SUBTEST III: Earth and Planetary Science

1) **Galaxies and Stars**
   a) **Identify and describe characteristics of galaxies**
      i) **Galaxy**: A large group of stars in space, held together by gravity; there can be billions of stars in a galaxy and there are billions of galaxies in the known universe; Ex: Milky Way Galaxy
      ii) There are 3 main types of galaxies:
         (1) **Spiral**
         (2) **Elliptical**
         (3) **Irregular**
      iii) Each type of galaxy has its own characteristics:
         (1) **Spiral Galaxy:**
            (a) A disk-shaped galaxy with spiral arms; contain a flat, rotating disk containing stars, dust, and gas
               (i) The spirals are glowing clouds illuminated by large, hot stars
            (b) Has a huge bulge in the center
            (c) Stars revolve around the central disk in one direction
            (d) Young stars are born in spiral arms; older stars are found in the central bulge
            (e) Ex: Milky Way Galaxies, Andromeda
            (f) Variations:
               (i) Normal Spiral Galaxies: They contain arms that spiral out from the center
               (ii) Barred Spiral Galaxies: These galaxies appear to have a straight bar of stars cutting across the center, with spiral arms curling away from the ends of the bar; about 2/3 of all spiral galaxies are barred, suspected that our Milky Way Galaxy may be a barred spiral galaxy; bars are thought to be temporary phenomena in the life of a spiral galaxy→ eventually the bar decays over time and the barred spiral galaxy becomes a regular spiral galaxy


Andromeda normal spiral galaxy


NGC1300 is a barred spiral galaxy

         (2) **Elliptical Galaxy:**
            (a) Found in centers of galaxy clusters; Contain massive blobs of stars, which are very close together, making the center look like one very bright star
            (b) Classified by an equation that uses the major and minor axis of the galaxy
            (c) If the earth were in an elliptical galaxy it would be bright both day and night
            (d) There is very little dust or gas
            (e) Contain mostly old stars, because elliptical galaxies don't actively create new stars, many of the stars were created 10 billion years ago
         (3) **Irregular Galaxy:**
            (a) Do not have a distinct shape like the elliptical or spiral galaxies, often chaotic in appearance

(b) Most irregular galaxies were once spiral or elliptical but were deformed by disorders in gravitational pull
(c) Do not fit any other class of galaxy
(d) Contain large amounts of hydrogen that in some cases indicate new star formation
(e) Classified into three categories: Irr-I, Irr-II, and dIrr


An Irr-I type galaxy


An Irr-II type galaxy


Dwarf galaxy

b) Explain the Evidence for the "Big Bang" Model

i) Huge explosion, in an instant everything expanded outward from that location forming the energy, atoms, and eventually stars and galaxies everything/matter emerged from this single point in space, before this "bang"= universe was previously contained in an infinitely small but infinite massive point

ii) Evidence (Four pillars of the Big Bang):

iii) **Redshift of Galaxies (Almost all galaxies are moving away from us)**

(1) In 1912, Vesto Slipher calculated the speed and direction of spiral nebulae by measuring the change in the wavelengths of light coming from them→ He realized that most of them were moving away from us, we now know that these objects were galaxies; In 1924, Edwin Hubble figured out that these galaxies are actually outside the Milky Way, he observed a special type of variable star that has a direct relationship between its energy output and the time it takes to pulse in brightness, by finding these variable stars in other galaxies he was able to calculate how far away they were

(a) Discovered that these galaxies are located outside our own Milky Way millions of light year away, so if these galaxies are far, far away and moving quickly away from us this suggests that the entire universe must have been located in a single point billions of years ago= now expanding

(2) The entire universe is spreading apart, with distant galaxies speeding away from us in all directions→ know this because of "red shifting" (things that are moving away from us in all directions appear more red) = bodies are moving away from each other

(3) Suggests that the entire Universe must have been located in a single point billions of years ago

iv) **Cosmic Microwave Background Radiation**

(1) If the universe was initially very, very hot (as the Big Bang suggests) then we should be able to find some remnant of this heat

(2) In the 1960s, Arno Penzias and Robert Wilson were experimenting with a 6 meter radio telescope and discovered a background radio emission that was coming from every direction in the sky, day or night

(3) From what they could tell the sky measured a few degrees above absolute zero→ Theories predicted that after a Big Bang there would have been a tremendous release of radiation and now billions of years later, this radiation would be moving away so fast from us that the wavelength of the radiation would have been shifted from the visible light to the microwave background radiation we see today (this is thought to be the remnant which scientists were looking for)

v) **Mixture of Elements**

(1) As the universe expanded and cooled down, some of the elements that we see today were created, the Big Bang gave rise to two elements: hydrogen and helium ("light elements")

(2) In the earliest moments after the Big Bang there was nothing more than hydrogen compressed into a tiny volume with crazy heat and pressure, the entire universe was acting like the core of a star, fusing hydrogen to helium and other elements→ known as Big Bang Nucleosynthesis

(3) When measuring the ratios of hydrogen, helium, and other trace elements= they exactly match what you would expect to find if the entire universe was once a really big star

(4) The Big Bang predicts how much of each element should have been in the early universe, predicts that some of the original hydrogen in the universe should have fused into helium during the era of nucleosynthesis, observations of the actual helium content of the universe closely matches the amount of the helium predicted by the Big Bang Model= 75% hydrogen and 25% helium

vi) **Formation of Galaxies and Large Scale Structure of the Cosmos**

(1) About 10,000 years after the Big Bang the universe cooled to the point that the gravitational attraction of matter was the dominant form of energy density in the universe→ this mass was able to collect together into the first stars, galaxies, and eventually the large scale structures we see across the universe today

c) Sun is a Typical Star and is Powered by Nuclear Reactions

i) Our Sun is a typical yellow dwarf: the star exists in a stable state where the gravitational forces pushing inward are balanced with the core nuclear fusion forces pushing outward

ii) Our Sun just happens to be part of the main sequence of stars; the Sun is not as big as a giant or super giant stars nor is it as small as a white dwarf so thus the Sun is in between

iii) The Sun is composed of the same material that the stars in the Universe and in Galaxies are made of; it is a typical stars of average size and temperatures, many stars are much bigger and hotter and many stars are smaller and cooler, there are billions of stars in the Universe like our Sun

iv) **Fusion** (energy source in stars, the process that creates all the energy and light that stars give off):

(1) Nuclear fusion requires extremely high temperature and density= these conditions are found deep in the core of the sun.

(a) In order for the Sun to shine steadily, it must have a way to keep the core hot and dense. It maintains these internal conditions through a natural balance between two competing forces: gravity pulling inward and pressure pushing outward (called a gravitational equilibrium). The outward push against gravity comes from internal gas pressure. The weight of overlying layers is greater as we look deeper into the Sun, the pressure must increase with depth. In the core, the pressure makes the gas hot and dense enough to sustain nuclear fusion. The energy released by fusion, in turn, heats the gas and maintains the pressure that keeps the Sun in balance against the inward pull of gravity. The sun began to fuse 4.5 billion years ago when gravitational contraction made the sun hot enough to sustain nuclear fusion in tits core.

(2) The Sun is a natural fusion reaction

(a) It is hot enough to produce collisions where fusion can take place

(b) The plasma is like a soup of hot gas with positively charge atomic nuclei and charged electrons whizzing about at very high speeds. At any one time, these nuclei are on a high-speed collision course with each other

(3) It is a main-sequence star and thus generates a tremendous amount of energy by nuclear fusion of hydrogen nuclei into helium, in its core the Sun fuses 620 million metric tons of hydrogen each second
  (a) (Definition of fusion) Two lighter atoms fuse together to make a heavier atom and in doing so release an incredible amount of energy→ form a new type of atomic nucleus

(4) Ex: (This happens in our Sun) Two hydrogen atoms that fuse together= two hydrogen nuclei combine= instead of one proton you have two= now it's a helium atom
  (a) As part of this fusing process, particles are given off→ neutrino particles in this reaction energy is given off as gamma radiation
    (i) The amount of energy given off as gamma rays is fairly small, but enormous amounts of these reactions happening in our Sun thus a lot of energy is given off
  (b) Fusion reaction releases both mass and energy
    (i) Stars are losing mass over time because that mass is being converted into the energy that's being given off, the light we see the gamma radiation the heat= all forms of energy that are coming from the star used to be mass
    (ii) The new atoms formed have less mass than the sun of the original atoms and the extra mass is given off as energy

d) Process of Nuclear Synthesis of Chemical Elements/ How Accelerators Simulate the Conditions for Nuclear Synthesis

(1) Stars start their life as a little piece of dust in huge clouds of dust and gas that exist in most galaxies
  (a) These clouds are calm, nothing happens in them for ages until something sets them off, the disturbance could be just a little turbulence, pressure from an explosion in space, or even a collision with another cloud
  (b) Then all of the sudden the dust particles begin to collide with one another
  (c) When the collide they stick together then more collide then more, these particles collide and grow until they are big enough to produce their own gravity, now they don't even have to collide, they can pull in other pieces of matter with their gravitational pull
  (d) Eventually this clump of particles gets so big it begins to collapse under its own weight, over millions of years of this collapse the center of the clump gets hot→ now called a Protostar= a developing star that isn't hot enough to do nuclear fusion
  (e) Protostar eventually becomes hot enough for nuclear fusion (when hydrogen atoms fuse and produce helium atoms, releases energy) to occur in its core, at this point it is considered a Star
  (f) The energy pushes outward on the star, so the weight of the star pushes in towards the core, energy produced by the nuclear fusion in the core pushes outward
    (i) Brown Dwarf: a protostar that never grew big enough to do fusion in its core; heavier than gas giant planets but not big enough to be a star
  (g) For stars that do achieve fusion= they continue to grow bigger for many years, which increase its size and heat in its core, until the pressure pushing outward equals the pressure pushing inward→ Star stabilizes= now a main sequence star and will remain in this state until it burns through all of its fuel

(2) Accelerators Simulate conditions for Nuclear Synthesis:

(a) Subatomic particles are propelled until they have attained almost the same amount of energy as found in the core of a star

(b) When these particles collide head on= new particles are created

e) Compare the Use of Visual, Radio, and X-Ray Telescopes to Collect Data that Reveal that Stars Differ in their Life Cycles

i) Telescope: A device used by an astronomer to magnify objects, it extends human vision by making distant things appear larger, sharper, and brighter; astronomers use radio and X-ray telescopes to look at things that emit lots of energy across the electromagnetic spectrum

(1) Telescopes that study different kinds of wavelengths vary in structure and design→ main idea behind all telescopes is to collect as much light as possible with as much resolution as possible

ii) By using different tools we can tell that stars differ in color, size, surface gravity, and temperature; It's impossible to actually watch a star grow from birth= study different stars to help us put together an average life cycle of a star

iii) Stars give off electromagnetic radiation (ex: visible light, gamma radiation, radio waves, etc) that can be measured

(1) Light comes in wavelengths from short to long, visible light the light humans see is in the middle of the range

(a) Long wavelength, low frequency→ short wavelength, high frequency

(b) Radio waves→ microwaves→ infra-red→ visible light→ ultra-violet→ X-rays gamma rays

iv) If scientists only studied stars in visible light= they would miss much of the picture because the human eye can only see certain wavelengths within the visible spectrum→ must use telescopes that look at other wavelengths of light because each wavelength shows something different about the universe/must use a variety of telescopes to look at the universe because each telescope shows them different things

(1) EX: The hot upper layers of the sun emit UV and X-ray, sometimes even gamma rays→ so stars emit light over a broad range of wavelengths

(2) Electromagnetic radiation that is emitted from the surface of the stars is the primary source that we can study them, different kinds of telescopes can collect the radiation in wavelengths such as x-rays to radio waves

v) **Visual (Optical) Telescopes→**

(1) Collect light from the visual part of the light spectrum, there are three types of optical telescopes: reflectors (uses mirrors), refractors (uses lenses), and catadioptric (uses both, lenses and mirrors)

(2) Use one mirror, or a combination of mirrors, to reflect light and form an image to the view, the design of this telescope allows astronomers to see things way out in space that don't emit much light

(3) Almost all of the major telescopes used in astronomy research are reflectors

vi) **X-ray Telescopes→**

(1) Collect light in shorter wavelengths, help astronomers study the Sun, supernova, and other stars

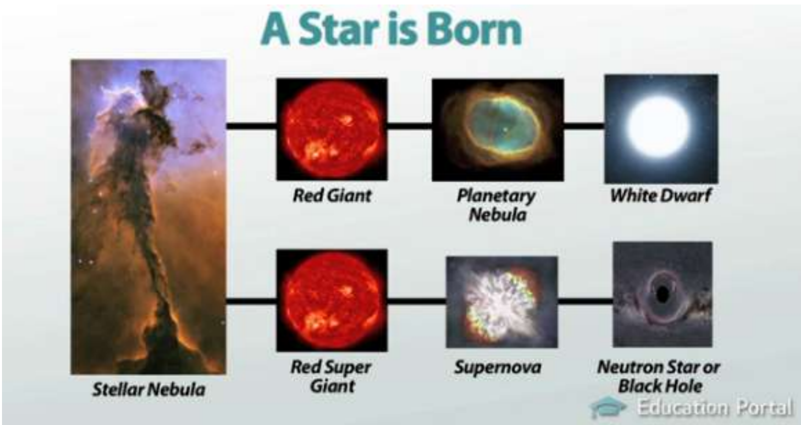
(2) Don't work well on Earth's surface because the short wavelengths get disrupted and weaken in the atmosphere, so scientists put these types of telescopes in space where atmosphere is not a problem

vii) **Radio Telescopes→**

(1) Collect long-wavelength light to investigate diverse things; observe objects in the radio spectrum; usually large, dish-type antennas; look at very long wavelength light and are able to see many diverse things, convert long wavelengths into pictures
   (a) EX: Can investigate how hydrogen gas is distributed in our galaxy and other galaxies
   (b) Scientists build them far away from populous areas to avoid interference from radio and TV

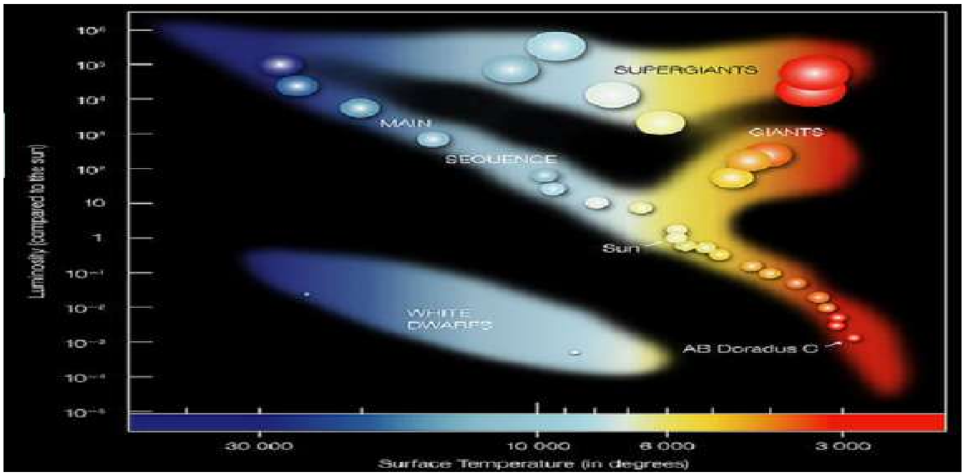
f) How the Evolution of a Star is Determined by a Balance between Gravitational Collapse and Nuclear Fusion

i) Some of the different stars in our galaxy include main sequence, red giants, white dwarfs, and brown dwarfs



ii) How stars are born:
   (1) A star starts in a stellar nebula, then depending on size it either:
      (a) Average stars become red giants, turn into planetary nebulae, and end their lives as white dwarfs
      (b) Massive stars become red supergiants, undergo supernova explosion, and become either a neutron star or a black hole
   (2) A nebula is a celestial cloud of gas and dust that gives rise to a star when it becomes massive enough that the pressure of its own gravity initiates nuclear fusion in its core→ This fusion of hydrogen into helium creates pressure, which pushes outward and counteracts the inward pressure of gravity
      (a) A newborn star that is undergoing hydrogen fusion in the core and has achieved a stable balance of forces is a main sequence star

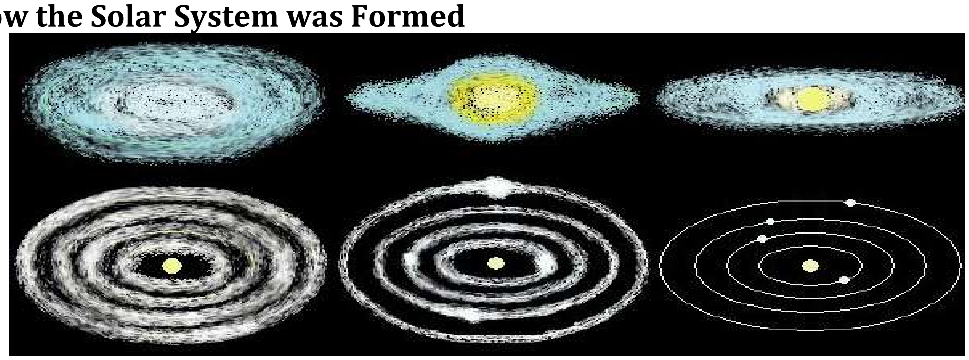
iii) Main sequence is a way astronomers have of classifying stars, they plot the color of a star versus its brightness
   (1) Main sequence star= Any star that is fusing hydrogen in its core and has a stable balance of outward pressure from core nuclear fusion and gravitational forces pushing inward
   (2) Any star during the 'regular' time in its life: not newborn, not dying, just burning in an ordinary stable manner= the longest phase of a star's life



(3) The Hetzsprung-Russell Diagram
(a) Stars can vary in size, color (determined by temperature), age, and luminosity (brightness)→ the color and luminosity of a star can be plotted on the H-R Diagram
(i) Nearly all stars are located in a swath that extends from the upper-left (bright and hot) to the lower right (dim and cool)
(ii) More than 90% of the stars in the universe are main sequence stars because this is the longest phase of a star's life
(b) The reason main sequence stars are so different is because they are born from diverse sizes of nebulae
(i) Tiny nebulae: Create very small stars that burn relatively cool→ lower part of main sequence
(ii) Large nebulae: Create very large stars that burn very hot→ upper part of main sequence; often break up into two or three stars
(4) The amount of time a star is on the main sequence structure depends on its size/temperature
(a) Large hot stars consume their hydrogen very quickly and only remain stable on the main sequence for thousands of years
(b) Tiny cool stars take billions of years to expand their core hydrogen
(c) All stars leave the main sequence when they have expended all of the hydrogen in their core, which causes the gravitational forces pushing inwards to overcome the now diminished outward core fusion pressure
(i) There will be different results caused by this imbalance, depending on the size of the star→ the large cool stars on the upper right of the H-R diagram are stars that have recently left the main sequence

2) Solar System

a) How the Solar System was Formed



i) The Solar Nebular Hypothesis:

(1) States that the sun, planets, moons, and asteroids were formed around the same time around 4.6 billion years ago

(2) Formed out of the remnants of a giant, rotating cloud of gas and dust known as a solar nebula, the nebula collapsed because of its gravity and condensed into the Sun and other objects of our solar system; gravitational pull from the large amount of mass in the Sun caused hydrogen to fuse with helium, creating the birth of our Sun

(3) The plane that the planets orbit in is a result from the nebula spinning and spreading out into a flat disk, as the disk got thinner and thinner, particles began to stick together and form clumps, some clumps got bigger as particles and small clumps stuck to them eventually forming planets and moons

(4) The gas that gave rise to our solar system was the product of billions of years of galactic recycling that took place before the birth of our solar system→ The gas that made up the solar nebular was made up of approximately 98% hydrogen and helium and 2% everything else, the Sun still has this basic composition, while the planets tend to have higher proportions of heavy elements

ii) Planet formation:

(1) Near the center of the cloud where planets like Earth formed, only rock material could stand the great heat; icy matter settled in the outer regions of the disk along with rock material where giant planets like Jupiter formed; as the cloud continued to fall in, the center eventually got so hot that it became a star, the Sun, and blew most of the gas and dust of the new solar system with a strong stellar wind

(2) In the center of the collapsing solar nebula, gravity drew together enough material to form the Sun. IN the disk, the gas was too spread out for gravity to clump it up. Instead, hydrogen clumped in some other way ("seeds") and grew in size until gravity could start pulling it together into planets

(3) The small "seeds" that eventually grew into planets was through a process called accretion (growth of a massive object by gravitationally attracting more matter), in which the planets began as dust grains in orbit around the central protostar= through direct contact these grains formed into clumps, which in turn collided to form larger bodies→ these gradually increased through further collisions

(4) Similarities between Terrestrial Planets and Gas Giants:

(a) All orbit the sun, all are spherical or almost spherical due to their gravity, all orbit the Sun in the same direction

(5) Inner Solar System (planets closest to the Sun):

(a) Area was too warm for volatile molecules like water and methane to condense= the planets that formed there could only form from compounds with high melting points such as metals and rocky silicates

(b) These rocky bodies would become the terrestrial planets: Mercury, Venus, Earth, Mars

1. All composed mostly of rock and heavy metals
2. Planets have a core of heavy metals that is mostly iron
3. The core is surrounded by a mantle of silicate rock
4. Much smaller than gas giants
5. Have varied terrain such as volcanoes, canyons, mountains, and craters
6. They have few or no moons (Mercury and Venus have none, while Earth has one, Mars has two small moons)
7. Do not have planetary rings like the gas planets
8. The atmosphere of planets can vary from Venus' thick carbon dioxide atmosphere to almost nothing on Mercury

9. Spin slowly
10. Orbit the Sun quickly
11. No rings

(6) Outer Planets (furthest from the Sun):

(a) Gas Giants: Jupiter, Saturn, Uranus, Neptune: Formed further out, beyond the frost line, the point between the orbits of Mars and Jupiter where the material is cool enough for volatile icy compounds to remain solid

(b) Gas planets formed as gravity drew gas around large, icy planetismal

(c) The ices that formed the gas giants were more abundant than the metals and silicates that formed the terrestrial planets, allowing the gas planets to grow massive enough to capture hydrogen and helium

1. Planets are much larger than the terrestrial planets
2. Most of the Outer planets are made of gas, it is likely that they have a much smaller solid or liquid center, it wouldn't be possible to stand on any of them
3. Smaller density than the terrestrial planets, they are less densely packed together causing them to be quite light for their size
4. Similar atmosphere: the atmospheres of the outer planets consists mostly of hydrogen and helium
5. Spin quickly
6. Orbit the Sun slowly: have a much greater distance to cover to complete an orbit, ex: Neptune takes over 164 years
7. Lots of moons: all the outer planets have many moons orbiting them
8. All of the outer planets have rings orbiting them

(7) The formation of the Sun:

(a) After the nebula collapsed and began to spin faster and eventually flatten into a disk→ most of the material was pulled toward the center to form the Sun

(b) Sun is the closest star to the Earth

(c) Essentially a huge burning ball of gas in the sky, the majority of the gas in the Sun is hydrogen and helium and it is so hot that all of these elements exist in the gaseous state which is held together by gravity= creates intense heat and pressure in the core

(d) The Sun has six layers→ three layer (the corona, chromosphere, and photosphere) comprise the Sun's atmosphere or outer layer; the other three layers (convective zone, radiative zone, and the core) comprise the inner layers; the Sun has blemishes on its surface known as sunspots, which are temporarily cooler spots on the surface of the sun, and solar flares, which are enormous explosions on the surface of the Sun

(8) Evidence on Earth and the Moon that the Solar System is 4.6 billion years old

(a) The most reliable method of measuring the age of rocks in through radiometric dating→ procedure that measures radioactive decay of rocks and minerals to calculate age; done using radioactive elements that break down at a predictable rate

(i) Relies on careful measurement of the proportions of various atoms and isotopes in a rock. This method works because some atoms undergo changes with time that allows us to determine how long they've been held within the rock's solid structure. Radiometric dating tells us how long it's been since a rock solidified

(b) Moon rocks date back to 4.4 billion years ago

(c) Meteorites have been dated as far back as 4.53 billion years ago
   (i) This is important because as the Earth was being formed it was constantly bombarded by meteorites, they were important in giving Earth its shape, can tell how old they are through age dating (explained above)
      1. Meteorites are rock and over time certain atoms in rocks change into other atoms through radioactive decay, since scientists can measure this process precisely, they can work out how many years its been since the rock was formed, the oldest meteorites age-date at about 4.6 billion years so that is how old the Earth is

b) Evidence that Planets Orbit Other Stars

i) The first discovery of a planet around another star, called 51 Pegasi, was in 1995, more than 200 exoplanets (a planet revolving around a star outside of our solar system) have since been discovered

ii) Scientists look for exoplanets by checking out their gravitational effect on stars, a large planet orbiting a star will cause it to wobble, we are able to make precise measurements of a stellar position in the sky, if a star wobbles gradually around its average position→ must be observing the influences of unseen planets
   (1) This wobble turns up as a particular kind of smudge on the photography of a star→ by monitoring the spectrum of the star= can tell whether it is moving toward us or away from us (known as the Doppler technique= looks for the Doppler shifts in a stars spectrum)
   (2) Star's spectrum is shifted toward red→ moving away from us
   (3) Star's spectrum is shifted toward blue→ moving toward us
   (4) Method is best suited to identify massive planets that orbit relatively close to the star because the stars orbital speed depends on the strength of the gravitation tug and gravity is strongest on massive planets

iii) Circumstellar disk
   (1) A disk around stars provide the conditions for planet formations

iv) Transit and Eclipses
   (1) A way to detect a distant planet is to observe slight changes in a star's brightness, which occurs when a planet passes in front of or behind it
   (2) When a planet passes between the star and us the result is a transit, because other reasons could dim a star's brightness= the dimming needs to repeat with a regular period
   (3) When the planet passes behind the star, it is called an eclipse→ during an eclipse we observe/measure the effect of the eclipse from combined light from the star and planet; whenever either blocks the other, there is a dip that occurs during an eclipse and are usually measurable in infrared wavelengths

v) OGLE (Optical Gravitational Lensing Experiment)
   (1) Finds exoplanets using its gravitational lensing, an effect predicted by Einstein's general theory of relativity that occurs when one objects gravity bends or brightens the light of a more distant object

vi) Exoplanets are believed to be gas giants like Jupiter but probably several times bigger
   (1) Think this because a smaller planet would not exert enough gravitational pull on its star for us to see it or measure it

c) Changes in the Solar System Over time

Chronology of the formation and evolution of the Solar System

Phase	Time since formation of the Sun	Time from present (approximate)	Event
Pre-Solar System	Billions of years before the formation of the Solar System	Over 4.6 billion years ago (bya)	Previous generations of stars live and die, injecting heavy elements into the interstellar medium out of which the Solar System formed.[14]
	~ 50 million years before formation of the Solar System	4.6 bya	If the Solar System formed in an Orion nebula-like star-forming region, the most massive stars are formed, live their lives, die, and explode in supernova. One particular supernova, called the *primal supernova*, possibly triggers the formation of the Solar System.[16][17]
Formation of Sun	0–100,000 years	4.6 bya	Pre-solar nebula forms and begins to collapse. Sun begins to form.[30]
	100,000 – 50 million years	4.6 bya	Sun is a T Tauri protostar.[9]
	100,000 - 10 million years	4.6 bya	Outer planets form. By 10 million years, gas in the protoplanetary disc has been blown away, and outer planet formation is likely complete.[30]
	10 million - 100 million years	4.5–4.6 bya	Terrestrial planets and the Moon form. Giant impacts occur. Water delivered to Earth.[2]
Main sequence	50 million years	4.5 bya	Sun becomes a main sequence star.[26]
	200 million years	4.4 bya	Oldest known rocks on the Earth formed.[117][119]
	500 million – 600 million years	4.0–4.1 bya	Resonance in Jupiter and Saturn's orbits moves Neptune out into the Kuiper belt. Late Heavy Bombardment occurs in the inner Solar System.[2]
	800 million years	3.8 bya	Oldest known life on Earth.[61][119] Oort cloud reaches maximum mass.[64]
	4.6 billion years	**Today**	Sun remains a main sequence star, continually growing warmer and brighter by ~10% every 1 billion years.[95]
	6 billion years	1.4 billion years in the future	Sun's habitable zone moves outside of the Earth's orbit, possibly shifting onto Mars's orbit.[98]
	7 billion years	2.4 billion years in the future	The Milky Way and Andromeda Galaxy begin to collide. Slight chance the Solar System could be captured by Andromeda before the two galaxies fuse completely.[114]
Post-main sequence	10 billion – 12 billion years	5–7 billion years in the future	Sun starts burning hydrogen in a shell surrounding its core, ending its main sequence life. Sun begins to ascend the red giant branch of the Hertzsprung–Russell diagram, growing dramatically more luminous (by a factor of up to 2,700), larger (by a factor of up to 250 in radius), and cooler (down to 2600 K): Sun is now a red giant. Mercury and possibly Venus and Earth are swallowed.[96][101] Saturn's moon Titan may become habitable.[103]
	~ 12 billion years	~ 7 billion years in the future	Sun passes through helium-burning horizontal branch and asymptotic giant branch phases, losing a total of ~30% of its mass in all post-main sequence phases. Asymptotic giant branch phase ends with the ejection of a planetary nebula, leaving the core of the Sun behind as a white dwarf.[96][106]
Remnant Sun	~ 1 quadrillion years (10^{15} years)	~ 1 quadrillion years in the future	Sun cools to 5 K.[120] Gravity of passing stars detaches planets from orbits. Solar System ceases to exist.[3]

