Tides

TIDE BASICS

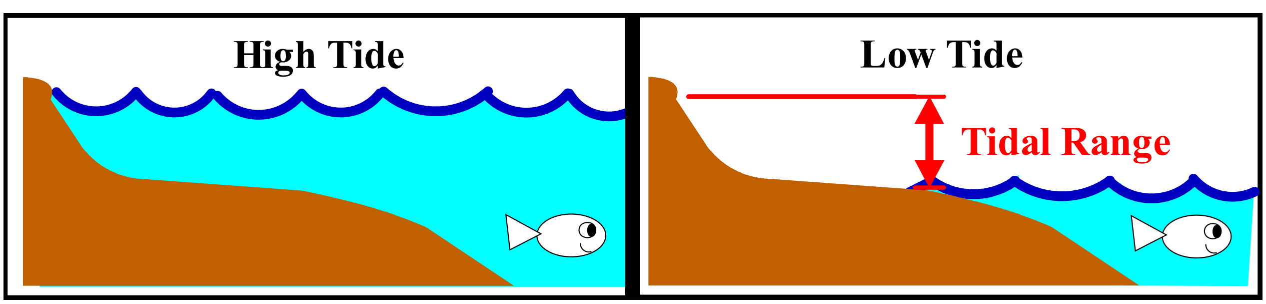
What are tides?

Tides are the slow, daily rise and fall of the ocean surface over a large area caused (primarily) by the gravitational pull of the Moon. In most places, there are 2 high tides and 2 low tides each day (24 hours), so it takes about 6 hours for the ocean to go from high tide to low tide.

High Tide

Low Tide

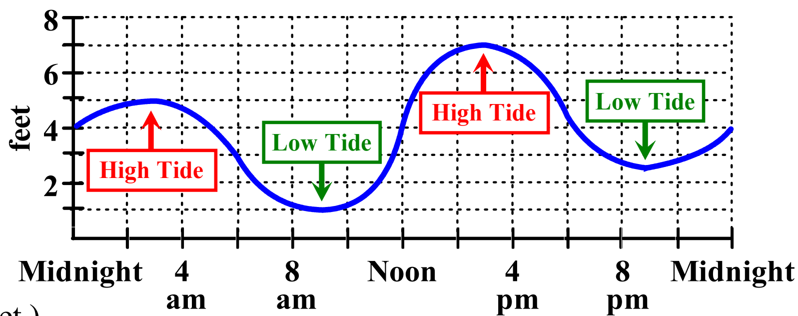
High Tide (right) and **Low Tide** (left). Courtesy of Samuel Wantman (CC BY-SA 3.0).



Reading Tide Charts

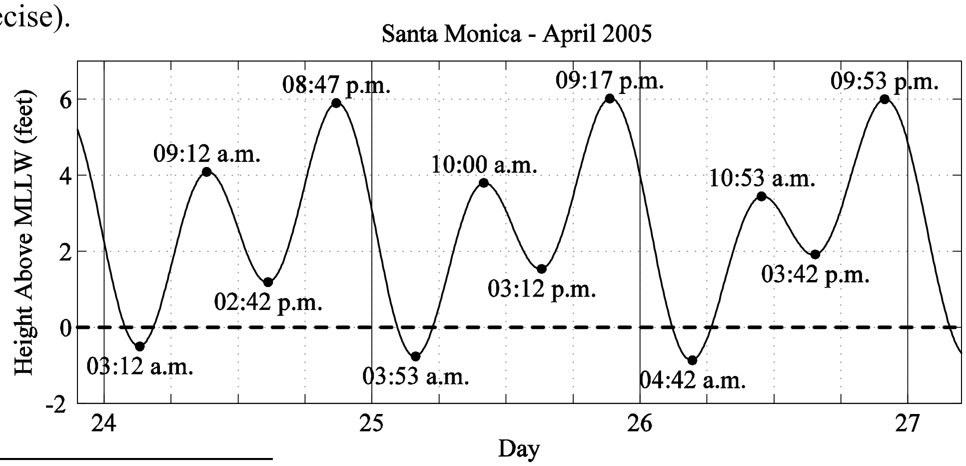
Tides are typically described using tide charts. Reading tide charts is fairly straightforward. The high points (peaks, crests) in the curve indicate high tides, and low points (valleys, troughs) indicate low tides. The chart below shows high tides at 3 a.m. and 3 p.m., and low tides at 9 a.m. and 9 p.m. Sea level rises to 5 feet during the 1st high tide, and 7 feet during the second. It drops to 1 foot during the 1st low tide, and 2.5 feet during the second. Sea level measurements are typically made relative to mean low low water (MLLW), the average of the lowest daily low tides over a long period of time. Thus, a high tide with a height of 4 feet is 4 feet above the typical lowest-low-tide-of-the-day.

The difference in height between successive high and low tides is called the called the ***tidal range***. In the chart shown on the right, the largest tidal range in 6 feet, the difference in height between the 1st low tide (1 foot) and the 2nd high tide (7 feet). (Tidal range = 7 feet – 1 foot = 6 feet.)

