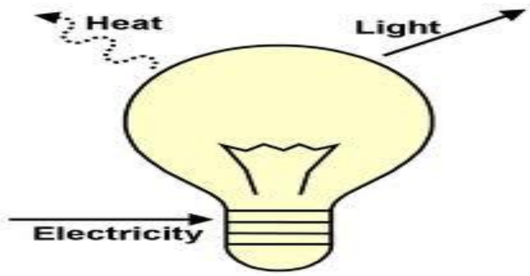
Topic 9: Energy in Earth Processes
Workbook pages 193-196; 228-233.

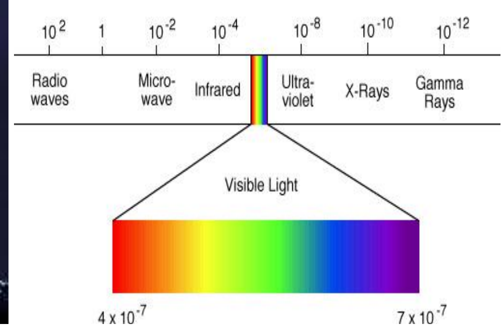
Energy is defined as the capacity to do work or cause change. Change often occurs when energy is transformed from one type to another.



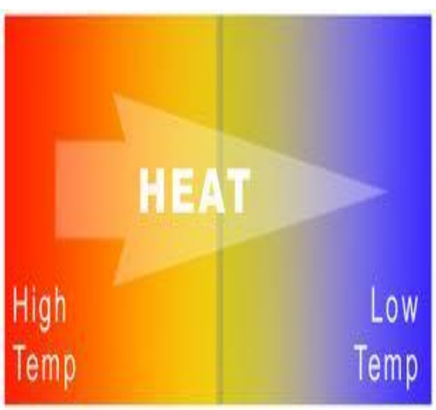
Energy can be classified into **6 different types**:

Mechanical

Electrical

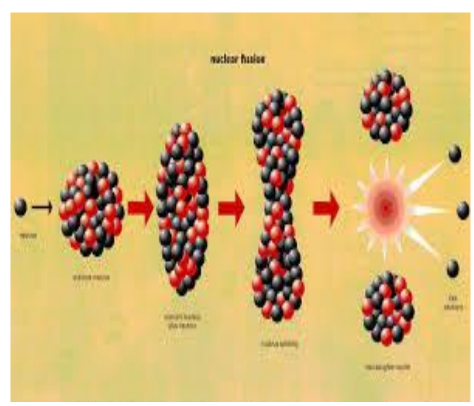


Electromagnetic



Thermal

Chemical



Nuclear

All energy forms can be classified as either **potential** (stored energy) or **kinetic** (energy of motion):

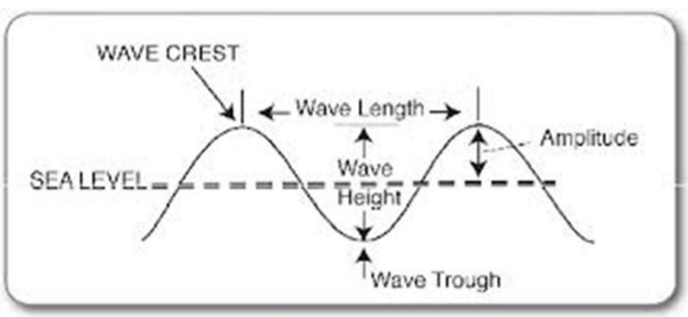
Potential	Kinetic
	Mechanical
Chemical	Electrical
	Electromagnetic
	Thermal
	Nuclear (fission and fusion)

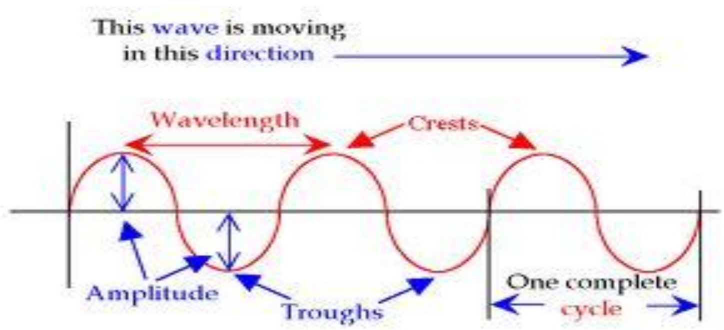
Energy is carried or transported by waves.

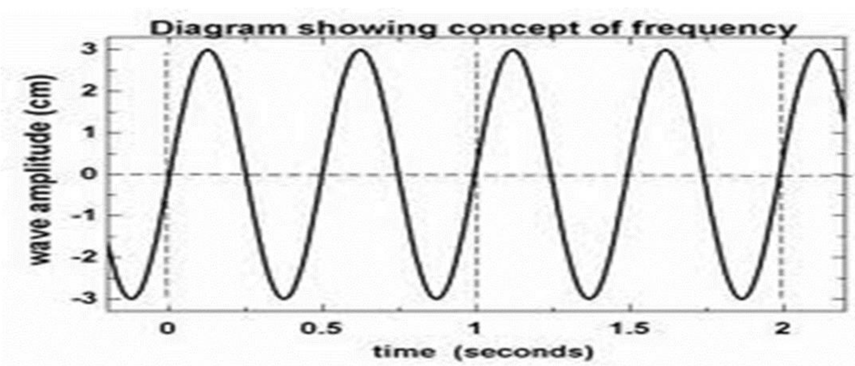
For example, an ocean wave forms when wind (kinetic energy)blows along the water's surface, transferring its energy to the water.

All waves have **3 main characteristics**: **wavelength, frequency and amplitude**.

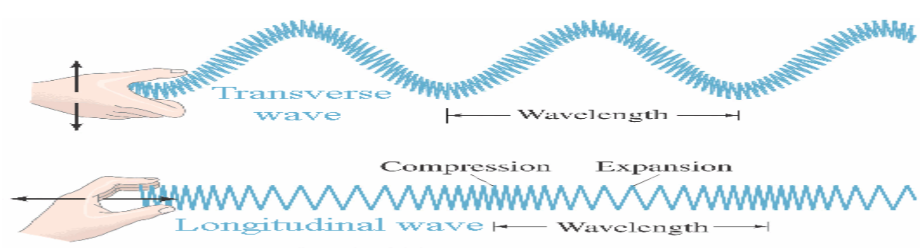
Wavelength is the distance between one wave to the next.
Frequency is how many waves pass per second.
Amplitude measures the magnitude or intensity of a wave's energy.







Waves can be classified as **transverse or compressional/longitudinal:**



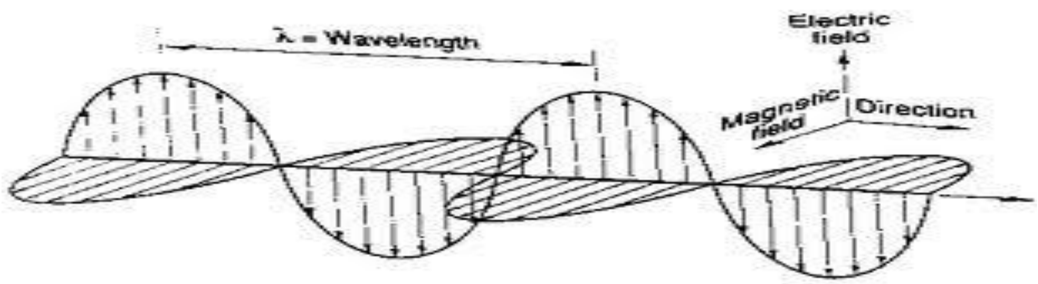
__Electromagnetic energy__

Our sun converts nuclear energy (nuclear fusion) to electromagnetic energy that is transported through space.

All matter above absolute 0 (0^{o} K) emits electromagnetic energy.

Atoms emit electromagnetic energy when their moving electrons cause a magnetic field to form.

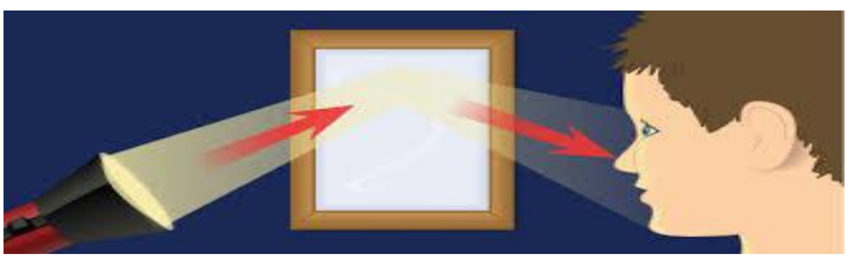
Electromagnetic energy is carried or transmitted by a transverse wave, in which the electrical field is perpendicular to the magnetic field:



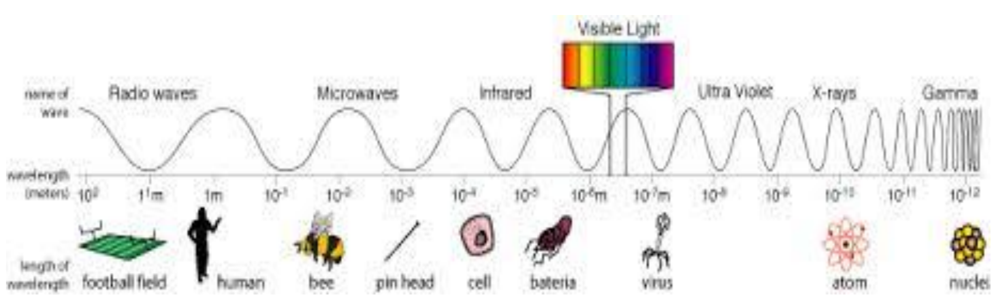
Most waves need a **medium** to travel through—for example, ocean waves travel through the medium of water.

