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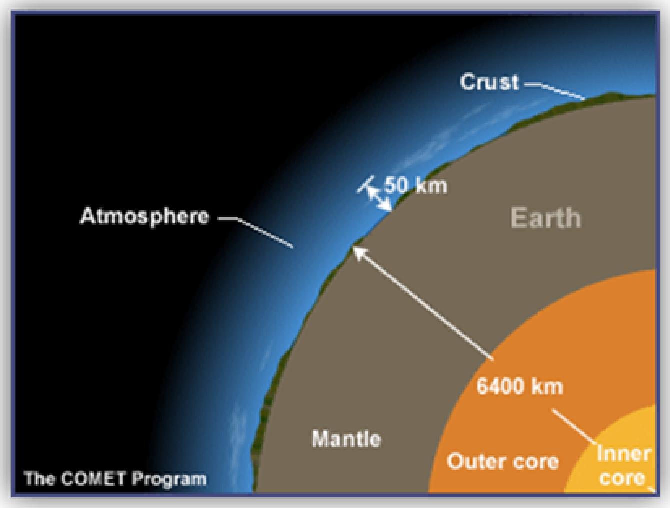
EARTH'S SPHERES AND CYCLES

Unit Overview

The remaining units in this course focus on the earth science strand. In this unit you will learn about the physical and chemical structure of the atmosphere, the way gases interact with solar energy and, the way interactions (cycles) among the atmosphere, land, and waters combine to make the atmosphere an integral part of the global biosphere. In a natural cycle, a substance is used over and over again in different forms as it travels through living and nonliving things. Biogeochemical cycles are processes that move inorganic materials such as water, nitrogen, oxygen, and carbon from the atmosphere or soil into living organisms and back again. These inorganic materials circulate throughout the earth's spheres.

Earth has a radius of some 6400 km. Ninety-nine percent of the earth's atmosphere is contained within a layer approximately 50 km thick. Life on earth inhabits a layer no more than 9 km thick, extending from a bare few kilometers above sea level (airborne organisms and life on mountains) to a few kilometers below (deep ocean basin creatures and subterranean microbial communities).

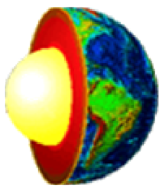


Everything in Earth's system can be placed into one of four major subsystems: land, water, living things, or air. These four subsystems are called "**spheres**." Specifically, they are "biosphere" (living things), "atmosphere" (air), "hydrosphere" (water), and "lithosphere" (land).

The **biosphere** is the portion of earth in which all known life forms exist. It occupies a thin layer of air (**atmosphere**), water (**hydrosphere**), and land (**lithosphere**). The names of the four spheres are derived from Greek words for life (bio), air (atmo), water (hydro), and stone (litho). Interaction among the four spheres shapes the earth's surface, weather, and ecosystems.

Lithosphere

The lithosphere is the solid, rocky crust covering the entire planet. This crust is inorganic and is composed of minerals. It covers the entire surface of the earth from the top of Mount Everest to the bottom of the Mariana Trench.



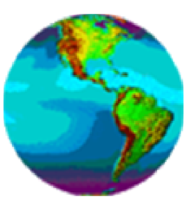
The surface of the lithosphere is very uneven (see image at right). There are high mountain ranges like the Rockies and Andes (shown in red), huge plains or flat areas like those in Texas, Iowa, and Brazil (shown in green), and deep valleys along the ocean floor (shown in blue).

If someone were to cut through Earth to its center, these layers would be revealed like the layers of an onion (see image above). The outermost layer of the lithosphere consists of loose soil rich in nutrients, oxygen, and silicon. Beneath that layer lies a very thin, solid crust of oxygen and silicon. Next is a thick, semi-solid mantle of oxygen, silicon, iron, and magnesium. Below that is a liquid outer core of nickel and iron. At the center of Earth is a solid inner core of nickel and iron.

Hydrosphere

The hydrosphere is composed of all of the water on or near the earth. This includes the oceans, rivers, lakes, and even the moisture in the air. Ninety-seven percent of the earth's water is in the oceans. The remaining three percent is fresh water; three-quarters of the fresh water is solid and exists in ice sheets.

A small portion of the water in the hydrosphere is fresh (non-salty). This water flows as precipitation from the atmosphere down to Earth's surface, as rivers and streams along Earth's surface, and as groundwater beneath Earth's surface. Most of Earth's fresh water, however, is frozen.



Ninety-seven percent of Earth's water is salty. The salty water collects in deep valleys along Earth's surface. These large collections of salty water are referred to as oceans. The image depicts different temperatures one would find on oceans' surfaces. Water near the poles is very cold (shown in dark purple), while water near the equator is very warm (shown in light blue). The differences in temperature cause water to change physical states. Extremely low temperatures like those found at the poles cause water to freeze into a solid such as a polar icecap, a glacier, or an iceberg. Extremely high temperatures like those found at the equator cause water to evaporate into a gas.

Biosphere

The biosphere is composed of all living organisms. Plants, animals, and one-celled organisms are all part of the biosphere. Most of the planet's life is found from three meters below the ground to thirty meters above it and in the top 200 meters of the oceans and seas.

Within the biosphere, living things form ecological communities based on the physical surroundings of an area. These communities are referred to as biomes. Deserts, grasslands, and tropical rainforests are three of the many types of biomes that exist within the biosphere.

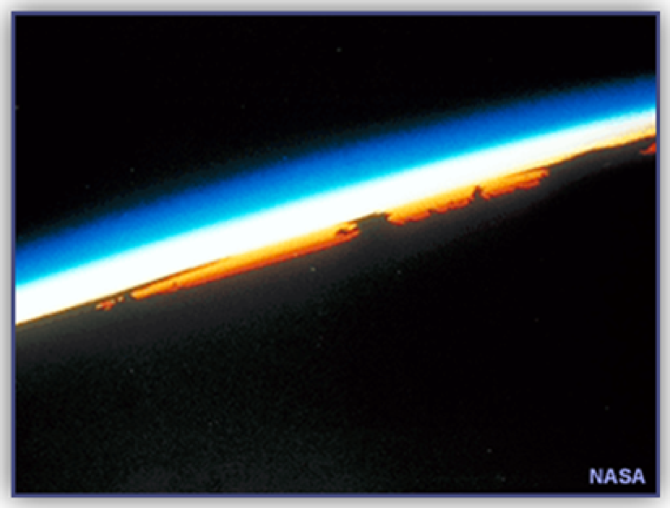
It is impossible to detect from space each individual organism within the biosphere. However, biomes can be seen from space. For example, the image above distinguishes between lands covered with plants (shown in shades of green) and those that are not (shown in brown).

