The moon's orbit does not line up with the Earth's equator, nor does it align with the Earth's path around the sun (the ecliptic). It is nearer the latter, however, intersecting the plane of the ecliptic at an angle of about 5°. The two points at which the moon each month crosses the plane of the ecliptic are called the **lunar** nodes.

The moon's path is further complicated. The plane of its orbit wobbles around continuously, as does a spinning coin just before it comes to rest. At a given season, for example, the side of the orbit which lies above (or north of) the ecliptic sometimes points away from the sun and sometimes toward it. This shift occurs slowly, the full cycle of oscillation taking 18.6 years. The cycle is sometimes called the regression of the nodes, since the nodes move constantly westward around the ecliptic.

Figure 2

Figure 2

The orbit of the moon at times slants in the same direction as the Earth's inclination to the ecliptic. At other times it slants in the opposite direction. As a result, the moon in some years may range farther north and in other years farther south in the sky. The slant and wobble of its orbit also account for the schedule of eclipses. These can take place only when the moon is in line with the sun and Earth, or very nearly so.

Eclipses occur at irregular intervals, and they repeat their cycle only approximately every 18 years. The combined number of total or partial eclipses of the sun and the moon cannot exceed seven or be less than two in a calendar year. (See also **Eclipse**.)

Other Variations of the Moon

There are other irregularities in the moon's motion caused by the attraction of the sun and the Earth. When the moon is between the sun and Earth, the sun tends to pull it away from the Earth. When the moon travels to the far side of the Earth, the sun tends to pull it toward the Earth. These effects are known as perturbations.

The moon shows the same side to the Earth at all times. To do this it must rotate once on its axis every time it travels around the Earth. If it did not turn, it would show its opposite side every time it traveled halfway around the Earth. Actually considerably more than half the moon, or about 59 per cent, is seen. This is due to librations, or slight tippings back and forth, of the face. The reason the moon rotates once each time it orbits the Earth is unknown. Scientists suspect that the moon's rotation may have adjusted itself to a force such as the Earth's gravitational pull. This theory might also explain why the diameter of the moon is bulged an estimated one third of a mile in the direction of the Earth.

The Moon's Timetable

The time it takes the moon to orbit the Earth is about 2713 days. This period is called the sidereal month. There are about 2912 days, however, between each appearance of the new, or dark, moon, which occurs when the moon appears closest to the sun. This time period is called the synodic, or **lunar**, month. It is longer because the Earth has also been moving around the sun. Thus the relative positions of the Earth, moon, and sun are altered. The moon must travel farther in order to become a new moon.

Because the moon moves in this way, its rising and setting times are later every day. On the average the delay is about 50 minutes each day. If it were fixed in the heavens like the sun or stars, it would seem to have a more regular schedule.

One full day, or 24 hours, later the rotating Earth would have brought the observer to the same position. The moon traveling in its orbit would have moved positions. The observer would now have to wait until the Earth's movement carried him to a different position before he or she could see the moon rise. The relative position advanced because in one day the moon covers about 127 of its monthly route around the Earth.

The tilt of the Earth accounts for the fact that the sun seems to ride high in the sky in summer and low in winter (see Seasons). The tilt has a similar effect on the height of the moon in the sky, because the plane of the moon's orbit is nearly in line with the sun. The moon's monthly revolution around the Earth also produces changes in the apparent height of the moon.

The Size and Phases of the Moon

Some idea of the size of the moon can be gained by comparing it with the size of the Earth. The Earth is almost 8,000 miles (12,870 kilometers) in diameter at the equator. The moon's diameter is some 2,160 miles (3,480 kilometers). How does it compare in size with the sun? Take a sharp pencil and make a dot on a piece of paper. The dot will represent the moon. To show roughly the comparative size of the sun you would need to draw a circle from eight to ten inches (20 to 25 centimeters) in diameter, since the diameter of the sun is about 865,000 miles (1,392,000 kilometers) (see Sun).