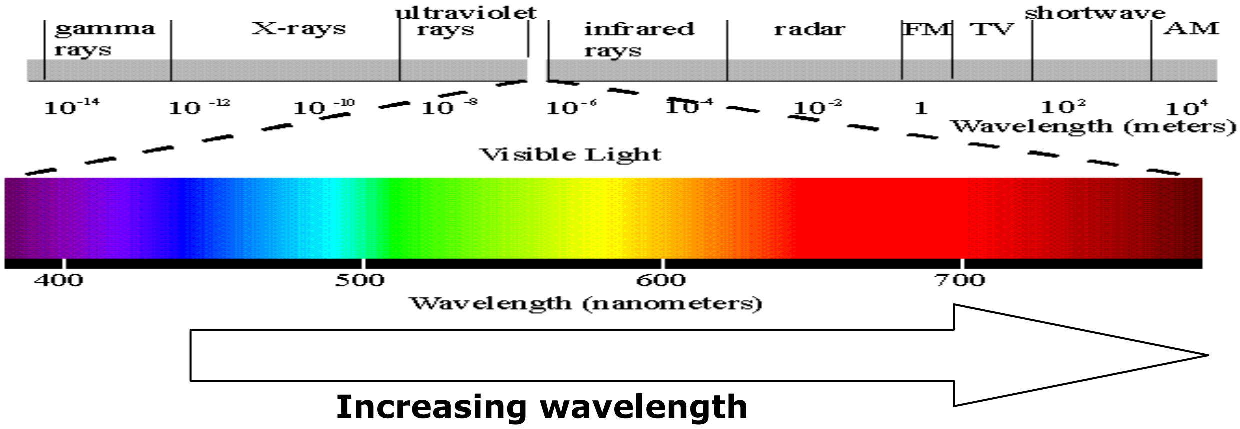
Electromagnetic waves do not need a medium—they can travel through the nearly empty vacuum of space.

Electromagnetic energy has what is called a “dual nature.” Sometimes it behaves like a wave, traveling though space; other times it acts like a particle—as when light bounces off a mirror.



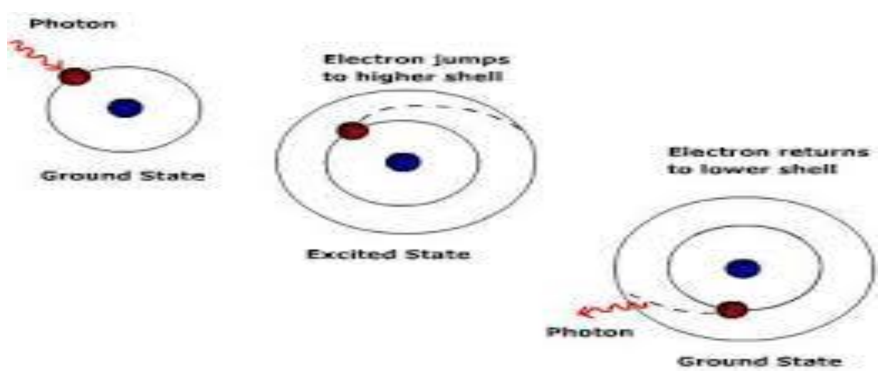
The **electromagnetic energy spectrum** includes many different wavelengths and frequencies of energy, all of which are emitted by our sun. They range from long wavelength, low frequency radio wavesto short wavelength, high frequency gamma rays:





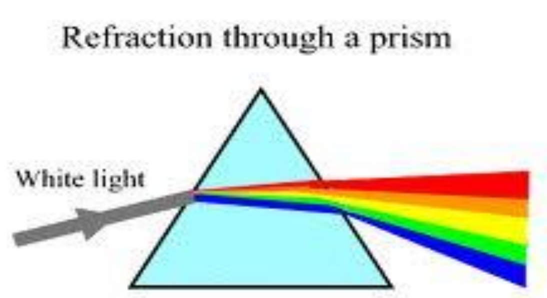
Electromagnetic waves travel at the speed of 300,000 km/second or 186,000 miles/second. At that speed, it takes light emitted from our sun about 8 minutes and 20 seconds to reach Earth.

Electromagnetic energy travels through space in bundles of energy called **photons.**

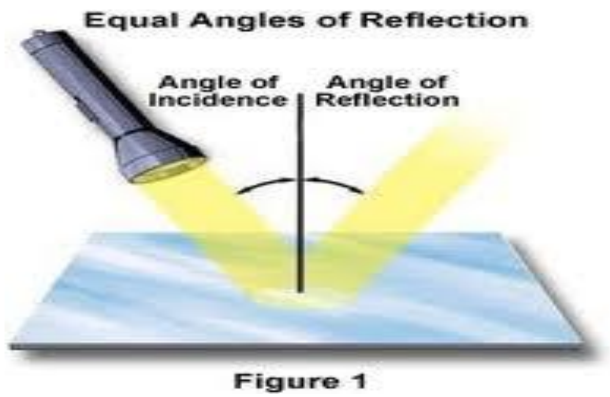


Interactions of electromagnetic waves with the environment

Refraction: waves change direction or are "bent" when they move from one medium another



Reflection: waves bounce back when they hit matter



Absorption: electromagnetic energy taken in by matter

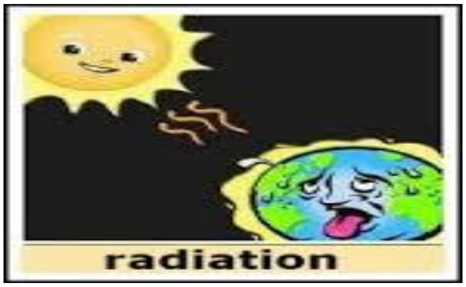
*The amount of energy absorbed depends upon the color and texture of the substance. **Rough, dark-colored surfaces absorb more energy than smooth, light-colored surfaces.**

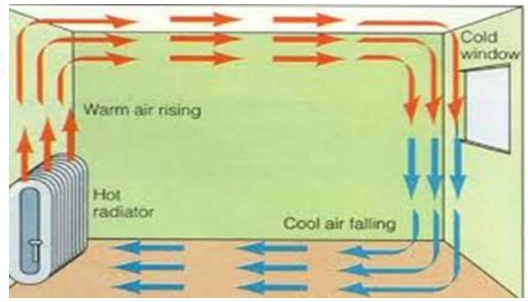
Transmission: electromagnetic energy passes through matter

Scattering: electromagnetic waves both reflect and refract when they interact with certain matter—for example--***clouds***

Transfer of Energy

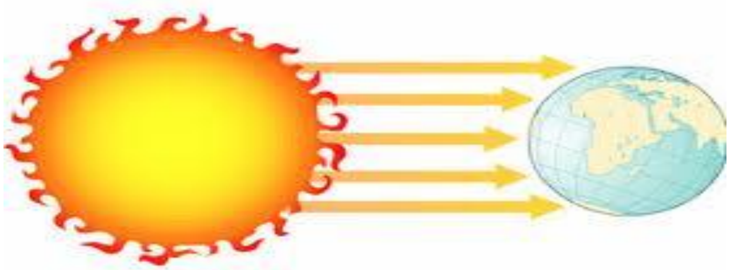
Heat energy travels from a **source** (hotter object) **to a sink** (cooler object).
Heat energy is **transferred** using 3 processes: **radiation, conduction, convection**



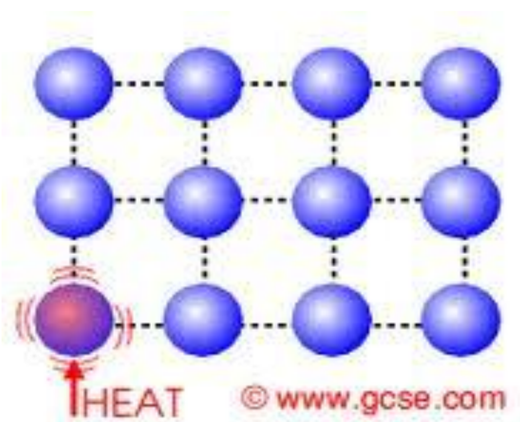


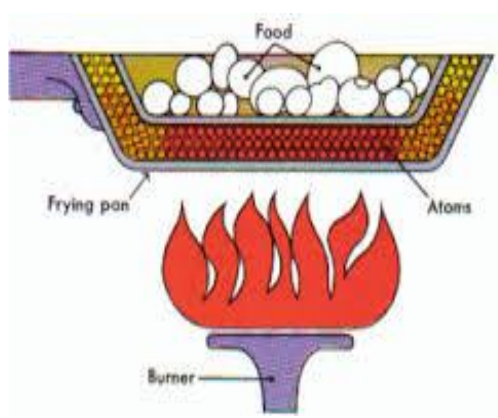
Conduction **Convection**

Radiation: energy is given off by a source and transferred in all directions to the area around it (sink)

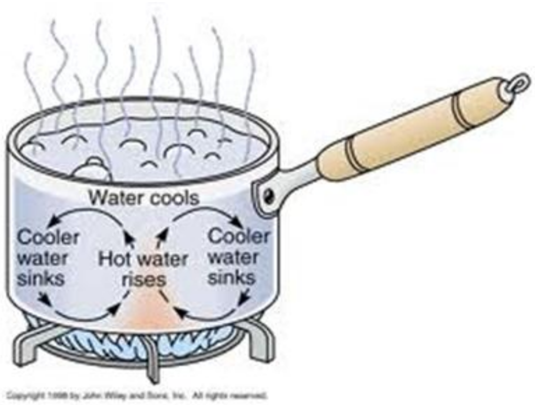


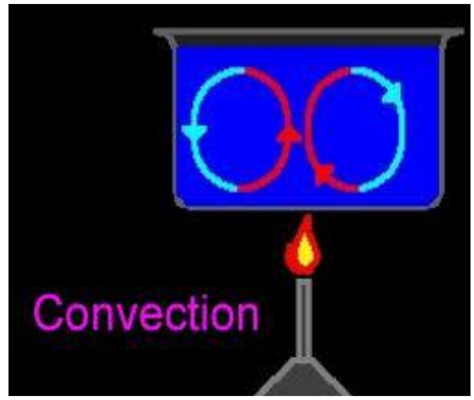
Conduction: energy is transmitted through a substance by collision of molecules





Convection: the circulation of heat energy due to differences in density; <u>occurs only in liquids and gases (fluids)</u>





How a radiator heats up a room:

Hot water or steam transfers its heat to the metal radiator: **conduction**
Heat energy given off by hot radiator to the air: **radiation**
Hot air rises (less dense), cools away from the heat source, sinks (more dense) and is drawn back into radiator to be reheated: **convection**

<u>Heat and Temperature</u>

Temperature is a measurement of the **average kinetic energy** of the molecules of a substance. The higher the kinetic energy, the higher the temperature.