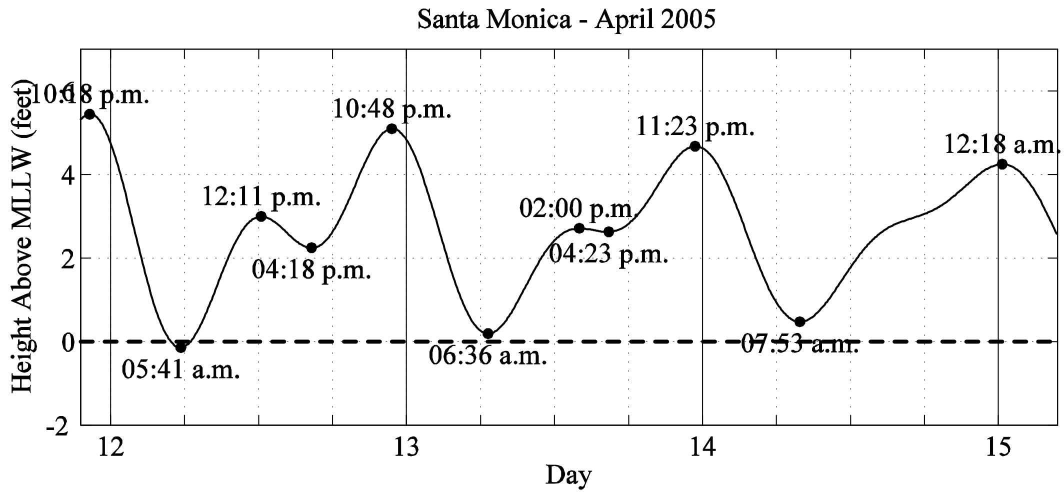


Observations of the Tides

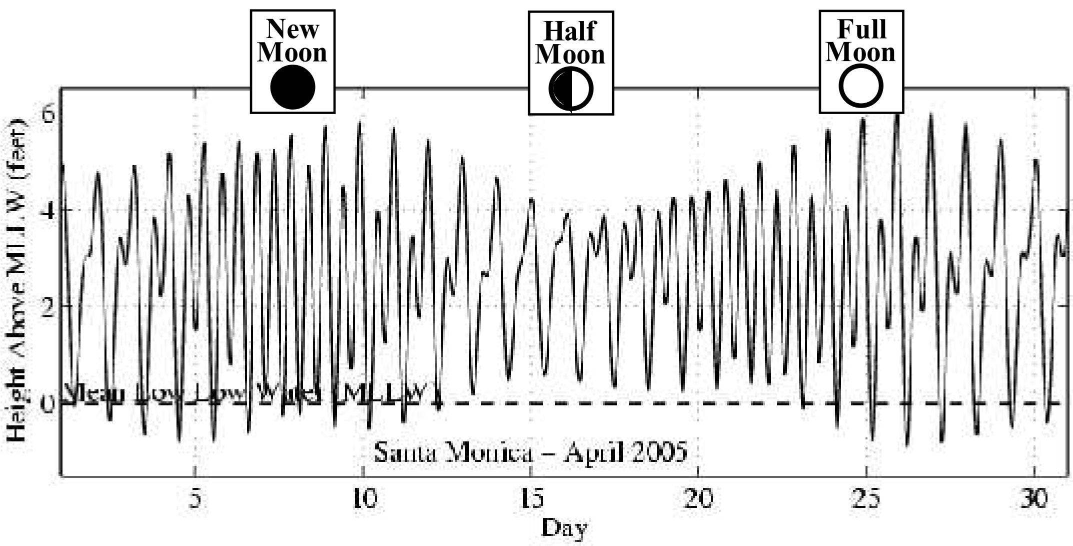
The tide chart below <u>and on the next page</u> shows the tides over a few days. Some interesting features stand out. Typically there are 2 high tides each day, but there are some days with only 1 high tide and/or 1 low tide[1] (e.g., April 14th on the next page). (In some places, this is normal!) Along our coast, the time between high and low tide can vary from about 4 hours to nearly 8 hours. On average, it takes about 6 hours and 10 minutes to go from high tide to low tide (and vice versa), so on most days it takes a little over 24 hours to complete the cycle. This means (and the chart shows) that tides typically get a little later each day. Some days, a tide may only be 20 minutes later than the previous day, on other days a tide may be 2 hours later than the previous day. On average, tides are close to an hour later each day (about 50 minutes, to be a bit more precise).



[1] Sometimes this is related to the fact that high and low tides are at little more than 6 hours apart on average. In other cases it is related to the competing pulls of the Moon and Sun on the ocean (they effectively "cancel" one another out).



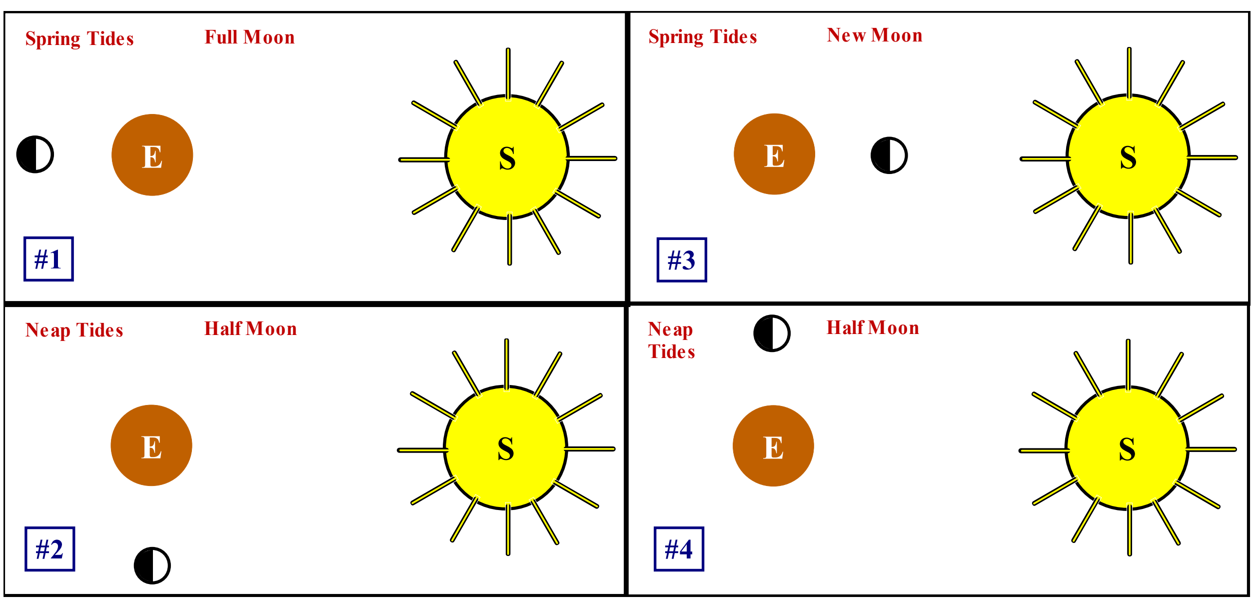
Notice the link between tides and the phase of the Moon in the tide chart below showing an entire month of tides. High tides are highest and low tides are lowest during the full moon and the new moon, whereas high tides are not very high and low tides are not very low during a half moon. We call the large tidal range (difference between high and low tides) during full moon and new moon "spring tides," and the small tidal range (very little difference between high and low tides) during half moons "neap tides." It takes about a week for the phase of the Moon to change, so tides switch from spring tides to neap tides in about a week.



Phases of the Moon during an entire month. (Public Domain)

Note that spring tides do not happen during the spring. Think of spring tides as "springing up" or "jumping" high. Of course, to jump high, you have to bend your knees (you have to go down low) first. (Just try jumping without bending your legs: you'll look pretty funny.) In the same way, spring tides have to go down very low before they can jump up high. Think of ***n***eap tides as ***n***ot very high and ***n***ot very low; associate the "N" in ***n***eap with the idea that tides are ***n***ot extreme during ***n***eap tides, that there is ***n***ot much change.

