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Moons

Moons are natural satellites. Satellites are objects in outer space that travel in a circle around a planet or other object. This circle is called an “orbit.” Some planets have no moons, while others have many. For example, Mercury and Venus have no moons, Earth has one, Mars has two, and Pluto, Jupiter, and Neptune each have four. Both Saturn and Uranus have large systems of moons. Astronomers have named all of the moons in the solar system. Earth’s moon is simply called "the Moon." Moons can be large or small, irregularly shaped or round. Larger moons tend to be more rounded in shape. Earth’s Moon is one of the larger moons in the solar system and is relatively round.

Earth has one large rounded Moon.

The Force of Gravity

Gravity, which is a force that draws objects together, holds the Earth in its orbit around the Sun and holds the Moon in its orbit around Earth. The strength of an object’s gravity depends on the mass of the object. Earth has a larger mass than the Moon; therefore, it has a stronger gravitational force. The Sun has far more mass than either Earth or the Moon, so it has the strongest gravity. The gravity of Earth, the Moon, and the Sun all affect Earth’s oceans. Earth’s gravity keeps the oceans on Earth, while the Moon and the Sun pull the water away from Earth.

People might expect the Sun to have the greatest influence on Earth’s oceans because it is so massive. However, the effect of a body’s gravitational force on another body also depends on how far away it is. Because the Sun is 39 times farther from Earth than the Moon is, the Moon exerts more than twice the gravitational force on Earth as the Sun does. Thus, the Moon’s gravity is the primary force pulling on Earth’s oceans. Because water is able to flow, Earth’s oceans are always bulging toward the Moon. The bulge corresponds to high tide and is sometimes referred to as a “tidal bulge.”

Centrifugal Force

At the same time, a second bulge forms on Earth’s opposite side. This bulge is not caused by a gravitational pull, but by centrifugal force, which is a force that draws a rotating body

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In this amusement park swing ride, centrifugal force causes riders to fly away from the axis of rotation.

away from the center of rotation. Centrifugal force is a type of "inertia," meaning that it does not exist if there is no movement. In this case the center of rotation is the point around which both Earth and the Moon rotate. One might assume that this point is at Earth's very center, but it is actually over 4,600 km away from Earth's center. This is about three-quarters of the way toward Earth's surface. As the Earth-Moon system rotates around this point, the side of Earth that is farthest from the Moon experiences a centrifugal force. Like the riders on an amusement park swing ride, ocean water is pulled away from the center of rotation. This forms a second tidal bulge that is the same size as the first. Thus, there are always two tidal bulges on Earth—one facing the Moon and one on the opposite side. Between these two bulges, the ocean water level is low. The low water forms a belt around Earth, and this low water causes low tide.

The Lunar Day

The position of the Moon relative to any location on Earth changes constantly. This is because Earth is rotating around its axis, and the Moon is orbiting Earth. Earth rotates once relative to the Moon every 24 hours and 50 minutes. This is called a "lunar day." It may seem strange that a lunar day is longer than a 24-hour solar day. This is because the Moon rotates around Earth in the same direction that Earth rotates on its axis. Therefore, Earth needs to rotate a little more in order to catch up with the Moon.

Tides

Because Earth has two tidal bulges, most locations on Earth will experience two high tides and two low tides during each lunar day. This is called a "semi-diurnal tide." However, some areas experience only one high tide and one low tide each day. This is called a "diurnal tide." Other places experience a tidal cycle that falls somewhere in between those two. This is referred to as a "mixed semi-diurnal tide." Some might wonder why each location on the ocean does not have two equal high and low tides each lunar day. The problem is that Earth's continents get in the way. They block the bulges of water from moving freely