Atmosphere

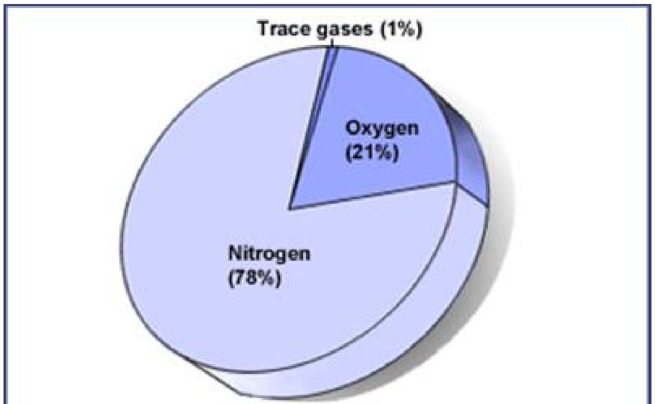
The atmosphere is the body of air which surrounds our planet. Most of our atmosphere is located close to the earth's surface where it is most dense. The air of our planet is 79% nitrogen and just under 21% oxygen; the small amount remaining is composed of carbon dioxide and other gasses.

The atmosphere contains all the air in Earth's system. It extends from less than 1 m below the planet's surface to more than 10,000 km above the planet's surface. The upper portion of the atmosphere protects the organisms of the biosphere from the sun's ultraviolet radiation. It also absorbs and emits heat. When air temperature in the lower portion of the sphere changes, weather occurs. As air in the lower atmosphere is heated or cooled, it moves around the planet. The result can be as simple as a breeze or as complex as a tornado.

Atmospheric Properties



The thin envelope of air that surrounds our planet is a mixture of gases, each with its own physical properties. The mixture is far from evenly divided. Two elements, nitrogen and oxygen, make up 99% of the volume of air. The other 1% is composed of "trace" gases, the most prevalent of which is the inert gaseous element argon. The rest of the trace gases, although present in only minute amounts, are very important to life on earth. Two in particular, carbon dioxide and ozone, can have a large impact on atmospheric processes.



Proportional volume of gases composing dry air. Nitrogen and oxygen obviously dominate.

Another gas, water vapor, also exists in small amounts. It varies in concentration from being almost non-existent over desert regions to about 4% over the oceans. Water vapor is important to weather production since it exists in gaseous, liquid, and solid phases and absorbs radiant energy from the earth.

The Goldilocks Principle: Looking at Atmospheric Gases

In this section, you will learn about atmospheric differences among three "sister" planets --Earth, Venus, and Mars--and get an overall appreciation of important similarities and differences. You will use this understanding in a later unit focusing on the greenhouse effect on earth.

Background

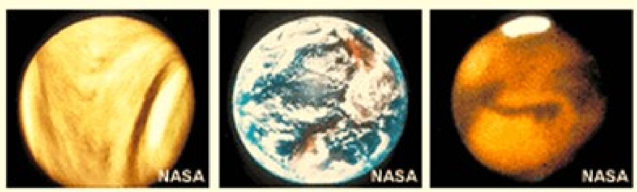
On earth, two elements, nitrogen (N_2) and oxygen (O_2), make up almost 99% of the volume of clean, dry air. Most of the remaining 1% is accounted for by the inert gaseous element, argon (Ar). Argon and the tiny percentage of remaining gases are referred to as trace gases. Certain trace atmospheric gases help to heat up our planet because they appear transparent to incoming visible (shortwave) light but act as a barrier to outgoing infrared (long wave) radiation. These special trace gases are often referred to as "greenhouse gases" because a scientist in the early 19th century suggested that they function much like the glass plates found on a greenhouse used for growing plants.

The earth's atmosphere is composed of gases (for example, CO_2 and CH_4) of just the right types and in just the right amounts to warm the earth to temperatures suitable for life. The effect of the atmosphere to trap heat is the true "**greenhouse effect**."

We can evaluate the effect of greenhouse gases by comparing Earth with its nearest planetary neighbors, Venus and Mars. These planets either have too much greenhouse effect or too little to be able to sustain life as we know it. The differences between the three planets have been termed the "**Goldilocks Principle**." Venus is too hot, Mars is too cold, but Earth is just right.

Mars and Venus have essentially the same types and percentages of gases in their atmosphere. However, they have very different atmospheric densities.

- **Venus** has an extremely dense atmosphere, so the concentration of is responsible for a "runaway" greenhouse effect and a very high surface temperature.
- **Mars** has almost no atmosphere; therefore, the amount of is not sufficient to supply a warming effect, and the surface temperatures of Mars are very low.
- **Mars is much further away from the Sun than is Venus.**



	Venus	Earth	Mars
Carbon Dioxide (CO_2)	96.5%	0.03%	95%
Nitrogen (N_2)	3.5%	78%	2.7%
Oxygen (O_2)	Trace	21%	0.13%
Argon (Ar)	0.007%	0.9%	1.6%
Methane (CH_4)	0	0.002%	0

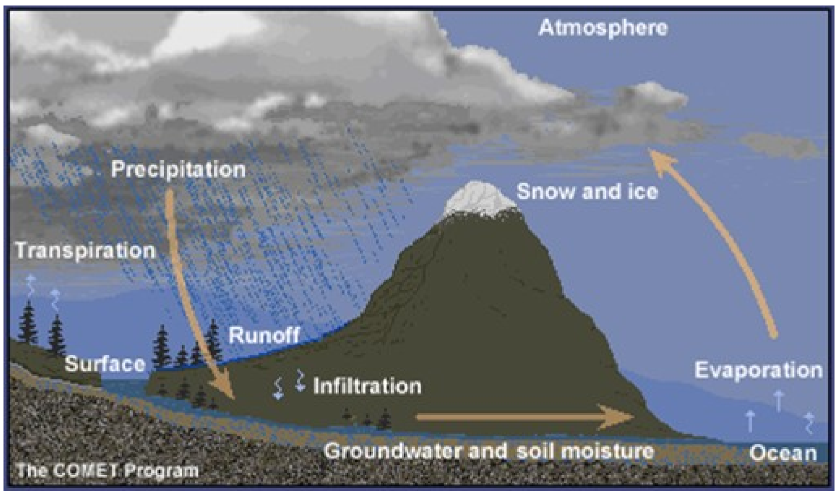
Earth has a very different type of atmosphere. Our atmosphere has much less than Venus or Mars, and our atmospheric pressure is close to midway between the two (1/90 that of Venus and 100 times that of Mars).

Many scientists believe the composition of our atmosphere is due to the presence of life. Life acts to keep Earth's atmosphere in a dynamic balance. In other words, if life were to completely disappear, eventually our atmospheric composition could come closely to resemble Mars or Venus. Only with life continually producing oxygen through photosynthesis and removing and re-circulating does Earth's atmosphere remain fairly stable.

Cycles

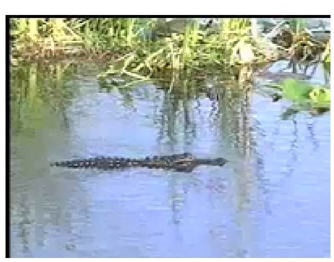
Just as we earthly organisms require a source of energy, water, and the chemical components of our bodies, so does the entire global biosphere. These services are provided to the biosphere by global energy and chemical cycles.

