Introduction: Tides—The Rise and Fall of Ocean Water

Thousands of years ago sailors and beachgoers began to notice the **tides**, or the rise and fall of the sea around the edge of the land. They put their observations to practical use. The sailor discovered that his beached ship would float when the tide began to rise. When the tide lowered, more of the coastline became exposed and left edible plants and animals easy prey for those who gathered food. Observers of the sea also noticed that changes in the tide followed a regular **rhythm**. They began timing and measuring tidal changes and eventually were able to **predict** their regularity.

When the tide lowers, more of the coastline is exposed.

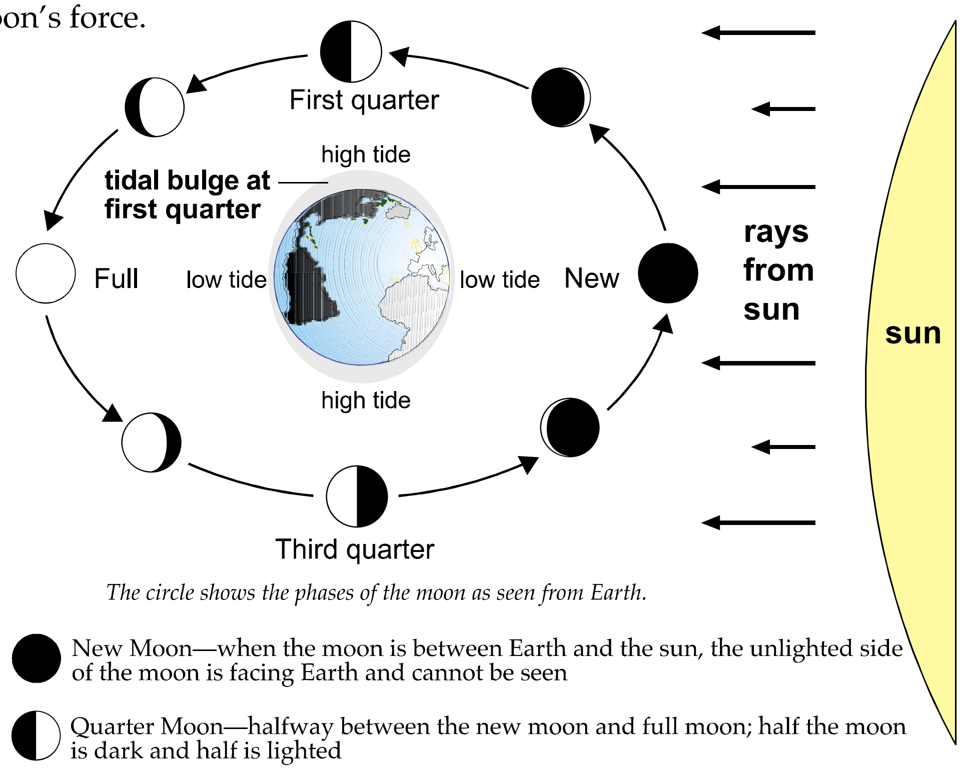
On most coastlines, observers noticed two high tides and two low tides occurring daily. Early observers must have been puzzled by the fact that the different tides occurred at different times each day. By 350 B.C., the famous Greek scholar Aristotle had discovered the link between the change in tides and the **phases** of the moon. But it was not until a few hundred years ago when Sir Isaac Newton (1642–1727) discovered the relationship between the moon's gravitational pull and the ocean's shifting tides that we began to understand what causes tides.

Causes of Tides: The Moon's Gravity

We're all familiar with the tale of Sir Isaac Newton sitting under a tree when a ripe apple fell on the noted scientist's brilliant head. The tale is a simple demonstration of Earth's *gravitational force*. Larger bodies of mass—such as the Earth, sun, and moon—exert a pull on smaller objects. We remain firmly rooted on Earth because of gravity. Earth remains in orbit because of the sun's gravitational pull, and the moon remains in orbit because of Earth's gravitational pull.

Tides are also the result of gravitational pull. Both the sun and the moon are large enough in mass to literally "pull" on the Earth's oceans. Because the sun is so far away from Earth, its pull in the oceans is less than half the pull of the moon.