Heat energy flows from matter with the higher temperature (the source) to the matter with the lower temperature (the sink).

The amount of heat energy needed to raise the temperature of a substance depends upon the **mass of the substance** and **the desired increase in temperature**.

The bigger the mass, the more energy needed to raise its temperature.
The higher the desired temperature increase, the more energy required to achieve the increase.

A **calorie** is a measurement of heat energy.

<u>1 calorie = the amount of heat energy needed to raise 1 gram of water 1° Celsius</u>.
It takes 2 calories to raise 2 grams of water 1° Celsius.
It takes 2 calories to raise 1 gram of water 2° Celsius.

<u>Specific Heat</u>

Specific heat is the amount of energy needed to raise the temperature of a substance by 1° Celsius. Specific heat is different for different substances (see ESRT table).

Note: the ESRT table measures heat energy in **joules** rather than in calories. (4.19 Joules = 1 calorie) **For example**, it takes 0.84 Joules of heat energy to raise 1 gram of copper 1° Celsius.

<u>Liquid water has the highest specific heat of all naturally-occurring substances.</u>
This means liquid water takes longer to heat up than other substances found in nature. For example, beach sand on a hot summer day feels hotter than the ocean water.

Formula for calculating heat energy requirements:

Joules = temperature change x mass x specific heat

$\triangle$T x mass x SH

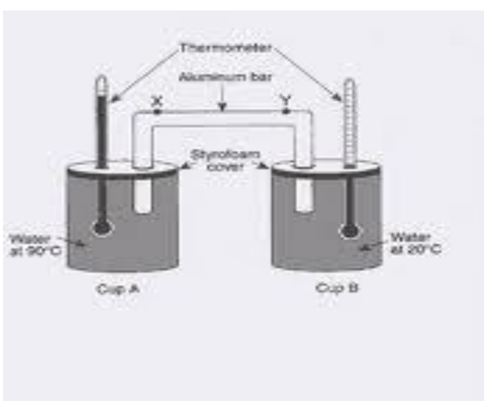
($\triangle$= change)

Example: How many Joules of heat energy are needed to raise 5 grams of copper 3° C?

Joules = 3°C x 5g x 0.38 J/g
= 5.7 Joules

<u>Law of Conservation of Energy</u>

In a closed system, the energy lost by a source is equal to the energy gained by a sink. (Energy is neither created nor destroyed).



	Temperature of Water (°C)	
Minute	Cup A	Cup B
0	90	20
1	88	20
2	86	20
3	85	21
4	83	21
5	82	22
6	81	22
7	80	22
8	79	22
9	78	23
10	77	23
11	76	23
12	75	23
13	74	23
14	73	23
15	72	24
16	71	24
17	70	24
18	69	24
19	68	25
20	67	25

If the system shown below is a closed system, what would be the final water temperature in cup B? (Cup A =90°C, cup B = 20°C)
Answer: 90 +20 = 110; 110/2 = 55°C
So: 35° was lost by Cup A and gained by Cup B
<u>In a closed system, the final water temperatures in each cup would be equal.</u>

Latent Heat

Water is the only naturally-occurring substance on Earth that is found in all three phases: **solid (ice), liquid water, and gas (water vapor).**

During a phase change (from ice to liquid water, for example), **the temperature of the substance remains constant, even though heat energy is being added.** The added heat energy that causes a phase change is called **latent heat.**

Latent heat changes the substance's molecular structure, causing it to change phase.

Once the phase change is complete, for example, once all the ice has melted, then any additional heat will increase molecular kinetic energy and the temperature of the liquid water will rise.

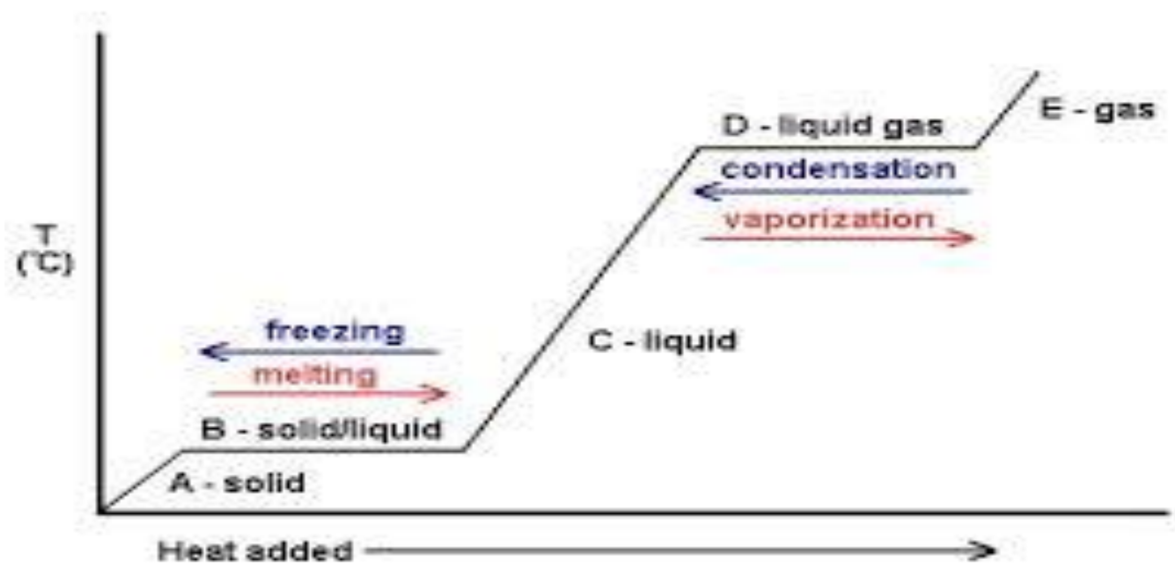
Latent heat is a form of potential (stored) energy. Latent heat stored during melting is released or given off during freezing, and is called **latent heat of fusion.**

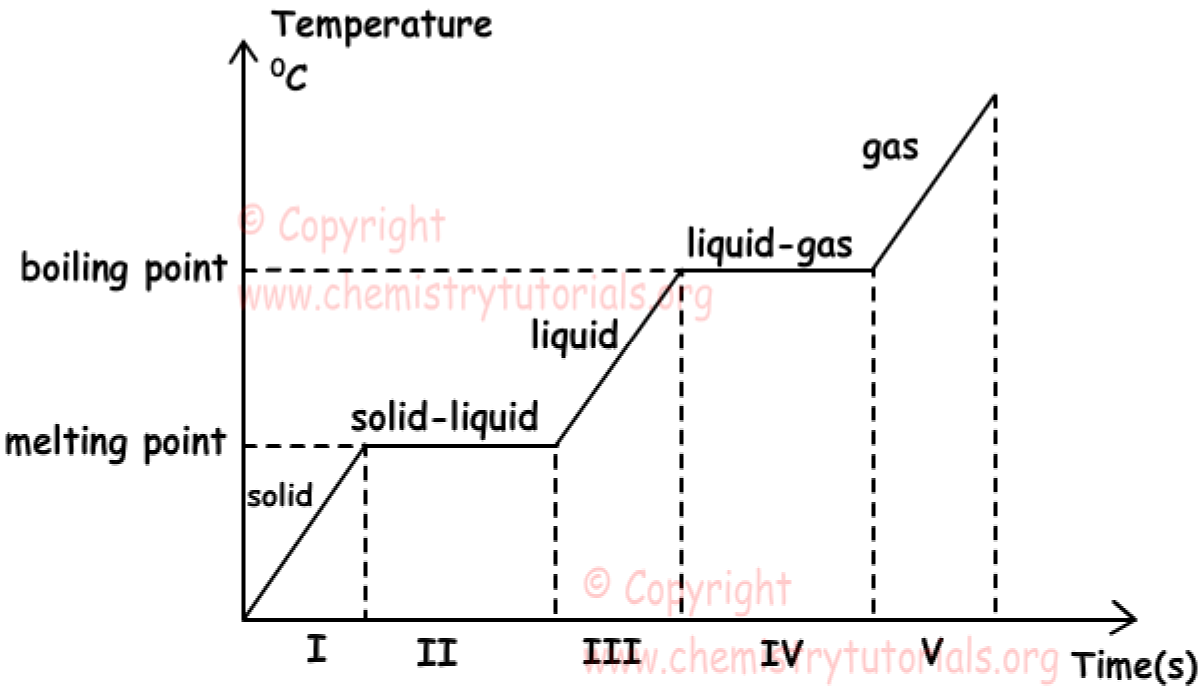
> **One gram of ice requires the addition of 334 Joules of heat energy to change to liquid water.** (see front of ESRT—"Properties of Water")

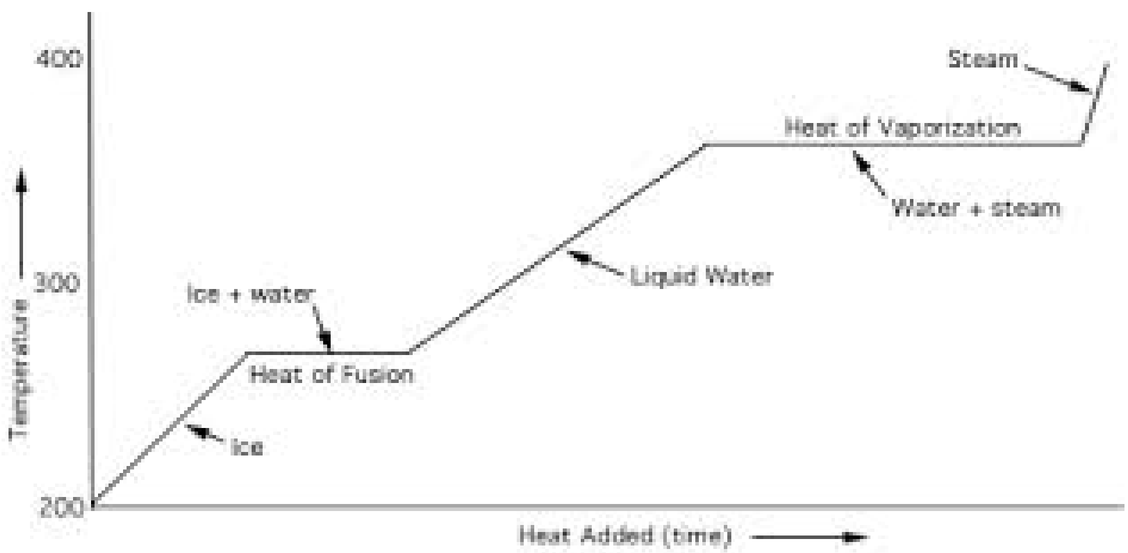
Latent heat added to change liquid water to water vapor is called **latent heat of vaporization,** and is released during the process of condensation.