3) **Planets and Satellites**

a) **Evidence that Indicates the Proximity of the Planets to the Solar System**

i) http://heasarc.gsfc.nasa.gov/docs/cosmic/solar_system_info.html

b) **Evidence that Earth and Other Planets Change Over Time**

i) Starting back from the very beginning: According to the Nebular Theory, Earth first formed approximately 4.567 billion years ago when an enormous rotating cloud, which consisted of microscopic dust grains, helium and hydrogen gases, and the ejected matter of dead stars began to rotate and contract. It began to rotate faster and faster (conservation of angular momentum) and eventually, the inward pull of gravity equaled the outward force of the rotation motion of the nebula. The nebula cloud flattened into a disk with most of the matter concentrated in the center, which eventually formed the Sun. The gravitational energy was converted to thermal (heat) energy, which caused temperature at the center region of the nebula to rise. On the other hand, the outer region of this nebula remained pretty cold

ii) The inner region began to cool and this allowed materials to condense into tiny partials. These tiny particles slowly began to coalesce and accreted into planetesimal, which eventually formed the four inner planets. The inner planets are made up of minerals such as silicon, calcium, and sodium. The planetesimal and materials that did not form into planets collided into the planets. These bombardments caused the planets to rise in temperature. Thus, because of the high temperatures and weak gravitational fields, they were unable to hold on to the lighter components of the nebular cloud, such as hydrogen and helium. These elements, which made up the first atmosphere, were eventually blown away by solar radiation. On Earth outgassing (volatiles escaping to the surface of the earth) is thought to have formed a second atmosphere. Most of the gases that made up of the second atmosphere were water vapor, small amounts of hydrogen, hydrogen chloride, carbon dioxide, carbon monoxide, nitrogen, and other gases. The atmosphere was originally anoxic (based on the amount of BIF's formed during this time period). Life began to form consisted of simple one-celled prokaryotic organisms that formed during the archan era. Around 3.5 bya, photosynthetic prokaryotes (mainly cyanobacteria) began releasing oxygen into the ocean, which eventually made its way to the atmosphere. Proof of oxygen levels rising during the Proterozoic Eon are the formation of redbeds, which are sediments that contain oxidized iron-bearing minerals

iii) For the inner planets, with the bombardments and radioactive decay, the internal temperature of the planets rose. The planets became hot enough for iron and nickel to melt. These heavy, high-dense, melted metals began to sink towards the center of the planet. The less buoyant masses (which consisted of elements such as oxygen, silicon, and aluminum) of molten rock rose toward the surface of the planet where they eventually solidified to form a primitive crust. The planets started to divide chemically into layers: the inner solid iron-rich core, the liquid out core, the viscous mantle, and the crust.

c) Influence of Collisional Processes on Early Earth and Other Planetary Bodies

i) The collision, heavy bombardments in the first few hundred million years did more than just batter the planets, also <u>brought materials from other regions of the solar system</u> (critical to our existence on Earth today)

ii) These impacts are left over planetesimal→ Planetesimals that grew within the inner solar system were made from metal and rock. Thus, the planetesimals probably contained no water or Hydrogen compounds since it was too hot for these compounds to condense in our region of the soar nebula. Thus, <u>water and other hydrogen compounds were brought to Earth through impacts of water-bearing planetesimals that formed farther from the sun</u>

iii) Our moon may also have formed when a Mars-size planetesimal hit the Earth at such an angle that broke off parts of the Earths outer crust, eventually the moon acclimated and grew→ called the Giant Impact Hypothesis

iv) Pluto's moon, Charon, shows signs of having formed in a giant impact, similar to our moon
v) Mercury's high density may be the result of a giant impact that blasted away its outer, lower density layers
vi) Impacts could have also been responsible for tilting the axis of many planets (including Earth's) and tipping Uranus on its side
vii) Venus' slow and backward rotation could also be the result of a giant impact

4) Tectonic Processes

a) Major Divisions of the Geologic Time Scale

i) Pregnant Camels Often Sit Down Carefully, Perhaps Their Joints Creak, Possibly Early Oiling Might Prevent Premature Rash

(Pre-Cambrian, Cambrian, Ordovician, Silurian, Devonian, Carboniferous, Permian, Triassic, Jurassic, Cretaceous, Paleocene, Eocene, Oligocene, Miocene, Pliocene, Pleistocene, Recent)

ii) This scale (see attached) is marked by events of noticeable change, such as catastrophic geological impacts (extinctions) and biological change

iii) **Pre-Cambrian (Super Eon) (4.6 billion years ago to 542 million years ago):**

(1) Contains the Hadean, Archean, and Proterozoic Eon and is the time between the birth of the planet and the appearance of complex forms of life (bacteria)

(2) More than 85% of the Earth's estimated 4.6 billion years fall into this time span

(3) **Hadean Eon (or hell-like environment/Hades):**

(a) Oceans of liquid rock, water vapor, boiling sulfur, and impact craters everywhere; any newly formed rock was quickly melted, covered, or blasted away

(b) Air is thick with carbon dioxide, nitrogen, and sulfur

(c) This is the time believed that an asteroid the size of Mars struck Earth and formed the Moon

(i) Terrestrial rock of this era have not been found, only lunar rock samples and meteorites are this old

(4) **Archean Eon (begins about 3.8 billion years ago):**

(a) Chronological boundary is marked by a significant cooling down of Earth's surface→ water vapor in the air has cooled and condensed to form oceans

(b) Carbon dioxide is changed into limestone and at the bottom of the newly formed ocean

(c) Air is rich with nitrogen and lacks "free" oxygen

(d) At the end of the eon→ tectonic movement is similar to today's Earth where "islands" of huge land masses have began to move

(e) Single celled organisms are present in the form of cyanobacteria (important in releasing free oxygen into the atmosphere)

(5) **Proterozoic Eon (early life, *begins 2.5 bya and finishes 542 mya):**

(a) Time segment exists before complex life evolves

(b) Important events that occurred in this eon=

(i) Oxygenated atmosphere, glacial formations (Snowball Earth), abundance of soft bodied multi-cellular organisms (eukaryotes)

(c) Time boundary between Proterozoic and Phanerozoic eons is marked by the appearance of animal fossils (trilobites= well known fossil group of extinct marine arthropods, form one of the earliest known groups of arthropods)

iv) **Phanerozoic Eon (covers present time/ means "visible life"):**

(1) Contains abundance in life, emergence of terrestrial and complex plants, emergence and variance of terrestrial animals, marked by extinctions and the

convergence of land masses into Pangea and its subsequent separation into current locations

(2) ***Paleozoic Era (542- 251 mya/means "Age of Ancient Life"):***

(a) Has significant geological, biological, and climatic change and ends with a mass extinction know was the Permian-Triassic extinction

(b) Gondwana (one of two super continents, formed before Pangea then become part of Pangea) is in process of formation during this era (510-180 mya)

(c) **Cambrian Period (542- 488.3 mya):**

- (i) Prior to this time organisms were small and unicellular (prokaryotes)
- (ii) During this period the Cambrian explosion occurred which resulted in a variety of multi-cellular organisms (eukaryotes)
  1. Eukaryotes already existed prior to the Cambrian period but it was during this time that eukaryotes multiplied exponentially
- (iii) Land was still barren leaving most living organisms present at sea
- (iv) Arthropods developed during this period and still make up around 80% of living animal life today
- (v) Trilobites flourished but were widely killed during the Cambrian-Ordovician extinction event which ended the period

(d) **Ordovician Period (488.3- 443.7 mya)**

- (i) Trilobites continued to thrive during this period, biological life also flourished such that arthropods are now joined by mollusks and the first fish appear→ mark the arrival of vertebrates with evidence of the appearance of jawed organisms
- (ii) This period is also where tectonic movement resulted in Gondwana heading south and the formation of the Appalachian mountains (480 mya)
- (iii) *The Ordovician-Silurian Extinct Event (second largest and first in record of five major extinctions) characterized by one of the coldest times in Earth's geological history
  1. Extinction described as a series of events where glaciations (colder temperatures and locking up of ocean waters) and interglaciation (warmer climatic temperature and release of ocean waters) caused sea levels to repeatedly rise and fall severely affecting geological niches and biological diversity

(e) **Silurian Period (443.7- 416 mya):**

- (i) Most significant during this period is the evolution and appearance of jawed and bony fish
- (ii) Corals and other invertebrates are dominant
- (iii) Transition of animals from sea to land
- (iv) Warm shallow seas cover much of North America
- (v) First land plants form and first insects appear
- (vi) Gondwana now covers a good chunk of the southern hemisphere and extends up to the equator
- (vii) Centipedes and scorpions were among the first animals to make their transition from sea unto land
- (viii) This time period is the shortest so far→ the end of the period is marked by The Lau Extinction Event= a minor extinction event in magnitude with major impact on fauna

(f) **Devonian Period (416- 359.2 mya):**

(i) Period characterized by the development of plants→ ferns, horsetails, and seed plants appeared, first trees and forest formation occurs

(ii) Period is significant for the increase in fish variation and is referred to as the "Age of Fish"

(iii) Gondwana is now accompanied by the slow formation of Euramerica (Laurussia= a minor supercontinent) and both land masses start to meet at the equator, marking the early formation of the much larger Pangea

(iv) The period ends by an *extinction more drastic than that of the Cretaceous (Dinosaur era)

1. One of the five major extinctions of geological history whose cause is still in dispute but theory exists that an asteroid impact severely affected shallow marine life, trilobites, ammonites and jawless fish

(g) **Carboniferous Period (359.2- 299 mya):**

(i) Means "coal bearing"= named like this because of large underground coal deposits that date to it

1. Coal was produced by bark trees that grew in large quantities

(ii) Subdivided into Mississippian and Pennsylvanian

(iii) Giant club mosses, ferns, giant trees, and large insects were present

1. These plants removed large amounts of carbon dioxide from the atmosphere and produced large amounts of oxygen (35% in comparison to today's 21%)→
2. This explains the giant centipedes (6 feet long), dragonflies (2.5 feet), huge cockroaches and scorpions
   a. The growth of these animals is said to be limited by the amount of oxygen available to them

(iv) Amphibians grew in size and variety; the development of amniote eggs by amphibians during this time lead to the appearance of the first "true terrestrial vertebrate": reptiles

(v) By the middle of this period an extinction occurred as the climate changed from hot and humid to cool and arid affecting tropical forest, which collapsed, and animals that depended on it such amphibians

(h) **Permian Period (299- 251 mya):**

(i) Pangea has taken form and characterized by a vast arid interior

(ii) Reptiles have been able to survive given better coping mechanisms in that environment→ their survival led to further evolution of the amniotic egg which will be significant for later animals such of mammals

(iii) This period was brought to a conclusion by the largest extinction ever experienced on Earth where 90% of marine life and 70% of terrestrial species died out; it took ecosystems more than 10 million years to recover

1. Causes for the Permian-Triassic Extinction vary from carbon dioxide accumulation in the atmosphere due to prolonged eruptions which raised temperature everywhere, supernova radiation, methane release from oceans, and deterioration of the ozone layer

(3) ***Mesozoic Era ("Age of Reptiles," 251- 65.6 mya):**

(a) Delineated by massive extinctions that brought the end and beginning to bordering eras; most notable and summarized below are the development and dominance of reptiles, their extinction, and the breaking up of Pangea

(b) "Meso" means "middle" and "zoic" "living beings"→ This is the "Age of Reptiles"
(c) Era is divided into three periods: Triassic, Jurassic, and Cretaceous

(d) **Triassic Period (251- 199.6 mya):**
   (i) A nearly 50 million year period where 10 million years involve recovery of ecosystems due to previous extinctions
   (ii) Reptiles were most fit to survive and developed with the appearance of the first dinosaurs
   (iii) The first true mammal, fly vertebrate, and cycad also appear during this time
   (iv) Pangea begins to break up half way through this period forming two large land masses: Laurasia to the North and Gondwana to the south
   (v) Triassic-Jurassic Extinction Event→ Another large extinction brings the Permian to a close→ is claimed to have been responsible for half the marine invertebrate life
      1. Tectonic movement has been hypothesized for the reason for the extinction event→ breaking up Pangea
(e) **Jurassic Period (199.60 145.5 mya):**
   (i) The true age of dinosaurs begins here and also responsible for giving the Mesozoic Era it's title: "Age of Reptiles"
   (ii) As a result of the break up of Pangea→ more coastlines appear creating a humid environment replacing what was commonly arid into a tropical rainforest
   (iii) Dinosaurs reach their peak during the Jurassic and birds branch out from theropods; Mammals are also present during this time
   (iv) No significant extinction marks the end of this period
(f) **Cretaceous Period (145.5- 65.6 mya):**
   (i) Dinosaurs continue to dominate on land, groups of mammals, birds, and angiosperms appear and develop
   (ii) Gondwana separates into present day Australia, Antarctica, South America, Africa and India
   (iii) Laurasia breaks up into North American and Europe
   (iv) Createaceous-Paleocene (K-T) Extinction Event= The impact of a meteor or comet is widely accepted as the reason for this event= ended with large animals (Dinosaurs) and organisms like plants that relied on photosynthesis, were also affected by the reduction of solar energy on Earth's surface; the lack of vegetation caused herbivores, carnivores to die and omnivores, insectivores, and carrion eaters to survive

(4) **Cenozoic Era ("Age of Mammals," 65.5 mya- present):**
(a) The "New Life" era is the current and most recent geological time; it took 1-4 million years for ecosystems to recover from the K-T extinction event
(b) Mammals replaced reptiles as dominant land animals, which were helped by the dominance of angiosperms
(c) The absence of large reptiles allowed mammals and birds to diversify with mammals occupying any available niche

(d) **Paleogene Period (65.6- 23.03 mya):**

(i) Subdivided **Paleocene Epoch** (began with the extinction of the dinosaurs, mountain building in Europe and Asia), **Eocene Epoch** (Horses, whales, and monkeys first appear in the fossil record), and **Oligocene Epoch** (Elephants and apes first appear in the fossil record)

(ii) Era is notable for the evolution of mammals from small simple forms into a large group of diverse animals

(iii) Hot and humid conditions that existed during the late Mesozoic era gave way to cool and dry climate

(iv) Continents continued to settle unto their current positions and India collided with Aria forming the Himalayas

(v) As Earth cooled= tropical forests became restricted to equatorial regions

(vi) The arrival of the first grass species which expanded and formed new ecological environments such as savannas and prairies

(e) **Neogene Period (23.03-2.58 mya):**

(i) Subdivided into **Miocene Epoch** (first Hominids first appear in the fossil record) and **Pliocene Epoch** (first human like animals appear)

(ii) Mammals and birds continue to evolve into current species unlike their organisms which remained relatively stable

(iii) Geologically North and South American join at the isthmus of Panama separating the Atlantic and the Pacific oceans→ thus affecting ocean currents and global climate conditions and forming the Gulf Stream

(iv) Global climate cooled during this time→ leading to glaciations on the next period

(v) Grassland animals diversify to the new environments such as savannas

(vi) Later during the Pliocene Epoch= these grassland animals began to die as the climate undergoes a cooling trend

(f) **Quartenary Period (2.58 mya- Present):**

(i) Subdivided into **Pleistocene Epoch** (the modern ice age, first modern humans appear) and **Holocene Epoch** (began with the end of the most recent glaciations)

(ii) Most recent of the three periods under the Cenozoic Era= which glaciations occur (ice ages) and the appearance and expansion of modern humans

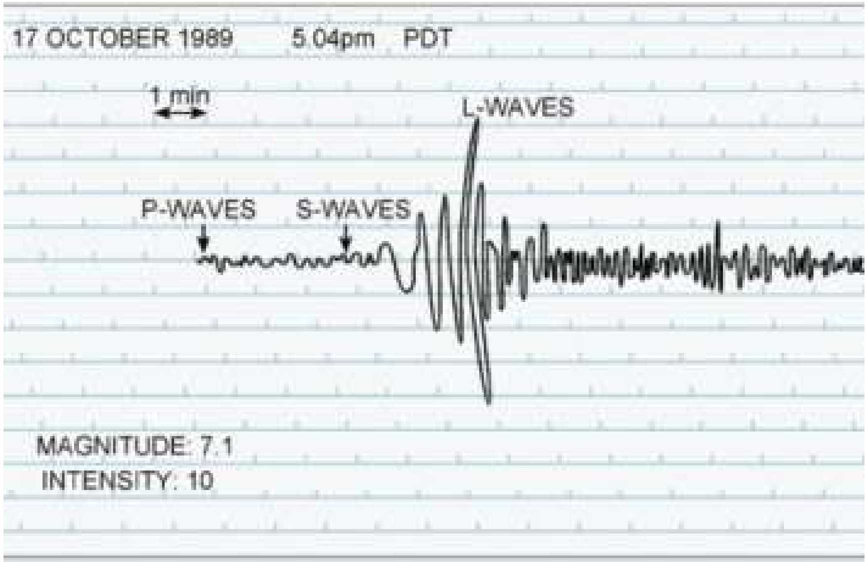
(iii) Human beings begin to dictate our next period with their impact on the natural world

(iv) Geologically much movement is not perceived during this short time but significant shift such as the land bridge between Europe and Great Britain, a connection of North American with Asia with the Bering Strait

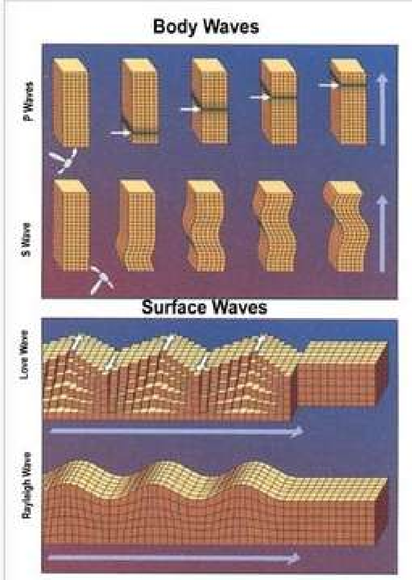
(v) Glaciations (ice ages) occur leading to the disappearance of many mammals from North America (horses and camels)

b) Earthquake intensity, magnitude, epicenter, focal mechanism, and distance are Determined from a Seismogram

i) Seismogram:



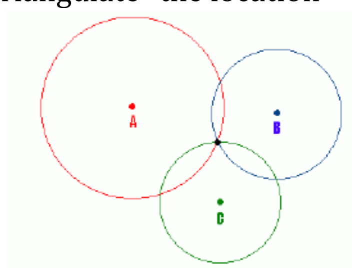
(1) The record written by a seismograph (pictured above) in response to ground motions produced by an earthquake, explosion, or other ground-motion sources
   (a) Focus: Point within the Earth where seismic waves first originate
   (b) Epicenter: Directly above the focus on the Earth's surface
   (c) Depth: The difference between the focus and the epicenter
(2) Earthquakes cause both vertical and horizontal ground motion→ surface waves and body waves are important in our understanding and reading of seismograms
   (a) Used to locate distance and epicenters
(3) Surface Waves:
   (a) Seismic waves that travel along Earth's surface
   (b) These waves move in rolling motions (Rayleigh waves) such as ocean waves and also side to side motion (Love waves) that parallel Earth's surface
(4) Body Waves:
   (a) Seismic waves that travel through the interior of the Earth as they spread outward from the focus in all directions; are refracted by varying density and stiffness underground (similar effect to the refraction of light waves); Two types that are define according to their mode of propagation:
   (b) Primary (P) waves:
      (i) Push and pull rocks in the direction the wave is traveling (compressional waves)= The rock vibrates back and forth parallel to wave propagation
      (ii) Solids, liquids, and gasses underground affect the waves compressed, thus P waves can travel through all these materials
      (iii) Fastest moving waves, hit before S waves
   (c) Secondary (S) waves:
      (i) Shake particles at a right angle to their direction of travel and travel more slowly than P waves (transverse waves)
      (ii) Higher amplitude (up and down) so they are more destructive
      (iii) Waves only transmit through solids, as liquids and gases do not resist changes in shape
      (iv) The farther body waves travel from an earthquake focus, the farther behind the S-waves get



(5) **Epicenter:**

(i) It is the lag time between the arrival of the P-waves and the first S-waves that is important in locating epicenters

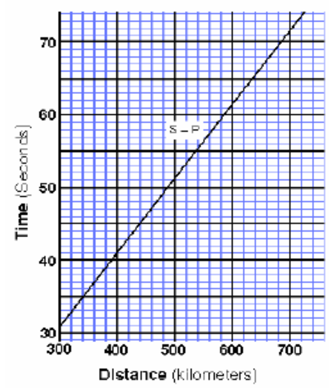
(ii) The location of the epicenter is determined by using three different seismographs recorded for the same earthquake→ these three stations are needed in order to "triangulate" the location



Earthquake epicenter requires at least 3 recording stations to localize.

(iii) On each of the seismograms the S-P time interval (in seconds) is measured, (it will be used to determine the distance the waves traveled from the origin to that station), then use a Travel Time Graph to pinpoint epicenter by converting the S-P interval to the epicenter distance→

1. To determine the distance from the epicenter to the recording station by:
    a. 1) Determine time interval between the arrival of the P wave and S wave
    b. 2) Use travel-time graph, find P-S interval on the vertical axis and use that info to determine the distance to the epicenter on the horizontal axis, find the direction by using three or more different seismic stations on a globe, draw a circle around each seismic station= each circle represents the epicenter distance for each station



c. The point where the three circles intersect is the epicenter of the earthquake= method is called triangulation

(6) **Intensity:**

(a) Measures the strength of shaking produced by the earthquake at a given location (varies with distance) determined by the effects on people, human structures, and environment

(b) Mercalli Intensity scale→ intensity scale that considered damage done to buildings and secondary effects (landslides and the extent of ground rupture)

(i) Developed by Guispeppe Mercalli

(ii) This scale helps seismologists to compare earthquake severity, based on effects of earthquakes that depends on the severity of ground shaking and also factors such as population, density, building design, and nature of surface materials

(7) **Magnitude:**

(a) Richter Magnitude Scale→ Charles Richter developed the first magnitude scale using seismic records to estimate relative sizes of quakes, assigns a single number to quantify the energy contained in an earthquake= Based on amplitude of the largest seismic waves (P, S, L/ surface and body waves) recorded on a seismogram

(i) Since seismic waves weaken as the distance between the earthquakes focus and the seismograph increases, Richter developed a method that accounted for the decrease in wave amplitude with decrease distances

(ii) Monitoring stations at various locations would obtain the same Richter magnitude for every recorded earthquake, although they would obtain slightly different Richter magnitudes due to the variations in rock types through which the waves traveled

(b) The Moment Magnitude Scale→ current method of measuring earthquake magnitudes

(i) This method measures the total energy released by an earthquake

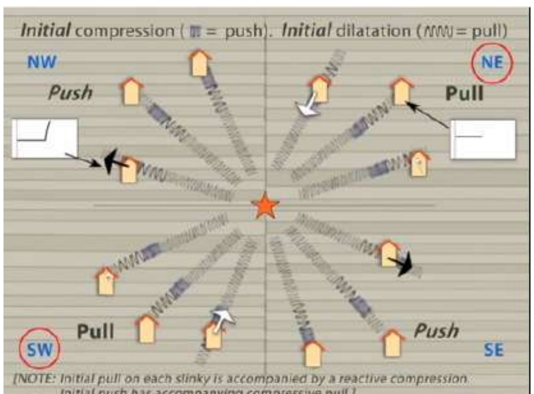
(ii) Calculated from the area of the fault that is ruptured and the distance the Earth moved along the fault

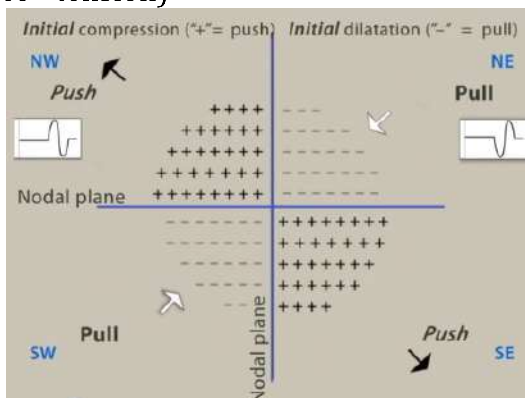
(c) Both a logarithmic scale= the magnitude is defined as the logarithm of the ratio of the amplitude of waves measured by a seismograph to an arbitrary small amplitude

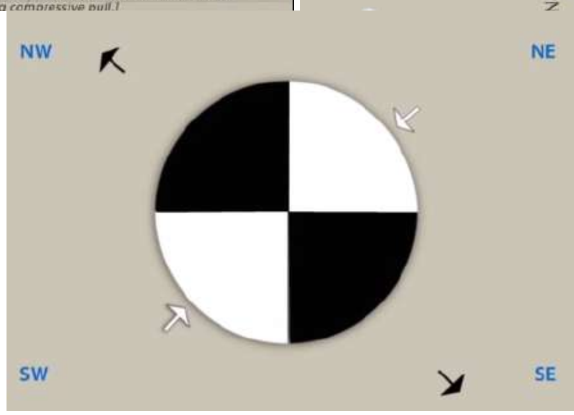
(i) An earthquake that measures 5.0 on the Richter scale has a shaking amplitude 10 times larger than one that measures 4.0

(8) **Locating focal mechanisms:**

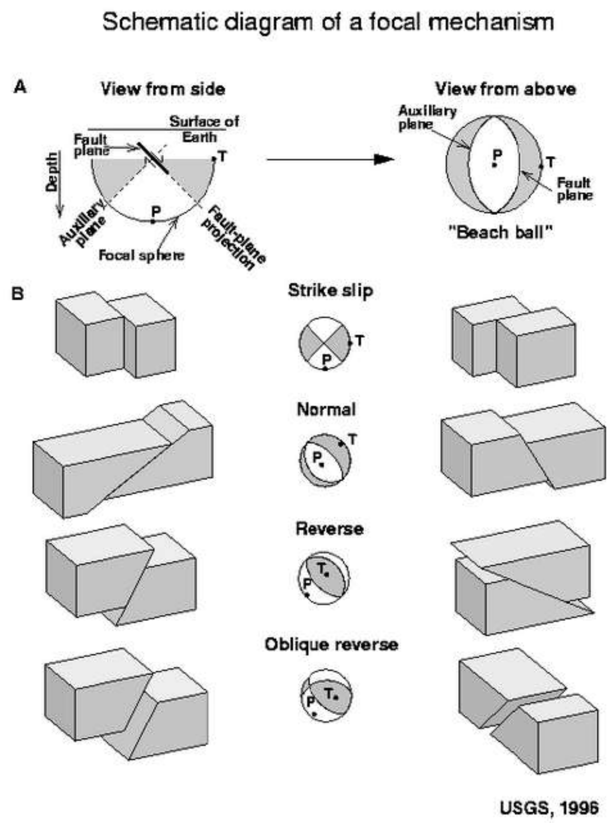
(a) Seismologists refer to this as the direction of slip in an earthquake and the orientation of the fault on which it occurs
(b) Seismograms around an earthquake are used to calculate the focal mechanism and use symbols that resemble a beach ball to display it on a map
(c) Seismic waveforms are observed= reveal patterns of first waves (P-waves)
    (i) Motions of these waves are checked at each seismography station to see if it's pushing (upward and away from source= compression) or pulling (downward and towards source= tension)