To understand why tides change, imagine the following illustration. Let a ball or sphere represent Earth, and a slightly smaller sphere represent the moon. Begin to rotate Earth, imagining that our planet makes a complete rotation each 24 hours. You'll notice that Earth is continually presenting a different "face" to the moon. The moon exerts its strongest pull on the center, or nose, of this constantly changing face. The point of Earth closest to the moon is called the **zenith**; the point farthest from the moon on the other side of the Earth, is called the **nadir**. At Earth's zenith, there is an upswelling of water known as a **tidal bulge**. As the Earth rotates, the face changes, and so does the location of the nadir, zenith, and the tidal bulge. Although the ocean or gulf nearest you may never be exactly at the Earth's zenith, it, like all waters on the Earth's face, is raised by the moon's force.



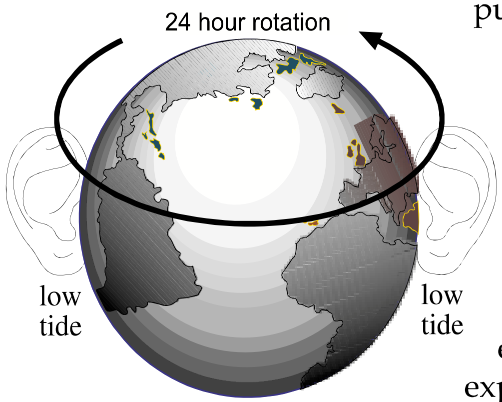
The circle shows the phases of the moon as seen from Earth.

New Moon—when the moon is between Earth and the sun, the unlighted side of the moon is facing Earth and cannot be seen

Quarter Moon—halfway between the new moon and full moon; half the moon is dark and half is lighted

Full Moon—when the moon is on the opposite side of Earth from the sun, the entire lighted side is facing Earth

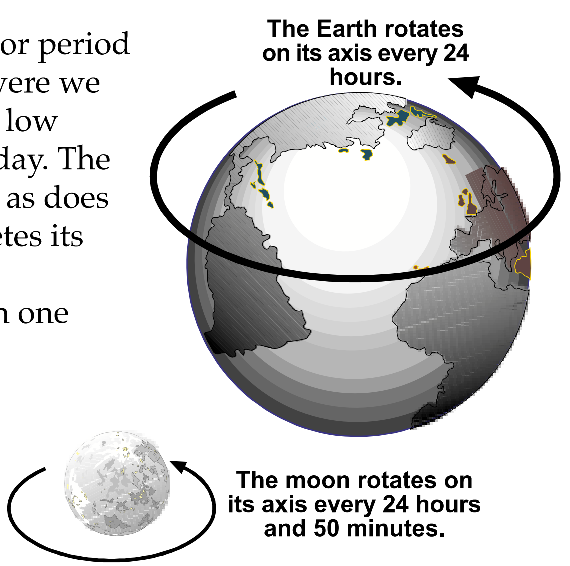
Remember, however, that there are usually two high tides and two low tides daily. Thus far we've explained why the beach nearest you experiences one high tide. What causes the other high tide? Surprisingly, the other high tide occurs when the ocean or gulf nearest you is at its furthest point from the moon or when it is at the back of Earth's face. At that point, a phenomenon called *centrifugal force* pulls water away from the Earth. Just as Earth and the moon exert a pull on one another, each is also pulled equally away from one another by the force of their rotations. Centrifugal force keeps Earth and the moon from colliding and exerts a pull on Earth's water farthest from the moon.



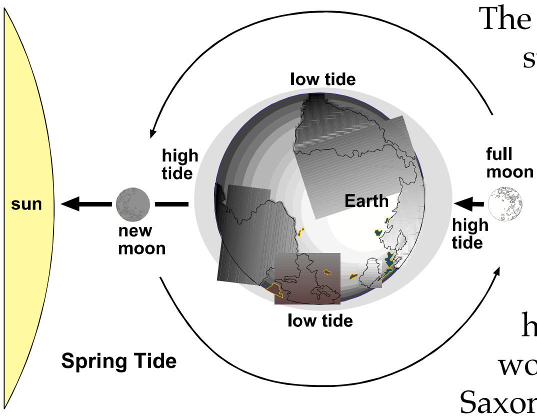
The Earth always shows a "face" to the orbiting moon and always hides a backside of this face. To complete our image, imagine two "ears" on either side of the face. When the ocean or gulf reaches each ear—two times every 24 hours—it experiences a low tide.

The Tidal Day: 24 Hours and 50 minutes

Not until we understood the cycle or period of the moon's orbit around Earth were we able to explain why high tides and low tides occur at different times each day. The moon rotates in the same direction as does Earth. The moon, however, completes its orbit at a slower speed than Earth. Consequently, it will take the moon one Earth day (24 hours) plus an extra 50 minutes to reach the same position that it occupied yesterday above your nearby coastal waters.