The moon's mean distance from the Earth is almost a quarter of a million miles (400,000 kilometers). This may seem like a great distance; however, astronomers consider it close. The distance from the moon or Earth to the sun is about 93 million miles (150 million kilometers); by definition, this is called one astronomical unit. Some stars are believed to be billions of trillions of miles away. (See also Star.)

The moon produces no light by itself. Except on the rare occasions when it is eclipsed by the Earth's shadow, the moon is exposed to the full light of the sun. Half of the moon is therefore almost always brilliantly lighted. From Earth all the illuminated side may be seen only when the moon is opposite the sun. When the moon is in the direction of the sun, no lighted part can be observed. Between these extremes only portions of the bright side are seen. These varying appearances are called phases. For convenience the phases are divided into four groups, or quarters:

New moon.

A new moon appears only when the moon is on the side of the Earth most directly in line with the sun. There is no illumination on the Earth's side, so it is also sometimes called the dark moon. If it were visible, it would ride very high in summer and very low in winter. It reaches an intermediate height in spring and fall. Within a few days after the dark moon, a thin waxing crescent moon may be seen low in the western sky shortly after sunset.

First quarter.

Half the side of the moon facing the Earth appears illuminated. It rises about noon, reaches its high point for the day at sundown, and sets near midnight. It rides low in fall and high in spring and takes a middle course during summer and winter.

Full moon.

The whole side of the moon is now illuminated to viewers from the Earth. The full moon rises in the east as the sun sets in the west. It stays up all night long, reaching its highest point about midnight. In summer it is as low in the sky as the sun is at noon in midwinter. In winter its apparent height is comparable with that of the sun at noon in summer. In spring and fall it rides at an intermediate height.

The full moon nearest the autumnal equinox, which occurs about September 23 (when the days and nights are of equal length), rises with the least delay of all. It lights the way for late-working harvesters and is called the harvest moon. The full moon of the following month, also an early riser, is known as the hunter's moon.

Third, or last, quarter.

Like the first quarter, it is seen illuminated on half the side facing the Earth. The third-quarter moon rises about midnight, is highest at dawn, and sets about noon. In the morning it is in the western sky. It rides high in the heavens in fall and low in spring and follows a middle course in summer and winter. The following crescent gets thinner and thinner. It is known as the waning crescent moon or the old moon as it approaches the phase of the new moon to complete the cycle.

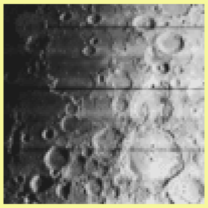
Sometimes within the horns of the bright waxing or waning crescent the rest of the disk can actually be seen dimly illuminated. The crescent glows from direct sunshine and the rest is made visible by earthshine. Earthshine is sunlight reflected to the moon from the daylight region of the Earth. This appearance is popularly called 'the old moon in the new moon's arms.' Between the full and the two quarter phases, the moon appears as a lopsided globe. It is then called the gibbous moon.

Horns of the Crescent Moon

The horns of the crescent moon always point away from the sun. Imagine a line joining the tips of the crescent. From this line imagine a perpendicular passing through the middle of the crescent. This will point roughly to the sun. About the time of the autumnal equinox the thin new moon seen near the horizon after sunset is tilted so that a line joining the tips of the horns is almost upright to the horizon. In spring the crescent of the new moon will be higher in the sky and almost directly over the place where the sun set. The imaginary line joining the horns will be nearly parallel to the horizon. On rare occasions when clouds obscure the sun an hour or two after sunrise, but leave a clear strip near the horizon, the new crescent moon may be seen with the horns down. The same is true of the old crescent moon if the sun is blacked out an hour or two before sunset.

Artists sometimes place a star within the horns of the crescent. Coleridge made the same mistake in 'The Rime of the Ancient Mariner':The horned Moon, with one bright starWithin the nether tip.No star can ever be seen there. Even though only a bright sickle of light is observed, the moon is a solid globe and a person cannot see through the dark part. Painters also have misplaced the phases of the moon in relation to the time of day or the seasons.