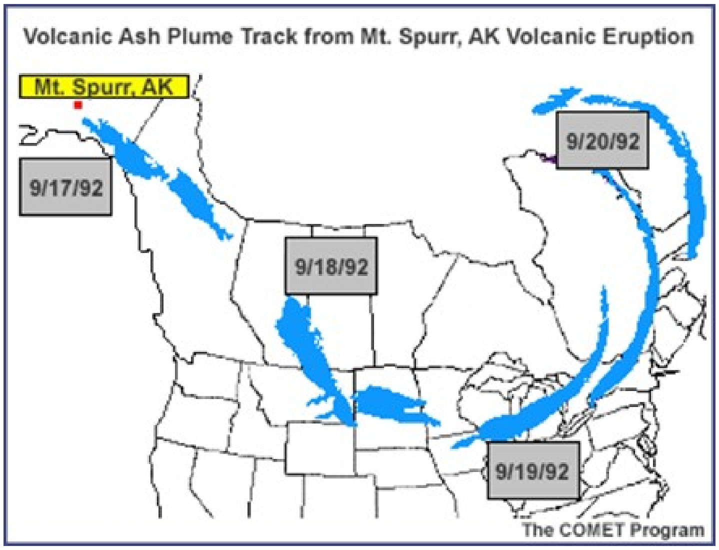
Most people are familiar with the concepts of cycles—that certain substances move endlessly throughout the earth's biosphere, hydrosphere, atmosphere, and lithosphere, existing in different forms and being used by different organisms at different times, but always moving, always circulating. You are probably familiar with the water cycle. Water, in its different forms, cycles continuously through the lithosphere, hydrosphere, atmosphere, and biosphere. Water evaporates into the atmosphere from the land and the sea. Plants and animals use and reuse water and release water vapor into the air. Once in the air, water vapor circulates and can condense to form clouds and precipitation, which fall back to earth. At one time or another, all of the water molecules on earth have been in an ocean, a river, a plant, an animal, a cloud, a raindrop, a snowflake, or a glacier!



In addition to **water**, many other substances such as **nitrogen**, **oxygen**, and **carbon** cycle throughout the earth and atmosphere. These cycles are important to individual animals and plants and even to entire ecosystems. But we're less familiar with the notion that these cycles fundamentally influence the planet as a whole, dramatically and unmistakably altering the earth's atmosphere. When you think about it, this influence only makes sense. The atmosphere is the greatest, fastest, and most reliable global transport system we have.

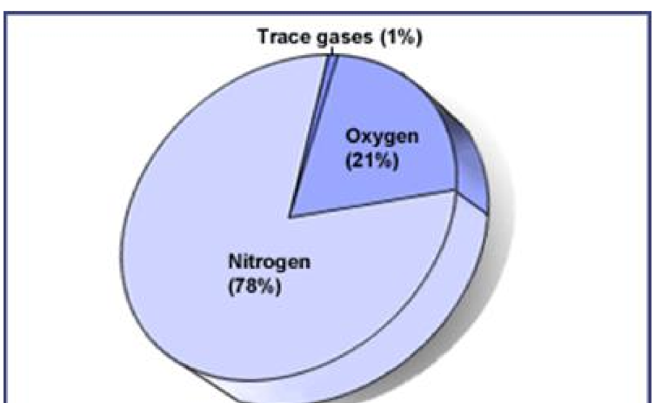
Inject almost any stable gaseous material into the atmosphere and before long it is spread worldwide. For example, the graphic below shows how the smoke and ash plume from the eruption of Mt. Spurr in Alaska spread and moved over a 4-day period, as detected by satellite imagery. During that time, the original plume was carried rapidly eastward from Alaska and spread over an area many times its original size.





Because cycles require the movement of substances, what better conveyor belt to use than the atmosphere? To explain what we mean, let's look at several important components of the earth's atmosphere and see how they are influenced by these cycles.

Nitrogen comprises the bulk of the atmosphere (approximately 78%). Nitrogen cycles slowly throughout the earth's system. To most of the biosphere, nitrogen in the atmosphere is like the ocean to a thirsty person—amazingly abundant but not quite in the right chemical form. A molecule of nitrogen gas is made up of 2 atoms very tightly bound together. It takes tremendous amounts of energy, such as produced by lightning or fires, to break the bond. Amazingly, an assortment of bacterial species that specialize in taking nitrogen from the air can also convert nitrogen into different usable forms. These bacteria also release nitrogen from organic material back into the atmosphere. Nitrogen is the one element found almost entirely in the atmosphere—there's very little on land or in the sea. Nitrogen is essential to life, a key element in proteins and DNA.



Proportional volume of gases composing dry air.
Nitrogen and oxygen obviously dominate.

Oxygen is found in the atmosphere at a stable concentration of approximately 21%. Because it is a very reactive element, it can quickly combine with other elements and disappear from the atmosphere. Yet it persists, and in high concentration. The cycling of oxygen through photosynthesis and respiration accounts for its presence and stability. A world without cycles, without life, would retain little if any oxygen in its atmosphere.

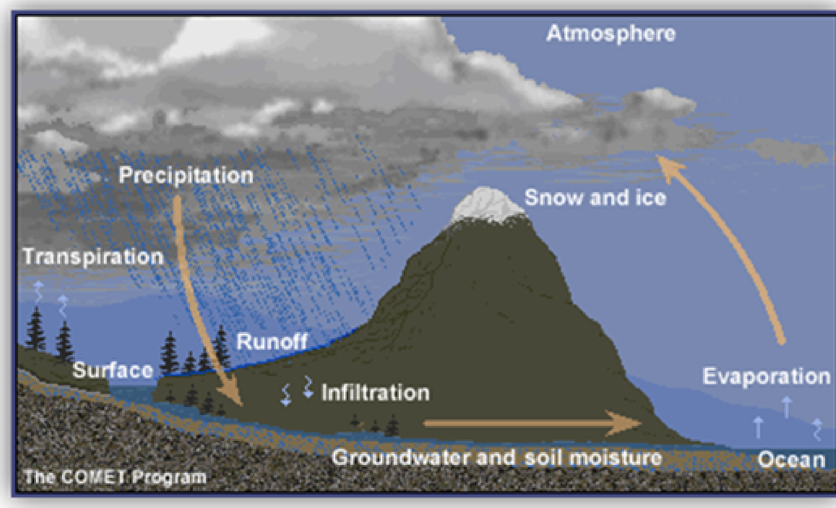
Oxygen does more, however, than simply move between organisms and the atmosphere. Some of the atmospheric oxygen () finds itself lofted high into the upper reaches of the atmosphere called the stratosphere. There, in a series of reactions powered by solar radiation, it is converted into a new compound, ozone (). The presence of stratospheric ozone benefits us creatures of the biosphere tremendously! Ozone serves to absorb biologically damaging ultraviolet (UV) radiation from the sun. Without an ozone layer, the earth's surface would be bathed in high intensity UV radiation; with an ozone layer, the amount of UV radiation received at the surface is vanishingly small. Eventually, each ozone molecule will come apart, reform, and may either be carried elsewhere in the atmosphere or may take part again in the ozone-forming reactions. Over hundreds of millions of years (at least), these ozone-forming and destroying reactions have generally been in equilibrium, forming a balanced - cycle within the greater cycle of atmospheric oxygen.

The Atmosphere in Dynamic Equilibrium

Oxygen and nitrogen are not the only elements that cycle through the biosphere. Most of the elements critical to life constantly cycle. This is why earth's atmosphere can be described as being in a state of **dynamic equilibrium**. Things are constantly moving and changing—substances enter and leave the atmosphere, forming different compounds at different times and in different places.