    (ii) This motion information is reported on half spheres (A on diagram) showing what direction seismic waves traveled as they left the quake focus
    (iii) The half sphere that you see on the diagram (A) shows an equal area projection of seismic movement; <u>the shaded areas represent compression (outward) and the white areas represent tension (inward movement)</u>
    (iv) The strike slip, represented by the beach ball under B, shows a normal earthquake where compressions and tensions are opposite each other and are equally divided on the circle (above diagrams); the fault that created the push and pull runs exactly between the shaded and white areas and solid motion (rocks) go from white to gray; the P and T labels relate to the maximum tension (P) and maximum compression (T)



(9) **Distance (depth):**
   (a) Earthquake can occur anywhere between the Earth's surface and about 700 km below the surface; divided into three zones: shallow, intermediate, deep
   (b) Most obvious indication on a <u>seismogram that a large earthquake has a deep focus is the small amplitude, or height, of the recorded surface waves and the uncomplicated character of the P and S waves</u>
   (c) The surface-wave pattern does generally indicate that an earthquake is either shallow or may have some depth= the most accurate method of determining the focal depth→ <u>read a depth phase recorded on the seismogram</u>

c) Major Types of Volcanoes

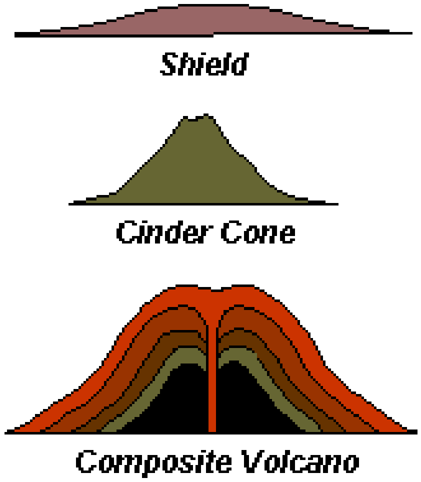
i) **<u>Cinder Cones:</u>**
   (1) *Smallest form of volcanoes (less than 300m high), most abundant of the three types of volcanoes, most are produced by a single-short lived erupture event, they frequently appear in groups next to each other
      (a) Due to the loss of gases when magma flows out from cinder cones it does not do so from above the crater but oozes through the base or wall of cones and spreads out
   (2) <u>Built from ejected lava fragments that take on the appearance of cinders as they begin to harden while in flight</u>→ these pyroclastic fragments range in size from fine ash to bombs that may exceed a meter in diameter
   (3) Have a simple, distinctive shape determined by the slope that loose pyroclastic material maintains as it comes to rest
      (a) *Very steep slopes→ the loose fragments have a high angle of repose (30-40 degrees)
   (4) They have large and deep craters→ somewhat symmetrical but one side may be higher because the side was downwind during the eruptions
   (5) <u>Rock Composition/Chemical make up:</u>

(a) Rock fragments that make up cinder cones are glassy and contain bubbles→ ejected magma that has exploded into the air and quickly cooled→ these gas rich magma ejections are dark in color and contain cavities
(b) *Extrusive igneous rocks make up cinder cones→ include basalt, andesite, or a combination of both (basaltic andesite); chemically basaltic andesite rocks contain 53% to 57% silica (SiO_2), andesites contain between 57%-63% silica (both are common to cinder cones)

ii) **Composite/Strato Volcanoes:**
(1) Mount Shasta in northern California is a stratovolcano; most dangerous volcanoes
(2) Formed by altering layers of lava and rock fragments, *tall and conical steep with periodic explosive violent eruptions, gentle lower slopes but steep upper slopes
(3) Rock Composition/Chemical make up:
(a) The lava that flowed or flows from these volcanoes typically cool and harden before spearing too far due to high thick viscosity, *the magma that forms this lava is felsic→ having high to intermediate levels of silica (rhyolite, andesite, dacite)
(b) *Rhyolitic magmas contain at least 70% silica (SiO_2), a compound that causes magma to be significantly more viscous than ones composed mostly of basalt
(c) *Rhyolitic magmas can be difficult to extrude through volcanic vents and can sometimes plug the vent entirely, this characteristics increases the likelihood of a buildup of pressurized gases, resulting in explosive eruptions of ash
(4) These volcanoes tend to occur along subduction plate boundaries
(a) Characterized by one plate diving below another at the point of collision, ex: when an oceanic plate runs into a continental plate
(b) Ex: Mount Shasta is in the Cascade Range, formed by the subduction of the Juan de Fuca Plate under the North America plate, as the Juan De Fuca Plate descends it begins to melt due to heat and pressure produced by friction at the zone; this melting produces magma which is less dense than surrounding material and rises to the top where it gradually forms volcanoes such as composite or stratovolcanoes
(c) Most volcanically active zone in the world= "Ring of Fire"→ an area of subduction zone surrounding the Pacific Ocean

iii) **Shield Volcanoes:**
(1) Are built entirely of fluid lava flows, flow after flow pours out in all directions from a central summit vent, or group of vents, building a *broad, gently sloping cone flat, domical shape, with a profile much like that of a warrior's shield
(2) Built up slowly by the accretion of thousands of highly fluid lava flows called basalt lava that spreads widely over great distances and then cool as thin, gently dipping sheets
(3) Built from *relatively weak viscous basaltic lava, low in silica content (less than 52%) with a very small percentage of pyroclastic material, that erupt in longer cycles than that of composite volcanoes
(4) Laval commonly erupts from vents along factures (rift zones) that develop on the flanks of the cone
(5) *Shield volcanoes are distinctive products of hotspot volcanism (Hawaii), but can form at rift and subduction zones, hot spots are volcanic regions fed by hot underlying mantle in comparison to the mantle elsewhere, these spots my be on, near or far away from tectonic plate boundaries

(6) Ex: The Hawaiian Islands are composed of linear chains of these volcanoes



d) Location and Characteristics of Volcanoes Due to Hot Spots and Subduction

i) See Composition and Shield volcanoes above

ii) **Hot Spots:**

(1) Occur WITHIN the plate boundaries not at a plate boundary; can develop in ocean or beneath continents

(2) Areas within the mantle where rocks melt to generate magma, Most hot spots are thought to be underlain by a large plume of anomalously hot mantle→ these mantle plumes appear to be generated in the lower mantle and rise slowly through the mantle by convection

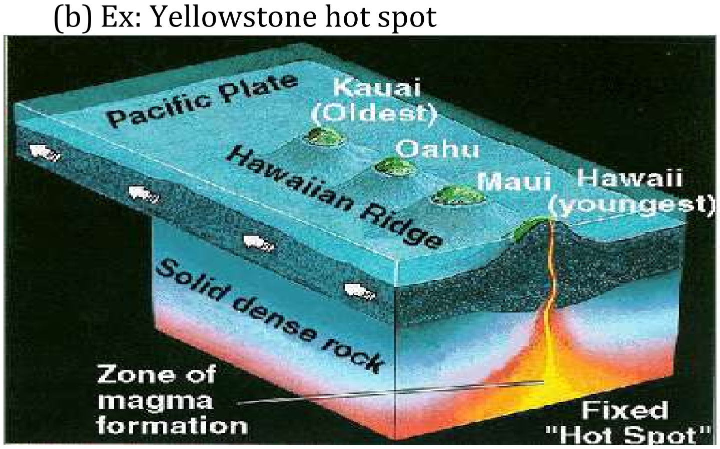
(3) The presence of a hot stop is inferred by anomalous volcanism

(a) Mantle plumes are areas of hot, upwelling mantle, a hot spot develops above the plume, Magma generated by the hot spot rises through the rigid plates of the lithosphere and produces active volcanoes at the Earth's surface

(4) May occur on, near to, or far from tectonic plate boundaries

(a) Ex: Hawaiian volcanoes within the Pacific Plate

(b) Ex: Yellowstone hot spot



iii) **Subduction:**

(1) Volcanoes produced by subduction zone volcanism= <u>typically stratovolcanoes</u>

(a) Incipient island arcs tend to be more basaltic in composition

(b) Continental volcanic arcs tend to be more andesitic in composition

(2) Subduction zone volcanism= Occurs where two plates are converging on one another; one plate containing oceanic lithosphere descends beneath the adjacent plate, thus consuming the oceanic lithosphere into the Earth's mantle, this on-going process is called subduction

(a) As the descending plate bends downward at the surface→ creates a larger linear depression called an oceanic trench= the deepest topographic features on the Earth's surface

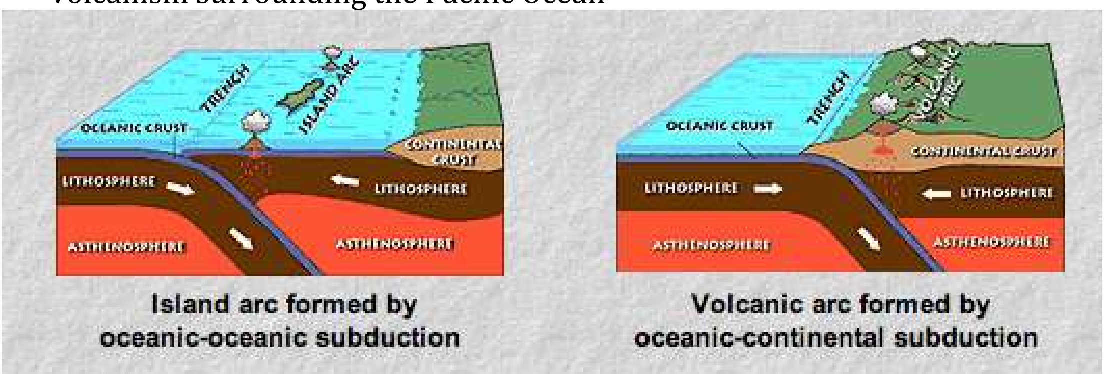
(3) <u>Oceanic-Oceanic subduction:</u>

(a) As the subducting slab descends to greater and greater depths= progressively encounters greater temperatures and greater pressures= causes the slab to release water into the mantle wedge overlying the descending plate, water has the effect of lowering the melting temperature of the mantle= causes it to melt→ the magma produced rises upward to produce a linear belt of volcanoes parallel to the oceanic trench→ called an <u>Island Arc</u>

(4) <u>Oceanic-Continental subduction:</u>

(a) Oceanic lithosphere subducts beneath an adjacent plate of continental lithosphere→ then a similar belt of volcanoes will be generated at the continental crust→ called a Volcanic Arc

(5) Most volcanically active belt on Earth= Ring of Fire→ a region of subduction zone volcanism surrounding the Pacific Ocean



Island arc formed by oceanic-oceanic subduction

Volcanic arc formed by oceanic-continental subduction

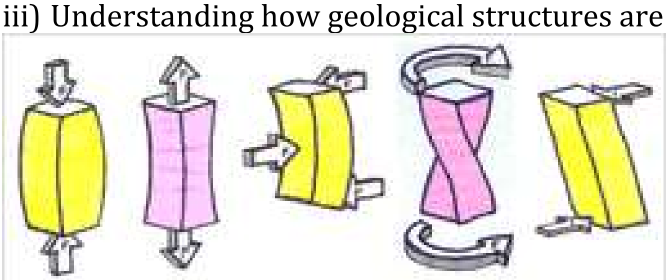
e) Geologic Structures and Tectonic Forces and Settings

i) Earth's surface is composed of several large plates that change position and size→ these plates are parts of the lithosphere and asthenosphere

ii) Geologic structures are the result of the powerful tectonic forces that occur within the earth→ these forces <u>fold</u> and break rocks, form deep <u>faults,</u> and <u>join</u> to build mountains

(1) Plate tectonic states that most of Earth's internal processes (formation of ocean basin, mountain building, volcanic activity, faulting, and earthquakes) and many external processes (circulation of ocean currents, glaciation, pluvial erosion) are controlled by the interaction of the thin, rigid plates that form the lithosphere

iii) Understanding how geological structures are formed:



(1) **<u>Stress</u>**: Defined as force per unit area and responsible for changes in rock shape

(a) First figure shows the effect of <u>compressional stress</u> where forces are being applied shortens the object

(b) Second figure shows <u>tension stress</u> applied and elongates the object

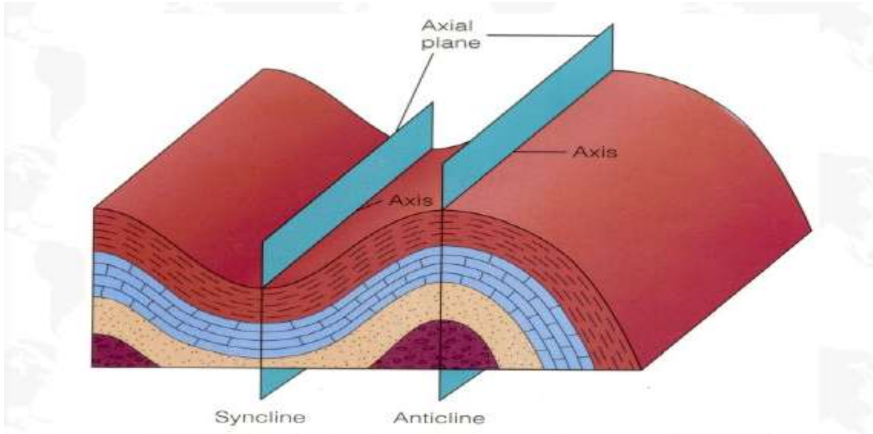
(c) Last figure shows where strain forces are being applied at different places of the object and in turn creating <u>shear stress</u>

(i) Compressional: causes rocks to shorten or flatten
(ii) Tensional: causes rocks to stretch or elongate
(iii) Shear: causes rocks to "smear"

(2) **Strain:** The deformation in a rock caused by stress; the type of rock, the temperature and pressure, and even the rate of stress all influence how a rock will accommodate strain
(a) When rocks are subjected to stressed greater than their own strength= they begin to **deform** usually by **folding** or **fracturing**
(b) Types of deformation:
(i) **Elastic**: Reversible, like a rubber band, where rocks return to nearly its original size and shape when stress is removed
1. Ex: P waves moving through a rock mass
(ii) **Plastic**: Results in permanent changes→ the size and shape of a rock unit are forever altered through folding and flowing
1. Ex: Rock mass at plate boundaries in Earth's interior
(iii) **Brittle**: Rocks can be brittle if it breaks under stress; takes place near the surface of the lithosphere, granitic rocks and cooler temperatures
1. Ex: Rock mass subject to tectonic stress at plate boundaries

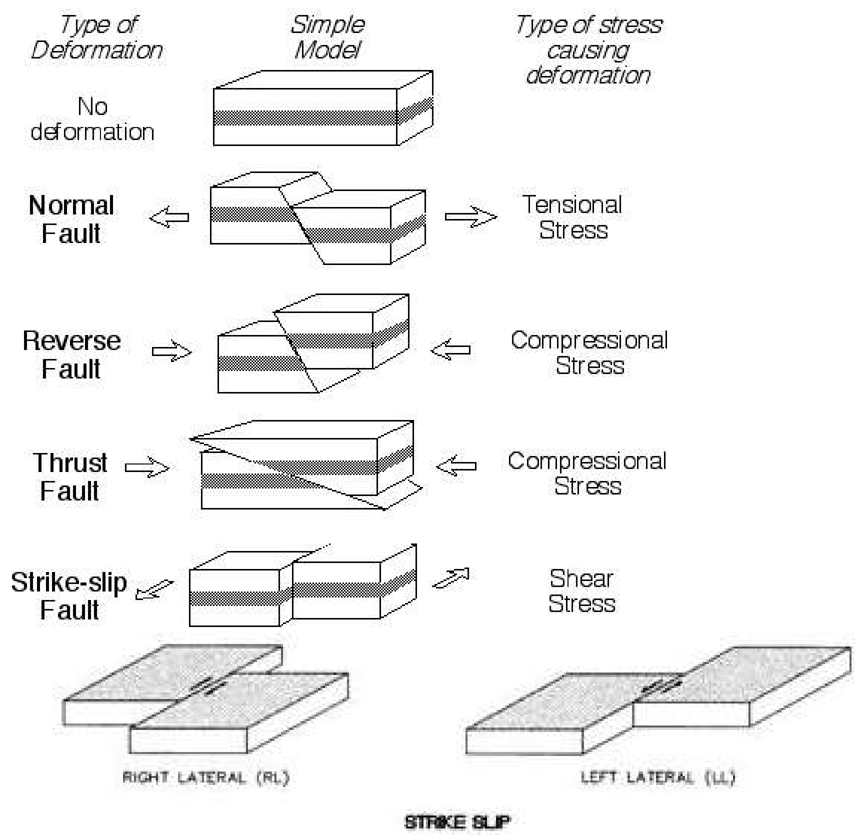
(3) The process of deformations generate geological structures and features at many different scales
(a) One extreme are Earth's major mountain systems, at the other extremes are highly localized stress points creating minor fractures in bedrock= called **rock structures**

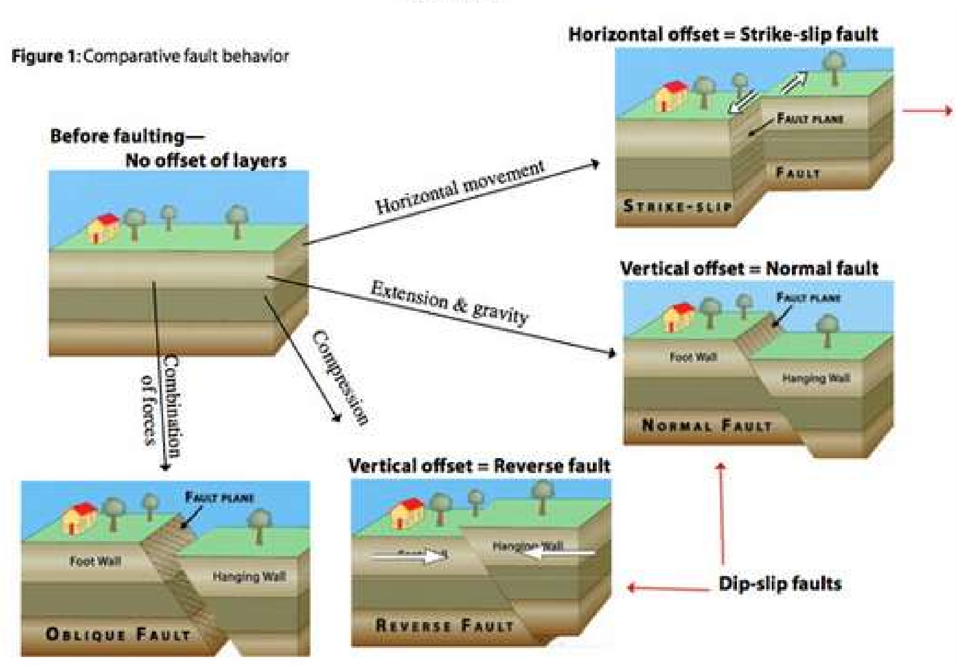
(4) **Rock Structures:**
(a) **Strike and Dip:**
(i) If a region of study is inclined, bent, or broken then it reveals that a period of deformation occurred following deposition
(ii) **Strike** is the geographic pattern or compass direction in which the surface lies, **dip** is their angle of inclination downward from the surface
(b) **Fold:**
(i) Wave-like bends in the rock
(ii) During mountain formation→ flat lying sedimentary and volcanic rocks were often bent into a series of wavelike undulations called folds
1. If you were to place a piece of paper on a flat surface and push it together from two ends you will create this geological effect
2. The two most common types of folds:
a. **Anticline**
i. Top most part of the fold
ii. Mostly formed by upfolding or arching of rock layers
iii. Oldest rocks are found at axial region of the anticline due to erosion
b. **Syncline**
i. Bottom part of the fold
ii. Downfolds
iii. Youngest rocks are found at the axial of the syncline



(5) **Faults:**
(a) Fractures in the crust along which noticeable displacement has taken place
(i) Hanging wall vs. Foot wall: The hanging wall is the side of the fault above the fault surface, the footwall is the side below the fault surface
(b) **Normal Fault:**
(i) The hanging wall moves down relative to the foot wall, accommodate lengthening, or extension of the crust, Have dips of about 60 degrees
(ii) Uplifted fault blocks are called horsts and down-dropped blocks are called grabens
1. Ex: Mount Whitney is an example of a mountain formed by normal faults or a fault block which is a large chunk of rock rising up while the east valley sinks
2. Ex: Sierra Nevada
(c) **Reverse Fault:**
(i) The hanging wall moves up relative to the foot wall
(ii) Reverse faults are a result of compressional tensions= generally produce folds as well as faults
(iii) **Thrust Fault:**
1. A low-angle reverse fault, forms due to compressional tension
(d) Both reverse and normal faults (often at an angle to the surface of the Earth)= Dip-Slip Faults
(i) Faults that are primarily parallel to the dip of the fault surface, movement is primarily horizontal
(e) **Strike-Slip Fault:**
(i) The displacement is horizontal and parallel to the strike of the fault surface (concept of hanging and footwall don't apply), usually vertical
(ii) The broken rocks produced from strike-slip faults are easily eroded and often form linear valleys and troughs
(iii) Transform Fault: A special kind of strike-slip fault that cuts through the lithosphere and accommodates motion between two large crustal plates
1. Ex: San Andreas fault is a transformation fault; runs about 810 miles and cleanly separates the North American Plate from the Pacific Plate
(iv) Two types:
1. **Right-Lateral Strike Slip:**
a. Opposite side of the fault moves to an observers right (if the observer is facing the fault)
2. **Left-Lateral Strike slip:**

a. Opposite side of the fault moves to an observers left (if the observer is facing the fault)





(6) **Joints:**

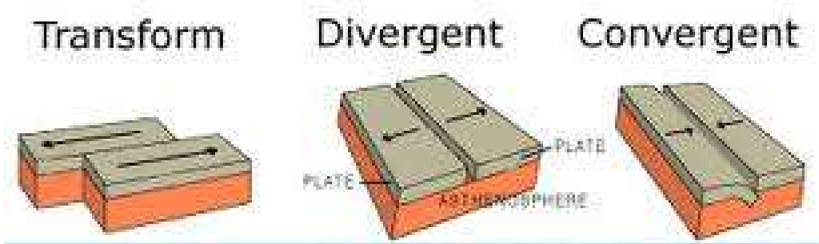
(a) Fractures that do not show evidence of slippage whereas faults do, the most common rock structures, can occur as a results of pressure release, tectonic stress associated with regional uplift

(7) **Plate Tectonics:**

(a) ***Divergent boundaries (constructive plate margin):***
   (i) Where the lithosphere is being stretched due to tensile stress, normal faults are common near Earth's surface
   (ii) Area where the lithosphere is cool and brittle
   (iii) Fractures that form are filled with molten rock that comes up from the mantle below= when the material cools forms new lithosphere
   (iv) Can cause rift valleys and low focus earthquakes
   (v) Divergent oceanic plates= caused Mid-Atlantic Ridge
   (vi) Divergent continental plates= caused the East Africa Rift Valley

(b) ***Convergent boundaries (destructive plate margin):***
   (i) Occur when two or more plates push in to each other= Results can be subduction zones or continental collision zones; Three types of convergent boundaries:
      1. Oceanic-Continental Convergence (subduction):
         a. Occurs when the denser oceanic slab and the buoyant continental slab move towards each other, the oceanic slab sinks into the mantel (subduction), when this slab reaches a depth of 100km, melting occurs due to the "wet" rock in the oceanic lithosphere (wet rock melts at substantially lower temperatures), the molten material is less dense than the surrounding mantle and thus gradually rises towards the surface, may then give rise to a volcanic eruption
      2. Oceanic-Oceanic- Convergence (subduction):
         a. When two oceanic slabs converge one descends beneath the other→ initiates volcanic activity
         b. The volcanoes grow up from the ocean floor→ eventually as the subduction continues a chain of volcanic structures will develop= called volcanic island arc
         c. Ex: Tonga islands
      3. Continental-Continental Convergence (collision):
         a. Continental lithosphere is buoyant so when two continental plates move towards each other= neither one is able to be subducted= a collision occurs and produces mountain ranges
         b. Ex: Himilayas, Alps, Appalachians
   (ii) Reverse faults and thrust faults are expected to form at shallow depths where rocks are cool and behave in a brittle fashion under compressional stress, at greater depths folding might be expected to happen where the rocks are warmer and under higher pressure

(c) ***Transform boundaries:***
   (i) A location where two plates are sliding past each other
   (ii) Shallow focused earthquakes are common on this type of boundary
      1. Ex: San Andrea Fault
   (iii) Strike-slip faults are common→ where strike-slip faults bend= localized compression and extension can develop= may give rise to associated tensile structures (normal faults) or compressional structures (reverse faults and folds



f) Evidence of Plate Tectonics on Sea Floor and Land

i) **Sea Floor: Fit of Continents**

(1) 1915- Alfred Wegener proposed a hypothesis that suggested that Earth's continents once were part of a large super-continent called Pangea→ the super continent broke into pieces over 200 mya, these pieces drifted over the surface of the Earth to their current positions, if you look at the outer boundary of a continent, its continental shelf, they can be fit together

(a) Ex: The fit of South America with Africa, fossil evidence, rock structures, and ancient climates support this idea

(2) Puzzle Pieces: The idea that continents fit together like pieces of a jigsaw puzzle originated with improved world maps

(a) Wagner's hypothesis was initially challenged because shorelines are continually modified due to erosion and a good "fit" of continents were seen as unlikely

(b) Another argument made was that fossil evidence showed that land areas had been uplifted (from the sea) or submerged in recent geological past, it wasn't until the 1960s when sonar technology was used to map the seafloor that Wegner's hypothesis gained support, a better approximation of the outer boundary of continents was perceived and called the continental shelf, it lies submerged off the coast of the continents and gave a remarkable fit to the "puzzle pieces"

ii) **Land: Fossil Evidence**

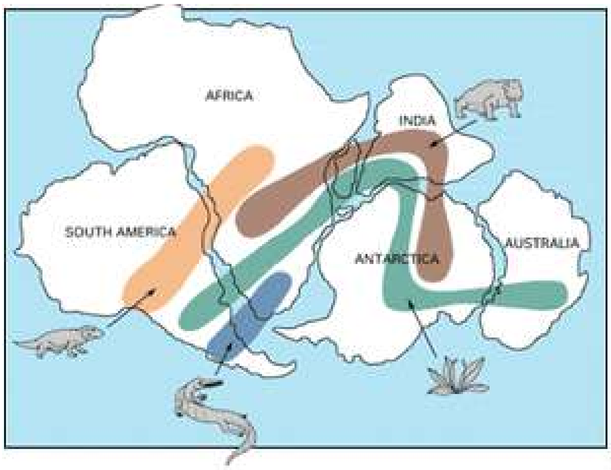
(1) Wegner needed something else to solidify his hypothesis= considered the fossil record, some kind of land connection was necessary to explain the existence of identical fossils on widely separated landmasses

(2) Fossil cited for evidence of Pangea:

(a) Classic example is the *Mesosauras= a presumably aquatic reptile whose fossil is limited to South America and Southern Africa (blue area on map)

(b) *Glossopteris= this plant was known to be widely dispersed among Antarctica, Africa, Australia, India, and South America (green area on map)