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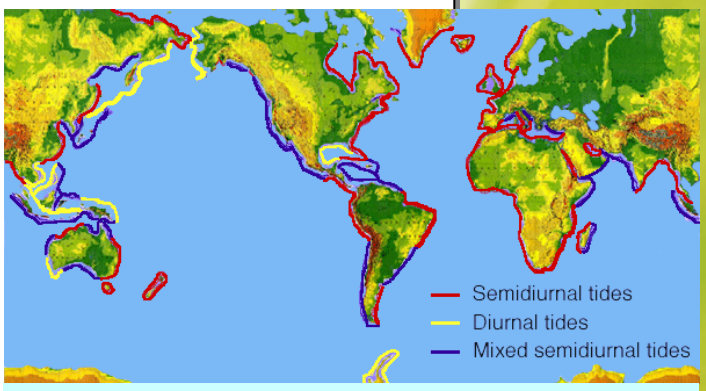
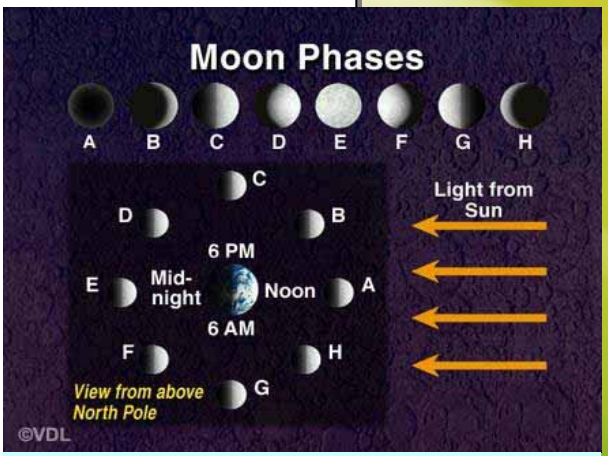
around the globe. This results in complex tidal patterns within each ocean basin.



This map shows the geographic distribution of different tidal cycles. Coastal areas experiencing diurnal tides are yellow, areas experiencing semi-diurnal tides are red, and regions with mixed semi-diurnal tides are blue.

Lunar Phases

Tides vary in height according to lunar phases. A lunar phase is defined by how the Moon looks to someone on Earth. There are eight lunar phases in all. A "full moon" is a lunar phase. About 2 weeks before a full moon, there is no visible moon. This is a "new moon"—another lunar phase. In the nights after a new moon, a small crescent-shaped moon can be seen. This phase is called a "waxing crescent." To "wax" means to grow or get bigger. After about a week, the moon looks like a half-circle. This lunar phase is called a "first quarter moon." The next phase is called "waxing gibbous." "Gibbous" means bulging outward. At this point the moon appears as a circle with the left edge erased. At about the 2-week point, the full moon appears—a complete circle. Over the next 2 weeks these phases are reversed. The moon gradually changes from full to new. This is called "waning." To "wane" is to fade or become smaller. The phases during this time are called "waning gibbous," "third quarter," and "waning crescent." A waxing moon and a waning moon are distinguished by which way the convex side (the side that curves outward) is pointing. A waxing moon points toward the right, while a waning moon points toward the left.



The moon appears different in each phase.

The shape of the Moon appears to change this way because it can only be seen when it is reflecting light from the Sun. The amount of the Moon that is visible and the shape of the lighted portion depend on the angles between Earth, the Moon, and the Sun. The Moon orbits Earth in approximately 27 days. Meanwhile, Earth

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orbits the Sun in about 365 days. This means that the angles between Earth, the Moon, and the Sun are constantly changing. When Earth, the Moon, and the Sun are aligned in that order, the side of the Moon that is receiving sunlight is not visible. Only the dark side of the Moon can be seen. This is the new moon. At the halfway point of the Moon's orbit, the opposite is true. The side of the Moon that is lit up by the Sun is visible, and the Moon is full. During the waxing and waning crescent, quarter, and gibbous moons, Earth is not lined up with the Moon and Sun. It is at an angle to them. As that angle changes, people can see more or less of the lighted side of the Moon.

High tides are very high and low tides are very low when Earth, the Moon, and the Sun are aligned. This effect is greatest at the perigee.

Spring and Neap Tides

We have seen that the number and frequency of high and low tides are controlled by the lunar day. However, the magnitude or height of the tide is controlled by the lunar phase. As mentioned above, during a full moon or a new moon, Earth is aligned with the Sun and the Moon. This combines their gravitational pull and results in very high tides and very low tides. The high tides are called "spring tides," but they have nothing to do with the season of spring.

The shape of Moon's orbit around Earth is an ellipse. This means that the distance between Earth and the Moon changes throughout the lunar month. The point at which the Moon comes closest is called the "perigee," and the farthest point is the "apogee." Sometimes the perigee coincides with a new moon. This increases the Moon's gravitational pull, causing a very high tide called a "perigean spring tide." These are relatively rare, occurring only every few years.

"Neap tides" occur during the moon's quarter phases. At these points the Sun and the Moon form a right angle with Earth and their gravitational forces work against each other. This results in lower high tides and higher low tides.