Do you know why the Moon has phases? Do you know why the face of the Moon changes over a m onth? The Moon orbits the Earth once per month; in other words, it takes a month for the Moon to travel all the way around the Earth. (Just look at our word "month:" it includes the word Moon! Perhaps we should call it a Moonth instead…just remember, you heard it here first.) The Moon shines at night because the Moon reflects the light of the Sun (the light bounces off of the Moon towards the Earth). Of course, only the part of the Moon facing the Sun receives light; the part facing away from the Sun is dark. As the Moon orbits the Earth, sometimes we see more of the bright side, the part facing the Sun, and sometimes with see more of the dark side, the side facing away from the Sun. Full moon is when we only see the bright side of the Moon, and new moon is when we only see the dark side of the Moon. Half moon is when we see equal amounts of the bright side and the dark side. As the picture below shows, full moon (#1) is when the Moon and Sun are on opposite sides of the Earth, so we see the bright side of the Moon. The Moon reaches the half moon position (#2) in about a week later as it travels around the Earth. (At this point, it is ¼ of the way around. A quarter of a month is approximately a week.) In about another week, the Moon and Sun are on the same side of the Earth at new moon (#3): we can only see the dark side of the Moon.



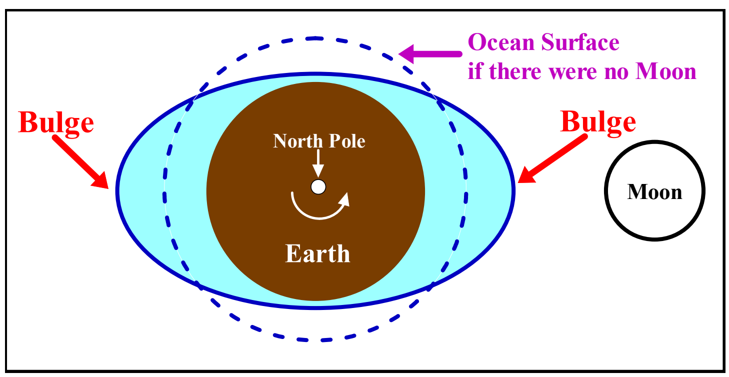
EXPLAINING THE TIDES:
THE BULGE THEORY OF THE TIDES

The "Bulge" Theory of the Tides is the Simplest, But Not the Best, Theory of the Tides

There are several "theories" of the tides. The "bulge" theory of the tides is better known as the "equilibrium theory of the tides." It was the first "good" theory of tides and was created by Isaac Newton with his Theory of Universal Gravitation and Laws of Motion. As is common in science, Newton made simplifying – but unrealistic – assumptions when trying to understand the basic issues of the phenomenon. (Otherwise, you get bogged down with details.) For example, the bulge theory assumes that there are no continents and that the ocean floor is perfectly flat and very deep (far deeper than 2.5 miles). The bulge theory makes accurate predictions about the number and approximate timing of tides as well as their relative sizes, but cannot be used to calculate the actual time and height of the tides with much precision (expect to be off by a few hours and a few feet) because of the poor assumptions. In this class, we will study the "bulge" theory of the tides, because it is the simplest theory of the tides which captures the basic causes of the tides.

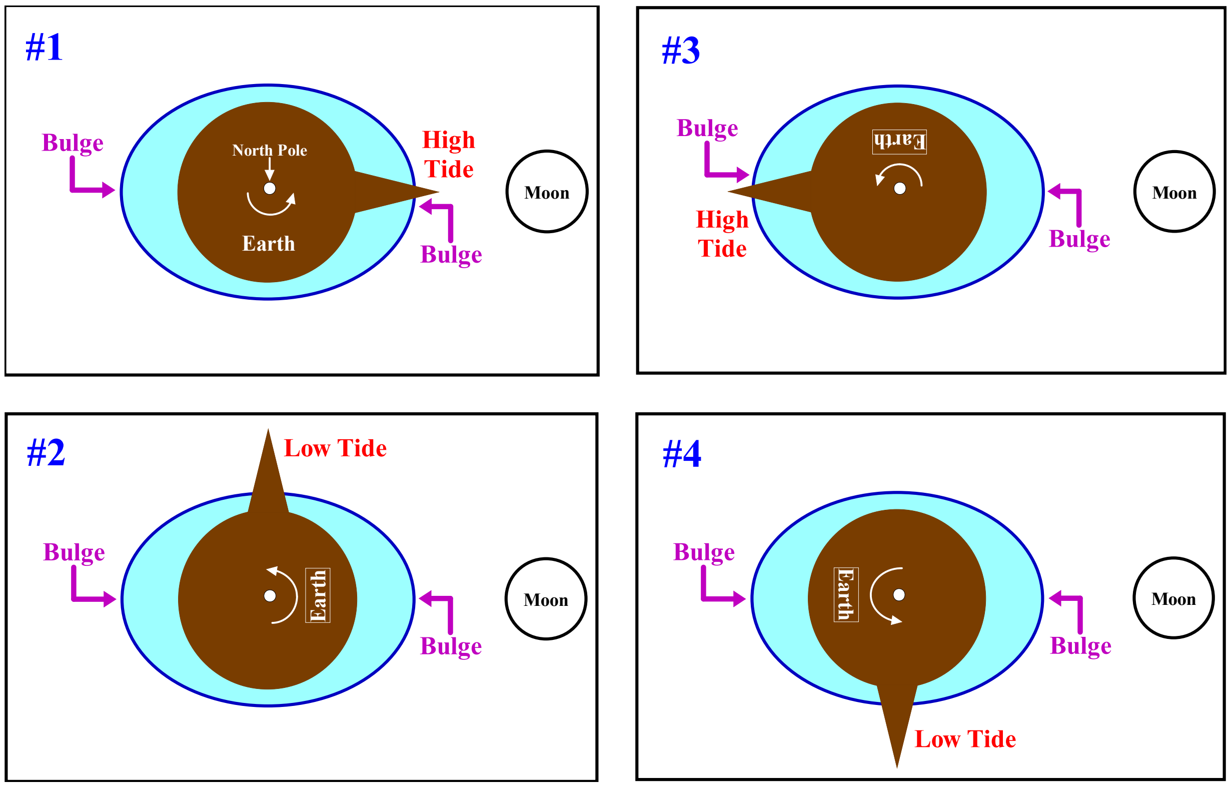
What is the bulge theory of the tides? How does it work?