(c) Lystrosauros (brown area) and Cygnognathus (orange area) helped support Pangea and consequently provided evidence for plate tectonics (used to explain land movement)



iii) **Land: Rock Types**

(1) Wegner looked for other similarities→ looked at rock types

(2) If the continents were once together= the rocks found in a particular region on one continent should closely match in age and type with those of an adjacent continent

(a) Ex: A good correlation between rocks found in northwestern Africa was made with rocks in eastern Brazil= in both regions 550 million year old rocks lie adjacent to rocks dated at more than 2 billion years

(3) More evidence to support the concept of continental drift via plate tectonics comes from several mountain belts that appear at the end of one coastline only to reappear again on a landmass across the ocean

(a) Ex: The mountain belt that includes the Appalachians trends northeastward through the US and disappears off the cost of Newfoundland, mountains of comparable nature are found in Greenland and Northern Europe

(4) Paleomagnetism:

(a) Studies in rock magnetism set out to investigate ancient changes in Earth's magnetic field (magnetic field has a north and south pole)

(b) Magnetic poles align closely but aren't exactly with geographic poles, *Iron rich minerals cool and become magnetized in the direction parallel to the existing

magnetic field and cone solidified, the magnetism will remain frozen in that position
   (i) These rocks formed in the past are said to "remember" the location of magnetic poles and possess fossil magnetism
  (c) Using these rocks= a plot of the position of the magnetic pole revealed that during the past 500 million years the position of the pole had gradually wandered from a location near Hawaii northward through Siberia and finally to its present location
   (i) It was clear evidence that either the magnetic poles had shifted through time (polar wandering) or the lave moves= continents had shifted

5) **Oceans**

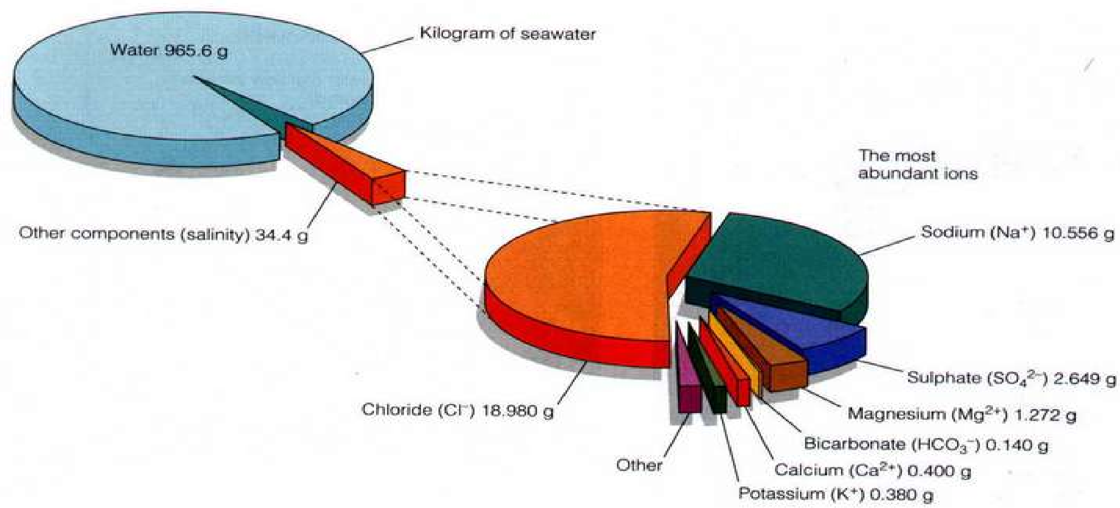
a) **Chemical and Physical Properties of Sea Water**

i) The most important components of seawater that influence life forms are salinity, temperature, dissolved gas (mostly oxygen and carbon dioxide), nutrients, and pH

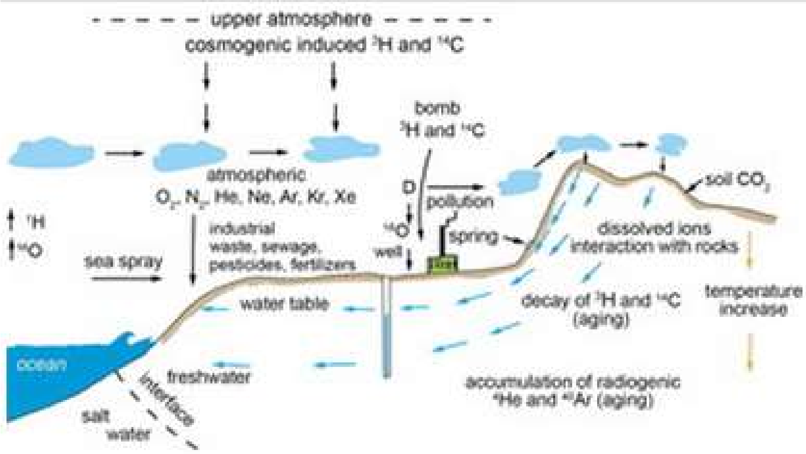
ii) **Chemical Properties of Sea Water:**

(1) Seawater is essentially water and a complex solution of salts
  (a) These salts comprise approximately 3.5% (by weight) of seawater
  (b) This percentage may appear small but the quantities of salt in the ocean are enormous→ if all the ocean water was to evaporate= there would still be a layer of salt 60m thick covering the entire ocean floor

(2) Six elements and compounds can be found in this complex solution of salts:
  (a) Chlorine [55% (Cl-)], Sodium [30.6% (Na+)], Sulfur [7.7% (SO4-2)], Magnesium [3.65% (Mg+2)], Calcium [1.17% (Ca+2), and Potassium [1.13% (K+)]
  (b) Sodium Chloride: Comprises almost 70% of all elements in the salt solution
  (c) Magnesium Chloride, Sodium Sulfate, Calcium Chloride comprise about 99% of the elements found in sea water
  (d) Trace elements make up the remainder of the composition, such as Chromium, Cobalt, Uranium, Fluoride, Iodine, Manganese, Selenium, and Zinc



(3) Dissolved Gases



- (a) Seawater contains a small amount of dissolved gases, many of these gases are added to seawater from the atmosphere through the constant stirring of the sea surface by wind and waves
- (b) The concentration of gasses that can be dissolved into seawater from the atmosphere is determined by the temperature and salinity of the water
  - (i) Increasing the temperature or salinity reduces the amount of gas that ocean water can dissolve
- (c) Some of the important atmospheric gases found in seawater include: Nitrogen, Oxygen, Carbon Dioxide (in the form of bicarbonate HCO3), Argon, Helium, Neon
  - (i) Compared to the other atmospheric gases→ the amount of carbon dioxide dissolved in saturated seawater is unusually large
  - (ii) Some gases found within seawater are also involved in oceanic organic and inorganic processes that are indirectly related to the atmosphere
    1. Ex: Oxygen and carbon dioxide may be temporally generated or depleted by such processes to varying concentrations at specific locations within the ocean

iii) **Physical Properties:**

- (1) Salinity:
  - (a) About 70% of Earth is covered with water and 97% of that amount is seawater; water contains about 3.5% by weight of salt, this means that one kilogram (1000 grams) will have 35 grams of dissolved salts
    - (i) This measurement is also known as 35 parts per thousand or 35 ppt
  - (b) Salinity varies and its combination with temperature has important effects on ocean currents
  - (c) The most common factor is the relative amount of evaporation or precipitation in an area
    - (i) If there is more evaporation than precipitation then the salinity increases (since salt is not evaporated into the atmosphere)
    - (ii) If there is more precipitation (rain) than evaporation then the salinity decreases
  - (d) Another factor that can change salinity in the ocean is due to a very large river emptying into the ocean
    - (i) The runoff from most small streams and rivers is quickly mixed with ocean water by the currents and has little effect on salinity
    - (ii) BUT large rivers (like the Amazon River) may make the ocean have little or no salt content for over a mile or more out to sea

(e) The freezing and thawing of ice also affects salinity
  (i) The thawing of large icebergs (made of frozen fresh water and lacking any salt) will decrease the salinity while the actual freezing of seawater will increase the salinity temporarily
    1. This temporary increase happens in the first stages of the freezing of seawater when small ice crystals form at about minus 2 degrees C, these tiny, needle-like ice crystals are frozen freshwater and the salts are not part of them so the liquid between these crystals becomes increasingly salty to the point of it become a brine, eventually though was seawater freezes the ice crystals trap areas with brine and the entire large piece of frozen sweater (ice floe) is salty

(2) Temperature and Density:
  (a) Temperature and salinity share an inverse relationship→ the freezing point of seawater decreases as salinity increases: At normal salinity freezing point is at 28F
  (b) Temperature and density share an inverse relationship→ as temperature increase the space between water molecules (also known as density) decreases; the cooler seawater is the denser it becomes
    (i) Normal seawater density is at 1020 kg per cubic meter, cooler waters can reach up to 1050
  (c) Increasing salinity increases density
    (i) Given two layers of seawater with similar salinity, the cooler layer will be denser and fall below the warmer layer when temperature is taken into account
    (ii) Temperature has a greater effect on the density of the water than salinity does
      1. So a layer of water with higher salinity can actually float on top of water with lower salinity if the layer with higher salinity is warmer than the lower salinity layer
  (d) The temperature of the ocean decreases and decreases as you go to the bottom of the ocean→ The density of ocean water increases and increases as you go to the bottom of the ocean
    (i) The deep ocean is layered with the densest water on bottom and the lightest water on top
    (ii) Circulation in the depths of the ocean is horizontal, making water move along the layers with the same density
    (iii) The temperature of seawater varies with the amount of sun that hits the area
      1. This includes the length of time as well as the angle of the sun's rays
      2. The longer the time and more direct the rays of the sun fall on the ocean, the greater the temperature of the seawater→ thus tropical areas that get more year-round sun and more direct sun have warmer surface waters than polar areas that may have no sun at all for several months each year and then very steep angles of the sun's rays
        a. Helps us understand that surface ocean temperatures are warm in the tropics and cooler at the poles
  (e) Currents:
    (i) Have a lot to do with temperature and density in sea water, ocean water is constantly churning underneath

(ii) The difference in density of cold water versus density of warmer water is responsible for ocean currents and upwelling

(iii) Warm seawater floats and cold dense seawater sinks, so ocean temperatures also vary across the surface and into the depths

(iv) Case Study: The California Current is a Pacific Ocean current that runs alongside the state of California. It begins off the southern end of British Columbia and finishes off southern Baja California. This movement of northern waters southward makes the coastal waters cooler. Additionally, upwelling of cooler deeper waters occur as winds push surface waters away from the shore allowing cooler waters to replace them, this lowers the temperature of the already cool California coastal waters. This translates into cold coastal waters during the summer, stretching from Oregon to Baja California. (This does not include the coastal water surrounding San Diego. There is a warm water anomaly off San Diego). Fog forms along the California coast as air in coastal valleys (Bay area or central valleys) heat up and expand during the day. This air rises, is displaced and replaced by air drawn in from offshore. A narrower weaker current flows south to north in the winter but by late February disappears as the California Current overrides it. By late spring and early summer, the California Current has fully arrived to southern California where a phenomena arises- June Gloom. When the ocean is that cold, water vapor in the air cools down to form fog or clouds when the dew point is reached (the temperature at which water vapor in the air starts to condense)

b) Mechanisms that Cause Wave Action and Tides

i) **Waves:**

(1) Waves are the forward movement of the ocean's water due to the oscillation of water particles by the frictional drag of wind over the water's surface

(a) Energy is transferred from the upper layer (wind) to the lower layer by shear stress, water is forced to acce1lerate as the wind is moving fast over the crest, creating turbulence, and speeding up as it goes over the crest

(b) Waves have crests (the peak of the wave) and troughs (the lowest point on the wave)

(c) The wavelength or horizontal size of the wave is determined by the horizontal distance between two crests or two troughs; the vertical size (height) of the wave is determined by the vertical distance between the two crests

(d) Waves travel in groups called trains

(2) As the water's energy moves forward toward the shore and the depth decreases= the diameter of these circular patterns also decreases

(a) Waves travel because gravity pulls the water in the crests downward, forced out from beneath the falling crests= the falling water pushes the former troughs upward, the waves move to a new position (waves continue to form and increase in height as long as the wind is blowing)

(b) When the diameter decreases the patterns become elliptical and the entire wave's speed slow

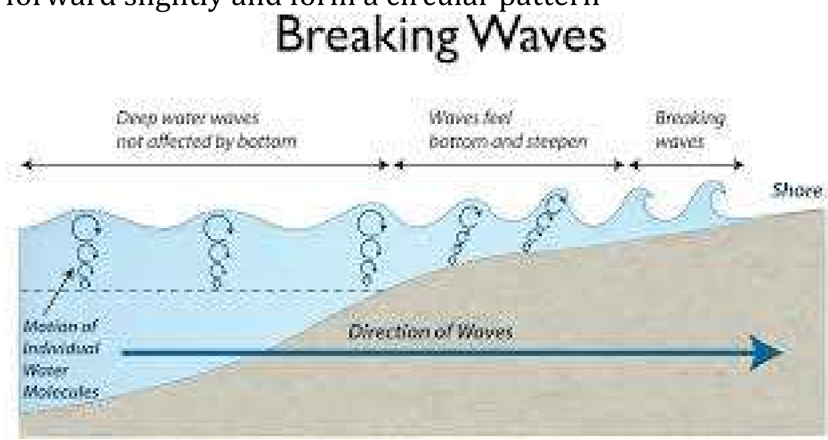
(c) Because waves move in groups= continue arriving behind the first and all of the waves are forced closer together since they are now moving slower→ they grow in height and steepness

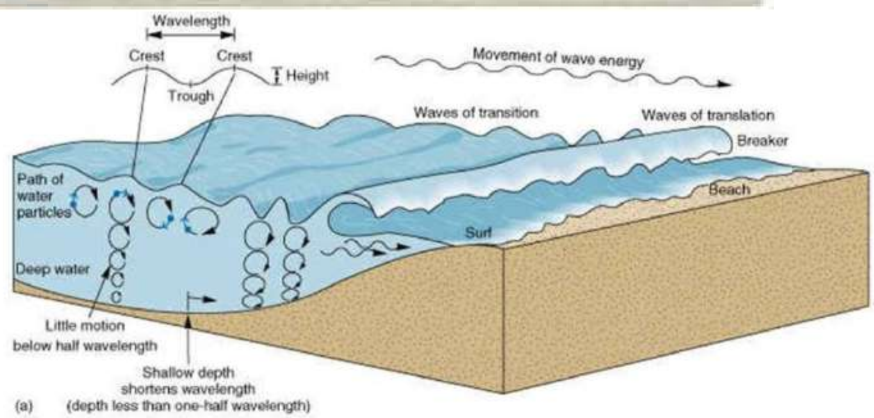
(d) When the waves become too high relative to the water's depth= the wave's stability is undermined and the entire wave topples forming a breaker

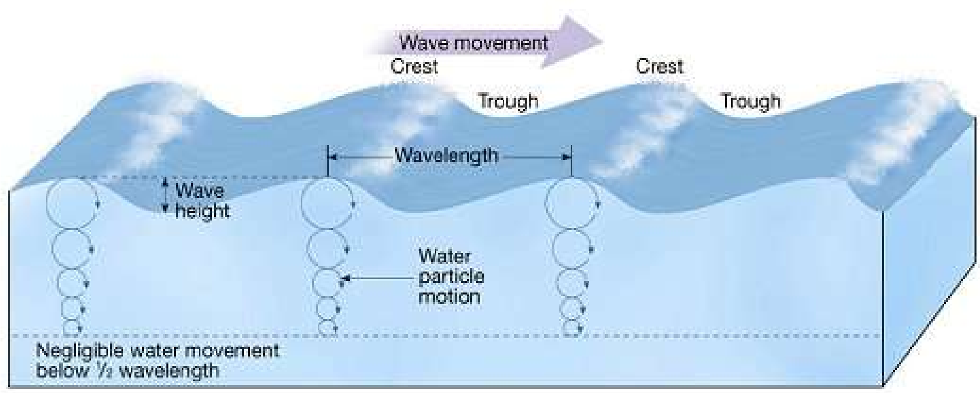
(3) It is important to note that while it appears that water is moving forward, only a small amount of water is actually moving= it is the wave's energy that is moving

(a) Since water is a flexible medium for energy transfer, it looks like the water itself is moving

(b) In the open ocean, the friction moving the waves generates energy within the water. This energy is then passed between water molecules in ripples called <u>waves of transition</u>. When the water molecules receive the energy, they move forward slightly and form a circular pattern



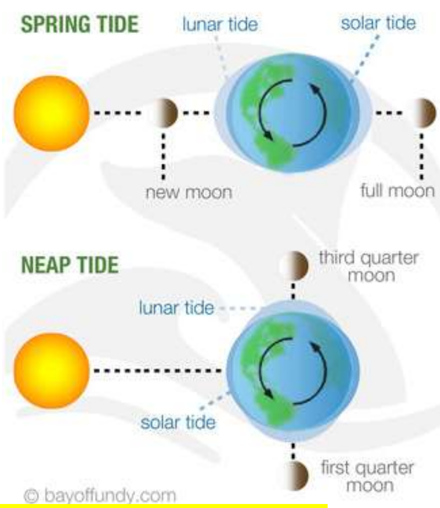




ii) **Tides**:

(1) Tides are considered the heartbeat of our planet's oceans, they are the periodic rise and fall of the Earth's bodies of open water→ <u>result of the gravitational pull of the Moon and Sun on the Earth, as well as the perpetual spinning rotation of the Earth itself</u>

(2) By far the largest influence is the gravitational effect of the moon as it pulls the water toward itself making a bulge on the surface of the ocean at the side of the moon (lunar tide)
(3) The ocean is constantly moving from high tide to low tide and then back to high tide; there is about 12 hours and 25 minutes between the two high tides
(4) When the Sun and moon are aligned (in which the moon is full or new)= there are exceptionally strong gravitational forces→ causes very high and very low tides= called Spring Tides (although they have nothing to do with the season)
(5) When the Sun and moon are not aligned (forming a 90 degree angle, in which the moon is at its first or third quarter)→ the gravitational forces cancel each other out, the tides are not as dramatically high and low= called Neap Tides
(6) The Sun also has a part to play with tide formation, but since the Sun is about 93 million miles away= its gravitational force is smaller, as compared to the moon, and thus the Sun's role is greatly decreased
    (a) But when the three are aligned (Earth, Sun, Moon)= the gravitational pull of the Sun adds to that of the Moon causing maximum tides
(7) The Earth, Moon and Sun are not static
    (a) The Earth rotates on its axis as it revolves around the Sun and the Moon has its own axial and revolutionary movement
    (b) Because Earth rotates on its axis the Moon completes one orbit in our sky ever 25 hours (not to be confused with the Moon's 27 day orbit around the Earth)→ we get two tidal peaks as well as two tidal troughs, these events are separated by about 12 hours
    (c) Since the Moon moves around the Earth it is not always in the same place at the same time each day so→ each day the times for high and low tides change by 50 minutes
    (d) Understanding how these orbits play out in tide formation:
        (i) Think about the effect the Moon has on Earth everyday as it creates a drag with all that water that's being displaced at both ends of the globe
        (ii) As a consequence of tidal interactions with the Moon the Earth is slowly decreasing its rotational period→ Moon is gradually receding from the Earth into a higher orbit, and calculations suggest that this would continue for about fifty billion years, by that time the Earth and Moon would become caught up in what is called a "spin-orbit resonance" or "tidal locking" in which the Moon will circle the Earth in about 47 days (currently 27 days) and both Moon and Earth would rotate around their axis in the same time always facing each other with the same side



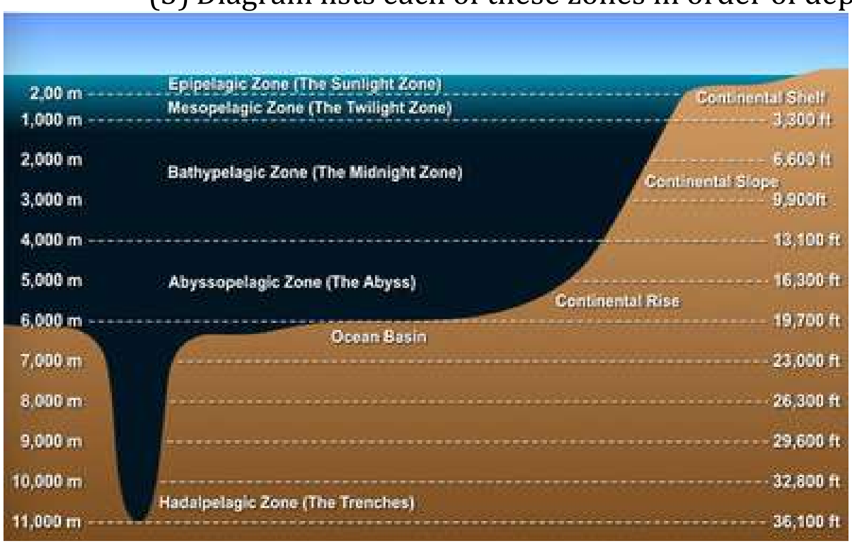
c) Layered Structure of the Oceans

i) **Ocean is divided into five main layers:**

(1) Layers are known as "zones"= they extend from the surface to the most extreme depths where light can no longer penetrate; these zones are where some of the most bizarre and fascinating creatures in the sea can be found

(2) As we go deeper= temperature drops and the pressure increases at an astounding rate

(3) Diagram lists each of these zones in order of depth



(4) **Epipelagic Zone**

(a) The surface layer of the ocean, also known as the sunlight zone because this is where most of the visible light exists

(b) Extends from 200 meters (656 feet)

(c) With light comes heat= is responsible for the wide range of temperatures that occur in this zone

(5) **Mesopelagic Zone**

(a) Below the Epipelagic Zone, extending from 200 meters (656 feet) to 1000 meters (3281 feet)

(b) Sometimes referred to as the twilight zone or the mid-water zone

(c) The light that penetrates to this depth is extremely faint

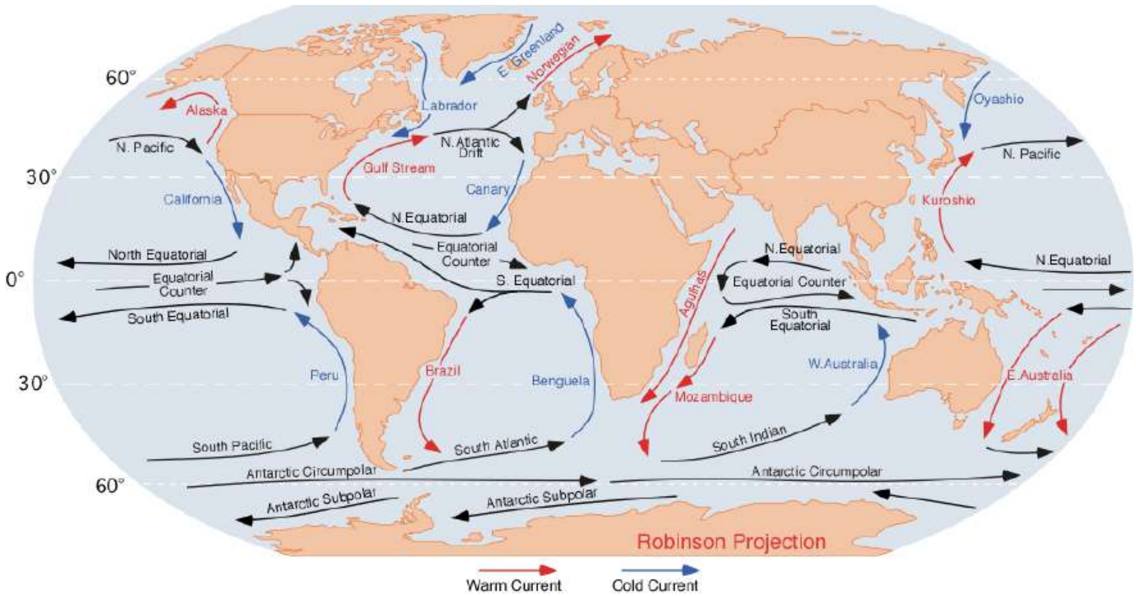
(d) It is in this zone that we begin to see the twinkling lights of bio-luminescent creatures→ a great diversity of strange and bizarre fishes can be found here

(6) **Bathypelagic Zone**
  (a) Extends from 1000 meters (3281 feet) down to 4000 meters (13124 feet)
  (b) Here the only visible light that is produced is by the creatures themselves
  (c) Sometimes referred to as the midnight zone
  (d) The water pressure at this depth is immense, reaching 5850 pounds per square inch
  (e) In spite of the pressure→ a surprisingly large number of creatures can be found here
    (i) Most animals that live at these depths are black or red in color due to the lack of light
    (ii) Sperm whales can dive down to this level in search of food

(7) **Abyssopelagic Zone:**
  (a) Also known as the Abyssal Zone or simply the Abyss→ comes from the Greek word meaning "no bottom"
  (b) Extends from 4000 meters (13124 feet) to 6000 meters (19686 feet)
  (c) The water temperature is near freezing and there is not light at all
  (d) Very few creatures can be found at these crushing depths, most of these invertebrates such as basket stars and tiny squid
  (e) ¾ of the ocean floor lies within this zone
  (f) The deepest fish ever discovered was found in the Puerto Rico Trench at a depth of 27460 feet (8372 meters)

(8) **Hadalpelagic Zone:**
  (a) Layer extends from 6000 meters (19686 feet) to the bottom of the deepest parts of the ocean
  (b) These areas are mostly found in deep water trenches and canyons
  (c) The deepest point in the ocean is located in the Mariana Trench off the coast of Japan at 35, 797 feet (10,911 meters)
  (d) The temperature of the water is just above freezing, the pressure is an incredible eight tons per square inch (that's approx. the weight of 48 Boeing 747 jets)
  (e) In spite of the pressure and temperature= life can still be found here
    (i) Invertebrates such as starfish and tube worms can thrive at these depths

ii) **Ocean Currents:**
(1) Radiation, Conduction, and Convection:
  (a) Radiation allows heat to travel through space and conduction allows it to move from one solid to another through contact→ Convection allows heat to travel through gas or liquids by movements of currents→ Water (like air) is a fluid that can carry heat as it moves from one place to another
  (b) Movement of fluids in the vertical direction driven by buoyancy= Convection, convection contributes (with radiation and conduction) to the movement of heat in the vertical direction; movement in the horizontal direction= Advection, essentially the sole process by which heat moves laterally over the surface of the earth
(2) Water= 1000 times as dense as air and since the amount of thermal energy transported by a moving fluids proportional to its density, a volume of water can transport about a thousand times as much heat as an equivalent volume of air



(3) This picture shows global currents with direction, temperature, and latitudinal location

(4) The Southern Hemisphere has major counterclockwise circulation gyres (large system of rotation current)

(5) The clockwise circulation patterns in the Northern Hemisphere include gyres in the North Atlantic and two cells in the North Pacific Ocean

(6) At latitudes above 30N and below 30S= circulation patterns become more complicated due to interactions with continents and the Arctic Ocean

  (a) The Gulf Stream carries warm tropical water off the east coast of the US in a direct path toward Great Britain and the Scandinavian countries, giving these regions a far warmer climate than say Alaska which is at comparable latitude

  (b) For example→ **Davidson Current** off the coast of California= travels counter-clockwise opposing the **California Current** (has a clockwise movement) during the winter months

    (i) Interesting consequence= in both hemispheres the west coasts of continents generally have flow toward the Equator and east coasts have a flow away form the Equator

      1. Suggests that west coasts of continents will have slightly cooler water offshore compared to east coasts at the same latitude
      2. In the US the water off northern California is much colder than off of New York at the same latitude

iii) **The Coriolis Effect:**

(1) Responsible for the clockwise movement of gyres above the equator and counter movement down below the equator