> **One gram of liquid water requires the addition of 2260 Joules of heat energy to change to water vapor.** (see front of ESRT—"Properties of Water")

The Heating Curve is a graph that shows phase changes from ice to water vapor, or from water vapor to ice:







Note:

*More heat energy is needed to change liquid water to water vapor than to change ice to liquid water.

*Evaporation of water occurs at temperatures below 100°C and occurs on the water's surface.

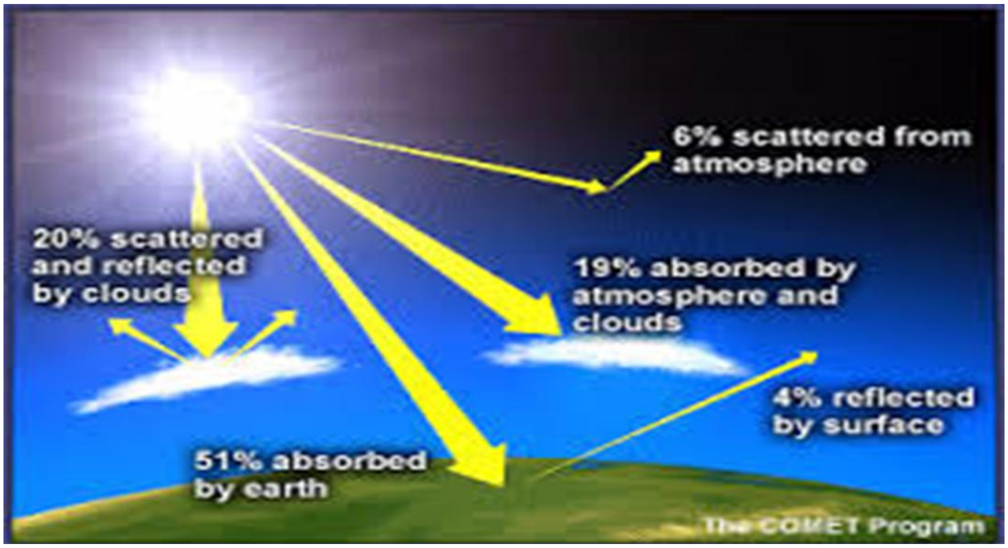
*Vaporization of water begins at 100°C and occurs in the interior of the liquid water.

*Latent heat gained as solid→liquid→gas   Latent heat release as gas→liquid→solid

Topic 9 notes (cont.)—pp. 228-234 in workbook

Insolation: incoming solar radiation

The amount of insolation reaching the Earth's surface is different from what hits the top of the atmosphere, because it can be reflected, scattered and absorbed as well as transmitted as it moves through the atmosphere.



Half of the energy that reaches Earth's surfaces is infrared radiation. The rest is visible light and other electromagnetic energy wavelengths.

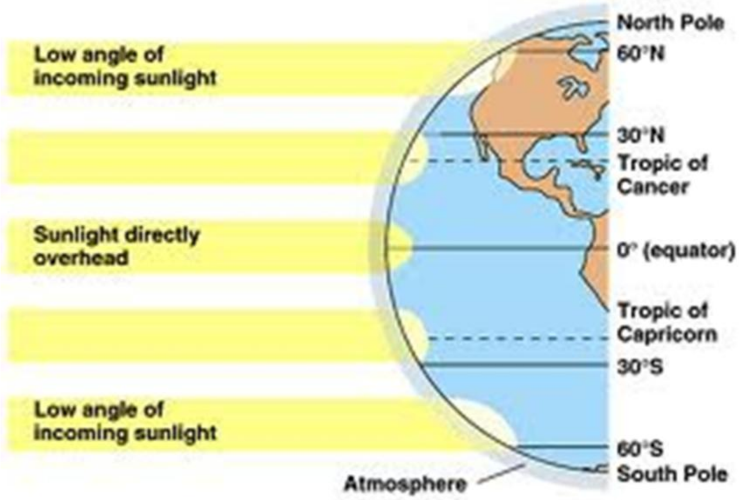
Radiation and Temperature

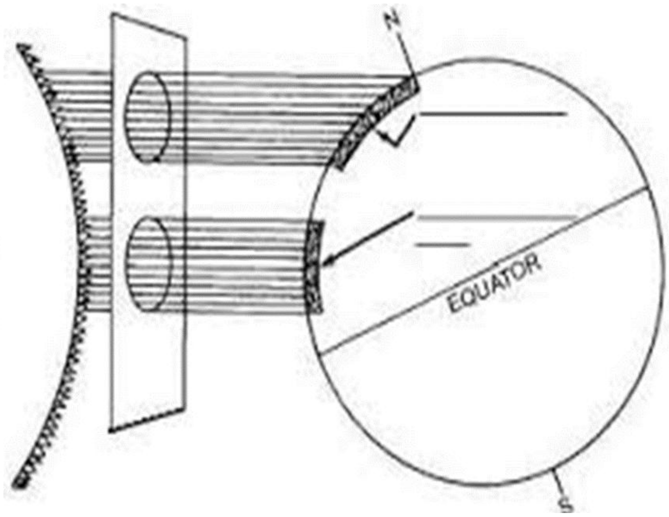
As objects get hotter, electromagnetic energy is given off at shorter wavelengths. Cooler objects reradiate longer wavelengths.

For example: an iron poker heated by fire first glows red-hot (longer wavelength), then yellow-white (shorter wavelength).

Intensity of radiation is the rate at which energy is transferred per unit time (in cal/second). As the intensity of radiation increases, the temperature increases.
The more heat energy is transferred, the higher the temperature.

Intensity of insolation is the rate at which insolation energy is received by a given area per unit time (in cal/sec/square meter). **Intensity of insolation depends upon the angle at which the sun's rays strike the Earth.** For example, on Long Island (41^{o} N) our angle of insolation at noon on June 21 is 72.5^{o}.
The greater the angle of isolation, the greater the intensity of insolation:

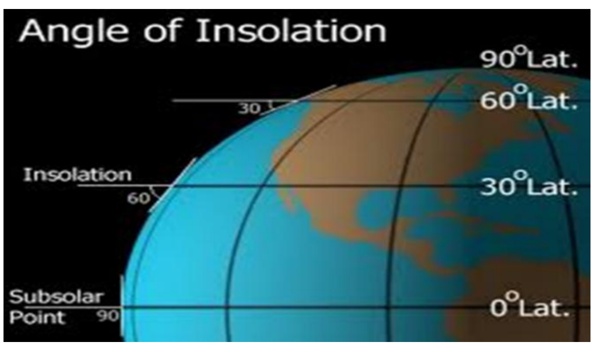




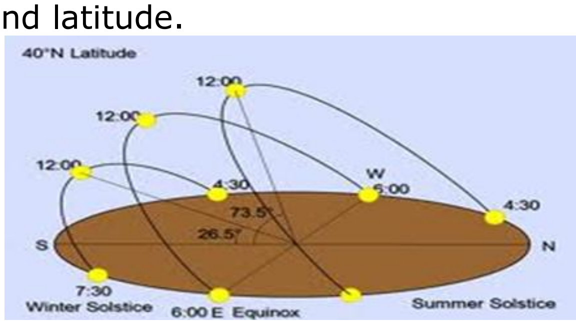
Insolation becomes less concentrated when the angle of insolation decreases less than 90^{o}; the sunlight spreads out over a larger surface area.

<u>Factors That Affect Insolation (how much incoming energy we receive)</u>

Earth's shape: spherical shape causes the sun's parallel rays to hit the surface at different angles:



Latitude: perpendicular, vertical rays are only received between 23.5^{o} N and 23.5^{o} S, depending upon the time of the year.
Seasons: Earth's tilt determines which area receives the vertical rays
Time of day: angle and intensity of insolation change during the course of the day. <u>Intensity of insolation increases to noon, decreases to sunset.</u>
Duration of insolation (the number of daylight hours): how long the sun shines depends upon season and latitude.



<u>Temperature and Insolation</u>

Temperature depends upon intensity and duration of insolation.

The greater the intensity, the more energy that is absorbed; thus, the temperature rises higher.

The longer the sun shines (duration), the more energy is absorbed, and the higher the temperature rises.

For example: the temperature is cooler at sunrise and sunset than it is at noon, because the angle of insolation is lower, making the intensity of insolation less. Because we have more sunlight hours (duration) in summer than winter, days are warmer.

If this is true, then why isn't June 21st the hottest day of the year?

The Earth radiates energy. Earth surfaces absorb the sun's energy, get warm, and radiate the energy back to the atmosphere.

The warmer Earth surfaces get, the more energy they reradiate.

When Earth radiates energy, its temperature drops. So Earth's temperature depends upon the balance between the energy it receives and the energy it gives off or reradiates. If Earth radiates more energy than it receives, its temperature decreases. If Earth receives more energy than it radiates, its temperature increases.