On earth, the dynamic equilibrium changes with season. For example, in the spring and summer, growing plants take carbon from the soil and atmosphere. In the fall and winter, plants release carbon to the soil and the atmosphere. Because most of the plant life on earth is found in the Northern Hemisphere, there are global seasonal changes of carbon dioxide in the atmosphere. An atmosphere in **static equilibrium** (like that of Mars) indicates a dead world. All the reactions have taken place and the elements have found their most stable chemical form. The atmosphere of a living planet, like ours, is quite different. Unstable, interesting, and improbable reactions happen all the time, thanks to cycles!

Atmospheric Processes



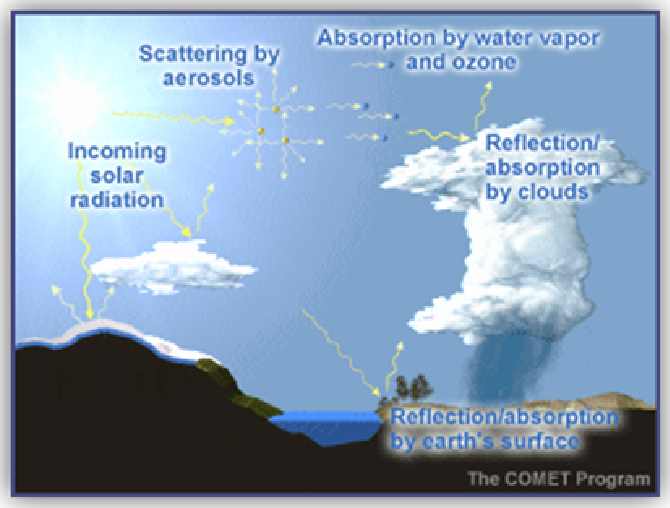
Interactions - Atmosphere and Ocean

Water is an essential part of the earth's system. Oceans cover nearly three-quarters of the earth's surface and play an important role in exchanging and transporting heat and moisture in the atmosphere.

- Most water vapor in the atmosphere comes from oceans.
- Most precipitation falling over land finds its way back to oceans.
- About two-thirds of precipitation returns to the atmosphere via the water cycle.
- You may have figured out by now that the oceans and atmosphere interact extensively. Oceans not only act as an abundant moisture source for the atmosphere but also as a heat source and sink (storage).

The exchange of heat and moisture has profound effects on atmospheric processes near and over the oceans. **Ocean currents** play a significant role in transferring heat pole ward. Major currents, such as the northward flowing Gulf Stream, transport tremendous amounts of heat pole ward and contribute to the development of many types of weather phenomena. They also warm the climate of nearby locations. Conversely, cold southward flowing currents, such as the California current, cool the climate of nearby locations.

Energy Heat Transfer



Practically all of the energy that reaches the earth comes from the sun. Intercepted first by the atmosphere, a small part is directly absorbed, particularly by certain gases such as ozone and water vapor. Some energy is also reflected back to space by clouds and the earth's surface.

Conduction is the process by which heat energy is transmitted through contact with neighboring molecules.

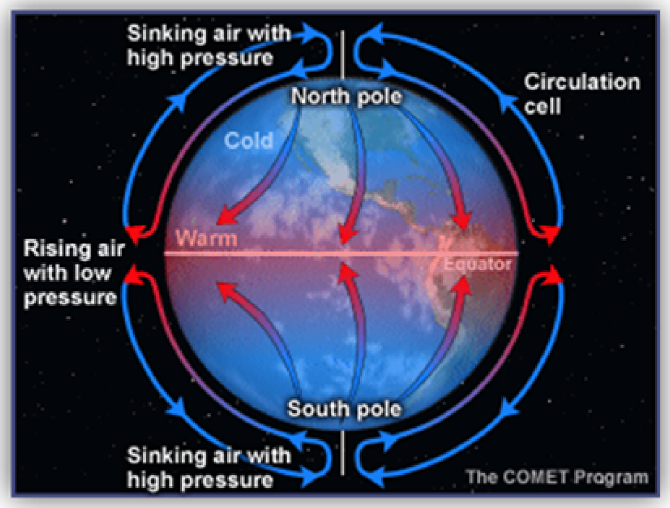
Some solids, such as metals, are good conductors of heat while others, such as wood, are poor conductors. Air and water are relatively poor conductors.

Since air is a poor conductor, most energy transfer by conduction occurs right at the earth's surface. At night, the ground cools and the cold ground conducts heat away from the adjacent air. During the day, solar radiation heats the ground, which heats the air next to it by conduction.

Convection transmits heat by transporting groups of molecules from place to place within a substance. Convection occurs in fluids such as water and air, which move freely.

In the atmosphere, convection includes large- and small-scale rising and sinking of air masses and smaller air parcels. These vertical motions effectively distribute heat and moisture throughout the atmospheric column and contribute to cloud and storm development (where rising motion occurs) and dissipation (where sinking motion occurs).

To understand the convection cells that distribute heat over the whole earth, let's consider a simplified, smooth earth with no land/sea interactions and a slow rotation. Under these conditions, the equator is warmed by the sun more than the poles. The warm, light air at the equator rises and spreads northward and southward, and the cool dense air at the poles sinks and spreads toward the equator. As a result, two convection cells are formed.



Meanwhile, the slow rotation of the earth toward the east causes the air to be deflected toward the right in the northern hemisphere and toward the left in the southern hemisphere. This deflection of the wind by the earth's rotation is known as the **Coriolis Effect.**

Radiation is the transfer of heat energy without the involvement of a physical substance in the transmission. Radiation can transmit heat through a vacuum.

Energy travels from the sun to the earth by means of electromagnetic waves. The shorter the wavelength, the higher the energy associated with it. This is demonstrated in the animation below. As the drill's revolutions per minute (RPMs) increase, the number of waves generated on the string increases, as does the oscillation rate. The same principle applies to electromagnetic waves from the sun, where shorter wavelength radiation has higher energy than longer wavelength radiation.

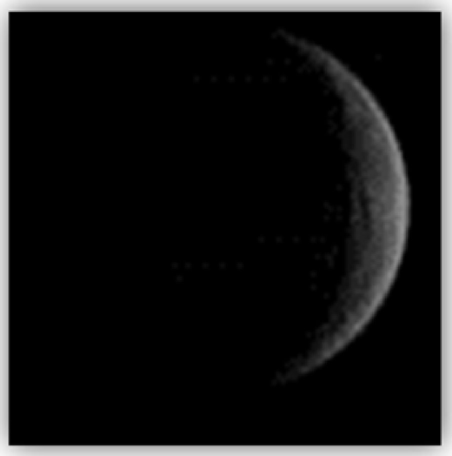
Most of the sun's radiant energy is concentrated in the visible and near-visible portions of the spectrum. Shorter-than-visible wavelengths account for a small percentage of the total but are extremely important because they have much higher energy. These are known as **ultraviolet wavelengths**.