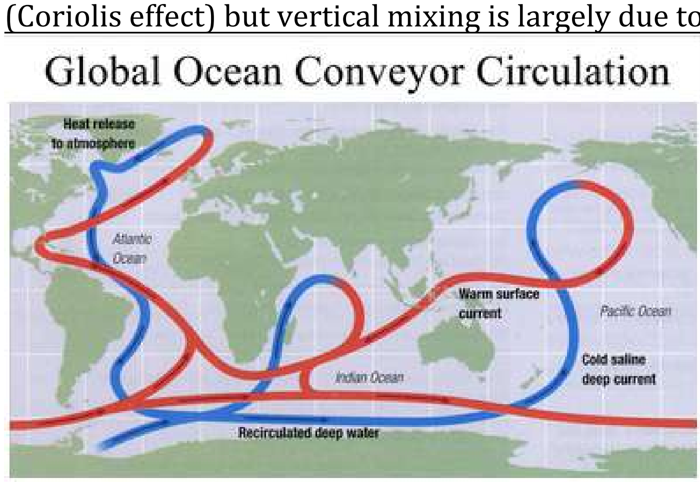
(2) The rotation in the major ocean basins is driven by a combination of wind stress at the ocean surface and the Coriolis force due to the Earth's rotation

  (a) Weather system is trying to flow in a straight line but the Earth is rotating underneath it

  (b) The wind induces an ocean drift current generally in the same direction in but rotated slightly→ deflected by the Coriolis force to the right of the wind direction in the N. Hemisphere and to the left of the wind in the S. Hemisphere

iv) **Temperature, Salinity, Density:**

(1) Vertical motions in the ocean are driven by small differences in water density due to differences in salinity (salt content) and/or differences in temperature
(2) Increased salt content increases density of water and generally cold water is more dense than warm water
(3) Density goes up as temperature decreases (colder temperature)
(4) Salinity goes up and density increases (more salt, heavier water)
   (a) These two factors (3 & 4) will play with density in different ways when put or mixed with different bodies of water
(5) The ocean does not have uniform salinity→
   (a) As ocean water flows toward the polar region from the Equator= it passes the subtropical high-pressure zones (latitudes 25 to 35 North and South) that have very little precipitation but increase solar radiation that promotes evaporation (So Cal is at this zone= with notable arid conditions and strong condensation events such as fogs and June gloom)
   (b) In regions where evaporation is high= the salt content of the remaining surface water increases thus increasing density
   (c) In regions where precipitation is high= fresh-water rain will ride on top of the saline ocean water→ because warm salt waters will be denser (heavier)
   (d) Melting ice in polar regions will be less dense than nearby ocean water of temperature because of its lower temperature and lack of salt
   (e) These concepts of density dependence on temperature and salinity explain the linkage of surface water to the Abyss (deep ocean) circulation
(6) In the North Atlantic ocean= water traveling northward at the surface passes through the subtropical high pressure zone and experiences a density increase due to evaporation, as it continues northward evaporation continues to increase the salinity and hence the density but cooling due to heat loss to the atmosphere also contributes to increasing in density
   (a) Ultimately the density increases to the extent that massive subsidence is created to the north of Iceland
(7) The subsidence region in the Southern Hemisphere is explained for the same reason→ since warm water from the tropical Pacific has experienced both evaporation and cooling
(8) The vertical circulation caused by density differences due to differences in ocean temperature and salinity is called the Thermohaline Circulation
(9) Horizontal global ocean circulation is driven by wind stress at the ocean surface (Coriolis effect) but vertical mixing is largely due to Thermohaline circulation



d) Geographic Distribution of Marine Organisms:

i) The geographic distribution of marine organisms depends on their responses to current, temperature, and physical barriers; their local distribution is affected by waves and tides, bottoms composition, salinity, and depth
ii) **Epopelagic Zone:** Home to the greatest biodiversity in the sea, largely because of the availability of sunlight that enables photosynthetic organisms to thrive, both marine plants and animals are found here
iii) **Mesopelagic zone:**
iv) **Bathypelagic Zone**: bioluminescent organisms live here, plants are non-existent in the bathypelagic zone, animals that can live here survive on the dead material that falls from the surface zones on other animals that live in the deep sea
v) **Abyssopelagic zone**: most animals are blind and colorless due to the complete lack of light
vi) Marine bio-cycles are mainly divided into **pelagic** (open water) and **benthic** (bottom) cycles
vii) Organisms that comprise the oceanic biome are widely distributed around the world, but may be divided into warm-water, Arctic, and Antarctic faunas; two biomes on the continental shelf subdivide into warm-temperature, temperate, Arctic and Antarctic faunas as well as into more restricted regions and sub-regions
(1) Coral reefs are found in the tropics
viii) The warmer water faunas are richest in species, especially in the Indo-Malayan and West Indian sub-regions
ix) Mollusks, fishes, birds, and mammals constitute nekton→ the taxonomic composition of the fish fauna varies with depth; bioluminescence is exceptionally well developed among deep-sea nekton and benthos
x) Marine benthos includes a great variety of sessile, creeping, and burrowing forms
(1) It is very abundant in the **littoral zone**, decreases in numbers with depth, although individuals are found in the deepest ocean trenches
(2) There is considerable difference in life-form and species composition of benthos occurring on rocky shores as compared to those found in sand and mud bottoms
(a) Zonation of species is more prominent on rocky than on depositing shores

6) Atmosphere

a) Layers of the Atmosphere: Chemical Composition and Thermal Structure

i) Phrase to help remember the order of the Earth's atmosphere:
ii) The Strong Man's Triceps Explode
iii) **Troposphere, Stratosphere, Mesosphere, Thermosphere, Exosphere**
iv) **Troposphere**
(1) The lowest layer of the atmosphere and measures about 7 miles (12 km); Composed of 70% Nitrogen and 21% Oxygen
(2) Density is very low at troposphere layer; contains the largest percentage of the mass of the total atmosphere
(3) It contains over 75% of all the atmosphere's gases and vast quantities of water and dust→ as the sun heats the ground it keeps this thick mixture churning
(a) All weather phenomena occur here; The weather is caused by these churnings of mass
(4) The troposphere is normally warmest at ground level and cools higher up where it reaches its upper boundary (Tropopause)
(a) The Tropopause (boundary between Troposphere and Stratosphere) varies in height

(b) At the equator its 11.2 miles high and at 50N and 50S its 5.6 miles and at the poles its 3.7 miles high

(5) Conveyance of heat, temperature, and most of the filtering effects of the atmosphere happen here (except for the ozone= in stratosphere)

v) **Stratosphere**

(1) Extends from the Tropopause up to its boundary (the Stratopause); 31 miles above the Earth's surface

(2) In this layer there is 19% of the atmosphere's gases and contains little water vapor

(3) Compared with the troposphere it's calm in this layer, the movements of the gases are slow

(4) Within the stratosphere is the ozone layer, a band of ozone gas that absorbs harmful ultraviolet rays of the sun

(a) Ozone is an unusual type of oxygen molecule that is relatively abundant in the stratosphere, heats this layer as it absorbs energy from incoming ultraviolet radiation from the Sun

(5) The higher you get in the atmosphere the warmer the air gets, the temperature rises from -76 degrees F at the bottom to a maximum of about 5 degree F at the Stratopause

(a) This is exactly the opposite of the behavior in the troposphere in which we live in, where temperature drops with increasing altitude

(b) Because of this temperature stratification there is little convection and mixing in the Stratosphere, so the layers of air there are quite stable

(c) Commercial jet aircraft fly in the lower stratosphere to avoid the turbulence that is common in the Troposphere below

vi) **Mesosphere**

(1) The next layer above the Stratopause; extends to its upper boundary (the Mesopause), at 50 miles above the ground

(2) The gases in the Mesosphere are too thin to absorb much of the Sun's heat but thick enough to slow down meteorites hurtling into the atmosphere

(3) They burn up leaving fiery trails in the night sky, the temperatures in the Mesosphere drop to -130 degree F at the Mesopause

vii) **Thermosphere**

(1) The layer above the Mesopause, where Auroras tend to occur

(2) The gases of the thermosphere are even thinner than those in the Mesosphere but they absorb ultraviolet light from the Sun→ because of this the temperatures rise to 3600 degrees F at the top

(3) The top of the Thermosphere is at a height of 430 miles off the Earth's surface, in the thermosphere there is the Ionosphere

(a) This layer extends 62 miles to 190 miles off the Earth's surface

(b) It is made of electrically charged gas particles (ionized)

(c) The particles get this electric charge by ultraviolet rays of the sun

(d) The Ionosphere has the important quality of bouncing radio signals transmitted from the Earth= that's why places all over the world can be reached via radio

viii) **Exosphere**

(1) The outermost layer of the atmosphere, extends from 430 miles to 500 miles above the ground

(2) Gases get thinner and thinner and drift off into space

(a) The main gases within the exosphere are the lightest gases, mainly hydrogen with some helium, carbon dioxide, and atomic oxygen near the exobase

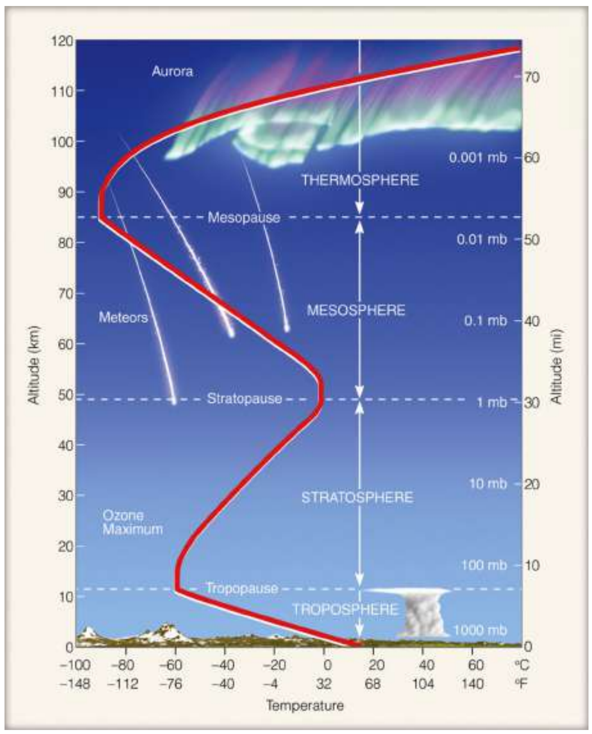
(3) Since there is no clear boundary between outer space and the exosphere, the exosphere is sometimes considered a part of outer space, the upper boundary of the exosphere can be defined theoretically by the altitude about 120,000 miles, half the distance to the Moon, at which the influence of solar radiation pressure on atomic hydrogen velocities exceed that of the Earth's gravitational pull

(4) The exosphere is observable from space as the geocorona is seen to extend to at least 62,000 miles from the surface of the Earth

(5) The exosphere is a transitional zone between Earth's atmosphere and interplanetary space

(6) The exosphere is almost a vacuum, the "air" is very, very thin there, when air is thin it doesn't transfer much heat to objects in the air, even if the air is very, very hot (but the exosphere would feel quite cold to use

(7) Since the "air" is so thin in the exosphere= it is almost a vacuum→ there are very few particles, we feel warmth when particles hit our skin and transfer energy to us, there are too few particles in the exosphere to transfer much energy even though each particle is quite "hot" itself



b) Evolution of Earth's Atmosphere:

i) **Outgassing:**

(1) When Earth's first atmosphere was formed= consisted primarily of hydrogen and helium (the two most abundant gases in the Universe)

(2) Through the process of outgassing (outpouring of gases from Earth's interior), methane, ammonia, carbon dioxide, and water vapors were introduced into the atmosphere (there was no free oxygen in the atmosphere yet)

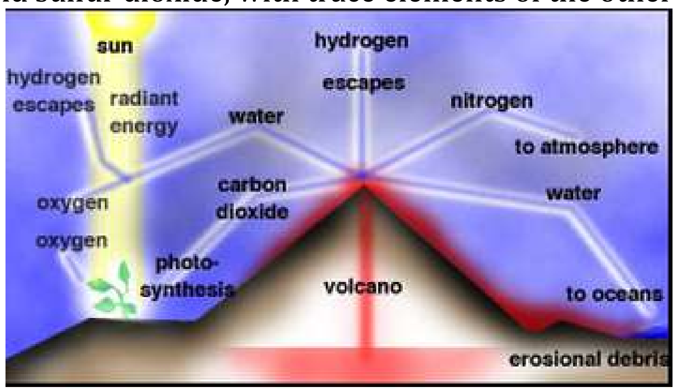
(3) Hydrogen and helium gases probably escaped into the space early due to the fact that these gases were too light to be held onto by Earth's gravity; many of the other gases may have been blown off of Earth by solar winds from the young and active star: Our Sun

(4) Outgassing occurs when gases are trapped in a planet and released into the atmosphere, this outgassing is still occurring today through volcanic activities and eruptions

(5) Gases emitted today are probably similar to the ones emitted in Earth's early life

(a) Gases emitted by volcanic activity include 35-90% water vapor, 5-30% carbon dioxide, 2-30% sulfur dioxide, and trace amounts of nitrogen, chlorine, hydrogen, and argon→

(b) Thus the early atmosphere must have consisted primarily of water vapor, carbon dioxide, and sulfur dioxide, with trace elements of the other gases



ii) **Origins of Atmospheric Oxygen:**

(1) Life started to have a major impact on the environment once photosynthetic organisms evolved→ these organisms, blue-green algae, fed off atmospheric carbon dioxide and converted much of it into marine sediments consisting of the shells of sea creatures (cephalopods)

(2) While photosynthetic life reduced the carbon dioxide content of the atmosphere= also started to produce oxygen

(a) For a long time the oxygen produced did not build up in the atmosphere since it was taken up by rocks

(b) Oxygen readily joined up with iron to form iron oxide

(c) To this day the majority of oxygen produced over time is locked up in the ancient "banded rock" and "red bed" formations

(d) It was not until probably only 1 billion years ago that the reservoirs of oxidizable rock became saturated and free oxygen stayed in the air

(3) Oxygen could have been found in the atmosphere as early as 2.45 bya→ but the amount slowly increased and became stable at around 1.5 bya; eventually as the oxygen molecules were bombarded by ultraviolet radiation, it formed ozone→ which eventually formed the ozone layer (which helped to protect Earth from solar radiation for the first time eve), only at this point did life move out of the oceans and respiration evolved

iii) **Variations of Carbon Dioxide Concentration:**

(1) The long-term evolution of carbon dioxide levels depend on weathering and magmatism, the relative fluctuations of CO2 levels are inferred from fluctuations of the isotopic (concentration of elements) records

(2) Around 4.5 bya (the beginning of Earth)→ believed that the atmosphere was predominantly composed of carbon dioxide= around 1 million ppm; Ever since then the CO2 content in the air has been dropping

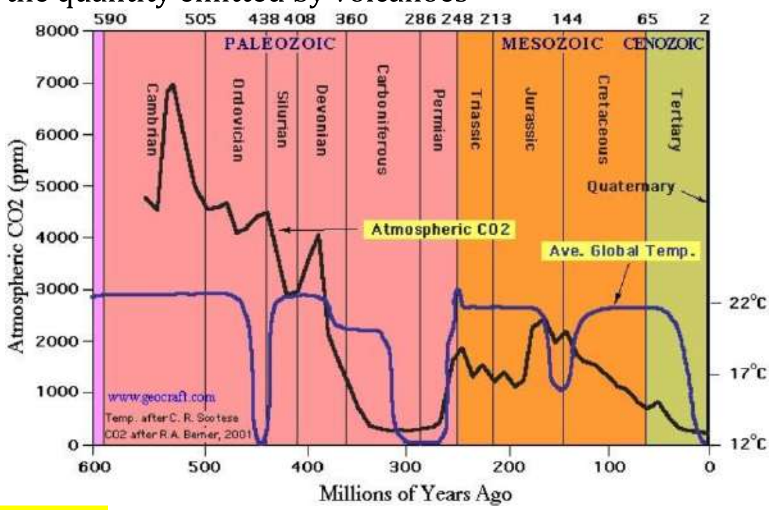
(a) 500 mya carbon dioxide was 20 times more prevalent than today, decreasing to 4-5 times during the Jurassic period and then slowly declining

(b) Continued to slowly decline until the inception of the Industrial Revolution

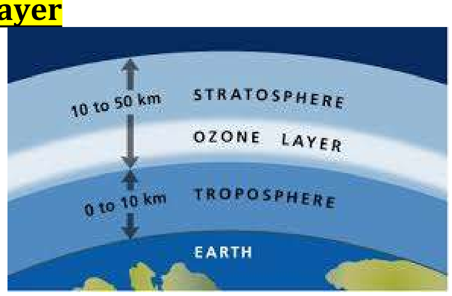
(3) Because of human activities such as the combustion of fossil fuels and deforestation have caused the atmospheric concentration of carbon dioxide has began an upward surge= increasing by about 35% since the beginning of the age of the Industrial Era

(a) Over the last 800,00 years or so atmospheric CO2 was never higher than 280 ppm, until we started adding CO2 into the atmosphere→ about 390 ppm, about 40% higher than it was when CO2 was only varying for natural reasons, we are now headed to about 500 ppm or more

(b) Emissions of CO2 by human activities are estimated to be 135 times greater than the quantity emitted by volcanoes



c) The Ozone Layer



i) Ozone is a gas that occurs naturally in our atmosphere, most of it is concentrated in the ozone layer, a region located in the **Stratosphere** several miles above the surface of the Earth

ii) Although ozone represents only a small fraction of the gas present in the atmosphere= plays a vital role by shielding humans and other life from harmful ultraviolet light form the Sun

(1) UV light strikes oxygen molecules in the stratosphere and splits them into two oxygen atoms, each of these atoms (when it encounters another oxygen molecule) combines with the molecule to make ozone

(2) The UV light also breaks the ozone into an oxygen molecule and oxygen atom= ozone-oxygen cycle and protects the Earth from UV radiation by converting the radiation to heat

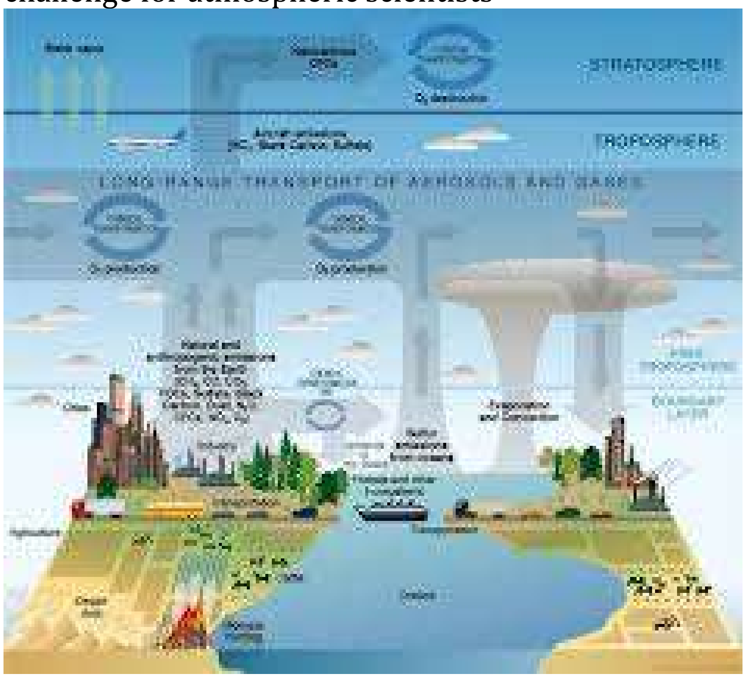
iii) Concentrations of ozone in the stratosphere fluctuate naturally in response to variations in weather conditions and the amount of energy being released form the Sun and to major volcanic eruptions

iv) Human activities in the last several decades have produced chemicals, such as chlorofluorocarbons (CFCs)→ have been released into the atmosphere and have contributed to the depletion of this important protective layer

v) When scientists realized the destructive effect these chemicals could have on the ozone layer→ international agreements were put in place to limit such emissions, as a result it is expected that the ozone layer will recover in the coming decades

vi) Ozone is also a greenhouse gas in the upper atmosphere and thus plays a role in Earth's climate, the increases in primary greenhouse gases, such as carbon dioxide, may affect how the ozone layer recovers in coming years

(1) Understanding precisely how ozone abundances will change in the future with increased CFCs emissions and increased emissions of greenhouse gases remains a challenge for atmospheric scientists



vii) **Origins and UV Radiation**

(1) Ozone in the Earth's stratosphere is created by ultraviolet light striking oxygen molecules containing two oxygen atoms (O2), splitting them into individual oxygen atoms (atomic oxygen); the atomic oxygen then combines with unbroken O2 to create ozone, 03

(2) The ozone molecule is unstable (although in the stratosphere, long-lived) and when ultraviolet light hits ozone it splits into a molecule of O2 and an atom of atomic oxygen, continuing process called the Ozone-Oxygen Cycle, thus creating an ozone layer in the stratosphere

(a) The region from about 33,000-160,000 ft above Earth's surface, about 90% of the ozone in our atmosphere is contained in the stratosphere

(3) Although the concentration of the ozone in the ozone layer is very small= vitally important to life because it absorbs biologically harmful UV radiation coming from the Sun

(a) UV-C (would be very harmful to all living things)= entirely screened out by a combination of dioxygen and ozone by around 115,000 ft altitude

(b) UV-B radiation can be harmful to the skin and is the main cause of sunburn, excess exposure can also cause genetic damage= resulting in problems such as skin cancer

(i) The ozone layer is very effective at screening out UV-B= some UV-B (particularly at its longest wavelengths) reaches the surface

(ii) For radiation the intensity at the top of the atmosphere is 350 million times stronger than at the Earth's surface

viii) **Natural Distribution of the Ozone Layer**

(1) Thickness of the ozone (the total amount of ozone in a column overhead) varies by a large factor worldwide

(a) In general smaller near the equator and larger towards the poles= Total ozone varies strongly with latitude and longitude within seasons

(i) Natural air motions mix and blend air between regions of the stratosphere that have high ozone values and those that have low ozone values, tropospheric weather systems can temporarily change the thickness of the ozone layer in a region= thus change the total ozone; the geographical variation in these air motions in turn causes variations in the distribution of total ozone

(ii) Ozone variations occur as a result of changes in the balance of chemical production and loss processes as air moves to and from different locations over the globe

1. This balance for example is very sensitive to the amount of sunlight in a region

(b) It also varies with season= In general thicker during the spring and thinner during the autumn

(i) The reason for this latitude and seasonal dependence are complicated, involving atmospheric circulation patterns and solar intensity

(ii) Ozone shows a maximum at high latitudes during Spring as a result of increased transport of ozone from its source region in the tropics toward the polar regions during late fall and winter

(iii) This ozone transport is much weaker during the summer and early fall periods and is weaker overall in the Southern Hemisphere

(iv) An important feature of seasonal ozone changes is the natural chemical destruction that occurs when daylight is continuous in the summer polar stratosphere= causes total ozone to decrease gradually

(v) In the Antarctic→ the minimum in totally ozone is observed during spring→ the minimum is a consequence of the "ozone hole"= describes the widespread chemical destruction of ozone by ozone-depleting substances

1. In the late 1970s, before the ozone hole appeared each year, much higher ozone values were found in Antarctic spring
2. Now the lowest values of total ozone across the globe and all season are found every Spring in the Antarctic
3. After spring these low values disappear from total ozone maps as polar air mixes with lower-latitude air containing much higher ozone values
4. In the tropics the total ozone changes are much smaller than the polar regions= because seasonal changes in both sunlight and ozone transport are smaller in the tropics than in the polar regions

(c) Most of the ozone is found in the mid-to-high latitudes of the Northern and Southern Hemispheres and the highest levels are found in the Spring, not the summer and the lowest in the Autumn not winter in the N. Hemisphere

(i) While most of the ozone is indeed created over the tropics the stratospheric circulation (known as the Brewer-Dobson Circulation) then transports it pole ward and downward to the lower stratosphere of the high latitudes

ix) **Ozone Response Due to Human Activities**

(1) The ozone layer is deteriorating due to the release of pollution containing the chemicals chlorine and bromine

(2) Chlorofluorocarbon (CFC) chemicals found mainly in spray aerosols heavily used by industrialized nations for much of the past 50 years as the primary culprits of the ozone layer breakdown

(3) When CFCs reach the upper atmosphere= exposed to UV rays= cause them to break down into substances that include chlorine, chlorine reacts with the oxygen atoms in the ozone and rips apart the ozone molecule

(a) One atom of chlorine can destroy more than a hundred thousand ozone molecules

(4) The ozone layer above the Antarctic has been particularly impacted by pollution since the mid-1980s; the region's low temperatures speed up the conversion of CFCs to chlorine

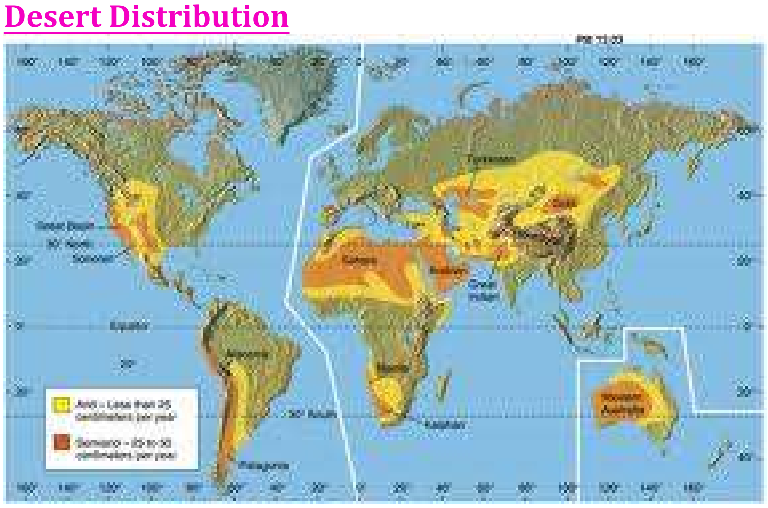
(a) In the Southern spring and summer (when the Sun shines for long periods of the day)→ chlorine reacts with UV rays, destroying ozone on a massive scale, up to 65%

(b) In other region's the ozone layer has deteriorated by about 20%

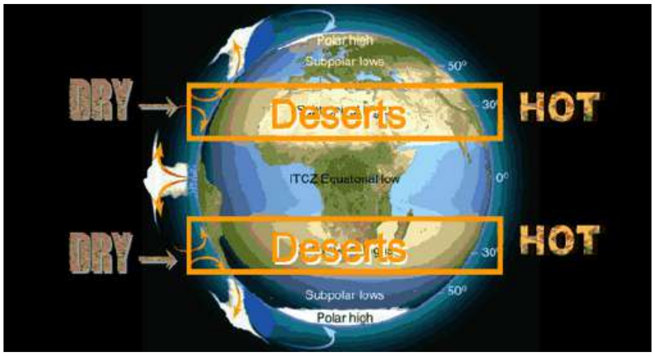
(5) About 90% of the CFCs currently in the atmosphere were emitted by industrialized countries in the Northern Hemisphere including the US and Europe; these countries banned CFCs by 1996 and the amount of chlorine in the atmosphere is now falling→ but scientists estimate it will take another 50 years for chlorine levels to return to their natural levels

d) Rainforest and Dessert Bands at Specific Latitudes and Causes of this Pattern

i) **Desert Distribution**



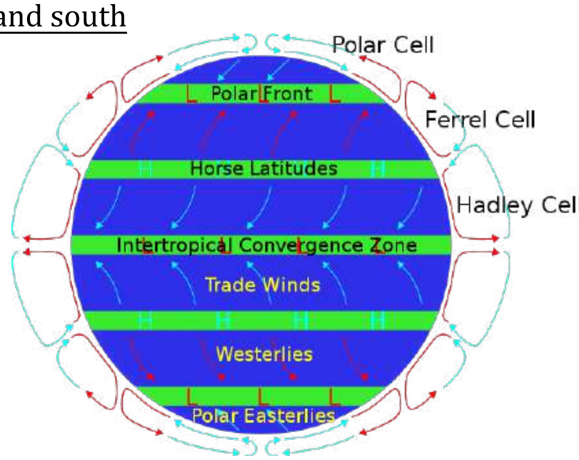
(1) Deserts occur in horizontal bands 30 degrees from the equator that correspond to the **dry**, **sinking heating** air of the Hadley Cells