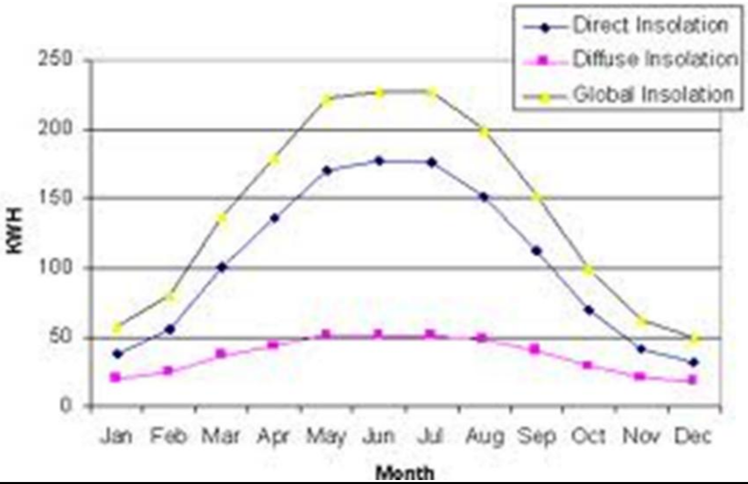
As the Northern Hemisphere approaches June 21, the rate of insolation is greater than the rate of reradiation. In other words, the Northern Hemisphere is receiving more radiation than it is giving off, so temperatures rise.

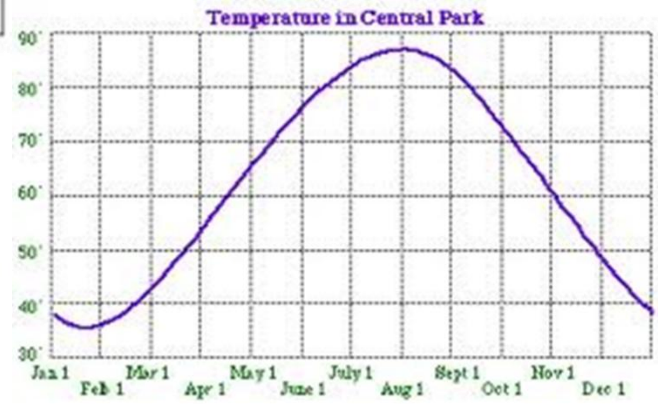
Even after June 21, the Northern Hemisphere continues to have long days and a high angle of insolation, and so temperatures continue to rise. However, there comes a point at which the amount of energy the Northern Hemisphere is receiving is equal to the amount of energy being reradiated from its warm surfaces.

At that point, the Northern Hemisphere is in a radiative balance—and temperatures are at their highest point for the year. After that, Earth reradiates more energy than it receives, and temperatures drop.

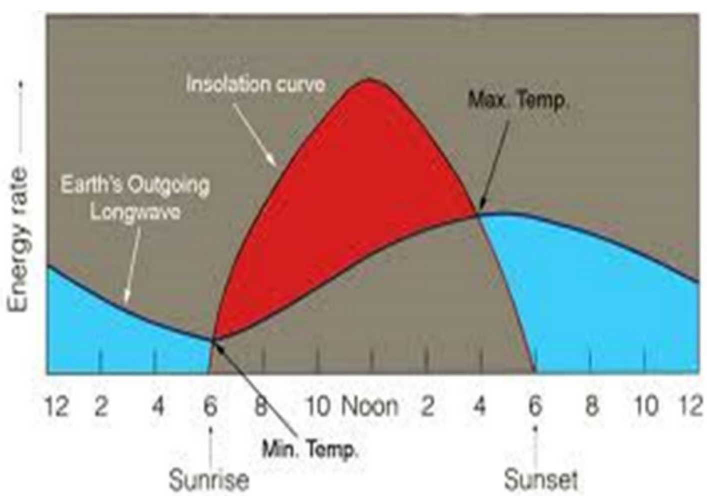
Thus, the highest and lowest temperatures during the year do not correspond with the days we receive maximum and minimum insolation (June 21 and December 21).

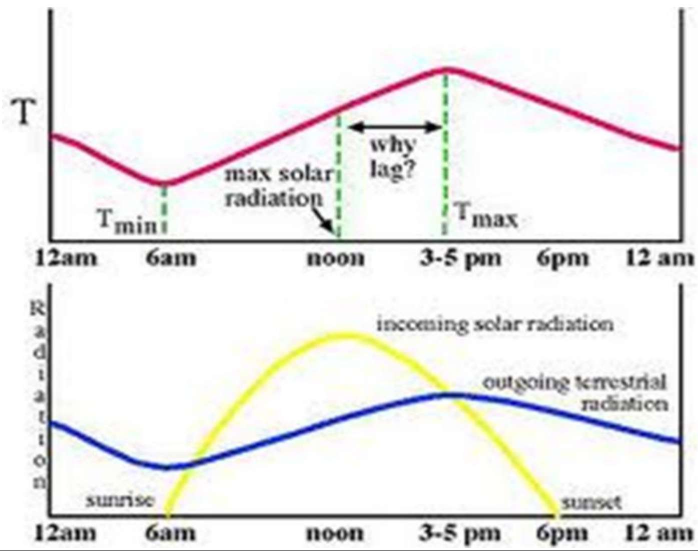
Maximum and minimum temperatures occur after June 21 and December 21--usually around August and February respectively.





<u>The same temperature lag happens during the day. The hottest time of the day is mid-afternoon, not at noon; the coolest part of the day is just around sunrise:</u>





<u>**The Affect of Atmosphere on Insolation**</u>

Various wavelengths of electromagnetic energy are affected differently once they enter our atmosphere.

Scattering: tiny solid and liquid particles (aerosols) scatter light. An increase in the amount of aerosols decreases the amount of insolation reaching Earth's surfaces. For example—volcanoes emit dust and other particles which decrease insolation and thus decrease temperatures.

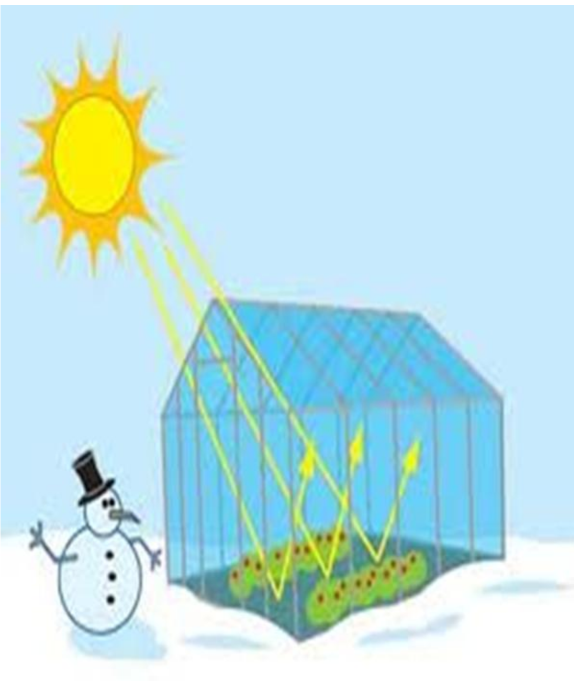
Absorption: All x-rays and most UV rays are absorbed by the upper atmosphere. Land surfaces (dark and rough) absorb energy and thus heat up faster than water surfaces (smooth). Water, too, has a higher specific heat than land materials; thus water takes longer to heat up and cool off than land surfaces.

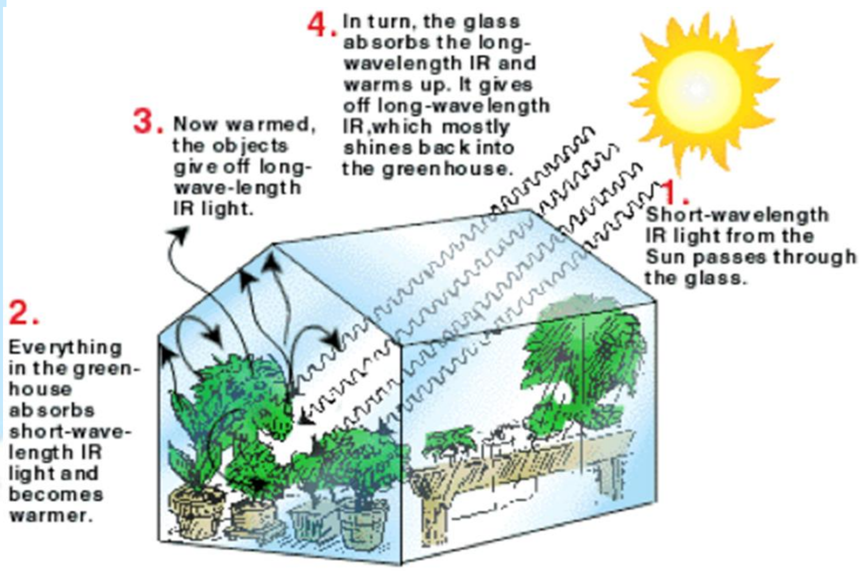
<u>**The Greenhouse Effect**</u>

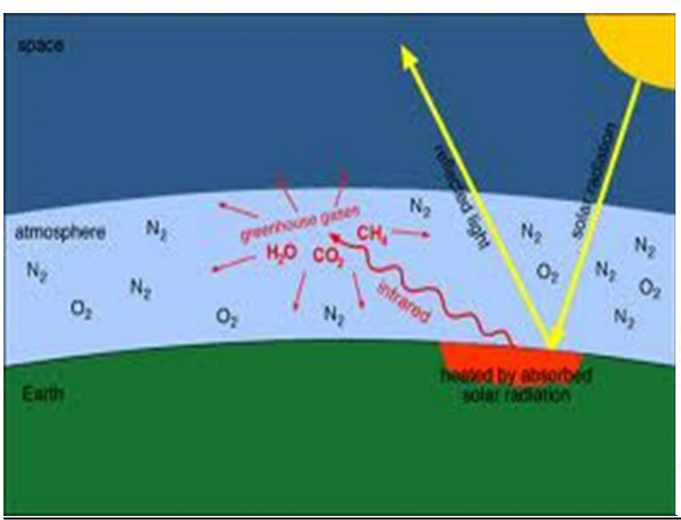
Carbon dioxide, water vapor and methane in the atmosphere **absorb infrared (heat**) wavelengths. This creates what is known as the Greenhouse Effect.