Another cycle that affects Earth yet is outside the atmosphere, is the phases of the moon. It takes 29 days for the moon to travel around the Earth. During this time we see different shapes on the moon. The light we are seeing is actually reflected sunlight. The lit part of the moon always points the way to the sun. There are 8 major stages in the phases of the moon. Phase changes depend on the position of the sun and the moon with Earth.

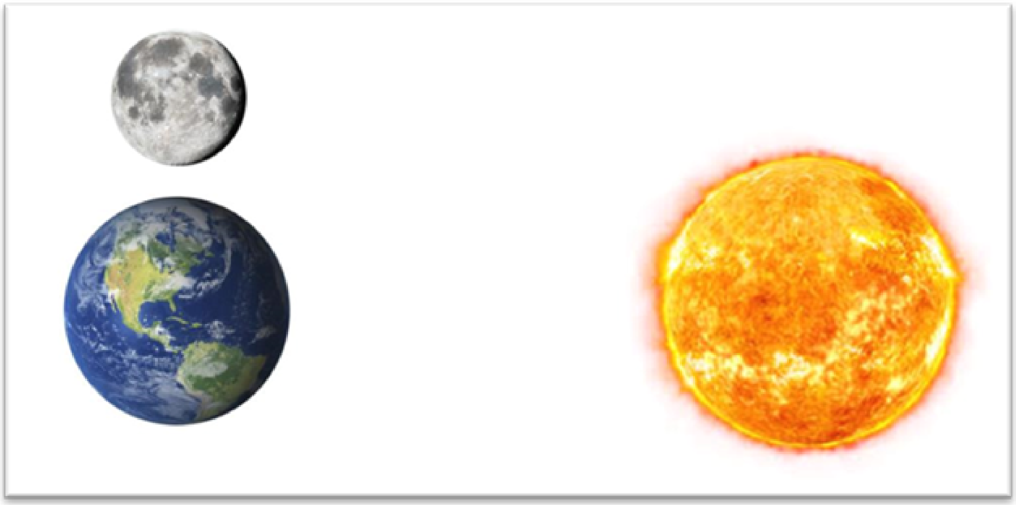
Phase 1: The New Moon
Description
The first phase is the New Moon. All you can see is a dark circle in the sky. This occurs when the moon is between the Earth and the sun.
Diagram

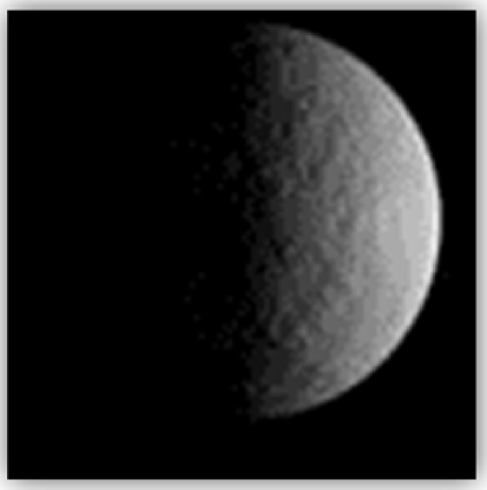
What we see on Earth


Phase 2: Waxing Crescent
Description
The second phase is called a Waxing Crescent and it has the shape of a crescent and it has the term **waxing** in front because the amount of light is **increasing**.
Diagram

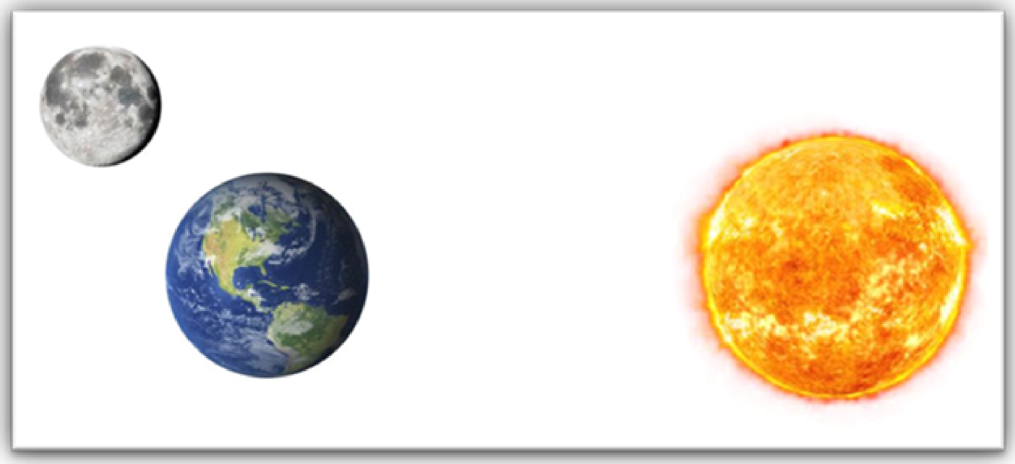
What we see on Earth


Phase 3: First Quarter Moon
Description
The third phase in called the First Quart Moon. It is called this because the moon has traveled a quarter of the way around the Earth. Half of the moon will be illuminated.
Diagram

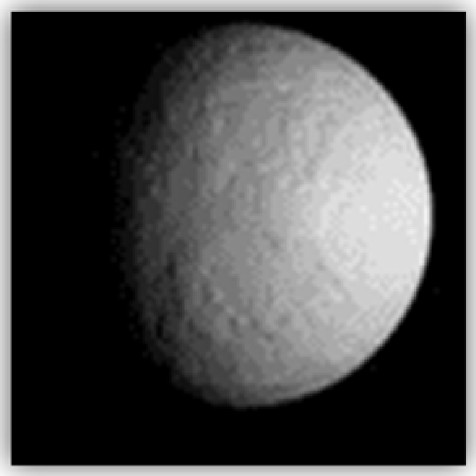


What we see on Earth


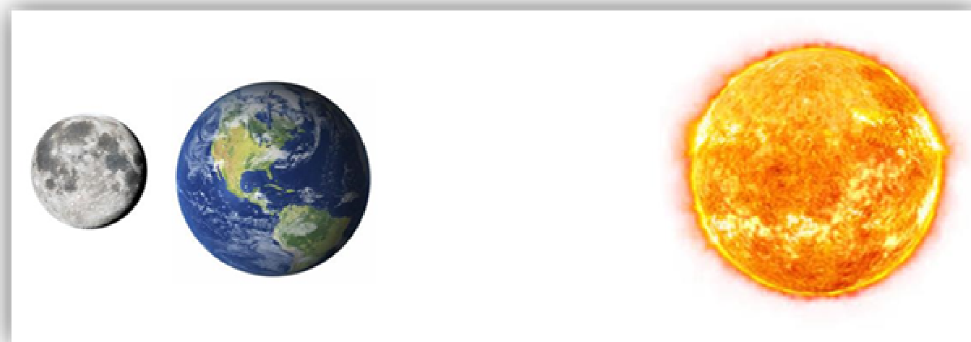
Phase 4: Waxing Gibbous
Description
The amount of light reflecting from the moon is still increasing, so the next phase in called a Waxing Gibbous. The moon will appear to be more than half way lilt.
Diagram



What we see on Earth



Phase 5: The Full Moon
Description
The fifth phase is the Full Moon. The entire side of the moon facing Earth is illuminated. The moon has traveled half way around the Earth.
Diagram