(2) There are four main interlinked causes of hot deserts:
   (a) The formation of the subtropical high pressure cell (Horse Latitudes)
   (b) The rain shadow effect of the belt of easterly trade winds
   (c) The effect of the cold currents off the west of the continents at these latitudes (Ex: California Current)
   (d) The depositing sands of a desert along its border into the fertile land

(3) A <u>desert</u> is a region that receives an extremely low amount of precipitation, less than enough to support growth of most plants, most deserts have an average annual precipitation of less than 400 millimeters (16 inches)
   (a) A common definition to distinguish between <u>true deserts</u> which receive <u>less than 250 mm</u> (10 in) of average annual precipitation, and semi deserts or steppes, which receive between 250 mm (10 in) and 400-500 mm (16-20 in)

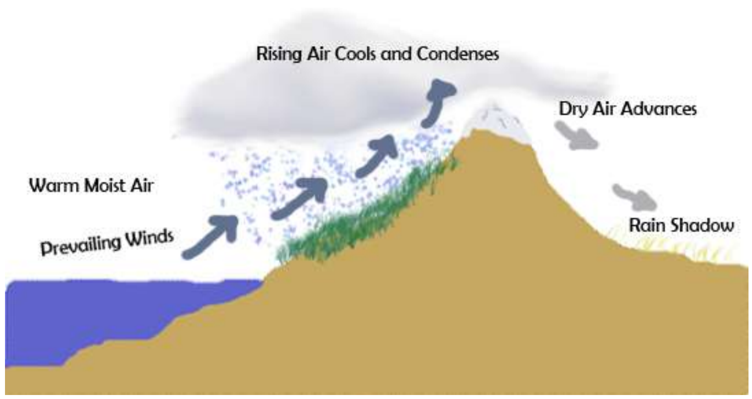
(4) <u>Horse Latitudes or Subtropical High</u> are subtropical <u>latitudes between 30 and 35 degrees both north and south</u>



   (a) This region under a ridge of high pressure called the subtropical high= an area that receives little precipitation and has variable winds mixed with calm
   (b) The consistently warm, dry conditions of the horse latitudes also contribute to the existence of temperate deserts such as the Sahara Desert in Africa, the southwestern US and northern Mexico, parts of the Middle East in the Northern Hemisphere, the Atacama Desert, the Kalahari Desert, and the Australian Desert in the Southern Hemisphere

(5) <u>A rain shadow</u> is an area of dry land that lies on the leeward (or downwind) side of mountains; winds carry air masses up and over the mountain range and as the air is driven upward over the mountain, falling temperatures cause the air to condensate and lose much of its moisture as precipitation
   (a) Upon reaching the leeward side of the mountain= the dry air descends and picks up any available moisture from the landscape below

(b) The resulting profile of precipitation across the mountain is such that rainfall and moist air prevails on the windward side of the mountain range while arid moisture-poor air prevails on the leeward side of the mountain range normally creating desert areas (Death Valley lies in the rain shadow of the Pacific Coast Ranges of California and the Sierra Nevada Mountains)



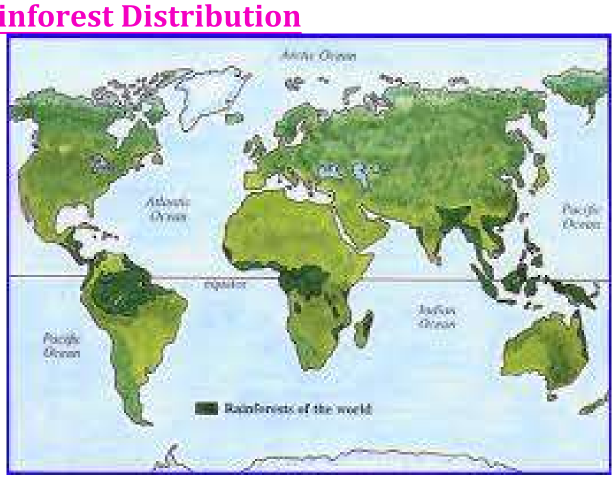
(6) Global currents with direction, temperature, and latitudinal location also play an important role in desert formation

(a) The Northern and Southern Hemispheres contain surface and deep ocean currents that affect global climates and in particularly in this case- Horse Latitudes

(b) Water from polar regions sweeps towards the equator along western coasts of continents, these cold currents cool the air, forcing it to rain over the sea, causing deserts to form on the coast

(c) When warm air currents meets cold seas= moisture reaches the coast by fog or in the form of June Gloom in So. Cal, the rainfall does not penetrate inland and forms deserts

ii) **Rainforest Distribution**



(1) Rainforests only cover a small part of the Earth's surface- about 6%--> they are home to over half the species of plants and animals in the world

(2) Tropical rainforests are located in a band around the Equator (0 degrees latitude), mostly in the area between the Tropic of Cancer (23.5 degrees N latitude) and the Tropic of Capricorn (23.5 degrees S latitude)

(a) This 3000 mile wide band is called the "tropics"

(b) Occur at the equator where the Hadley cell starts with **hot wet** air **rising** and cooling (low pressure→ cloudy and rainy)

(3) Temperatures at the equator are high, these high temperatures cause accelerated evaporation of water, which results in frequent rain in forested areas in the tropics

(4) In an average year in a tropical rain forest= the climate is very humid because of all the rainfall (amounts to about 168- 1000 cm per year); it rains more than 90 days a year and the strong sun usually shines between storms

(a) The rainforests has lots of rain because it is very hot and wet, type of climate is found near the equator

(i) That means that there is more direct sunlight hitting the land and sea there than anywhere else

(ii) The Sun warms the land and sea and the water evaporates into the air, the warm air can hold a lot of water vapor, as the air rises it cools, that means it can hold less water vapor, then as warm meets cold, condensation takes place and the vapor forms droplets and clouds form, the clouds then produce rain, The water cycle repeats often along the equator

(5) The main plants in this biome are trees→ a lot of the rain that falls on the rain forest never reaches the ground, it stays on the trees because the leaves act as a shield, and some rain never gets past the trees to the smaller plants

7) Earth's Energy Budget: Inflow and Outflow

a) Compare the Amount of Incoming Solar Energy, the Earth's Internal Energy, the Energy Used by Society, and the Energy Reflected Back to Space:

i) **Solar Energy**

(1) Because of the tilt of the Earth's axis= incoming solar radiation is not evenly distributed on the Earth's surface and seasonal changes occur

(2) The Sun is not in the exact center of the Earth's orbit

(a) During the S. hemisphere summer the Earth is closer to the Sun than during the N. Hemisphere summer

(b) The Earth is farthest from the Sun during the S. hemisphere winter

(3) As the Sun's electromagnetic radiation penetrates the Earth's atmosphere→ selectively absorbed and scattered by molecules of gases, liquids, and solids; the energy coming from the Sun to the Earth's surface is called solar insulation or shortwave energy

(4) Energy goes back to space from Earth system in two ways: reflection and emission

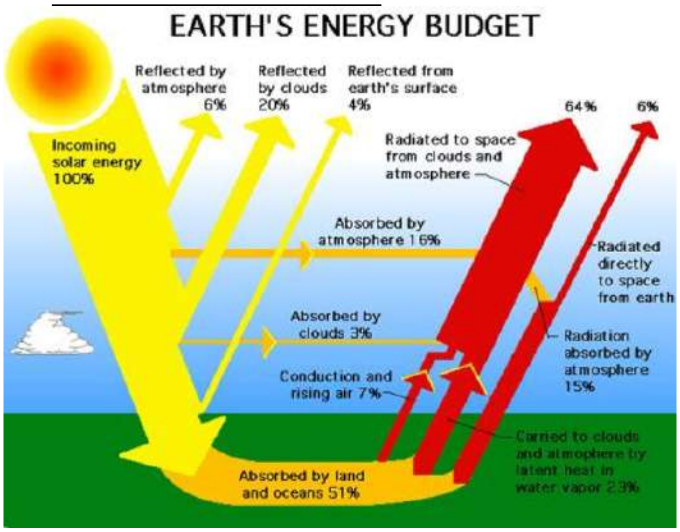
(a) Part of the solar energy that comes to Earth is reflected back out to space in the same, short wavelength in which it came to Earth

(b) The percentage of solar energy that is reflected back to space is called the surface albedo

(c) Different surfaces have different albedos→ over the whole surface of the Earth, about 30% of incoming solar energy is reflected back to space

(i) Ocean surfaces (26% albedo) and rain forests (15% albedo) reflect only a small portion of the Sun's energy

(d) A Cloud usually has a higher albedo than the surface beneath it, the cloud reflects more shortwave radiation back to space then the surface would in the absence of the cloud, thus leaving less solar energy available to heat the surface and atmosphere, a cloud can absorb radiation emitted by the Earth's surface and radiates in all directions



ii) **Earth's Internal Energy**

(1) The Earth's internal heat source provides the energy for our dynamic planet, supply it with the driving force for plate-tectonic motion, and for on-going catastrophic events such as earthquakes and volcanic eruptions

(2) This internal energy was much greater in the early stages of the Earth than it is today, having accumulated rapidly by heat conversion associated with three separate process, all of which were most intense during the first few hundred thousand years of Earth's history: 1) Extraterrestrial impacts, 2) Gravitational contraction of the Earth's interior, 3) The radioactive decay of unstable isotopes

(3) (1) Under the Nebular Hypothesis→ proto-planet Earth would have grown over time from a barrage of extraterrestrial impacts, increasing its mass with each bombardment; as the proto-planet grew in size its increased gravitational field would have attracted even more objects to its surface, the composition of these colliding bodies would have included metal-rich fragments, rocky fragments, and icy fragments

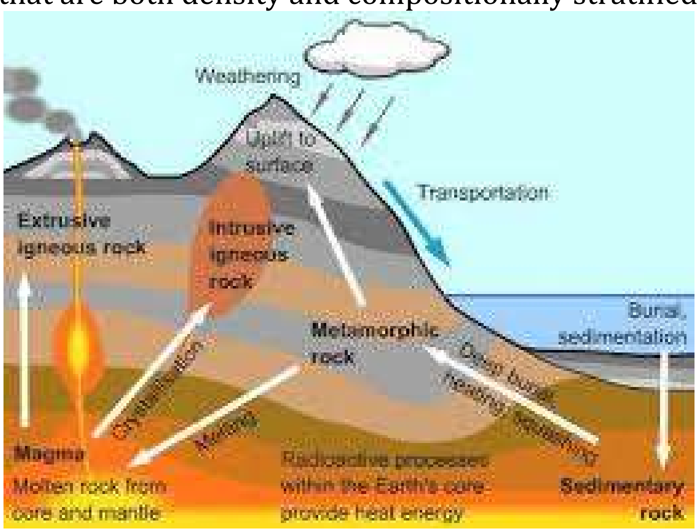
(a) Although accretion was much more prevalent in the early stages of Earth's history= extraterrestrial collisions are still occurring today, exemplified by shooting stars and fireballs in the night sky, and by the occasional impact of larger bodies on the Earth's surface→ the very large amount of kinetic energy inherent in these moving bodies converted to heat energy upon impact= thus providing a component to the Earth's internal heat source

(4) (2) In the early stages of planetary accretion the Earth was much less compact than it is today, the accretion process led to an increasingly greater gravitational attraction forcing the Earth to contract into a smaller volume, increased compaction resulted in the conversion of gravitational energy into heat energy (much like a bicycle pump heats up due to the compression of air inside it); heat conducts very slowly through rock so that the rapid build up of this heat source within the Earth was not accommodated by an equally rapid loss of heat through the surface

(5) (3) Radioactive elements are inherently unstable, breaking down over time to more stable forms, EX) the unstable isotope Uranium-238 will slowly decay to Lead-206, all such radioactive decay processes release heat as a by product of the on-going

reaction, in its early stages of formation the young Earth had a great complement of radioactive elements, but many of these (ex: aluminum-26) are short-lived and have decayed to near extinction, others with more lengthy rate of decay are still undergoing this radioactive process, thus still releasing heat energy, the greater complement of unstable elements in the early Earth= generated a greater amount of heat energy in its initial stages of formation

(6) The heat build up inside Earth reached a maximum early in the Earth's history and has declined significantly since, the greater heat content of the early Earth was the product of the above situations, The initial accretion of particles resulted in a rather homogeneous sphere composed of a loose amalgam of metallic fragments (iron meteorites), rocky fragments (stony meteorites), and icy fragments (comets). However, the increased heat content of the early Earth resulted in melting of the Earth's interior, so that the young planet became density stratified with the heavier (metallic) materials sinking to the center of the earth, and the lighter (rocky) materials floating upward toward the surface of the earth. The very lightest volatile materials (derived from comets) were easily melted or vaporized, rising beyond the Earth's rocky surface to form the early oceans and the atmosphere. We now have a differentiated earth due to melting and mobilization of materials driven by the Earth's internal heat engine. This has resulted in the development of a series of concentric layers that are both density and compositionally stratified



iii) **Energy Used by Society**

(1) Energy in forms other than food is also essential for the functioning of a technical society

(2) Prodigious amounts of energy are used to power automobiles, heat homes, manufacture products, generate electricity, and perform various other tasks

(3) In order for our society to function in its present patterns= vast amounts of coal, natural gas, and oil are extracted from the Earth and burned to provide this energy

(a) These fossil fuels supply about 85% of the energy used in the US, these resources evolved hundreds of millions of years ago as plant and animal matter decomposed and was converted under conditions of high temperature and pressure under the Earth's surface into the hydrocarbon compounds that we now call fossil fuels

(4) To a lesser extent we also derive energy from hydroelectric plants, nuclear reactors, electric wind generators, and geothermal plants, and we all benefit enormously from the energy obtained directly from the Sun

(5) Since the beginning of the Industrial Rev, industrial societies have become increasingly depended on fossil fuels; 150 years ago the muscular effort of humans and animals played an important role in the American economy and firewood supplied most of the heat energy→ Now less than one percent of our energy comes from firewood and we rely much less on physical effort of people and animals

b) Incoming Solar Radiation as it Relates to Reflection, Absorption, and Photosynthesis

i) Of all the sunlight that passes through the atmosphere annually= only 51% is available at the Earth's surface to do work, this energy is used to heat the Earth's surface and lower atmosphere, melt and evaporate water, and run photosynthesis in plants

(1) Of the other 49%= 4% is reflected back to space by the Earth's surface, 26% is scattered or reflected to space by clouds and atmospheric particles, and 19% is absorbed by atmospheric gases, particles, and clouds

ii) **Incoming Solar Radiation**

(1) 30% of incoming solar radiation is reflected back to space by clouds and Earth's surface

(a) Process where sunlight is redirected by 180 degrees after it strikes an atmospheric particle

(b) Percentages vary due to the type of material that covers it, factors such as cloud cover= clouds are effective at absorbing infrared radiation and thus cooling the Earth, if the sky is overcast a much higher percentage or light is going to be reflected back into space than if it is a clear sunny day

(2) 70% of incoming solar radiation is absorbed by the atmosphere, land, oceans

(a) Process in which solar radiation is retained by a substance and converted into heat energy

(3) The high concentration of incoming solar radiation is in the visible region

(4) Incoming radiation is higher at the equator and lower at the poles due to Earth's curvature

iii) **Kinds of Radiation that Reach the Surface**

(1) The fate of solar radiation is determined by its wavelength

(2) Longer wavelengths (ex: infrared) are absorbed by the atmosphere

(3) Shorter wavelengths particularly visible light are not absorbed by the atmosphere

(a) An exception to this is the absorption of the ultraviolet radiation by the ozone layer

iv) **Photosynthesis**

(1) Plants and other photosynthetic organisms contain chlorophyll that absorbs light

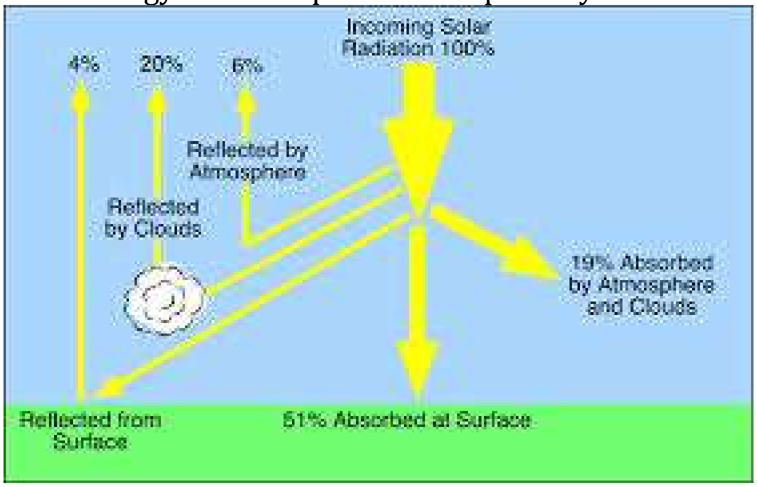
(2) Chlorophyll absorbs orange, short-red, blue and ultraviolet light

(3) Absorption of green and yellow light is lower, their reflection makes leaves green

(4) Chlorophyll uses light energy to convert water and carbon dioxide into sugar and oxygen

(5) Photosynthesis causes carbon dioxide to decline in the summer and increase in the winter

(6) Solar energy stored in plants is the primary source for life on Earth



c) Mechanism and Evaluation of the Significance of the Greenhouse Effect

i) Emission of Electromagnetic Radiation

(1) Every object emits electromagnetic radiation that is characteristic of its temperature; hotter objects emit higher energy radiation→ called "blackbody" radiation

(2) The Sun is much hotter than Earth= emits higher energy, shorter wavelengths; predominately in the visible or near-visible part of the spectrum (ex: ultraviolet)

ii) The Energy Budget

(1) To achieve balance, incoming solar energy must either by reflected or reradiated to space

(2) If incoming energy is not equal to outgoing energy= Earth will heat up or cool down

iii) **The Greenhouse Effect**

(1) About 1/3 of the solar energy that reaches the top of Earth's atmosphere= reflected directly back into space; Remaining 2/3= absorbed by the surface and by the atmosphere (to a lesser extent)

(2) To balance the absorbed incoming energy the Earth must on average radiate the same amount of energy back to space

(3) Because the Earth is much colder than the Sun= radiates at much longer wavelengths, primarily in the infrared part of the spectrum

(a) Much of this thermal radiation emitted by the land and ocean is absorbed by the atmosphere (including clouds) and reradiated back to Earth= called the Greenhouse Effect

(i) Analogy: The glass walls in a greenhouse reduce airflow and increase the temperature of the air inside

(4) Earth's greenhouse effect warms the surface of the planet, without the natural greenhouse effect→ average temperature at Earth's surface would be below freezing point of water→ Thus Earth's natural greenhouse effect makes life possible

(5) However→ human activities primarily the burning of fossil fuels and clearing of forests have greatly intensified the natural greenhouse effect= causing Global Warming

(a) The two most abundant gases in the atmosphere→ nitrogen and oxygen exert almost no greenhouse effect

(b) The greenhouse effect comes from molecules that are more complex and much less common

(i) Water vapor (most important greenhouse gas), Carbon dioxide (2nd most important), methane, nitrous oxide, ozone, and several other gases present in the atmosphere in small amounts= contribute to the greenhouse effect

(6) Industrial era= human activities have added greenhouse gases to the atmosphere

(a) Adding more of a greenhouse gas (such as CO2) to the atmosphere intensifies the greenhouse effect→ warming Earth's climate, the warming depends on various feedback mechanisms

(i) Ex: As the atmosphere warms due to rising levels of greenhouse gases= its concentration of water vapor increases→ further intensifying the greenhouse effect, causes more warming→ causes an additional increase in water vapor= a self-reinforcing cycle

d) Differences of Greenhouse Conditions on Earth, Mars, and Venus; the Origins of The Conditions; Climatic Consequences of Each

i) **Earth**

(1) See above

ii) **Mars**

(1) Without the Greenhouse Effect Earth's climate would be much colder like Mars

(2) Mars has a very thing atmosphere depleted in greenhouse gases→ thus has little greenhouse warming

(3) Mars does not effectively store heat because it lacks oceans and has a thin atmosphere, the result is large temperature swings: high during the day and low at night

(4) For much of its first billion years of existence→ thought that Mars was a warm and wet planet= now appears to be a lifeless, frozen wasteland

(5) Because Mars did have active volcanoes at one point→ thought that the outgassing from the volcanoes helped provide atmospheric gas to form a thick atmosphere. Much of the gases from the volcanic eruptions were water vapors and carbon dioxide (similar to volcanic outgassing here on Earth)= would have warmed the planet. If the amount of gas produced by the volcanoes were similar to the amount on Earth, than Mars may have had enough water to fill oceans

(6) Heat from meteorite impacts would have also helped release water vapor into the atmosphere, helping to enhance the greenhouse effect. At one point, carbon dioxide was lost and the greenhouse effect became weak until eventually the planet froze over. Some of the carbon dioxide condensed and froze to make the polar caps while others were bound to surface rock. The majority of the carbon dioxide was lost to space, although it is not clear as to why

(a) One theory is that as Mars cooled, the magnetic field in the core (like on Earth) became weak as the core began to harden. Because the magnetic field became weak, the solar wind particles were able to strip the atmosphere and blow it into space

iii) **Venus (and Earth)**

(1) If greenhouse gas concentrations on Earth became too high→ heating would occur and produce a climate like Venus

(2) Venus has a thick atmosphere rich in greenhouse gases and the highest surface temperature in the Solar System

(3) Why does Venus have such a strong greenhouse effect? Mainly, it's due to the large amounts of carbon dioxide in Venus' atmosphere, with approximately 96% of its atmosphere composed of carbon dioxide (200,000 times that of the Earth's atmosphere)

(a) We know that Earth and Venus have similar sizes and composition. So, what happened on Venus that allowed it to have such a high amount of carbon dioxide in its atmosphere? One main difference is that Venus has hardly any water. Another big difference is that Earth doesn't have a lot of carbon dioxide in its atmosphere. On Earth, the outgassing of water from volcanoes condensed into rain, eventually forming the oceans. In addition, carbon dioxide on Earth dissolved in the ocean and eventually was locked away in rocks. It was measured that Earth has about 170,000 times as much carbon dioxide trapped in rocks than it has in its atmosphere

(b) Looking at the figures, we can see that Venus and Earth actually have the same amount of carbon dioxide. The difference is that on Venus, it is in a gaseous stage in the atmosphere whereas on Earth, it is stored in rocks. So, if all of the carbon dioxide was to be released into our atmosphere, then Earth would become as hot as Venus

(4) Difference between Venus and Earth was water. Venus doesn't have much water on its planet. What little water was on Venus was baked away from the heat. Without any oceans on Venus, there was no way that carbon dioxide could dissolve and became trapped in the rocks

(a) When water vapor was outgassed from volcanic eruptions, it is thought that the UV light from the sun broke apart the water molecules. The hydrogen atoms escaped into space and the oxygen atoms was lost to chemical reactions

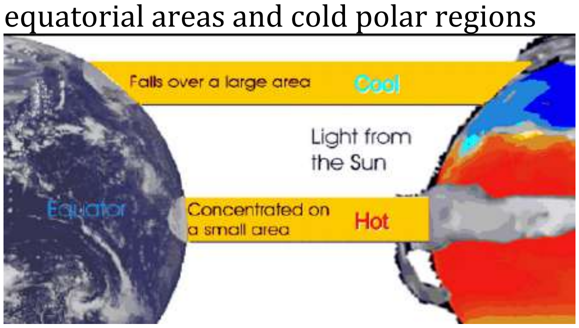
(b) Venus also had a weak magnetic field→ left its atmosphere vulnerable to the sun's solar wind (similar to what happened with Mars). After billions of years of breaking water molecules down into oxygen and hydrogen, this prevented the formation of oceans on land, thus, prevented carbon dioxide from ever dissolving and being stored within rocks.

(c) The oceans, from the start would have never been able to fully form, or was evaporated quickly, due to the high amount of sunlight that Venus receives. Venus would be around 113 F, below boiling point. But, this high temperature would increase evaporation of water from the oceans (if there were any). There would be more water vapor in the atmosphere. And, since water vapor is a greenhouse gas, it would have helped strengthen the greenhouse effect. The greenhouse effect would have then warmed the planet even more, increasing evaporation and water vapors in the atmosphere, which would then strengthen greenhouse effect even more. This cycle is known as the runaway greenhouse effect. This cycle would continue until there weren't any more oceans left on the planet

8) Circulation in the Oceans and Atmosphere

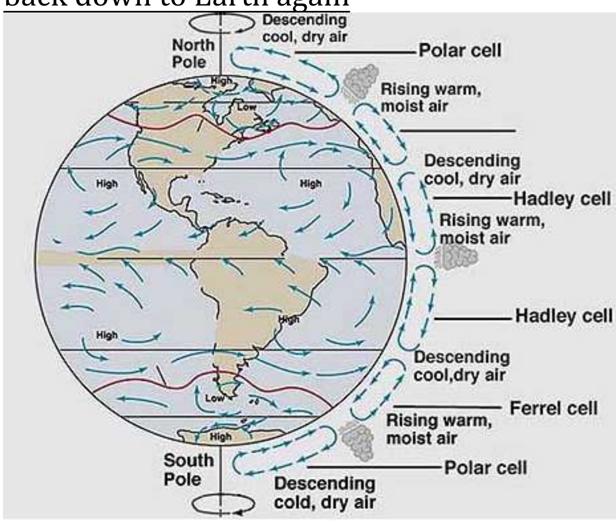
a) Differential Effects of Heating on Circulation Patterns in the Atmosphere and Oceans

i) Differential heating= caused by the round shape of the Earth, this creates warm equatorial areas and cold polar regions

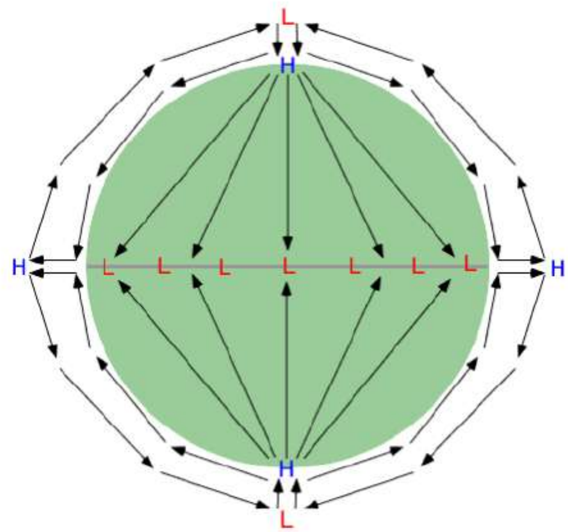


ii) There are two major reservoirs of water in the Earth's hydrologic cycle: atmosphere and oceans
   (1) Work together→ the heat of the Sun causes water to evaporate from lakes, rivers, and oceans, as well as from the leaves of the plants, water is absorbed into the atmosphere and carried around the world by currents of air, eventually the water in the air condenses to form clouds, which return it to Earth as rain or snow, the water that collects on land flows back to the oceans in rivers or streams to begin the cycle all over again, this interaction between atmosphere and ocean is what gives us our weather and climate

iii) Atmospheric Circulation/Convection
   (1) Weather is the condition of the atmosphere at a specific time and specific place, includes temperature, atmospheric pressure, humidity, precipitation, wind velocity
   (2) The amount of heat in the atmosphere varies from place to place, this keeps it moving constantly (circulating)
   (3) Most atmospheric circulation takes place in the troposphere, the layer of the atmosphere closest to the Earth, the troposphere extends to an altitude of 10-15km and contains about 90% of the mass of the atmosphere
   (4) Circulation happens because of **convection** a form of heat transfer in which a gas or fluid expands and rises as it gets warmer
   (5) The Earth gets more of the Sun's heat at the equator than it does at the poles, so as the air at the equator gets warmer it expands and rises, it continues to rise until it gets to the top of the troposphere where it spreads out toward the poles and then comes back down to Earth again



iv) The Simple Model of Global Circulation
   (1) Assumptions made for this model: 1) The Earth is not rotating in space, 2) The entire surface of the Earth is covered by the same material, 3) The air is hotter at the Equator and colder at the poles (only assumption that's actually true)
   (2) In this model= surface air flows from the poles to the Equator, when it reaches the Equator it gets heated and rises to the top of the troposphere where it spreads back toward the poles, when it gets to the poles it descends back to the surface again to complete the cycle
   (3) Based on these assumptions air circulation on the Earth should approximate the patterns shown