According to the bulge theory of the tides, there are two bulges in the ocean, places where the sea surface is higher than normal, on opposite sides of the Earth. One bulge points towards the Moon, and the other bulge points away from the Moon. The water that makes the sea surface higher at the bulges comes from the other 2 sides of the sides of the Earth (it has to come from somewhere) which lowers the sea surface at these locations. The 2 places where the sea surface is higher are, of course, experiencing high tides, and the 2 places where the sea surface is lower are experiencing low tides.



Two bulges in the Earth's ocean results in 2 high tides and 2 low tides per day, with 6 hours between high and low tide. Each day, the Earth rotates on its axis (spins all the way around 1 time). The bulges, on the other hand, stay facing the Moon and facing away from the Moon as the Earth turns underneath. As a result, every location on the Earth goes into a bulge (high tide), then out of the bulge (low tide), then into the other bulge (high tide), and then out of the bulge (low tide). Thus, each location on the Earth experiences 2 high tides and 2 low tides per day. It takes 24 hours (1 day) for the Earth to turn all the way around, so it takes 6 hours for the Earth to turn a quarter ($1/4^{th}$) of the way around and therefore for a location to move from a place in a bulge (high tide) to a place outside a bulge (low tide) or vice versa.

> Note:
> The Earth moves, not the bulges.



Why are there 2 bulges in the surface of the ocean?

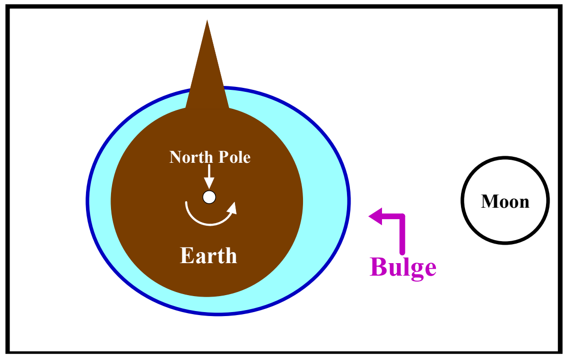
Pay attention to the island – the brown triangle – in the pictures above as the Earth spins all the way around in a day.

Anyone with a basic familiarity with gravity may be confused by the claim that there are 2 bulges in the surface of the ocean. Gravity is an <u>attractive</u> force; all objects in the universe are attracted to all other objects in the universe. (So you feel a gravitational attraction towards all men, all women, tables, chairs, pencils,…you cannot deny it!) The strength of the attraction depends upon the mass of the objects (the "heavier" the objects, the stronger the attraction) and how far apart they are (the farther apart the objects, the weaker the attraction). For example, the Earth exerts a stronger pull on me than a person, because it is much more massive. The Earth also exerts a stronger pull on me than the Sun (otherwise I would fly up into the sky at dawn): even though the Sun is much more massive, it is also much farther away.

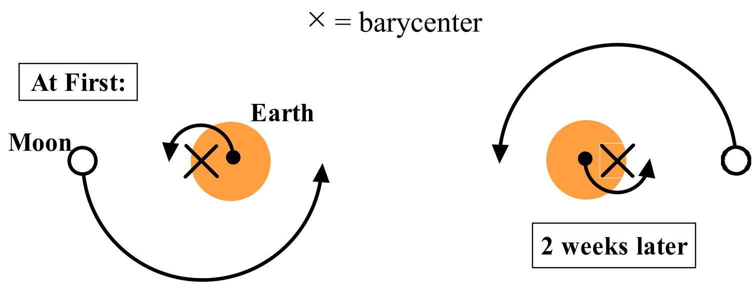
There is one final rule for gravity: the objects feel exactly the same attraction for one another. (The attraction is mutual, equal, and in opposite directions.) Thus, the Earth is attracted to me exactly as much as I am attracted to it. When I jump, I'm pulled down a lot more than the Earth is pulled up, because I'm much less massive (easier to push around). Similarly, if you go up to a person and give them a push, you could probably knock them down, but if you give the same push to a car, it is not going anywhere (it is much more massive than the person, so the force has a much smaller impact on it).

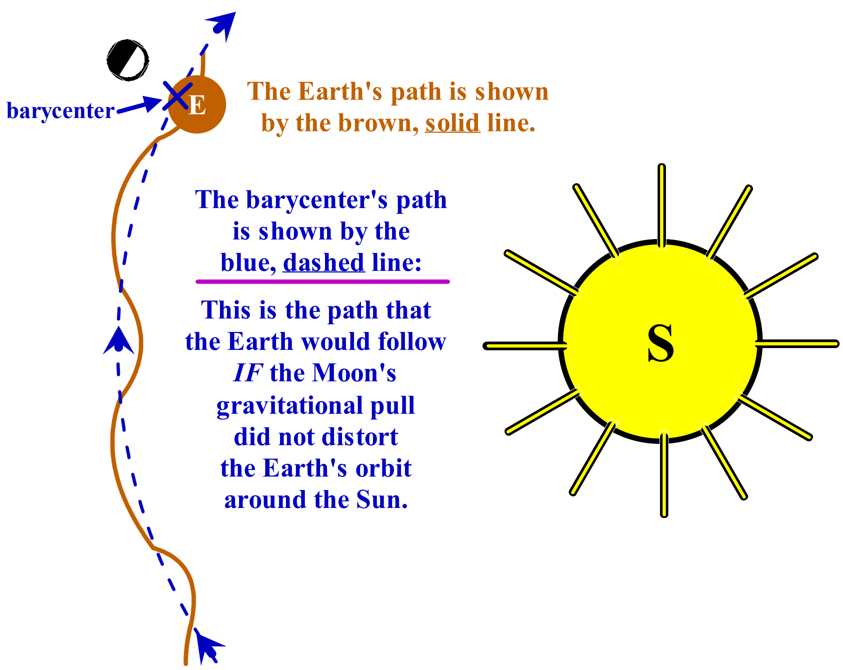
Suppose that romantic attraction worked liked gravity. Sumo wrestlers (very massive = very attractive) would be on the covers of our celebrity magazines, long distance relationships would not work out (absence does not make the heart grow fonder; instead, it weakens the attraction), and there would be no such thing as unrequited love (when you love someone else, but they don't love you): if love worked like gravity, then attraction would always be mutual and exactly equal.