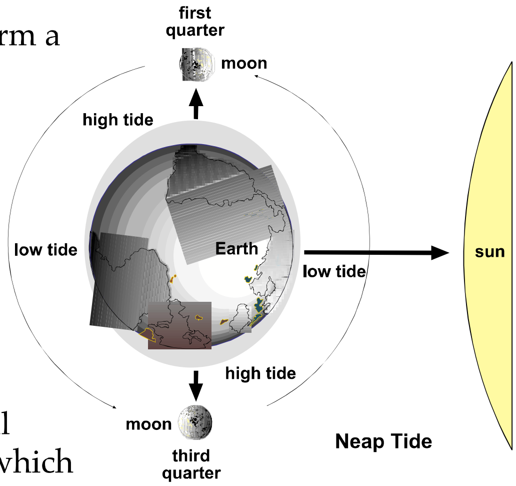


Spring and Neap Tides: Extra High and Low Tides



The orbits of Earth, the moon, and the sun place them in a straight line twice a month—at the full moon and new moon. In this alignment, the moon and sun work together in creating the strongest gravitational pull on Earth's oceans. This super-pull produces a higher tide called a **spring tide**. The word *spring tide* comes from the Anglo-Saxon word *springen*, meaning to *jump up*.

When Earth, the moon, and the sun form a right angle with the Earth at its intersection, the gravitational pull on the ocean is at its weakest. This weaker tide is called a **neap tide** and also occurs twice a month during the first and third quarters of the moon.

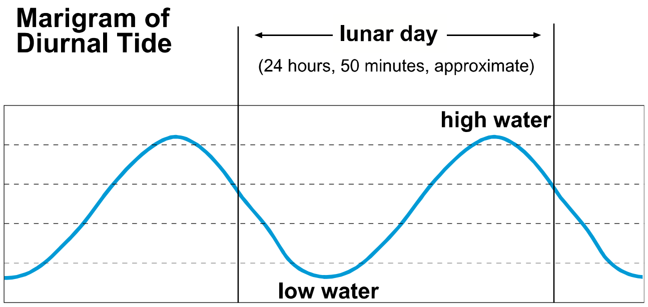


Types of Tides

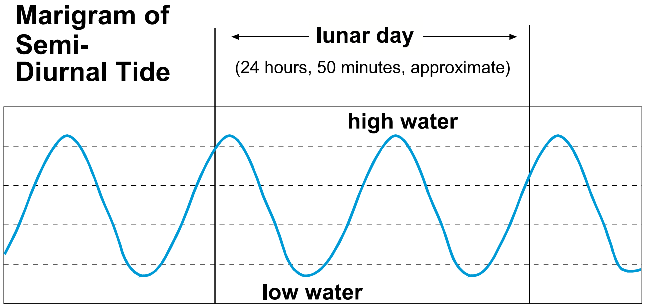
Along some coastlines there are coastal bays and channels. Unlike the ocean, which is nearly equal in its width and length, bays and channels are long and narrow. This shape alters the incoming tide. It may increase or decrease the height of the ocean's tides. In addition, differences in coastlines and seafloor topography also alter the tides.

Bays, channels, and **estuaries** often have a wide **tidal range**, or the difference between the heights of a consecutive high tide (**flood tide**) and a low tide (**ebb tide**). They have higher ranges than other coastal formations because a lot of water must go in and out of a small area. In estuaries, the tidal range can be extremely high. The largest tidal range known in the world occurs in the Bay of Fundy. Water levels in the Bay of Fundy can range over 50 feet at times. High rock walls and narrow passages force the water higher, creating higher tides. When the wave front is a steep wall of turbulent water, it is called a **tidal bore**. Some adventurous people have been known to surf this wall of water! Some scientists and engineers are studying tidal bores for their potential use in generating electrical power.

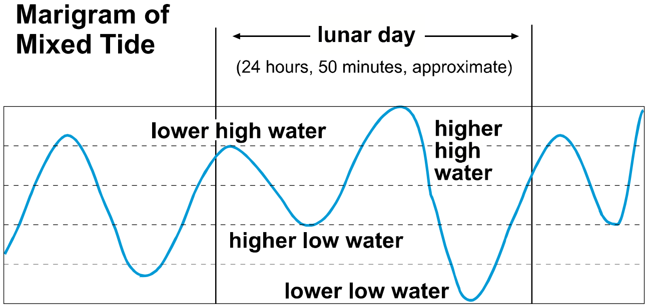
Although most bodies of water have two high and two low tides daily, there are exceptions. Some places in the Gulf of Mexico (off the West Coast of Florida) have only one high tide and one low tide each day. Such tides are called **diurnal tides** and are also common along the coasts of Vietnam and China.