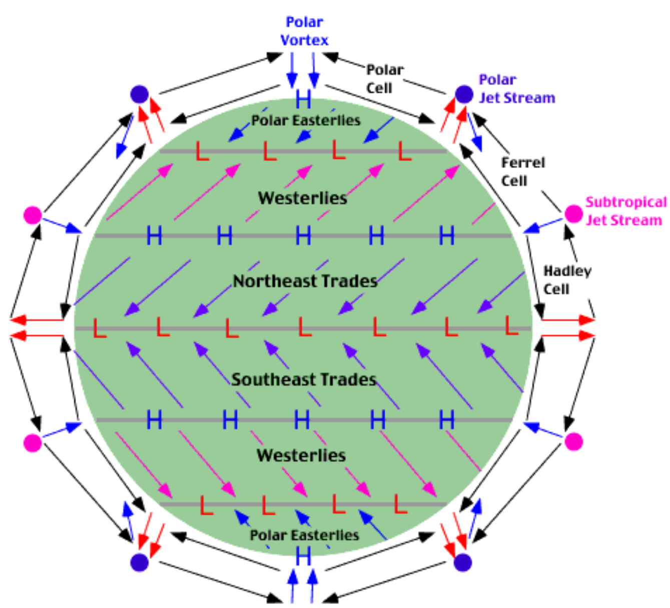
v) Three Cell Model of Global Circulation/Coriolis Effect

(1) We need to eliminate our first assumption in order to get a little closer to what really happens, now our circulation patterns become more complicated because of the **Coriolis Effect**

(a) Causes moving objects or currents on the surface of a rotating planet to veer to the right (clockwise) in the Northern Hemisphere and to the left (counterclockwise) in the Southern Hemisphere

(b) Rotation causes the development of three circulation cells in each hemisphere: **Hadley Cell, Ferrel Cell, and Polar Cell**

(2) Demonstrates the formation of the northeast and southeast trade winds, the westerlies, the polar easterlies and the subtropical and polar jet streams



vi) Actual Global Surface Circulation

(1) The circulation patterns differ from those shown on the Three-Cell Model:

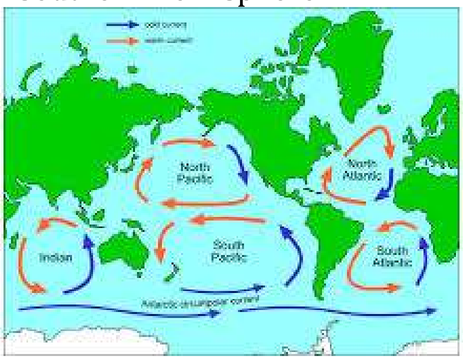
(a) The entire surface of the Earth is not composed of the same material which eliminates the second assumption we made in the Simple Model, the surface of the Earth is made up of both land and water (which behave differently when it comes to heating and cooling)

(b) Different elevations (like high mountains) cause different pressure centers, which is what creates atmospheric circulation

vii) Gyres

(1) Coriolis Effect affects oceans too, global atmospheric circulation patterns create large circular ocean currents in each hemisphere→ called Gyres

(a) Move clockwise in the Northern Hemisphere and counterclockwise in the Southern Hemisphere



viii) Wind (Atmospheric circulation)

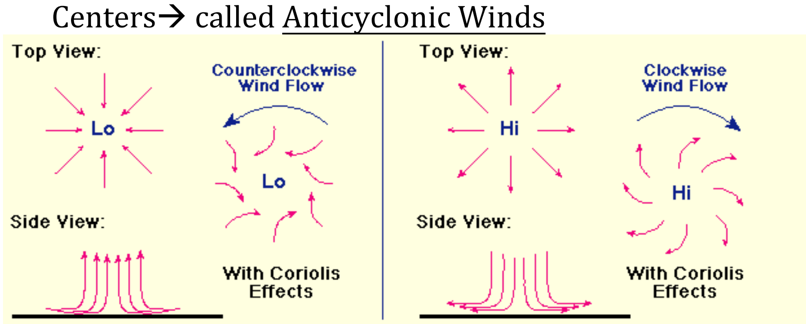
(a) Low Pressure Centers

(i) An area where air is rising is less dense than its surroundings, since winds blow from high pressure to low pressure areas→ expect the surface winds would always blow towards a Low Pressure Center but they don't because of the Coriolis Effect

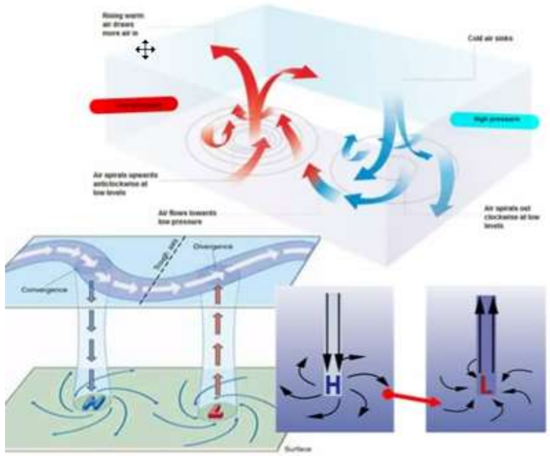
(ii) In the Northern Hemisphere they are deflected to the right and in the Southern Hemisphere to the left→ means that they don't actually arrive at a Low Pressure Center= they circulate around it= called Cyclonic Winds

(b) High Pressure Centers

(c) An area where air is descending is more dense than its surroundings, might expect that winds would blow away form it but again because of the Coriolis Effect winds are deflected toward the right in the Northern Hemisphere and toward the left in the Southern Hemisphere, winds which circulate around High Pressure Centers→ called Anticyclonic Winds



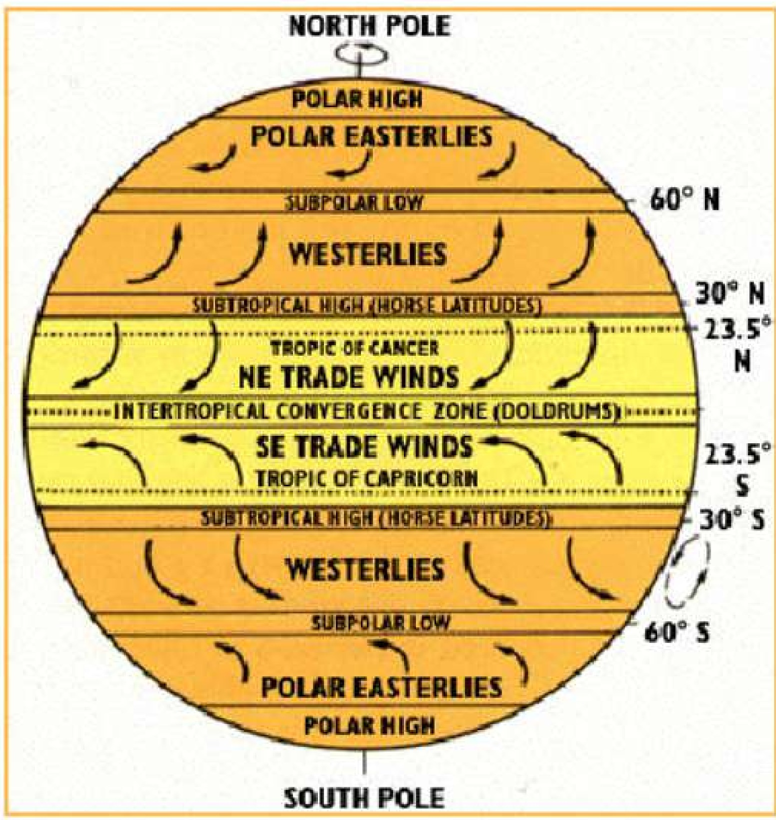
Low pressure systems (left) and high pressure systems (right) in the Northern hemisphere



ix) Pressure Belts

(1) At the Equator there is a belt of low pressure called the doldrums, 30 degrees north and south of the Equator there are belts of high pressure called horse latitudes, about 60 degrees north and south= belts of low pressure where the polar fronts are located, high pressure areas at both the north and south poles

(a) These high and low pressure belts are what cause our wind and weather



(2) From the Doldrums to the Jet Stream (description of some of the components of our wind/weather system starting at the Equator and moving toward the poles)

(a) The Doldrums/ITCZ

(i) Doldrums are a belt of low pressure along the equator where the Sun's heat is the hottest, as the hot air expands and rises it leaves long periods of windless calm, sailing ships used to be trapped here for days or weeks

(ii) Today they are known as the Intertropical Convergence Zone (ITCZ) since this is where the trade winds from each hemisphere converge, the weather here is hot and humid and is home of the Earth's major rainforests

(b) <u>Horse Latitudes</u>

(i) Hot air that rises in the doldrums comes down again in two high pressure areas called the horse latitudes (30 degrees north and 30 degrees south of the Equator)

(ii) Also known as the mid latitudes or the subtropics, the winds are light here and the weather is hot and dry

(iii) Air flows from the horse latitudes toward the Equator (as part of the trade winds) or toward the poles (as part of the easterlies)

(c) <u>Trade Winds</u>

(i) Winds that blow from the horse latitudes toward the Equator, they blow from the northeast in the Northern Hemisphere and from the southeast in the Southern Hemisphere

(ii) These winds blow almost constantly, they are called the trade winds because they gave ships a steady dependable ocean route to the New World

(d) <u>Prevailing Westerlies</u>

(i) A prevailing wind is the wind that blows most frequently across a particular region, different regions on Earth have different prevailing winds

(ii) At between 30-60 degrees latitude= prevailing winds blow almost constantly toward the poles

(iii) <u>Because of the Coriolis Effect these winds appear to curve to the east (this means they come from the west)= since winds are named for the direction they come from these winds are called Westerlies</u>

(iv) Responsible for much of the weather across the US and Canada

(e) <u>Polar Easterlies</u>

(i) <u>Winds that form when the air over the poles cools and sinks to the surface</u>

(ii) As the air flows away from the poles it is turned to the west by the Coriolis Effect, since these winds come from the east= called Easterlies

(f) <u>Polar Jet Stream</u>

(i) Formed by the deflection of upper air winds by the Coriolis Effect, it resembles a stream of water moving from west to east at an altitude of 13-19km

(ii) Wind velocity is highest in its core (about 130 km/hour in the winter and 65 km/hour in the summer (why you can fly from NF to NY-west to east in less time than you can fly from NY to SF- east to west)

(g) <u>Polar Front</u>

(i) Polar jet stream is associated with the polar front (a front is where two air masses of different temperatures or humidity meet)

(ii) The polar front is the zone where warm air from the subtropics meets cold air from the poles

(h) <u>Subtoprical Jet Stream</u>

(i) Located approximately 13km above the subtropical high pressure zone

(ii) Like the polar jet stream it flows from west to east and is characterized by relatively fast uniform winds concentrated within the upper atmosphere in a narrow band, it does not exist in the mid-latitudes

(3) There are winds that are either highly seasonal or highly local:

(a) Seasonal winds

(i) Some of the better known seasonal local winds are:

1. Monsoons: occurs because of the different ways land and water retain heat, in the summer winds flow from the water to the land causing heavy rains over the land
2. In the winter the winds flow from land to sea resulting in dry land conditions

(ii) Siroccos, Chinooks, Santa Anas

1. Sirocco: hot, dry, dust-laden wind that blow from the deserts of North Africa across the Mediterranean into southern Europe, occurs mainly in the spring, flow mostly over flat terrain, caused by a low pressure area
2. Santa Ana: hot, fast moving wind that blows down the side of the Santa Ana Mountains toward the Pacific Ocean in S. California, occurs between October and February, wind is very dangerous in the case of wildfire, caused by a high pressure area, down slope flow is one of the causes
3. Chinook: similar to a Santa Ana, blow down the east side of the Northern Rocky Mountains in the winter and spring, produces rapid temperature rise and thaw, important for agriculture, down slope flow is one of the causes

(4) http://etap.org/demo/Earth_Science/es5/instruction1tutor.html

b) Rotation of Earth to the Circular Motions of Ocean Currents and Air in Low and High Pressure Centers (see above)

i) Approximately 70% of the Earth's surface is ocean, the waters of the ocean are in constant motion, these moving waters= **Currents**

ii) These currents flow in complex patterns and are affected by many things, including wind, salinity (saltiness), the topography of the ocean floor, the rotation of the Earth, and heat (temperature)

iii) Scientists divide the ocean into three different temperature zones: **Surface Zone, Thermocline, Deep Ocean**

(1) **Surface Zone:**

(a) Begins at the ocean's surface and extends to a depth of about 400 meters, under ideal conditions sunlight can reach to the bottom of this zone but usually only gets down about 100 meters

(b) Water in this zone is well mixed by currents, winds, waves→ means that it is uniformly dense and salty, wave energy is concentrated on headlands and dispersed in bays by wave refraction (a process by which waves approach the shore change direction because of the slowing of those parts of the wave that enter shallow water first), these waves often end up roughly parallel to the coast

(c) Temperature throughout the Surface Zone varies, but world wide year round average= warm 71.6 degrees F

(2) **Thermoline:**

(a) Zone of separation between the Surface Zone and the Deep Zone, begins at 400 meters, extends down to 800 meters

(b) Temperatures drop rapidly from warm surface conditions to frigid deep water conditions, this is not a mixed layer but haloclines occur throughout

(i) Halocline= vertical zone in which salinity changes rapidly with depth

(3) **Deep Zone:**

(a) Makes up about 90% of the ocean, starts at about 800 meters and extends all the way down to the ocean floor, conditions are very harsh, no sunlight and temperatures hover just about the freezing point of water, enormous water pressure

iv) There are two kinds of ocean currents: Surface and Deep Water Currents, both are affect by primary forces like heat from the Sun, Winds, Gravity, and the Coriolis Effect

v) **Surface Currents:**

(1) The Sun's heat causes water to expand, since the Sun's heat is hottest at the Equator the water rises higher here than it does in other latitudes, causes a slight slope and water flows down the slope

(2) Winds blowing on the surface of the ocean also push the water, a wind blowing for 10 hours across the ocean will cause surface waters to flow at 2% of the speed of the wind, water will pile up in the direction the wind is flowing, gravity then pulls the water down the slope across the pressure gradient, this results in a force that is directed from high to low pressure→ it is what trigger the initial movement of air or water

(a) In other words= winds want to blow from high pressure areas to low pressure areas, but Coriolis Effect intervenes and causes the water to move in a circular motion around the mound of water→ large mounds called **Gyres**

(i) The North Atlantic Gyre is separated into four different currents: The North Equatorial Current, the Gulf Stream, the North Atlantic Current and the Canary Current

vi) **Gulf Stream:**

(1) Mostly a surface current- Western Boundary Current, it is the strongest, warmest, deepest, and fastest of all the Western Boundary Currents

(2) Begins in the Caribbean and ends in the North Atlantic, it transports a significant amount of warm water and salt toward the North Pole and eventually warms the European subcontinent

(3) It separates open-ocean water from coastal water and fluctuates with the seasons, carrying more water in the fall than in the spring

vii) **Other Major Currents:**

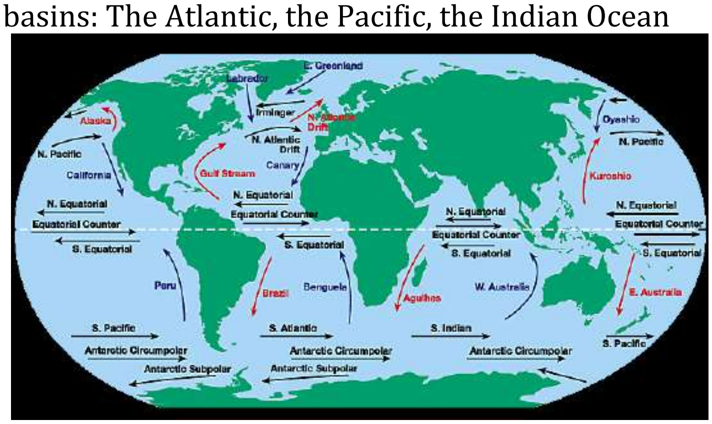
(1) Earth's rotation and its seasonal winds push surface water away from some western coasts so water rises on the western edges of the continents to replace it= upwelling

(2) Colder and/or saltier water tends to sink, so when seawater enters the Polar Regions it cools or freezes= makes it more salty and dense

(3) A global "conveyor belt" is formed and set in motion when this deep dense current is formed in the North Atlantic, sinks, moves in a southernly direction and circulates around Antarctica

(4) From Antarctica this current moves northward to the Indian, Pacific, and Atlantic basins

(5) Large ocean currents are held in check by continental masses bordering the three ocean basins: The Atlantic, the Pacific, the Indian Ocean



c) Causes and Structures of Various Cloud Types, Precipitation, Air masses, and Fronts

i) **Clouds** are classified according to their height above and the appearance from the ground

ii) Clouds form when air rises and condenses into water droplets or freezes into ice crystals, the elevation at which this takes place depends on the amount of moisture in the air and the stability of the air

(1) Cold clouds form at high altitudes containing only ice crystals, warm clouds form at a lower-altitude and contain only water droplets= Rain drops that fall from these types of clouds are warm, the rain they produce is called no-freeze rainfall

(a) A mixed cloud (both warm and cold) contain both

(2) Snowflakes form when ice crystals and water droplets cool to below freezing, water evaporates from the droplets and is deposited on the ice crystals→ these ice crystals collide and form snowflakes

(3) Fog and dew forms when condensation occurs at ground level

iii) Air can be forced to rise in three different ways:

(1) Through Convection: Hot air will rise leaving a vacuum that will pull in cooler air, When the air is heated as a result of contact with a warm surface, this forms small fair-weather cumulus or cumulonimbus clouds, may produce showers or short-lived storms

(2) Orographic Lifting: Moving over a mountain causes the air to rise, cool and condense into water droplets, this results in orographic cloud formation, orographic lifting produces frontal clouds of rain and drizzle

(3) Warm air rises when cold air mass pushes beneath it at a weather front, this action forms frontal clouds, if the clouds are thick enough then water droplets and ice crystals join together and falls as precipitation

iv) The height at which water vapor condenses in a rising air mass marks the cloud base, Classification of the different kinds of clouds based on heights:

(1) **Cirrus (curl)**

(2) **Stratus (layer)**

(3) **Nimbus (rain)**

(4) **Cumulus (heap)**

v) Each type of cloud is grouped as high, middle, or low level based on what height the cloud base most often occurs, clouds are grouped into 10 basic types:

(1) **High Level Clouds:**

(a) **Cirrus**- Forms worldwide and all year long, are thin and wispy, the air above the region where cirrus clouds forms is very dry, these high-level clouds consist entirely of ice crystals, once the ice crystals have grown large enough= drift down until a wind blows it in the direction it is moving in, stretching the cloud into long tails that curls (hence the name cirrus, which means curl), are produced from stable wind lifting up along a weather front, as the air rises= different types of clouds form along the way as more and more moisture condenses, cirrus is the last cloud to form

(b) **Cirrostratus-** Forms worldwide and all year long, are associated with warm fronts, consists entirely of ice crystals, these types of clouds will produce halos around the sun or moon, which is an indicator that rain is about to come

(c) **Cirrocumulus-** Forms worldwide and all year long, associated with cold fronts, consist entirely of ice crystals, has a fibrous appearance, like the other cirrus type clouds, Cirrocumulus actually began as a cirrus or cirrostratus that was reshaped by wind movement

(2) **Medium Level Clouds:**

(a) **Altocumulus-** Form worldwide and all year long, are associated with <u>cold fronts</u>, composed primarily of water droplets

(b) **Altostratus**- May form worldwide and is most common in the mid-latitudes form all year round, Altostratus clouds are associated with <u>warm fronts</u>, especially in temperate climates, contains ice crystals near the top of the cloud and water droplet further down= where warm moist air is being lifted above the cooler air, usually can find cirrostratus ahead of the altostratus cloud, these types of clouds results in rain or snow

(3) **Low Level Clouds:**

(a) **Nimbostratus-** Forms worldwide and all year except in Antarctica, these types of clouds may produce steady rain or snow, depending on the temperature= these clouds may consists of all water vapors or it may be a mixture of water at the bottom on the cloud and ice at the top, or it may consists primarily of ice, associated with <u>warm fronts</u>

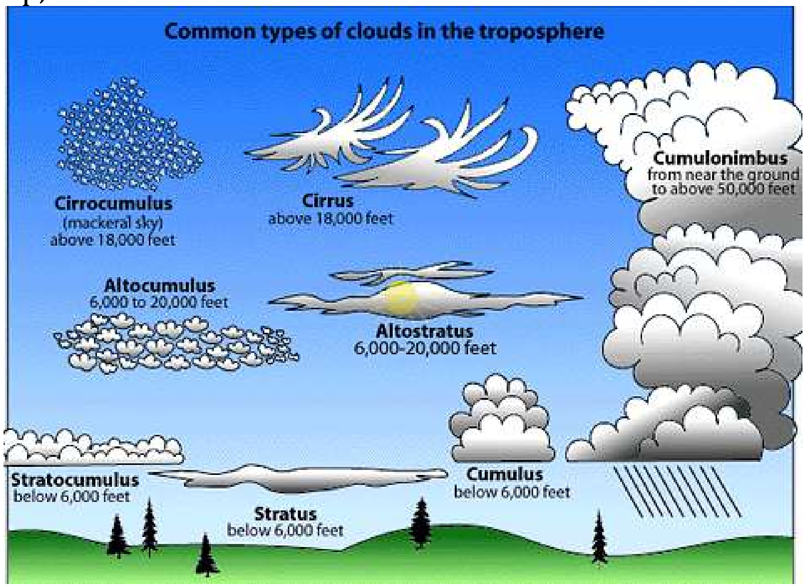
(b) **Cumulonimbus-** These clouds are found worldwide, expect in Antarctica, form all year and are <u>associated with tropical cyclones and thunderstorms</u>, have the greatest vertical height and may even extend beyond the tropopause, made up of liquid droplets in the lower region and ice crystals at the top, produce thunderstorms, hailstorms, tornadoes, heavy rain, and snow, formed through convection currents in unstable air→ As warm, moist air rises rapidly, it cools and its moisture condenses, releasing latent heat and warms the air, so it continues to rise, air is drawn into the cloud to form upcurrents, with speeds reaching up to 100 mph; Ice crystals and hailstones fall down through the cloud and produces downcurrents that exits the cloud as strong winds, this cools the air adjacent to the upcurrents which will eventually suppress the upcurrents; Convection begins to cease and the clouds begins to dissipate= Cumulonimbus clouds are very short-lived; as the clouds begin to dissipate= may release tons of moisture all at once in a very large storm cloud; Cumulonimbus clouds may also develop into a tornado, associated with <u>cold fronts</u>

(c) **Cumulus-** Are found worldwide but are common in humid regions, form all year round, but mostly in the summer, form by convection, they form in the columns of rising air called thermals= as air rushes upward a thermal draws in the surrounding air at the sides and at the base→ this action mixes the clouds with dry and cool air, cloud droplets evaporate in the drier air, and fragments of the cloud sink into the cool air→ this action prevents cumulus clouds from growing wider at the sides, also prevents other clouds from forming close to it, which is why cumulus clouds are found in patches in the sky, separate from each other

(d) **Stratus-** Found worldwide but is most common near mountains and coastal regions, form all year round, but mostly during the winter months; Forms a gray layer that covers most of the sky, made up of liquid droplets; When stratus forms at ground level, then it is called fog; there is no vertical air movement, so stratus clouds only produces drizzle or snow grains; form overnight in fine weather, particularly over water; generally dissipates in the morning when temperature rises and the cloud droplets evaporate

(i) Frontal stratus forms along <u>warm fronts</u>, as warm air slowly moves up by the cooler air; Cirrostratus and altostratus are formed first, then stratus clouds

(e) **Stratocumulus**- These clouds are found worldwide and are formed all year round, composed of liquid water vapors, form patches, sheets, or layers of white or grayish clouds, form when rising air meets up with warmer air and is pushed up, flattened on its underside



vi) **<u>Precipitation:</u>**

(1) <u>Rain</u>: Drops of liquid water fall from the clouds when water vapor condenses around dust particles in the clouds, forming tiny droplets that eventually get too big for the cloud to hold so they fall, growing larger as they collect more water on their way down

(2) <u>Snow</u>: Is ice that falls from the sky, each snowflake is a delicately complex arrangement of ice crystals, a snowflake forms when water vapor sublimates, or turns directly from a gas into its solid form, ice

(3) <u>Hail</u>: Is ice that falls from the sky, often in round shapes, hailstones form within thunderstorm clouds when upward moving air keeps pellets of frozen from falling, the pellets grow larger as drops of very cold water hit them and freeze, eventually the balls of ice become so large and heavy that they fall to the ground as hailstones

(4) <u>Sleet</u>: Like slush falling from the sky, sleet forms when raindrops freeze into ice as they fall to the ground, they are usually smaller and wetter than hailstones

vii) **<u>Air Masses</u>:**

(1) The volume of air that covers a large part of the continent or ocean and acquires characteristics from the surface below→ meaning <u>air over a continent will be drier than the air over the ocean, Air over a continent will also be warmer in the summer and cooler in the winter</u>, air mass extends from the surface of the Earth all the way up to the end of to the tropopause, the moisture content in an air mass is related to its temperature, the names of air masses are based on where they developed: <u>**Continental**= air mass that forms over land,</u> **Maritime**: <u>air mass that forms over the sea, there are air masses that form at certain latitudes: **Arctic, Polar, Tropical, or Equatorial**</u>

(2) Seven types of air masses:

(a) <u>Continental Arctic (cA)-</u> <u>These form in stable air, are extremely cold and dry</u>; provides record breaking cold temperatures because they form in the polar region where they receive 24 hours of darkness in the winter

(b) <u>Continental Polar (cP)-</u> <u>These produce cold and dry air in stable air</u>, they are not as cold as the cA air mass, they form further south and dominate the weather in the US during winter time, when cP moves southward from Canada into the US during summer time it passes over warmer land and the thermal contrast across the cold from decreases

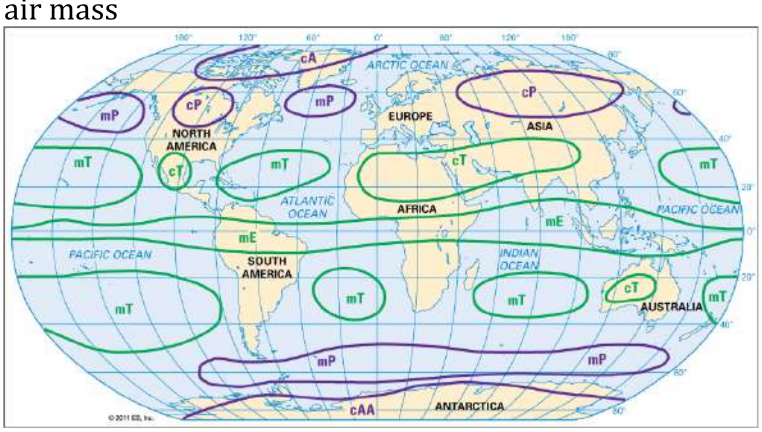
(c) Continental Tropical (cT)- Produces hot, dry air, brings record heat, forms over the desert southwest and north Mexico during summer, brings record heat to the plaints and the Mississippi Valley during the summer, moisture evaporates into the air making it more like mT air mass, rare in winter, has the highest surface temperature

(d) Maritime Arctic (mA)- Cold air mass that forms over the arctic, acquires moisture as it moves south over cold waters of North Atlantic and North Pacific Oceans, the difference between maritime arctic and maritime polar is that maritime polar moves further out into the ocean and becomes more warm and moist than mA air