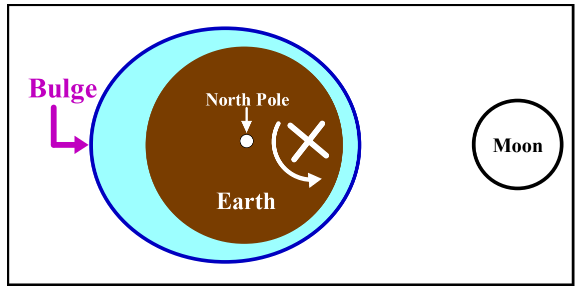
Thus, the Moon's gravity pulls on the ocean water, pulling it towards the side of the Earth that it is on and pulling water ***away*** from other side. As you can see in the picture on the right, this only causes 1 bulge in the surface of the ocean. As one day passed, every location on the Earth would go into the bulge (high tide) and then out of the bulge (low tide) leading 1 high tide and 1 low tide each day, 12 hours apart. Clearly this is wrong. What, then, causes the other bulge?



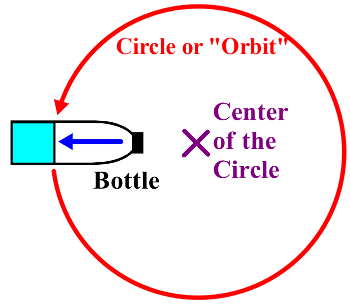
Not only does the Moon's gravity pull on the ocean water, it also pulls on the Earth, and it is strong enough to move the Earth a little (if you push a car, it won't go anywhere because your push is too weak, but you can make it rock or wiggle a bit). The Moon's gravitational attraction makes the Earth do a small orbit around a place in space we call the "barycenter" (the "×" in picture above). Barycenter means "heavy center," because the Earth orbits this place as if there were a heavy object there. The orbit is so small that the barycenter is always inside the Earth!





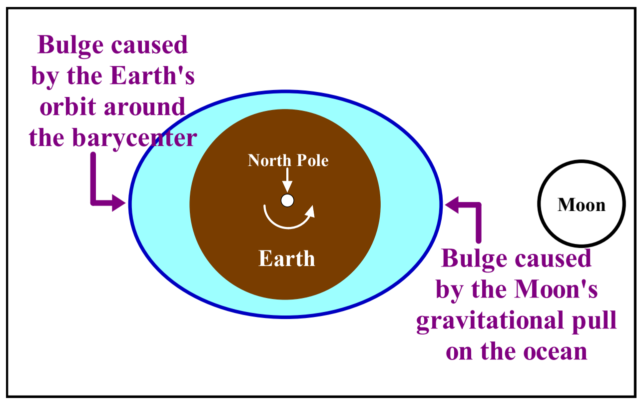


The ocean's water also goes around the barycenter with the Earth, but it isn't solid, so it sloshes around. If you think of your own experiences going in a circle, you know that objects get "flung" towards the outside, away from the center of the circle (e.g., riding on a merry-go-round or that amusement park ride where you stand against a wall and as it spins, you are "pressed" up against the wall – better yet, do the experiment in the box below!). In the same way, the water on the Earth gets "flung" away from the barycenter (and the Moon!) owing to this orbit around the barycenter, causing a bulge on the side of the Earth away from the Moon and creating the second bulge!



Experiment: Fill a clear bottle with some liquid, about halfway or less (or just go get any partially empty, clear bottle out of your refrigerator). Now, spin in place and watch the liquid. Notice how it moves away from you, <u>away from the center of the circle</u>.

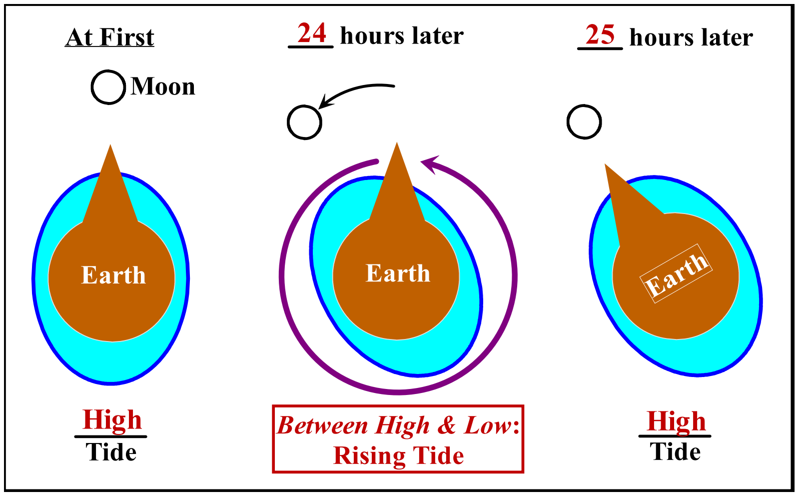
Someone who has been paying attention will say: "Wait a minute, don't the two affects cancel one another out? Won't the stronger one win, resulting in just 1 bulge?" The answer to this question is "no, the two effects do not cancel," because the Earth is very large. Recall that the farther apart two objects are, the weaker the gravitational attraction is. Thus, the Moon's gravity exerts a stronger pull on ocean water on the side of the Earth close to it, and a weaker pull on the ocean water on the far side of the Earth. On the side of the Earth closest to the Moon, the Moon's gravity overcomes the tendency for the water to get flung away from the barycenter, creating a bulge towards the Moon. On the side of the Earth away from the Moon, the Moon's gravity is not strong enough to hold the ocean water in, so it gets flung away from the barycenter, creating the 2nd bulge.



Which bulge is larger? Both effects ***do*** cancel out <u>at the center of the Earth</u>, midway between the two bulges, so the two bulges are the ***same size***!

It is accurate to say that Moon's gravity causes the tides. Note, though, that it is the Moon's gravitational pull on ***both*** the ocean water and the Earth (causing the small orbit around the barycenter) that results in the tidal bulges. Also, it is <u>not</u> just the strength of the Moon's gravitational pull that determines how large the bulges become, but how <u>different</u> the strength of the pull is on each side of the Earth. As we will discuss soon, the Sun also affects the tides. The Sun clearly exerts a stronger gravitational pull on the Earth than the Moon (even though it farther way, the Sun is much, much larger than the Moon), because the Earth orbits the Sun, not the Moon. However, each side of the Earth is about the same distance from the Sun, so there is a much <u>smaller difference</u> in the strength of the Sun's pull on the ocean water on each side of Earth, resulting in a smaller effect on the tides.