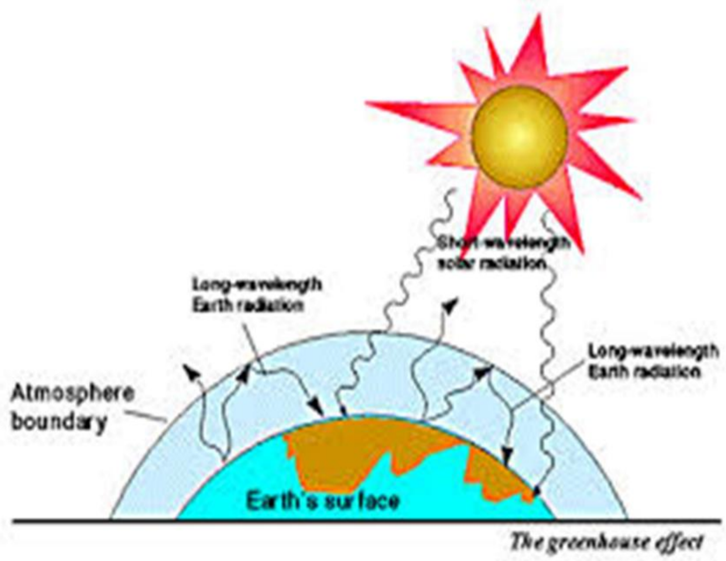
Like the glass of a greenhouse, Earth's atmosphere **allows shorter wavelengths—visible light—**to pass through. Earth surfaces absorb visible light, warm, and **reradiate the energy as heat or infrared energy—a longer wavelength.**

Carbon dioxide, methane and water vapor, "Greenhouse Gases," absorb the infrared energy, warming the atmosphere—just as the glass in a greenhouse traps longer heat wavelengths inside.









Energy Transfers Between Earth and the Atmosphere

When water from Earth surfaces evaporates, it absorbs heat energy (latent heat).

Condensation of water vapor to form rain or sublimation of water vapor to form snow releases latent heat into the atmosphere.

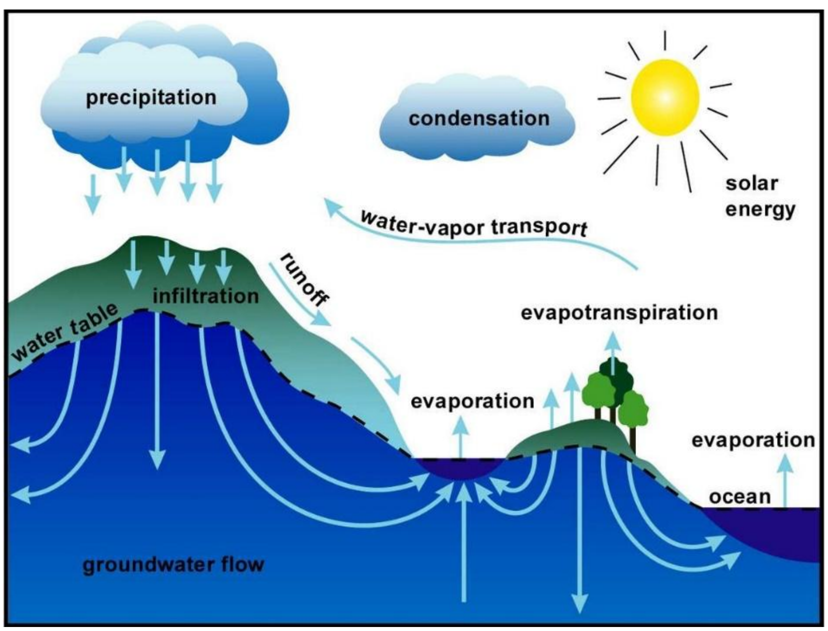
Earth reradiates heat to the lower part of the atmosphere, which warms by conduction. Convection circulates warmer air.

Topic 9 Notes—Part 2: water cycle, water movement in the ground, climate
Workbook pages 219-228; 236-240

The Water Cycle (Hydrologic Cycle)

Evaporation and transpiration fill the air with water vapor. Condensation empties the air of water vapor.

There is a balance between these two processes because the amount of water on Earth remains relatively constant over time. **The recycling of water on the Earth is called the water cycle.**



What happens to rain?

Rain water either runs off, evaporates or infiltrates into the surface of the Earth.
Infiltration = water that gets absorbed or sinks into the ground

Run off = water not absorbed that flows over Earth's surfaces. Whether water infiltrates into the surface or runs off depends upon two soil characteristics:

porosity and **permeability**

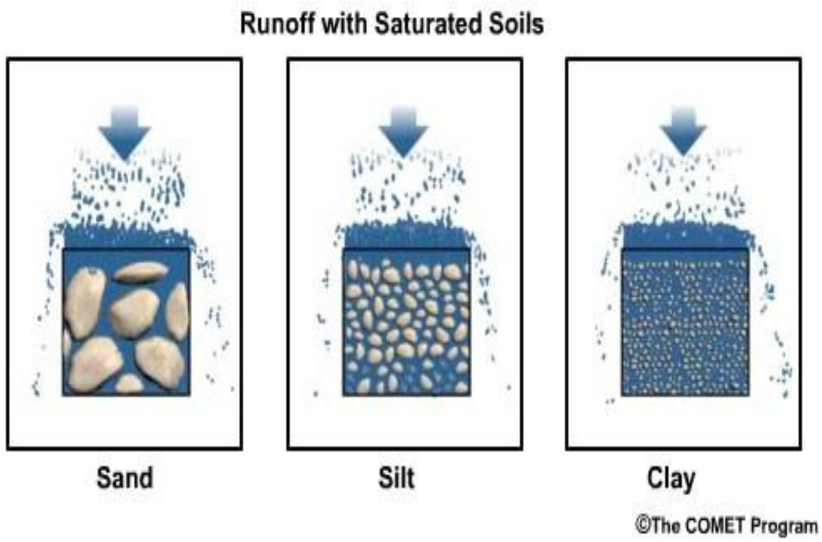
Porosity is the amount of space available between soil particles that can be filled with water. It's measured as **the percent** of open space available compared to the total volume of soil.

Permeability is a **rate** that shows how easily water can flow into the spaces between particles. **The faster water can move through soil, the higher the permeability rate.**

Factors affecting infiltration:

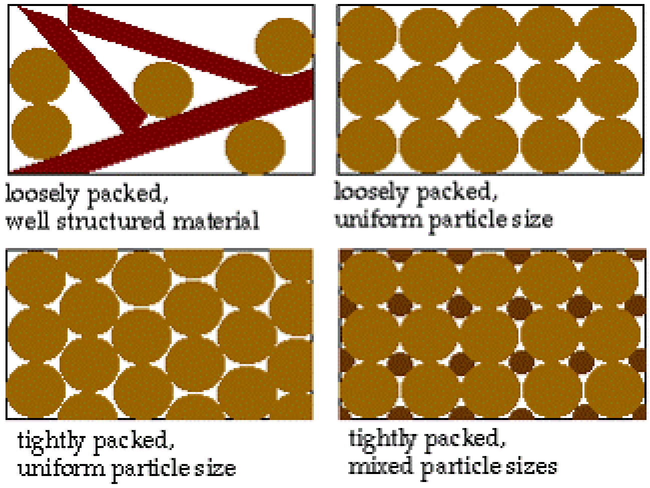
- Soil saturation: saturated soil has no pores left to hold water
- Shape of land: the steeper the slope, the less water will infiltrate (gravity makes it run downhill before it can infiltrate)
- Impermeability: the area water falls onto is dense, impermeable rock.

So: **infiltration** will occur when the surface is **unsaturated**, **permeable** and the **slope** of the surface is **gentle**.



Factors Affecting Porosity:

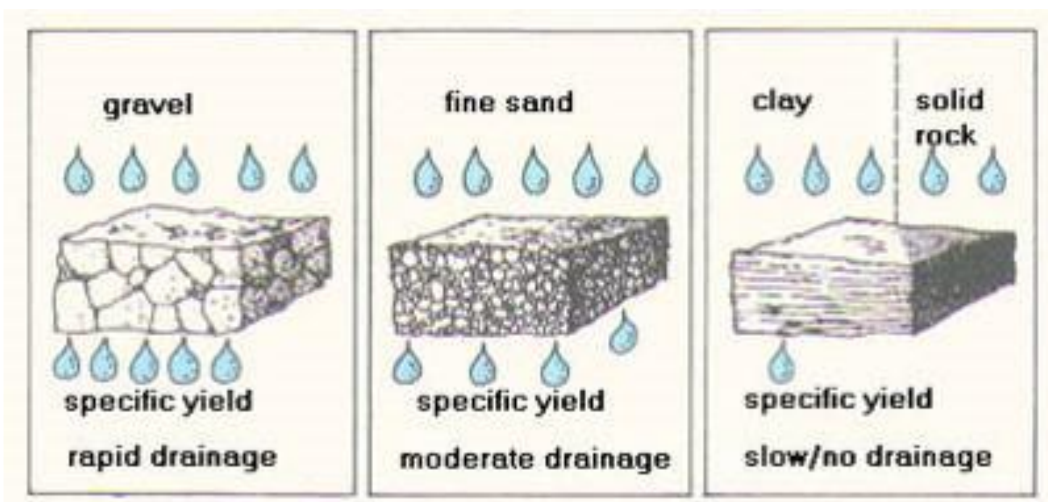
- **Particle shape**: the rounder the soil particle shape, the greater the porosity. Flat soil particles stack on top of each other leaving few open spaces.
- **Packing:** loosely-packed soil has more spaces between the particles
- **Particle size:** sorted particles have the same shape and size.
  Large, round, sorted particles have the same porosity as small, round, sorted particles (Large round particles have bigger spaces, but fewer pores per volume. Small round particles have smaller spaces but more pores per volume).
- **Sorting:** unsorted soil particles (small and larged mixed) has less porosity because the smaller particles fill the spaces between larger particles.