Most locations in the world experience little or no difference between their two high- or low-water heights. In a waterway such as the Mediterranean Sea, there is practically no difference between the heights of two high and low tides. This type of tide is called a **semidiurnal tide**. Most tides along the East Coast of the United States and around the Atlantic Ocean are *semidiurnal*.



The **mixed tide** has two high-water levels and two low-water levels each day but with extreme differences between the heights of the two high- and/or the two low-water heights. Tides along the Pacific Coast of the United States and many Pacific Islands have *mixed tides*.

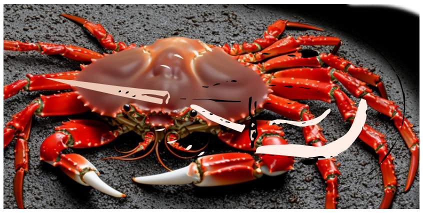


You can determine the type of tide in a particular area by plotting the times and heights of the tides. This type of graphic record is called a **marigram**.

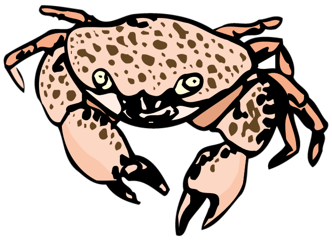
Tidal Influences: The Highs and Lows of Marine Organisms

The ocean's shifting tides present both benefits and hardships for organisms living near the coastlines in the **intertidal zone**. The intertidal zone, also known as the *littoral zone*, is the area between high tide and low tide. At high tide, many areas are covered by water, and at low tide the areas are exposed to the air. This causes changes in temperature, humidity, and the salinity of the seawater these organisms live in. Organisms that cannot adapt cannot survive the changing environment.

Many organisms have evolved to use the changes in tides for their own benefit and depend upon the tides for their survival. For example, the horseshoe crab's life cycle relies on the rhythm of the tides. In May and June, large numbers of horseshoe crabs gather in the shallow estuary areas along the Atlantic and Gulf coasts to mate. The horseshoe crabs wait in the shallow waters for a new or full moon. When the full or new moon arrives, the tide is at its highest, and the horseshoe crabs come ashore in male and female pairs. The smaller male horseshoe crab typically will hitch a ride onshore attached to the larger female crab's back. The female horseshoe crab has a cluster of eggs on her abdomen which is fertilized externally by the male horseshoe crab. The female crab deposits the fertilized eggs in a nest she has hollowed out in the sand. At the time of the next high tide, usually a month later, the eggs hatch and the young move back into the ocean. Horseshoe crabs have developed a natural cycle that matches the phases of the moon and lay their eggs at the time of month when their offspring are most likely to survive. Do you know of any other marine organisms that depend upon the tides for mating or survival?



The horseshoe crab's life cycle relies on the rhythm of the tides.



Small creatures such as crabs live in tide pools at low tide.

Outgoing tides do not always carry back all of the water from incoming tides. If the ground near the shore is not smooth, pockets of water can be trapped, forming **tide pools**. Tide pools are often found on rocky coasts, marshy areas, or sandy beaches. Small creatures such as crabs, fish, and sea urchins live in these pools at low tide. These animals must be able to withstand high temperatures and salinities during low tide.

Summary

Gravitational pull by the moon and sun produces tides, or changing levels of water, in Earth's oceans. These tides are really long waves that rise and fall according to their position in relationship to the moon and, to a lesser degree, from the sun. As the Earth and moon rotate, different regions of the ocean rise and fall as they move nearer and farther away from the moon and the sun. This constant shift in water elevation will periodically expose some coastlines and their organisms to air and change the chemistry of coastal waters. Organisms must be adapted to these constant changes in temperature, humidity, and salinity if they are to survive. Tides are important to marine life. The daily change of tides allows for nutrients to flow from an estuary to the open ocean. Tides also transport marine organisms from one location to another and provide many marine organisms with a mechanism for reproduction. Tides create the environmental conditions of marine organisms that live in the harsh *intertidal* zone between the high-water mark and the low-water mark.