Why do the tides get later by about an hour each day?

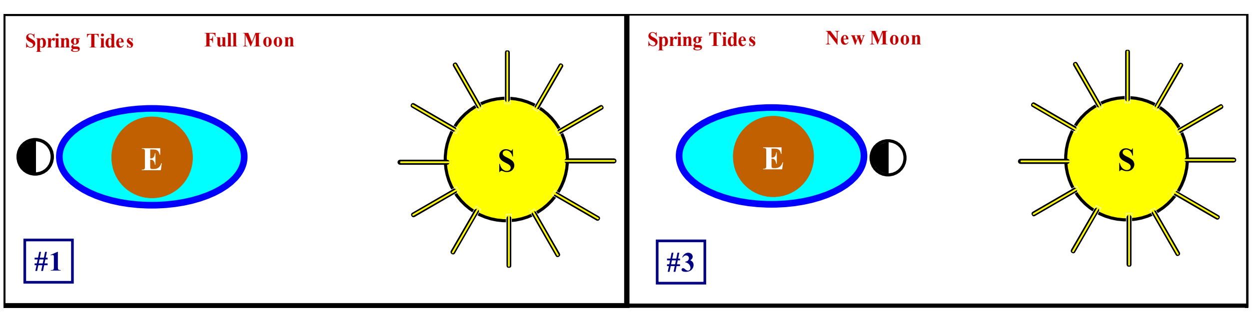


It takes the Moon about a month to orbit the Earth, so in a single day it moves "a little" (about 1/30th of its orbit). If a location is at high tide (beneath the Moon), and then the Earth spins 1 time all the way around (1 day passes), the location will not be underneath the Moon again and at the high point in the bulge, because the Moon and bulge have shifted a little bit. The Earth needs to turn a little bit farther to bring the location underneath the Moon and thus to high tide. (We call a day plus the amount of time it takes to come back underneath the Moon a "lunar day" which is a bit longer than an ordinary day.) How long does it take the Earth to "catch up" with the Moon? Well, if the Moon goes through 1/30th of its orbit, then the Earth needs to turn 1/30th more, which is 24 hours / 30 = 48 minutes (about an hour, as we discussed in the observations section).

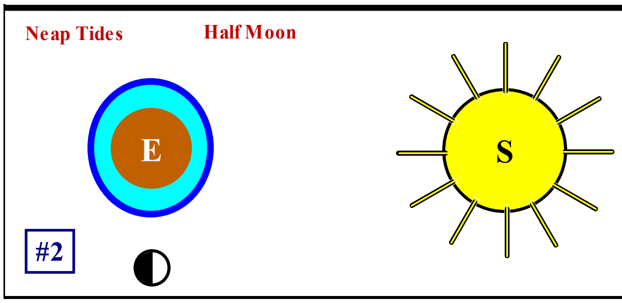
What causes spring tides and neap tides? Why are they linked to the phases of the Moon?

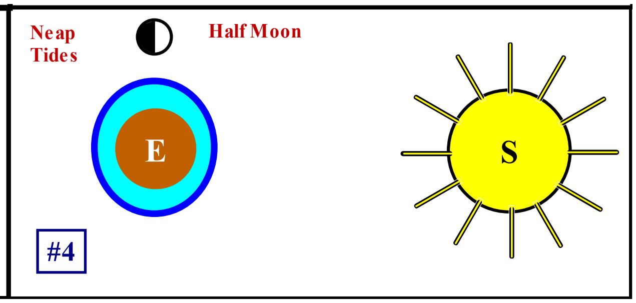
Recall that spring tide conditions are when the tidal range is large (high tides are very high and low tides are very low) at new moon and full moon, and that neap tides conditions are when the tidal range is small (high tides are not very high, and low tides are not very low) at half moon. Spring and neap tides result from the Sun helping the Moon create the tides or working against it. Like the Moon, the Sun tries to create 2 tidal bulges, one towards the Sun and one away from the Sun. However, the Sun's effect on the tides is smaller than the Moon's effect (about ½), so the Moon always "wins;" in other words, the Moon determines where high and low tide will be.

Notice that spring tide conditions are strongest when the Earth, Moon, and Sun are all in a line (new moon and full moon). Under these conditions, the Moon and Sun are trying to create high and low tides in the same places. (Remember, they both try to make a bulge on the side of the Earth facing them and the side of the Earth facing away from them.) Thus, the Sun is helping the Moon pull water from the low tide places to the high tide places, making the high tides higher and the low tides lower.



Neap tide conditions are strongest when the Earth, Moon, and Sun are in an "L"-shaped formation (with the Earth in the corner or "bend" in the "L"). Under these conditions, the Moon and Sun are working against one another: the Moon is trying to create bulges towards and away from the Moon, and the Sun is trying to create bulges towards and away from Sun. Because the Moon has a stronger effect on the tides, it "wins," and the high tide bulges face towards and away from the Moon. However, the bulges are unusually small, because the Sun is pulling water from high tides places to the low tide places, making the high tides lower and the low tides higher.





Other Factors

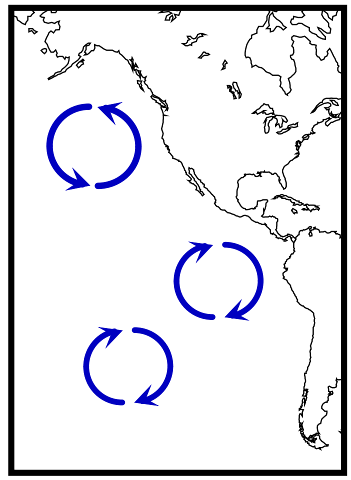
There are many more features of the tides that can be explained using the bulge theory of the tides. At the moment, though, I suspect your brains are probably "full." Now that we have discussed an oversimplified view of the tides, let's look at how real tides behave.

For example, at the mid-latitudes, the 1st high tide of the day is usually higher than the 2nd high tide of the day (or vice versa). This is caused by the fact that the Moon's orbit does not keep it over the Equator; it orbits at an angle to the Equator. So, sometimes the Moon is above the Equator and sometimes it is below the Equator, which shifts the bulges, making each one larger in one hemisphere and smaller in the other. Another example: orbits are elliptical, not circular, so sometimes the Moon is closer to the Earth (high tides are higher and low tides are lower). The same is true of the Earth's orbit around the Sun.