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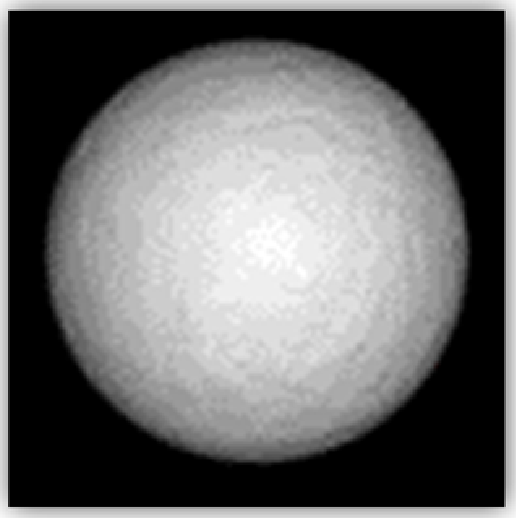
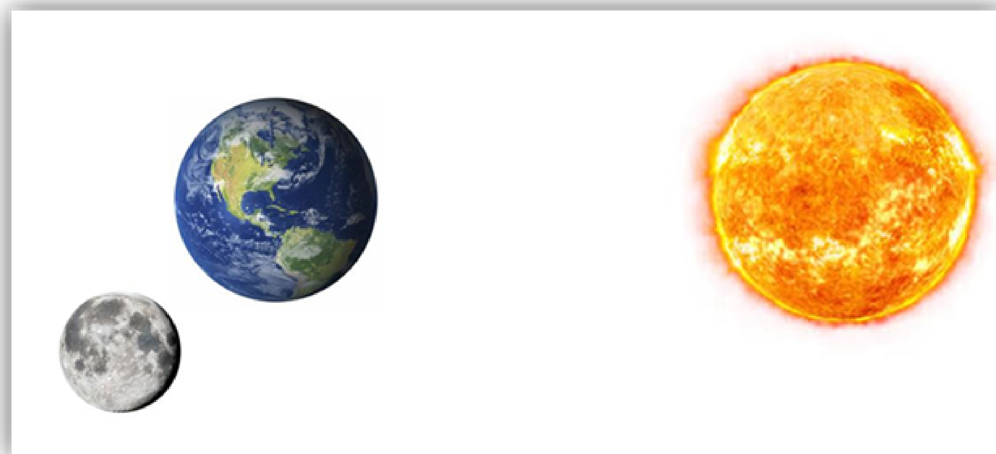
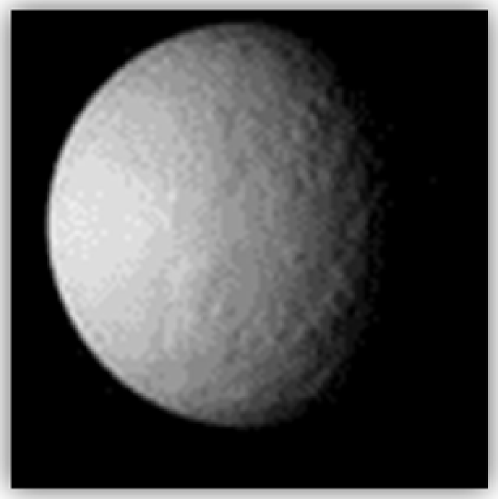


Phase 6: Waning Gibbous
Description
Now the amount of lighted reflected from the moon is **waning** or **decreasing**. The next moon phase is called a Waning Gibbous. The moon is getting darker but more than half is still lit.
Diagram



What we see on Earth

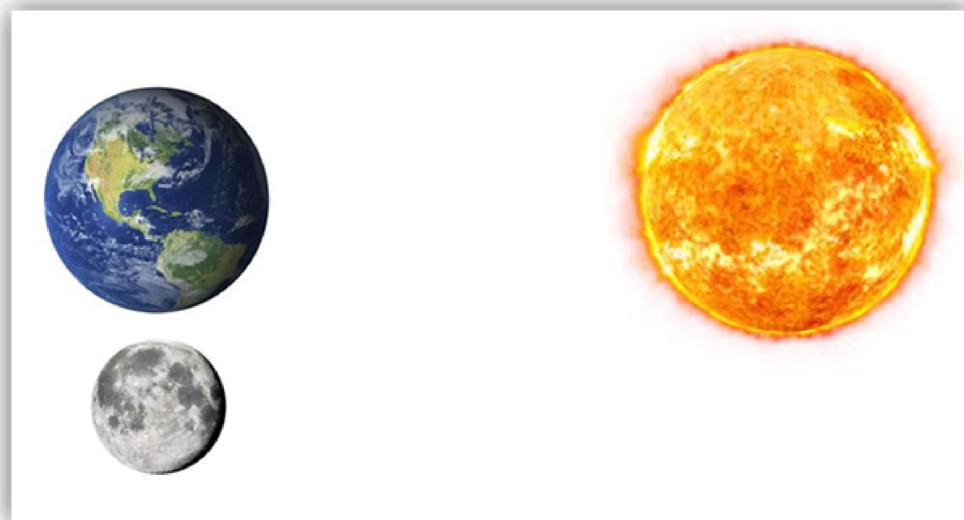


Phase 7: The Last Quarter Moon

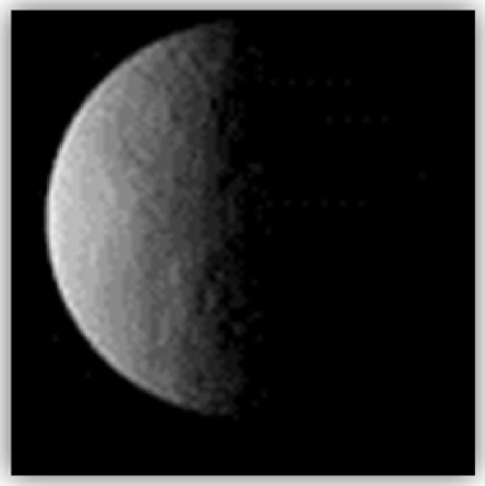
Description

The seventh phase is the Last Quarter. The moon has one quarter or 1/4th of the way left to travel around the Earth. The moon appears to half lift.