Factors Affecting Permeability:

Permeability depends upon the size of pore space available, **not the amount of pore space.**

Sand has high permeability because its pores are large and interconnected. However, water flows more slowly through fine-grained sand, whose pores are smaller. Different types of sand may have the same porosity, but different permeability.



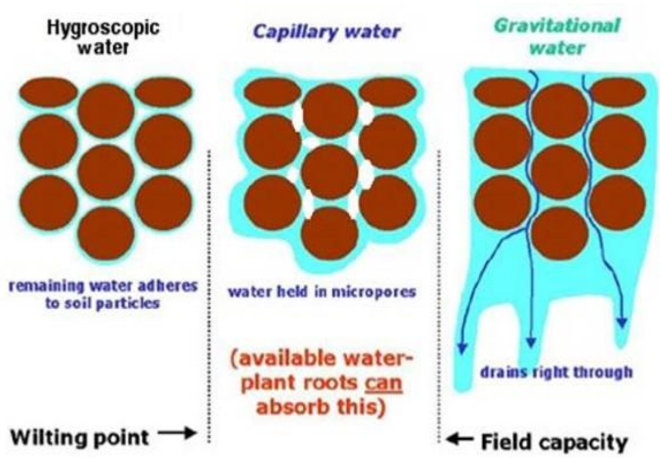
When rainfall exceeds the permeability rate, run off occurs. This can be due to soil saturation or the slope of the land. Heavy downpours where rain is falling faster than it can permeate the soil is also a cause for run off.

Capillarity

Water will move downward through soil (infiltrate) until it reaches an impermeable layer (bedrock). As water moves through the soil, it clings to soil particles due to **adhesion** (attraction of water molecules to other surfaces due to the water molecule's polarity).

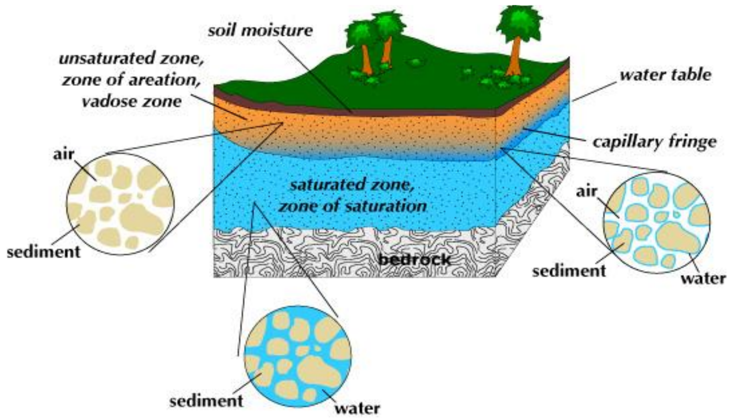
Capillary action is the **upward movement** of water **due to adhesion and cohesion** (attraction of water molecules to each other).

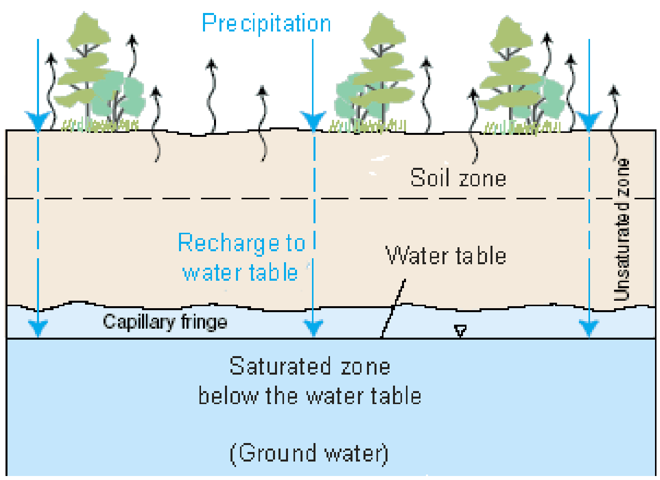
Capillary action only occurs spaces between soil particles are **small and interconnected.**



Note: There is an inverse relationship between capillarity and permeability.
As permeability increases, capillarity decreases.

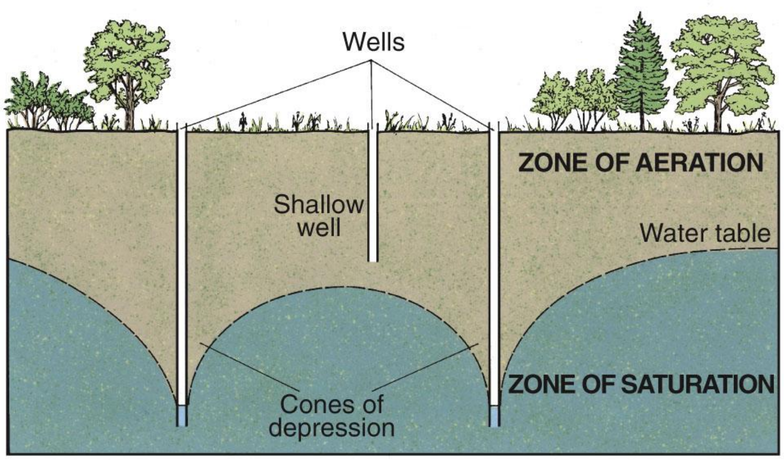
Zones of Subsurface Water :





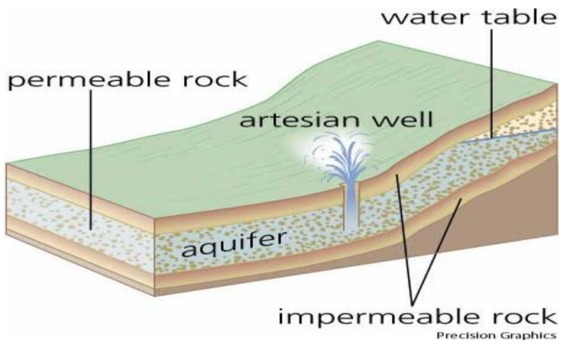
WATER SUPPLY

Gravity wells: holes are drilled into the ground until they reach water. Pumps bring water to the surface.



Artesian wells: holes are drilled into a permeable layer that lies between two impermeable layers. Water in this layer is under pressure because it is caught between two impermeable layers. The pressure exerted by the top layer forces the water up the well.

Long Island's water supply is chiefly from aquifers like the one shown here



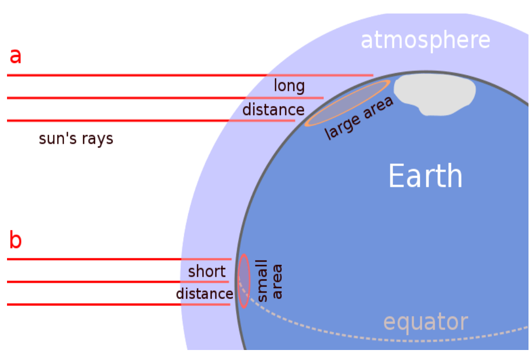
CLIMATE

Climate is a description of the pattern of weather over a long period of time.
It includes average weather conditions as well as how weather varies over time.
The **two main factors** that determine a region's climate are:

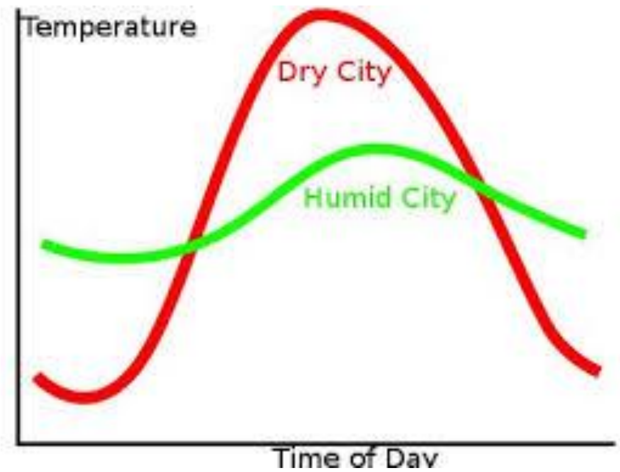
1. **Temperature**
2. **Precipitation**

Factors Affecting Temperature

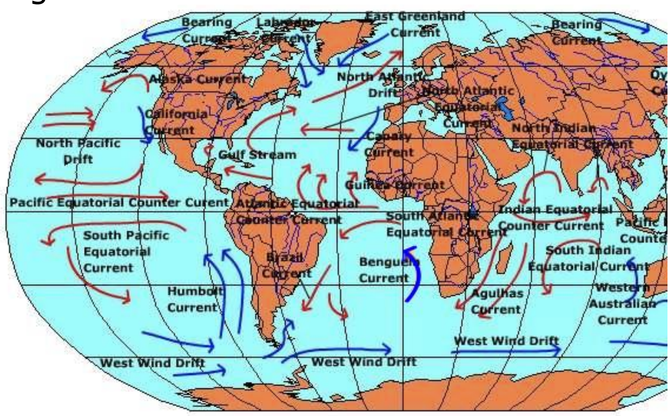
1. **Latitude** – most important.
   - Higher latitudes are cooler, lower latitudes are warmer



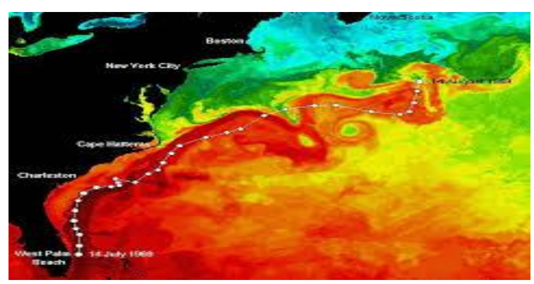
2. **Distance from large bodies of water**.
   - The air over large bodies of water has less variation in temperature, so areas near the water have less variation in temperature
   - This causes inland temperature ranges to be greater than coastal temperature ranges



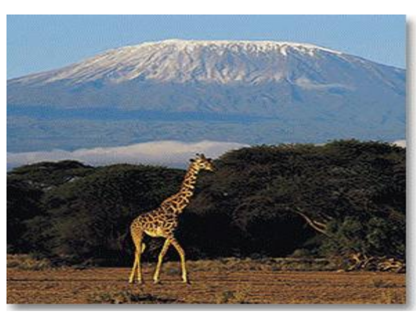
3. Ocean currents can be warm or cool, and thus have an effect on the temperature ranges of coastal areas



For example, the warm Gulf Stream current modifies temperatures along the east coast of the United States.