REAL TIDES

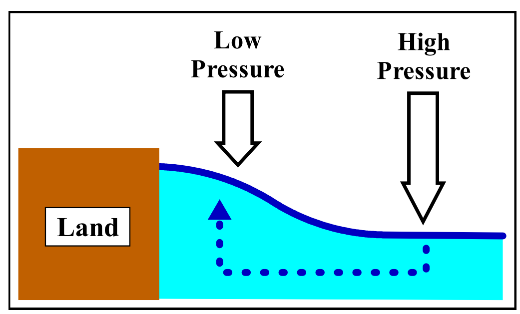
Real tides can differ significantly from the predictions of the bulge theory of tides, because the bulge theory does not take into account a variety of factors like the presence of the continents, the depth of the ocean, weather conditions, and the shape of the shoreline. These factors can be strong enough to drastically alter the tides. For example, there are some places with only 1 high tide and 1 low tide each day. (This is the normal tidal pattern for these places.)

Global Factors

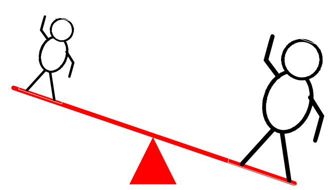


Perhaps the most obvious reason that the bulge theory of tides fails to accurately predict the tides is that the continents get in the way of the bulges. As the Earth turns, the bulges try to stay underneath the Moon (and on the side away from the Moon). In doing so, the bulges move over the ocean floor, but they cannot travel over the continents. Instead, the bulges bounce off the continents, split up into smaller bulges that travel around the ocean basins in large circles, and try to reach the positions predicted by the bulge theory of tides. The motion is partially related to the Coriolis effect, something discussed in more detail in section 8A "The Atmosphere and Winds." In essence, the Coriolis effect causes objects (the tidal bulges) moving over the surface of the Earth to bend off course (owing to the Earth's rotation). In addition, "drag" from the bottom of the ocean also slows down the bulges, keeping them from remaining under the Moon. Tides "feel the bottom" at all times, because they have huge orbitals (due to their very large wavelength, the distance between the bulges). Only at the Poles (where there is less distance to cover) can they move fast enough to stay under the Moon. In other places, the bulges are often "ahead" of the Moon, because the Earth rotates faster than the Moon orbits the Earth, the bulges tend to be pushed out from under the Moon owing to friction with the bottom of the ocean.

Local Factors

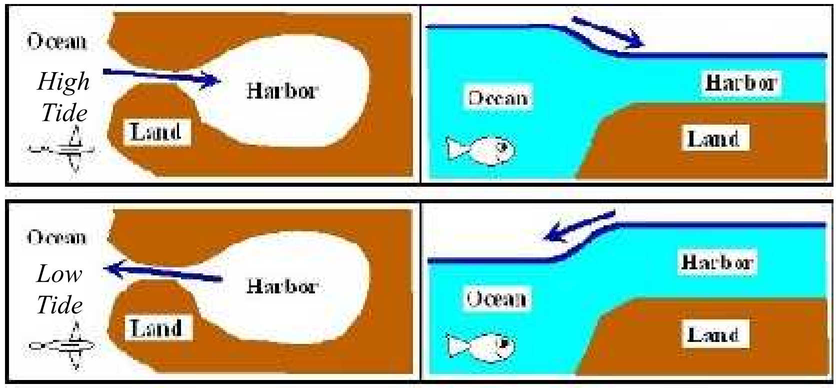


Storms are low-pressure systems, causing the sea surface to rise beneath them. Very large storms (e.g., hurricanes) cause the sea surface to rise significantly (20+ feet), and the resulting "storm surge" can flood the shoreline when they hit land. (This is how Hurricane Katrina broke the levees in New Orleans.) Recall that air pressure is caused by the weight of the air above pressing down. Outside the storm, air pressure is higher and therefore pushing down more strongly on the ocean surface. The ocean surface goes down beneath the high-pressure air, and rises up where the downward push is weakest (and therefore cannot keep it from rising), beneath the storm. (The water that is pushed down has to go somewhere.) This is somewhat like a "teeter-totter" or "see saw" on a playground. If a heavy person sits on one end and a light person sits on the other, the end with the heavy person goes down and the

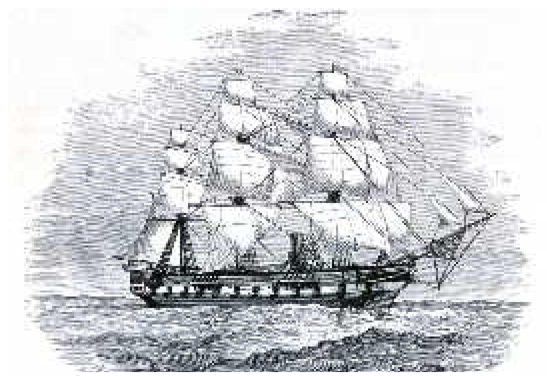


end with the light person goes up; the downward pressure of the light person is simply not enough to keep it down.

Tides play an important role in ***creating currents*** in many estuaries. As sea level rises towards high tide in the ocean, water flows into the estuary (because sea level in the estuary is now lower than in the ocean), and when it sinks towards low tide in the ocean, water flows out of the estuary (because in the estuary sea level is now higher than in the ocean). In estuaries that are large and have narrow or shallow connections with the ocean, it can take a long time for the water to flow in or out. Thus, the tides inside estuaries are often delayed, and may not have the same height as the tides along the coast.



The greater the size of the estuary and the smaller connection with the ocean, the faster the water moves into or out of estuary. (The water has to move fast to get water in and out through a small opening in the required amount of time.) Tidal flows can be quite treacherous and are often an important cause of mixing in estuaries. Sailors must be aware of these flows, or their ship could get pushed into rocks or shallow water and run aground. In the days when all ships were powered by the wind via sails, ships could not leave port if the tidal currents were against them. There is an old saying: "time and tide wait for no man." If members of a ships' crew did not get back to the ship in time, the captain would have to decide to whether to leave without them or to wait for them and the next tide (for the "tide to turn").



National Oceanic and Atmospheric Administration / Department of Commerce

Tides: More Power to Them

In some places in the world, tides are used to generate electrical power. All you need to do is to build a dam that blocks the flow of the water into or out of an estuary. Then, once the water on one side is at its highest, let the water run through, just like hydroelectric power on a river. The flowing water spins turbines containing magnets (spinning a magnet produces electricity). This is only economical in big estuaries with narrow entrances (smaller dams are cheaper to build and maintain) and large tidal ranges (more water = more electricity).