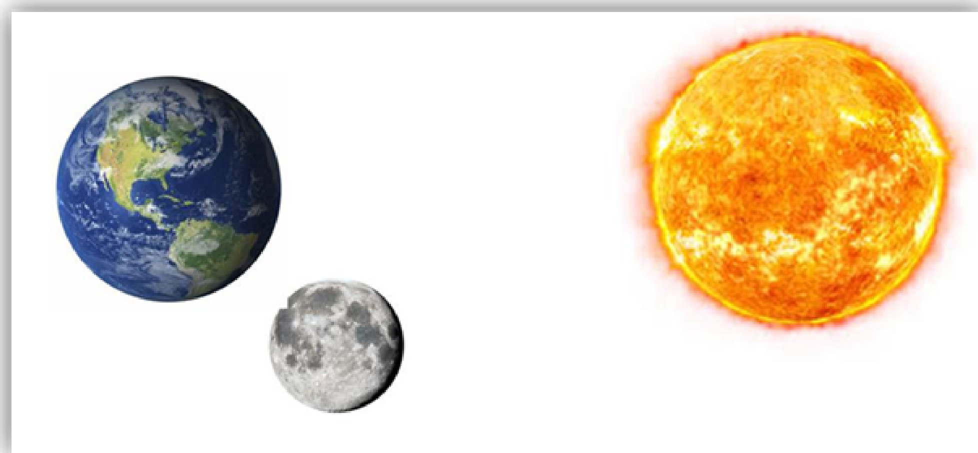
Diagram



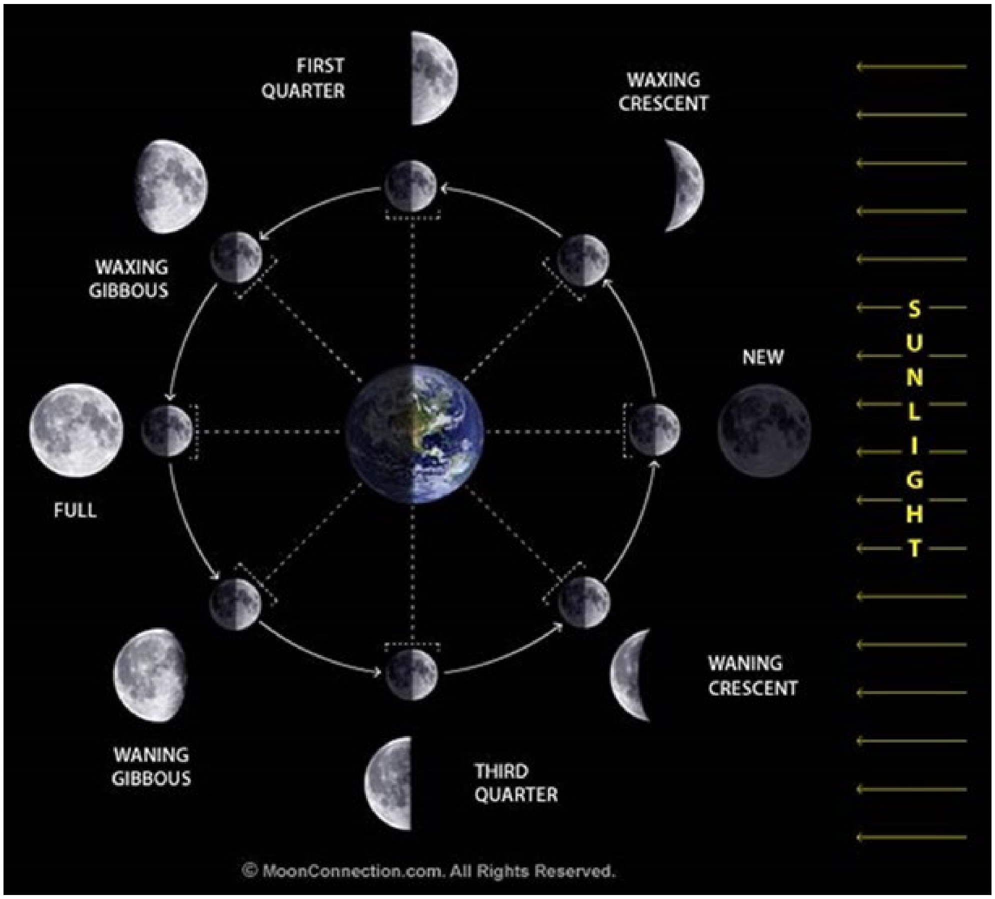
What we see on Earth



Phase 8: Waning Crescent
Description
The final phase is the Waning Crescent. A very little portion of the moon is lit. The amount of light is still decreasing.
Diagram


What we see on Earth


Then the cycle continues and after the Waning Crescent comes the New Moon and so on.



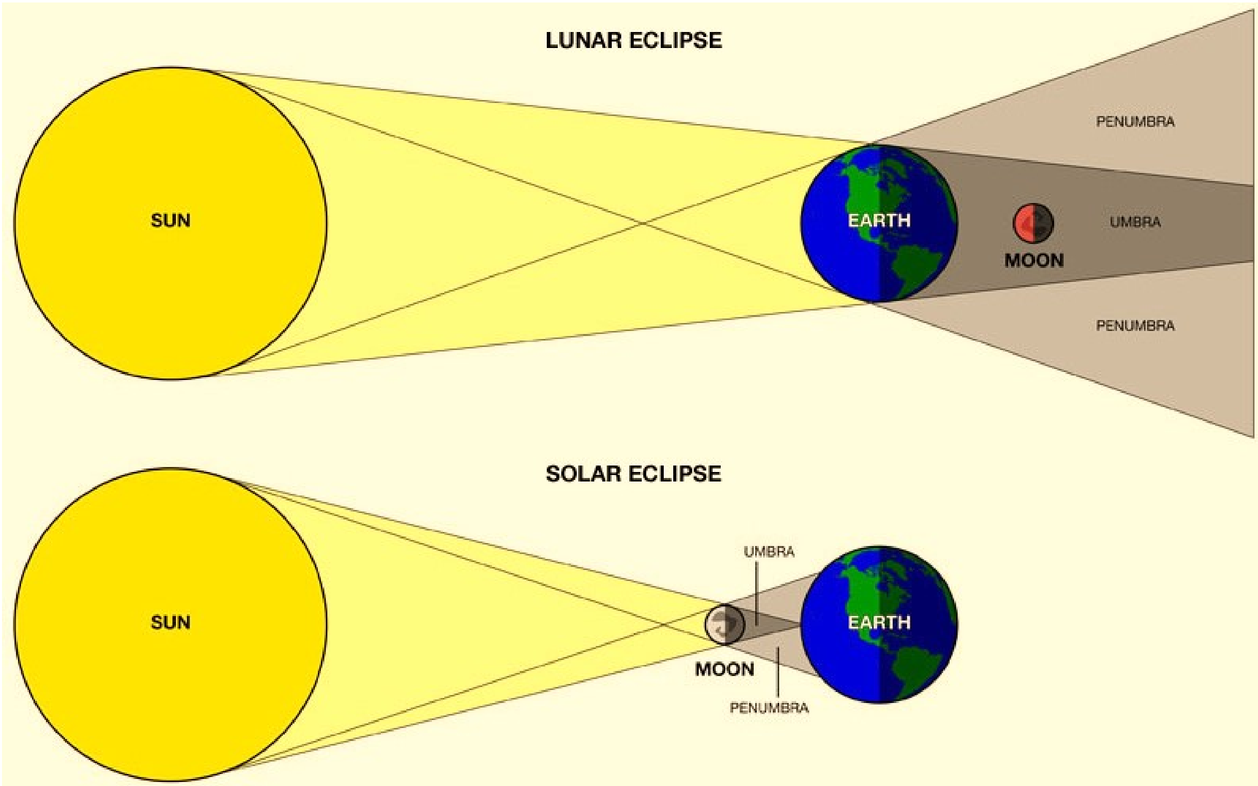
Some times when everything lines up just right we get eclipses. Lunar eclipses happen when the Earth's shadow is casted on the moon. This will happen when the Earth is between the moon and the sun. The moon's shadow is casted on Earth during a solar eclipse. This will happen when the moon is between the sun and Earth. Now why don't we have a lunar eclipse every month on the Full Moon or a solar eclipse every New Moon. Notice in the definition of a Lunar eclipse it said, the Earth's **shadow** has to be on the moon, to be even more specific it has to be in the darkest part of the shadow the umbra. The lighter part is called the penumbra. This is also the case for solar eclipses. The Earth and moon have different orbits or paths they follow. The shadows only align in two places, and because the Earth and the moon are always moving these places will different. If this these points happen when the moon is behind the Earth, we will see a lunar eclipse. If the moon is in between the sun and Earth then we see a solar eclipse. A total solar eclipse happens when the moon completely covers the sun. This happens when the moon is closest to Earth. Because the moon's orbit is an ellipse and not a perfect circle, there are times that the moon is closer. If the moon is farther away we get an annular eclipse. During an annular eclipse you can still see the outer edges of the sun. Any type of solar eclipse can only been seen at a specific place on Earth. Lunar eclipses can be seen whatever place on the planet that is experiencing night.   Lunar eclipses are more common than solar eclipses and last longer.