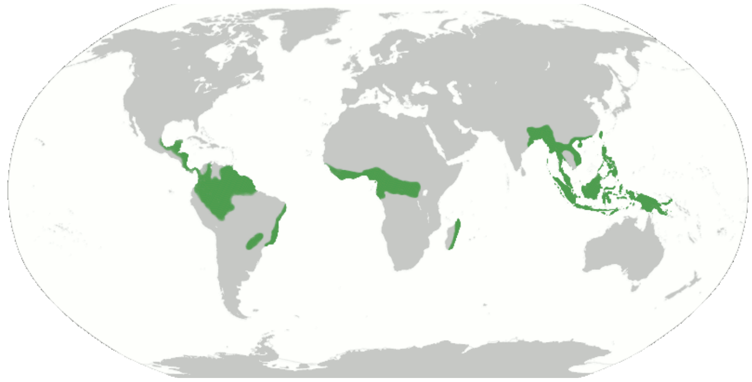


4. Altitude--Places that are higher above sea level tend to be cooler.

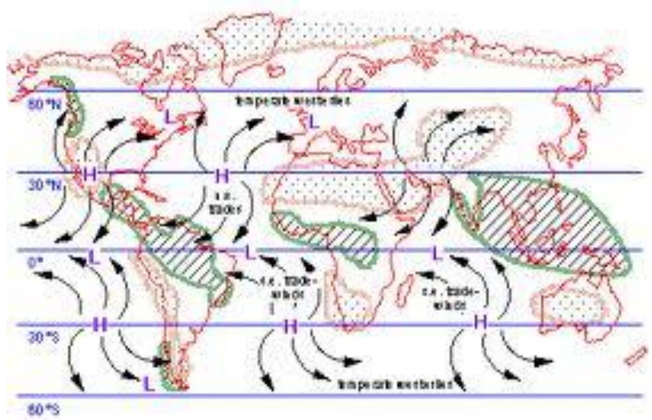


Factors that Affect Precipitation

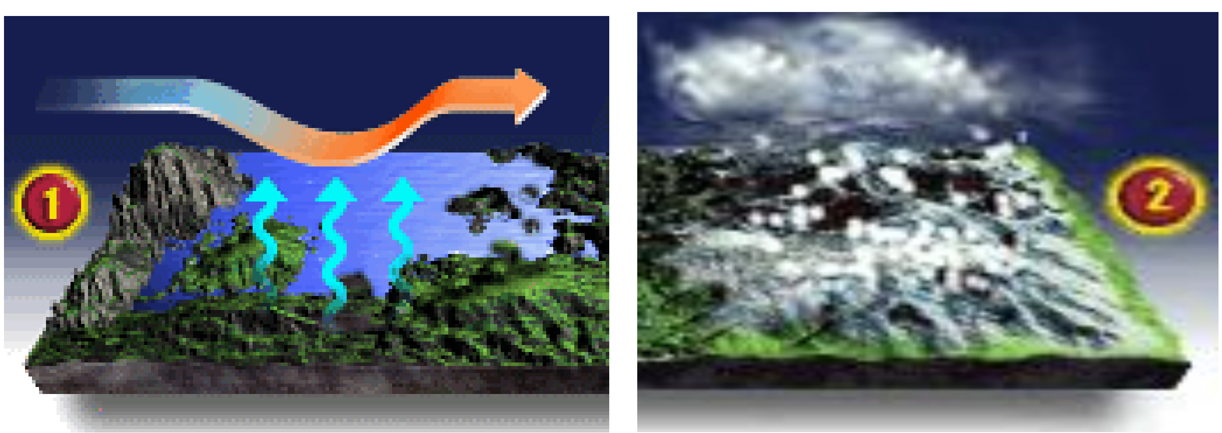
1. **Latitude** – warm air over the Equator holds more water vapor than cold air over the poles.



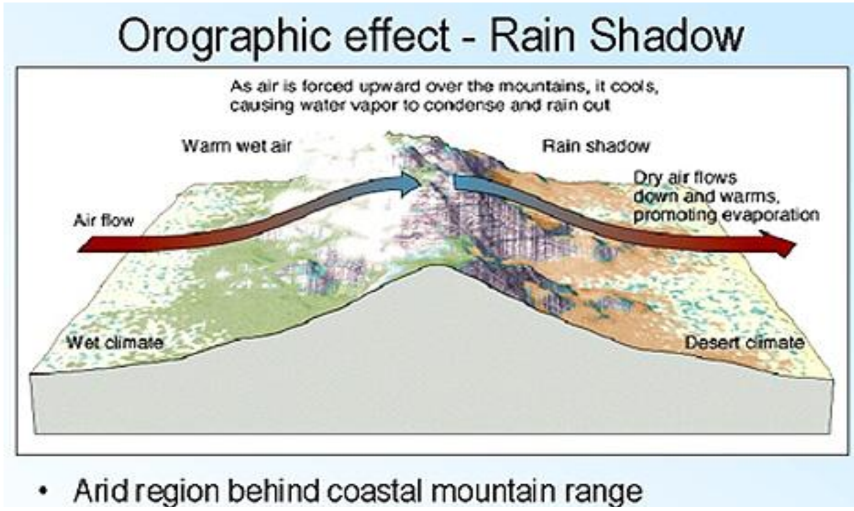
2. **Air pressure systems-** Deserts are located in areas that have high pressure systems. (In high pressure areas, air sinks and warms)



3. **Global winds** – If the prevailing winds blow from water over land, the land will have more rain or snow.



4. **Mountain barriers**: a mountain range can form a barrier to moving air, forcing it to rise. This creates a cool, humid climate on the windward side of the mountain range, and a warm, dry climate on the leeward side of the mountain range.



Whether a climate is classified as **humid or arid** (moist or dry) is based on the balance between **precipitation** and **potential evapotranspiration** (evaporation + transpiration).

The balance is expressed as a ratio**:** P/Ep: $\frac{\text{precipitation}}{\text{potential evapotranspiration}}$

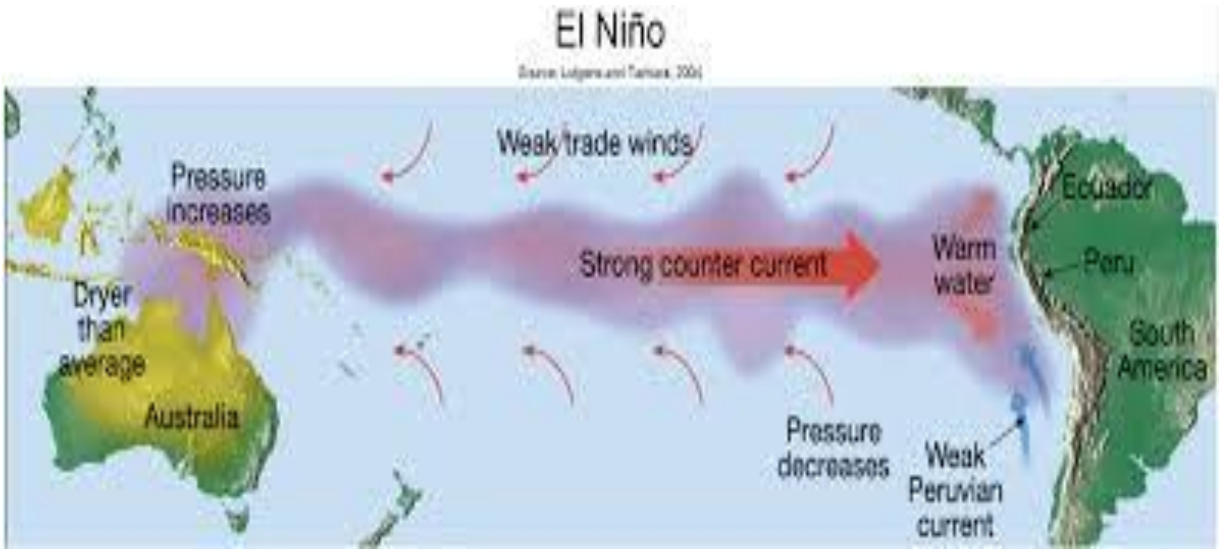
Humid climates have more precipitation than evapotranspiration. Arid climates have less precipitation than evapotranspiration.

P/Ep ratio	Type of Climate
Over 1.2	**Humid**
0.8 to 1.2	**Subhumid**
0.4 to 0.8	**Semiarid**
Less than 0.4	**Arid**

Natural Climate Changes

1. **Ice ages** – glaciers covered a large part of the Earth during certain times in its history. There have been 4 major ice ages in the last 2 million years. The most recent ended 10,000 years ago. Possible causes include changes in the Earth's orbit, the Earth's tilt or volcanic activity.

2. **El Nino** – every 3-7 years, prevailing eastward winds near the Equator (Trade Winds) seem to weaken, causing the water in the central Pacific Ocean to be warmer than usual. This creates climate changes, such as droughts in Africa and Australia, and heavy rains and flooding on the western US coastal areas.



3. **Global Warming:** Human activities seem to be changing the climate.
More carbon dioxide, methane, and other gases in the atmosphere are causing a "greenhouse effect", which is warming the planet.
Glaciers and icecaps are melting, raising sea levels.