Moon Geography



Meteorite craters on the surface of the Moon, p...

Meteorite craters on the surface of the Moon, photographed by Lunar Orbiter IV

The features viewed as 'the man in the moon' are a combination of craters, mountain peaks, deep narrow valleys, and level plains, or maria. The largest of the maria is called Mare Imbrium, or Sea of Rains. It is about 700 miles in diameter.

There are some 20 other prominent maria on the side of the moon that faces the Earth. They have such names as Mare Serenitatis (Sea of Serenity), Mare Crisium (Sea of Crises), and Mare Nubium (Sea of Clouds). Although they are called plains because they are the most nearly level of all the **lunar** surfaces, the maria are not completely flat. They are crossed by ridges, pockmarked by craters, and interrupted by cliffs and walls.

One theory is that the maria were caused by terrific meteorite collisions billions of years ago when the moon's interior was hot. The impact would have caused great heat, melted the moon's surface, and released molten rock from the interior, forming the maria from lava. A more recent theory holds that a meteorite collision would be more likely to pulverize rock than to melt it. Three United States Ranger probes which photographed the moon in 1964 and 1965 increased speculation among scientists about whether the moon's maria are composed primarily of volcanic ash or lava flows, dust, or some unknown material.

The maria are surrounded by huge mountains. They were given such names as Alps, Pyrenees, and Carpathians, after Earth ranges. The loftiest **lunar** range is the Leibnitz, with peaks up to 30,000 feet.

Tens of thousands of craters are scattered over the moon's surface, often overlapping one another. Astronomers have long debated their origin. The craters may have been created by volcanoes, now extinct for billions of years. A more widely accepted theory holds that they were caused both by showers of meteorites and by volcanic activity.

Many of the craters of the moon are named for astronomers. Tycho (for Tycho Brahe), Copernicus, Kepler, and some of the other craters have rays. These are light-hued lines radiating from the craters like the spokes of a wheel. Some rays are more than 1,000 miles long. None is more than about 12 miles wide. In 1964 the Ranger 7 moon probe provided the first closeup photographs of these rays. They were discovered to be clusters of small craters. Most scientists believe they were formed by the impact of fragments ejected from the large craters that were formed by the impact of meteorites. The large craters range from less than a mile to nearly 150 miles in diameter. Like the maria, they are surrounded by high peaks.

There are more than 1,000 deep valleys, called rills, or clefts, on the moon. They are 10 to 300 miles long and 2 miles or less wide. Their depths are unknown. The rills are believed to be cracks in the surface that formed along zones of weakness caused by some type of internal heating and expansion. During a solar **eclipse**, sunlight shining down valleys on the edge of the moon may form a circle of bright points known as Baily's beads.

Does the Moon Have an Atmosphere?

For years scientists believed there was no trace of gas or an atmosphere on the moon. Now there is some evidence of an atmosphere, though it may be almost too thin to measure. During an occultation of the Crab nebula, astronomers using a radio telescope at Cambridge University detected a slight bending of the rays of the nebula. This deflection could have been due to a thin **lunar** atmosphere.

In 1956 observers reported what appeared to be a cloud above the crater Alphonsus. In 1958 a Soviet astronomer, Nikolai A. Kozyrev, announced an apparent eruption from the crater. He took spectrograms, which indicated the presence of rarefied gases. His findings caused a revival of debates on the volcanic versus the meteoric origin of moon craters. Many scientists believed that Kozyrev had seen not a true volcanic eruption but a puff of gas and dust from below the surface, probably caused by heat. Some small craters within Alphonsus have 'black halos' believed to be deposits of material that have filled the rills along which they are located.

Most scientific evidence has supported the theory that the moon is cool and solid below the surface. Its diameter, directed toward the Earth, is only very slightly enlarged. If the interior of the moon were still hot and molten, gravity would probably have produced a far greater effect upon its diameter.