Eclipses

Lunar

Total Solar

Annular Solar

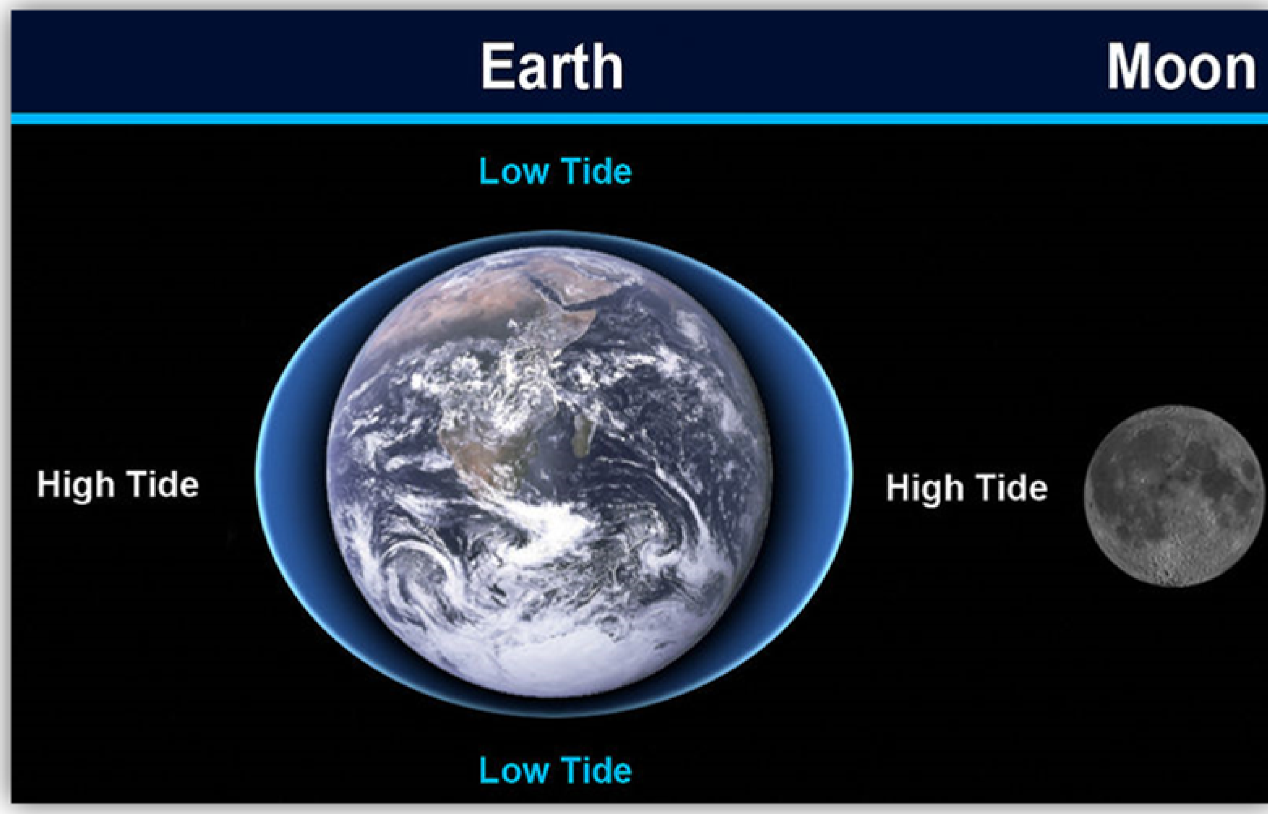


Lunar Eclipse Phases

Solar Eclipse Phases

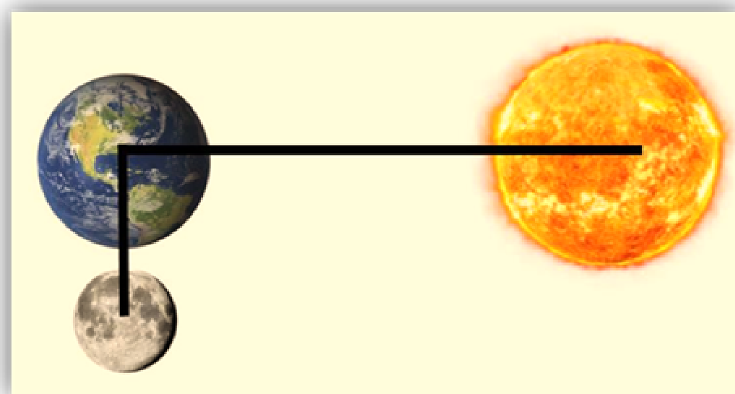
Solar and Lunar Eclipses Explained (03:47)

As the moon travels around the Earth, we do not just experience different moon phases or eclipse. The moon has a gravitational pull on Earth. It is not great enough to affect the lithosphere, but it does affect the oceans. Have you ever been to the beach in the morning then come back later to find the water is lower on the beach? This is the moon's doing. The moon is responsible for tides. There are two high tides and two low tides every day. During high tide the water level is higher up on the shore than the low tide. How much water and how much higher on shore the water level is depends on the type of coast line. High tides occur nearest and farthest away from the moon. Look at the picture below, the blue oval represents the gravitational pull on the ocean. The spots closed to the moon received the greatest amount of pull and on the opposite side of Earth the oceans get much less gradational pull. That is why you see two ocean bulges; these are where the high tides are occurring at. The low tides are an effect of the ocean being pulled in the other directions. The Earth is rotating and the moon is also moving, so there is a constant change of position. This is why there are two high and two low tides every day.



Do high tide bulges stay exactly with the moon? Click the video link to find out.

There are different types of tides. Neap tides occur at the First and Last Quarter moons. If you look at both of those moons' diagrams above you will notice that the sun, Earth, and Moon form a right angle. The difference between low and high hide are small because the gravitational force of the sun and the moon almost cancel each other out.



Spring Tides occur at New and Full moons. This means the sun, Earth, and moon are all aligned. The tides rise higher and falls lower during these phases because both the sun's and moon's gravity contribute.

Tides Crash Course Astronomy #8 (09:46)