If the captain did not have enough men to handle the ship and had to leave (time is money), the captain might "impress" some sailors: find some drunk sailors (or knock some sailors unconscious), bring them onboard his ship, and untie them once they were out to sea. At that point, the deal is "work for me" or get thrown overboard. This was actually one cause of the War of 1812: British warships would impress American sailors (who speak English, of course, a big help when serving on their ships) in foreign ports, because they needed the manpower to fight Napoleon in Europe. We declared war on Britain over this, and, fortunately for the United States, they could not spare too many men to fight us. After they burned down Washington, D.C. and other American losses, the British were just as happy to end the war as we were. The one bright spot in the war that we could point to was the rag-tag bunch of volunteers led by Andrew Jackson that took New Orleans, a victory that eventually won him the presidency. Ironically, he fought and won the battle after the war had ended; both sides didn't know that the war was over, because it took so long for the news to travel there by ship.

Speaking of getting news, another word for "news" is "tidings:" ships could not come into port with the news until the tidal currents flowed in the right direction. Thus, the timing of the tides determined when new information and gossip could spread through a community. (As the old Christmas carol goes, "Good tidings to you, to you and your kin, good tidings for Christmas and a happy new year." The "good tidings" of Christianity are, of course, the good news of the birth of the messiah, the baby Jesus.)

An interesting phenomenon that occurs in some estuaries, particularly the mouths of rivers, is a ***tidal bore***. If something slows down the motion of the water into the estuary, then the rise in sea level at the shoreline causes water to build up into a wave crest that moves up the river or narrow estuary. (A narrow estuary can "funnel" all the water, causing it to build up.) Sometimes the bore travels for miles, and people have been known to surf such waves. (Search for "bore riders" on the internet if you are interested in seeing and learning more.)

A bore is a kind of wave in which the water is just surging forward. An everyday example of a bore is the film of water that rushes up the slope of the beach after a wave breaks along the shoreline.

If the ***timing*** of the tides is related to how long it takes the tidal wave crest to move up or down a bay or harbor, then the crest of the incoming tide can interfere (add) with the crest of earlier tides that reflected off the end or sides of the harbor (same for the troughs). This causes the high tides to be extremely high (tidal crests adding), and the low tides to be extremely low (tidal troughs "adding"). This is known as a ***seiche***. Harbor/port designers need to take this into account, otherwise the ships could easily run into the bottom at low tide. The pictures at the beginning of this reading assignment show high tide and low tide in the Bay of Fundy, a place famous for having the highest and lowest tides in the world owing to the seiche effect.

Tidal Bore. Courtesy of Arnold Price (CC BY 2.0).

TIDES AND LIFE

"Tide pooling" is going to the coast to look at organisms (animals and algae) that live in "tide pools." Tide pools are small depressions or "bowls" in the shoreline where water is caught when the tide goes down.

The region exposed to the air by low tide – the intertidal zone – is one of the harshest environments where ocean organisms try to live. The area is exposed to the air and submerged underwater daily by the tides. The area can be drenched by freshwater during storms (causing the organisms to bloat and interfering with their bodies' chemistry) and tide pools become increasingly salty (causing dehydration) as water evaporates in the Sun. If the tide is low during the day, the Sun itself bakes and dehydrates organisms, and if the tide is low at night, they freeze. (Remember: ocean water does not get as warm or cold as the land, in part owing to its high heat capacity.)

Many organisms "close up" during low tide, and wait for high tide when they can feed and breathe (they have gills, not lungs, so they can only extract oxygen from water). Most capture small plankton that are drifting in the water, though some graze algae off the rocks or hunt other animals who live there.

The coast is pounded by waves, which not only smash the organisms, but try to pick them up and throw them into rocks or the ground. To avoid this, organisms have adaptations that help them quickly dig down and hide beneath sandy sediments, or hold securely onto large rocks (e.g., "suction" cups, cementing glue, sticky threads). The waves also cause large rocks to roll over the organisms, or pick up and fling small sediments at them. (A grain of sand is no big deal to you or me, but to a tiny animal, it is a large rock.)

In addition to the physical conditions (waves, oxygen, temperature, salinity, sediments, etc.), biological conditions are also tough. Predators such as birds attack during low tide and marine predators like sea stars and whelks (predatory snails) attack at high tide. Moreover, there a constant battle for the best real estate, places that are covered by water most of the time (e.g., tide pools).

Shells and exoskeletons (skeletons on the outside, rather than on the inside like our own) are common adaptations to life in this environment. They not only offer protection from predators, but also from pounding by waves and sediments, drying out in the Sun, salty tide-pool water, and so on.

> **So if conditions are so tough, why do so many ocean animals live want to live on coast?**
>
> The key reason is lots of food. Remember: there is more life around the coast. The most valuable property is the part of the coastline that is always underwater, but just a little bit. No one wants to live higher up on the shore, but you might choose to do so because there is less competition for the space, and you still get the big benefit of the coast (lots of food), at least at high tide.

Courtesy of PDPhoto.org (public domain).

Good Tide Pooling Behavior

When you go tide pooling, be careful where you step, and if you lift up a rock to look underneath, put it back the way you found it (it offers the organisms on the bottom protection from waves, the Sun, predators, and so on). Do not pull on animals like sea stars that are stuck to the rocks; you can damage their suction cups. Do not take any shells or rocks home; the organisms need them for protection (e.g., sea anemones put them on their bodies like clothing). If everyone who visited a tide-pool took home just 1 or 2 shells, the tide pools would be completely wiped out within a few years, at most.

Courtesy of Megan Thompson

The Moon's Gravity and Life on the Early Earth

The Moon is slowing down a little bit each year and its orbit is getting a little larger as well. This has been happening for a long time. Therefore, when the Earth and Moon first formed, the Moon was much closer to the Earth. The early Earth experienced much larger tides owing to the early Moon's stronger gravitational pull: each day vast amounts of water washed over the early continents and carried nutrients from the land into the ocean, thus preparing the way for ocean life.

The Earth's rotation (or "spin") is slowing down owing to friction with the tides and other effects. When the Earth and Moon formed, it took only about 6 hours for the Earth to turn once around! In other words, on the early Earth, a day lasted 6 hours: 3 hours of daylight, 3 hours of night, and it took only 1.5 hours for the ocean to shift from high tide to low tide at any given spot.