The surface of the moon absorbs heat when it faces the sun. At these times the temperature may reach 215°F. When the sun's rays are cut off by the rotation of the moon, the surface cools to temperatures as low as -243°F. Instruments have detected that the surface cools more rapidly than does the subsurface. This is considered as evidence that the surface material differs from the material below it.

Missions to the Moon

At the start of the International Geophysical Year in 1957, both the United States and the Soviet Union increased their **lunar**-probe research. In the next few years much was learned about the moon.

In 1958 the United States sent a Pioneer 1 rocket about one third of the distance to the moon. The Soviet Union's Luna 1 in 1959 passed within 4,660 miles of the moon and went into orbit around the sun. Pioneers 4 and 5, launched in 1959 and 1960, also passed the moon and went into solar orbit.

Luna 2 crash-landed on the moon in 1959. In the same year Luna 3 transmitted to Earth the first pictures of the moon's far side. On July 31, 1964, Ranger 7 became the first United States spacecraft to photograph the moon. All the early probes either bypassed the moon or crashed on it.

More advanced spacecraft soft-landed on the moon or went into orbit around it. The first to land on the moon intact, the Soviet Luna 9, touched down in the Oceanus Procellarum on Feb. 3, 1966. Luna 9 sent only a few pictures before its batteries died. Surveyor 1, a United States probe, landed on June 2, 1966, also in the Oceanus Procellarum. It transmitted more than 11,000 pictures. Succeeding Luna and Surveyor soft-landing vehicles carried both cameras and surface-study devices.

Other Soviet Lunas were placed in orbit around the moon as were **Lunar** Orbiter spacecraft of the United States. From 1966 to 1967 the **Lunar** Orbiters made broad surveys of the moon's surface, seeking areas suitable for landings by manned spacecraft of the Apollo series. An Apollo was the first manned spacecraft to orbit the moon, in December 1968, and in July 1969 Apollo 11 carried the first men to the **lunar** surface. United States astronauts made five other expeditions to the moon from 1969 to 1972. They took thousands of photographs, collected numerous samples, and performed a wide array of experiments, several of which were designed to reveal more about the moon's internal structure. The United States program of manned **lunar** landings ended with Apollo 17 in December 1972. Although the Soviet Union never landed a manned spacecraft on the moon, it placed robotic vehicles on the **lunar** surface in 1970 and again in 1972. The Soviet Union continued launching unmanned **lunar** probes until 1974.

In 1998, the first **lunar** mission in 25 years was launched from Cape Canaveral in Florida. The **Lunar** Prospector, a small, drum-shaped spacecraft weighing only 650 pounds (295 kilograms), was expected to spend 1998 orbiting the moon to study its structure and determine its resources. Six experiments onboard the robotic mission were designed to collect data as the spacecraft traveled at an altitude of 63 miles (100 kilometers) above the moon's surface. Among the first data expected to be returned was information on the possible presence of ice in polar craters. Prior to the mission, scientists had found evidence, via radar surveillance from U.S. Defense Department spacecraft, of ice in a huge crater on the southern pole of the moon. Probing the 1,500-mile- (2,400-kilometer-) wide, 8-mile- (13-kilometer-) deep crater, they received patterns of radar readings that suggested the presence of crystallized water. The scientists hypothesized that whatever water may exist on the moon probably came from collisions with large comets, which are known to contain water.

The Prospector mission was unique in the history of NASA **lunar** missions. Unlike the Apollo missions, which mapped approximately 25 percent of the **lunar** surface around the moon's equator, Prospector was designed to map the entire **lunar** surface. Another difference was the relative cost. The **Lunar** Prospector mission was much less expensive than any of the Apollo missions. The third mission of NASA's Discovery Program, which was designed to provide 'Faster, Better, Cheaper' space missions, the Prospector was a small, unmanned spacecraft with a payload of only five instruments. The relative simplicity of the mission's design was expected to enable the spacecraft to make observations over a longer period of time than was available for previous missions to the moon. (See also Space Travel.)