(e) Maritime Polar (mP)- Not as cold as cP, produces cool moist air and brings cloudy drizzly damp weather, forms over North Atlantic and North Pacific, forms anytime in the year

(f) Maritime Tropical (mT)- Forms in unstable air, produces warm, moist air, most common along the weatern USA, originates over southern Atlantic and Gulf of Mexico, forms year round, responsible for humid days in the south and east, brings convectional rainfall to the southern US

(g) Maritime Equatorial (E)- There is no continental equatorial air mass because there is no land mass in the equatorial region that is large enough to produce an air mass



(h) **Continental Polar and Maritime Tropical=** most influence on the weather in US. The US is not a favorable source region because of the relatively frequent passage of weather disturbances that disrupts any opportunity for an air mass to take on the properties of the underlying region

(i) **Lake-Snow Effect:** Cold Canadian air, associated with cP, moving over the relatively warm Great Lakes is often responsible for the Lake-Snow effect. May result when cold, dry air moves across the relatively warm waters of the lake

(j) **Nor-easter:** Have strong winds out of the northeast, pulling in mP air along the Atlantic Coast

viii) **Front:**

(1) When two air masses meet up, they do not merge or mix due to the fact that they are at different temperatures, they have different densities→ Instead the denser air moves beneath the less dense air, causing it to lift away from the surface, the boundary between two air masses= called a front

(a) Warm Front: cold air being replaced by warm air

(b) Cold Front: warm air being replaced by cold air

(2) Fronts generally move from WEST to EAST in the US→ because of the Jet-stream

(3) **Cold Front:**

(a) Cause more severe and violent weather than warm fronts (water goes from being a gas to being a liquid= becomes rain, snow, etc.); when a cold front meets a warm front= water condenses and causes precipitation

(b) Cold fronts travel at a speed of around 22 mph

(c) With a cold front, the denser cool air forces the warm air to rise steeply upward along the line of the front→ As a result, strong convection currents develop, which leads to the development of storm clouds (cumulus-type clouds) and heavy rainfall

(d) Cold fronts are associated with a high-pressure system, called an anticyclone= Advances rapidly and brings violent weather

(e) Cold front's are steeper slope than warm fronts because cold air has a higher density, which allows it to hug the ground= this slows down the advancement of the lower portion of the front

(4) **Warm Front:**

(a) Warm fronts travel at a speed of around 15 mph→ Because of its slow speed it also covers a large area of land with its weather for a considerable length of time; Warm front weather lasts longer than a cold front weather because a warm front has a low angle slope and covers a greater area with its weather

(b) As warm front passes through a region, temperature gradually rise

(c) Warm air rises over cold air more gradually→ Moisture condenses as the warm air moves up and produces clouds (thick rain clouds at the lower elevation and thin, stratus-type clouds at higher elevation) and precipitation

(i) The type of clouds produced depends on how rapidly the warm air moved over the cold air mass

(d) Warm fronts are associated with a low-pressure system, called a cyclone

(e) The wind often comes from the south to southeast direction, Warm fronts often precede cold fronts as the low-pressure systems spin counterclockwise, When warm air mass gently rises over cold air mass= then it forms cirrus clouds first at high altitudes, followed by altostratus, and then stratus clouds; Cirrus clouds often signal this front is on the way; A series of high, middle, and low clouds form in advance of the surface position of a warm front

(5) **Occlusion:** Because cold fronts move faster than warm air fronts, it will eventually overtake the warm front and lift it off of the ground= event is known as an occlusion, Warm occlusion occurs when the cold front rises over the warm one. A cold occlusion occurs when the cold front undercuts the warm front. Complex weather patterns take place here

(6) **Stationary Front:** Indicated on a map with both semicircles and triangles on either side; When warm and cold fronts meet up, neither is strong enough to replace the other; clouds, prolonged precipitation, and storm trains can be found here; Stationary fronts will either dissipate or change into a cold or warm front; the Rocky Mountains help to lead the development of stationary fronts when shallow cold air mass from Canada cannot move over the mountains

ix) **Severe Weather:**

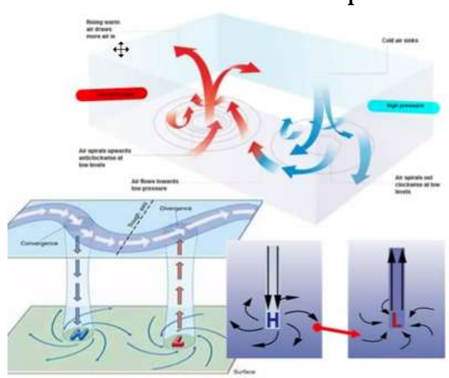
(1) **Tornadoes:** Erratic in their pathways, always characterized by high pressure; Forms primarily during spring-early summer time because there is a huge contrast in temperatures between cold, dry Canada and Warm, humid Gulf of Mexico; are associated with cumulonimbus clouds, occur in advance of a cold front of a mid-latitude cyclone, and move generally southwest to northwest

(2) **Hurricane:** Begin as tropical disturbances in warm ocean waters with surface temperatures of at least 80 degrees F, these low pressure system are fed by energy from the warm, moist ocean air and sea and release it through condensation of water vapor in thunderstorms, if a storm achieves wind speeds of 38 mph= becomes known as a tropical depression, if it reaches or sustains wind speeds of 39mph becomes a tropical storm, given a name, if it reaches or sustains 74mph becomes a hurricane

(3) **Thunderstorms**: A distinguishing feature of thunderstorms is their anvil top; violent convective storms accompanied by thunder and lightening; most common in the central and southern states as these regions are open to invasions of warm, moist subtropical air from the Gulf of Mexico; form most often in warm, moist unstable air when vertical currents develop over heated ground

(4) **Anticyclone:** Rotating area of low pressure where the flow is outward from the center, air flows clockwise around anticyclones in the Northern hemisphere and the opposite in the Southern Hemisphere

(5) **Cyclone:** Rotating area of low pressure where flow is inward toward the center, over the N. Hemi sphere air flows counterclockwise around cyclones, Moves cold air towards the equator and warm air poleward; the temperature contrast on either side of the polar front serves as a source of potential energy for developing cyclones; Cyclones derive energy from latent heat released by condensing water vapor; Innermost isobar encircles the zone of lowest pressure



(6) **Mid-latitude Cyclones:** Are the cause of most of the stormy weather in the US, especially in the winter. Low pressure, a warm sector of a mid-latitude cyclone experiences a southerly windflow, Develops along a feature called the polar front

d) Features of the ENSO Cycle (El Nino Southern Oscillation)

i) The ENSO cycle is a scientific term that describes the fluctuations in temperature between the ocean and atmosphere in the east-central Equatorial Pacific

ii) El Nino and La Nina are opposite phases of what is known as El Nino-Southern Oscillation cycle

(1) El Nino is characterized by unusually warm temperatures, La Nina by unusually cold temperatures

iii) These deviations from normal surface temperatures can have large-scale impacts not only on ocean processes, but also on global weather and climate

(1) Major impacts of El Nino are temperature anomalies, changes in precipitation variability, floods and droughts throughout the world

(2) Often sea surface temperatures are used to identify this oscillation but changes in sub-surface ocean temperatures are the first to oncoming change in the ENSO phase

iv) El Nino and La Nina typically last nine to 12 months but some prolonged events may last for years, they often begin to form between June and August, reach peak strength between December and April and then decay between May and July of the following year

(1) While their periodicity can be quite irregular= El Nino and La Nina events usually occur about every three to five years
(2) Typically El Nino occurs more frequently than La Nina

v) **El Nino**

(1) Means little boy, Originally recognized by fisherman off the coast of South America, with the appearance of unusually warm water in the Pacific Ocean
(2) In the US temperatures in the winter are warmer than normal in the North Central States and cooler than normal in the Southeast and Southwest
(3) The warming of the Pacific occurs as a result of the weakening of trade winds that normally blow westward from South America toward Asia
   (a) The prevalent surface winds across the equatorial Pacific ocean are easterly trade winds, these drag warm surface water away from the coast of Peru and cause colder deep ocean water to come to the surface; trade winds and equatorial upwelling maintain warm sea surface temperatures at the western equatorial Pacific and cold surface temperatures in the east
      (i) When trade winds weaken→ equatorial upwelling decreases and the ocean surface along the coast of South America becomes warmer and the trade winds weaken even more→ causes surface waters in the eastern Pacific to become even warmer and so on
(4) The warm phase of ENSO cycle refers to the large scale ocean atmosphere climate interaction linked to a periodic warming in sea surface temperatures across the central and east-central Equatorial Pacific along with:
   (a) Weaker low-level atmospheric winds along the equator
   (b) Enhanced convection across the entire equatorial pacific
   (c) Effects are strongest during Northern Hemisphere winter→ because the ocean temperatures worldwide are at their warmest, this increased ocean warmth enhances convection, which then alters the jet stream, such that it becomes more active over parts of the US during El Nino Winters→
      (i) Effects include warmer than average temperatures over western and central Canada, and over the western and northern US;
      (ii) Wetter than average conditions in tropical latitudes of North America, from Texas to Florida→ intensive wintertime storms
      (iii) Extreme rainfall and flooding in California, Oregon, Washington
      (iv) Milder winters and late autumns in northwestern Canada and Alaska due to pumping of abnormally warm air
      (v) Drier than normal North American monsoons, drier than normal autumns and winters in the US Pacific Northwest
         1. Drought occurs→ Drier than average conditions can be expected in southern US, the Ohio Valley and Pacific Northwest
      (vi) Shift of thunderstorm activity eastward from Indonesia to the south pacific→ leads to abnormally dry conditions and severe droughts in Australia, Philippines, Indonesia, Southeastern Africa, Brazil
      (vii) Much wetter conditions at the west coast of tropical S. America

vi) **La Nina**

(1) Sometimes but not always El Nino conditions give way to the other extreme of the ENSO cycle
(2) Global climate impacts tend to be the opposite of El Nino impacts
   (a) Patterns result from colder than normal ocean temperatures inhibiting the formation of rain-producing clouds over the eastern equatorial Pacific region

while at the same time enhancing rainfall over the western equatorial Pacific region (Indonesia, Malaysia, and northern Australia)

(b) Below normal precipitation in the Southwest, the central and southern sections of the Rockies and Great Plains and Florida

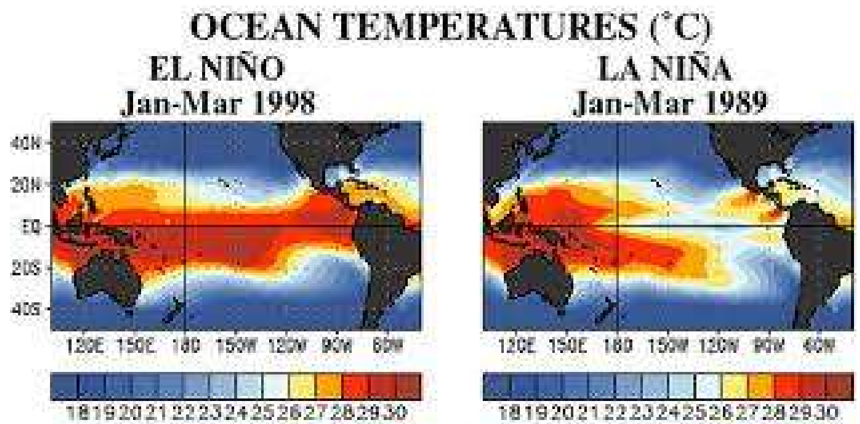
(c) The odds of surplus precipitation increase across the Pacific Northwest, northern intermountain West and over scattered sections of the north-central states, Ohio Valley and Upper Southwest

(d) Colder weather in the Northwest, northern California, the northern intermountain West, and the north-central States

(3) In the tropics ocean temperature variation in La Nina tend to be opposite

(a) Trade winds are unusually strong due to an enhanced pressure gradient between the eastern and western Pacific, as a result= upwelling is enhanced along the coast of South America, contributing to colder than normal surface waters over the eastern tropical Pacific and warmer than normal surface waters in the western tropical Pacific

(4) Winter temperatures are warmer than normal in the Southeast and cooler than normal in the Northwest



9) Climate Variations in Time and Space

a) Weather and Climate in Relation to the Transfer of Energy Into and Out of the Atmosphere

i) Weather= occurs over the short term and varies

ii) Climate= long-term average of weather and is fairly constant

iii) **Maritime Climate:**

(1) Coastal areas are known for mild temperatures, the ocean is very large and the water has a very high heat capacity, it can receive a lot of energy and the temperature will only change a little, water has a high specific heat

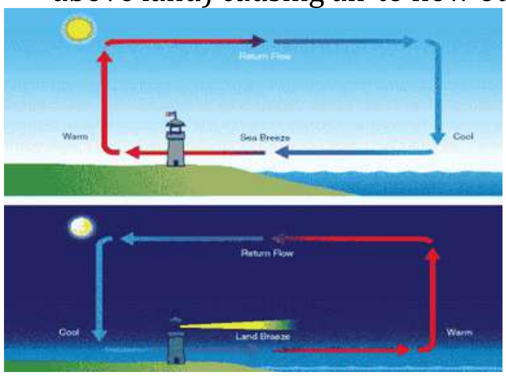
(a) This affects the direction of the wind flow in the day and night along the shore:

(i) During the day (oceans are a lot cooler than the land):

1. Water has a higher specific heat→ air above water is cooler, not releasing as much heat into the air as the land which doesn't have a high specific heat so it can't store as much heat from the Sun and releases more heat into the air= air above land is warmer
2. Since hot air rises, the air above the hot land begins to rise, creating a low pressure zone, there is a high pressure zone over the ocean, so the cooler air from over the ocean begins to take the empty space over the land= wind flows onshore

(ii) During the night:

1. Water is now warmer than land because land has a lower specific heat and begins to cool quickly once the sun goes down
2. Air above the land is cooler than the air above the ocean where lots of heat is still stored in the water, keeping air above the water a little warmer
3. Hot air rising over water (leaving low pressure)→ moves to higher pressure over land (wind is filling the space left by the hot air that rose above land) causing air to flow out= Wind Flows Offshore



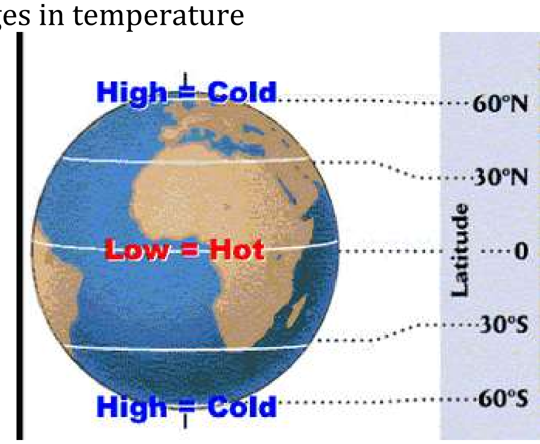
(2) Solar radiation penetrates the ocean, most is penetrated, some bounced back, the surface interaction with the atmosphere creates waves and energy that is distributed through the mixed zone

b) Factors that Affect Climate Change

i) <u>**Latitude**</u>

(1) Lower Latitude→ hotter climate

(2) Higher Latitude→ cooler climate, solar energy received decreases, have larger changes in temperature



(3) The amount of sunlight a surface receives cause the climate on Earth, each area receives more or less direct heating from the Sun

(4) <u>Low Latitudes: Tropical Climates</u>→ the regions near the equator receive direct sunlight each day of the year→ Tropical climates, resulting warmth causes water vapor to evaporate and form clouds, the clouds become heavy with moisture= rain falls nearly every day

(5) <u>Middle latitudes: Seasonal Climates</u>= the Sun's rays strike directly only during the summer months, this heats the region producing warm summer temperatures, during the winter months sunlight is less direct and less efficient at heating the surface; have four distinct seasons

(6) <u>High Latitudes: Polar Climates</u>= do not get direct sunlight at any time of the year

ii) <u>**Elevation**</u>

(1) The <u>higher the elevation the cooler the climate and more variability</u>

(2) With elevation gain= there is a <u>decrease in air pressure which causes the air to expand, when air expands it becomes cooler</u>

(3) <u>The higher you are the less density the air has, the air that is less dense will not hold heat very well thus the colder climates</u>

iii) **<u>Topography</u>**

(1) Topography also causes rain shadow (mountains make clouds dump precipitation on the side nearest water, while the other side is dry) and localized differential heating

(2) Topography causes valley and mountain breezes

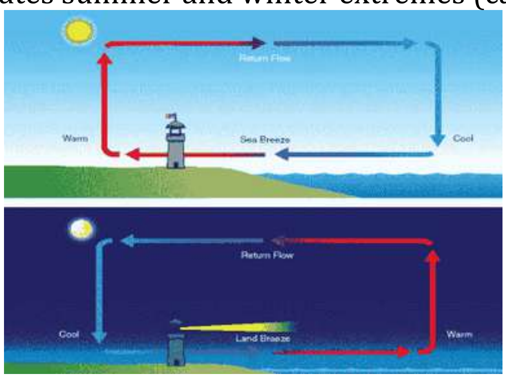
iv) **<u>Proximity to Large Bodies of Water</u>**

(1) The ocean has a large temperature inertia (resistance to change)= oceans or other large bodies of water heat and cool more slowly than land

(2) Because land heats and cools faster than water→ places near water have less variation in climate; the weather and climate are more mild/less extreme

(3) The ocean acts like an energy sponge, giving and taking energy from coastal regions

(4) The prevailing wind systems move air from the ocean onto the shore where it moderates summer and winter extremes (called maritime influence)



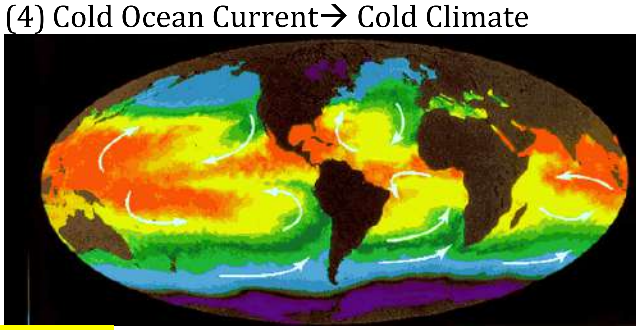
v) **<u>Proximity to Cold or Warm Ocean Currents</u>**

(1) Climate changes are strongly controlled by surface and deep ocean currents

(2) Oceans bring moisture and temperature to neighboring land

(3) Warm Ocean Currents→ Warm Climate

(4) Cold Ocean Current→ Cold Climate



10) <u>Rock Cycle</u>

a) Properties of Rocks Based on Physical and Chemical Conditions

i) Rock cycle→

(1) Rocks are constantly being formed, worn down, and formed again

(2) This cycle takes place over million of years

(3) Processes in the Rock Cycle

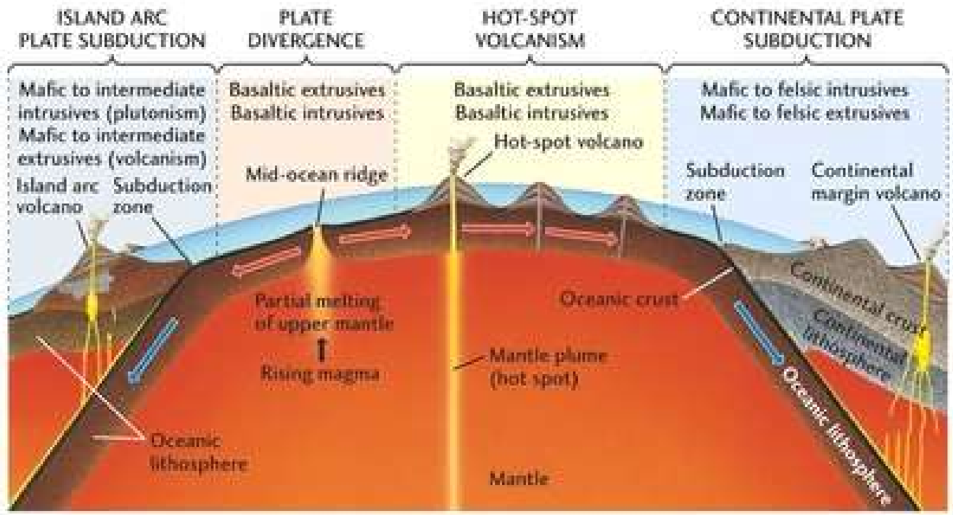
(a) **Weathering→** the breakdown of one mineral/rock into another

(b) **Erosion→** process by which soil and rock are removed from the Earth's surface by natural processes such as wind or water flow, and then transported

(c) **Transportation→** once the rock has been broken down into smaller bits it moves by means of streams and rivers (sometimes connect to the ocean)
(d) **Deposition→** Sand and sediments eventually settle down

ii) There are three types of primary rocks:
(1) Any of these rocks can be transformed into any of these types of rocks over a geologic time scale (long period of time)
(2) **Igneous Rocks**
(a) Begins as a hot fluid (the word "igneous" comes from the Latin word for fire
(b) Material could have been "lava-erupted" at the Earth's surface or magma (un-erupted lava) at shallows depths, or magma in deep bodies (plutons)
(c) Rock formed from lava= **Extrusive**, rock formed from shall magma= **Intrusive**, rock from deep magma= **Plutonic**
(d) Form in three main places: where lithospheric plates pull apart at mid-ocean ridges (Plate divergence, see diagram); where plates come together at subduction zones; where continental crust is pushed together, making it thicker and allowing it to heat and melt
(e) Distinguish between the three types of igneous rock by: texture, starting with the size of the mineral grains:
(i) Extrusive rocks cool quickly (over periods of seconds to months) and have invisible or very small grains; some extrusive rocks have distinctive textures
1. Obsidian= formed when lava hardens quickly, has a glassy texture
2. Pumice and scoria= volcanic froth, puffed up by millions of gas bubbles giving them a vesicular texture
3. Tuff= rock made entirely of volcanic ash, fallen from the air or avalanched down a volcano's sides, has a pyroclastic texture
4. Pillow lava= lumpy formation created by extruding lava underwater

(ii) Intrusive rocks cool more slowly (over thousands of years) and have small to medium sized grains
(iii) Plutonic rocks cool over millions of years, deep underground, and can have grains as large as pebbles (even a meter across)
(f) Because they solidified from a fluid state, igneous rocks tend to have an equigranular texture, a uniform fabric without layers, and the mineral grains are packed together tightly (piece of bread as a similar texture)
(g) Two best known igneous rock→ **basalt and granite** (differ in composition)
(i) Basalt (mafic and extrusive or intrusive)= dark, fine-grained stuff, made of many lava flows and magma intrusions, its dark minerals are rich in magnesium (Mg) and iron (Ferrum), hence basalt is called a mafic rock
(ii) Granite (felsic and plutonic)= light, coarse-grained rock formed at depth and exposed after deep erosion, it is rich in feldspar and quarts (silica), called a felsic rock
(h) The deep sea floor (the oceanic crust)→ made of basaltic rocks, with ultramafic rocks underneath, basalts are also erupted above the Earth's great subduction zones, either in volcanic island arcs or along the edges of continents, but continental magmas tend to be less basaltic and more granitic
(i) The continents are the exclusive home of granitic rocks, nearly everywhere on the continents, no matter what rocks are on the surface, you can drill down and reach granitoid eventually, granitic rocks are less dense than basaltic rocks, thus the continents actually float higher than the oceanic crust on top of the ultramafic rocks of the Earth's mantle



(3) **Sedimentary Rocks**

(a) In most places on the surface= igneous rocks which make up the majority of the crust are covered by a thin veneer of loose sediment, the rock which is made as layer of this debris gets compacted and cemented together

(i) Called secondary because they are often the result of the accumulation of small pieces of broken off pre-existing rocks

(b) Three main types of sedimentary rocks:

(i) **Clastic**

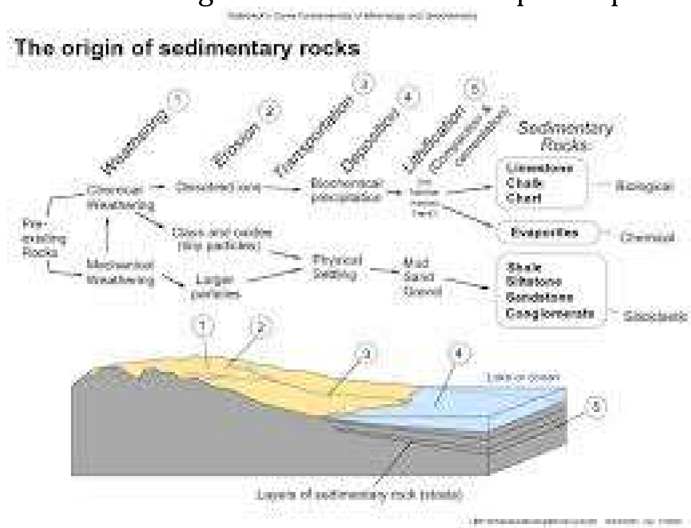
1. The most common set of sedimentary rocks consist of the granular materials that occur in sediment: **mud, sand, gravel, clay**
2. Sediment mostly consists of surface minerals: **quartz** and **clays**= made by the physical breakdown and chemical alteration of rocks, (Feldspar and other minerals may also be in sediment if they have not had time to break down), carried away by water or wind and laid down in a different place.
3. Sediment may also include pieces of stones and shells and other objects, not just grains of pure minerals
    a. Geologists use the word *clasts* to denote particles of all these kinds, and rocks made of clasts are called clastic rock
4. World's clastic sediment goes:
    a. Sand and mud= carried down rivers to the sea, mostly, sand is made of quartz, and mud is made of clay minerals. As these sediments are steadily buried over geologic time, they get packed together under pressure and low heat, not much more than 100°C. In these conditions the sediment is cemented into rock:
        i. Sand becomes **sandstone** and clay becomes **shale**. If gravel or pebbles are part of the sediment, the rock that forms is **conglomerate**

(ii) **Organic**

1. Forms in the sea as microscopic organisms (plankton) build shells out of dissolved calcium carbonate or silica. Dead plankton steadily shower their dust-sized shells onto the seafloor, where they accumulate in thick layers, to form an "organic" sedimentary rock
    a. That material turns to two more rock types, **limestone** (carbonate) and **chert** (silica)

i. Another type of sediment rock forms where limestone settle and combines with calcite and makes **chalk**
ii. Calcite is calcium carbonate and forms under reasonably deep marine conditions from the gradual accumulation of minute calcite plates

2. Sedimentary rocks become exposed when the land rises. This is common around the edges of the Earth's lithospheric plates



(iii) **Chemical**

1. Ancient shallow seas sometimes allowed large areas to become isolated and begin drying up→ As the seawater grows more concentrated, minerals begin to come out of solution (precipitate), starting with calcite, then gypsum, then halite= resulting rocks are certain limestones or dolomites, gypsum rock, and rock salt respectively→ these rocks are called **evaporites** (part of the sedimentary clan)

(4) **Metamorphic Rocks**

(a) Happen when sedimentary and igneous become changed, or metamorphosed, by conditions underground, all that is required is for the rock to be moved into an environment in which the minerals which make up the rock become unstable and out of equilibrium with the new environmental conditions, most cases this involves burial which leads to rise in temp and pressure, the metamorphic changes in the minerals always move in a direction designed to restore equilibrium
   (i) Common metamorphic rock= slate, schist, gneiss, marble
(b) Four main agents that metamorphose rocks= **heat, pressure, fluids, strain**
   (i) These agents act and interact in an infinite variety of ways, as a result most of the thousands of rare minerals known to science occur in metamorphic ("shape-changed") rocks
(c) **Heat** and **pressure** usually work together because both rise as you go deeper into the Earth
   (i) At high temperatures and pressures most rocks break down and change into a different assemblage of minerals that are stable in new conditions
      1. The clay minerals of sedimentary rocks are a good example: clays form as feldspar and mica break down in the conditions at the Earth's surface, with heat and pressure they slowly return to mica and feldspar, even with their

new mineral assemblages, metamorphic rocks may have the same overall chemistry they had before metamorphism

(d) **Fluids**= an important agent of metamorphism, every rock contains some water, but sedimentary rocks hold most:

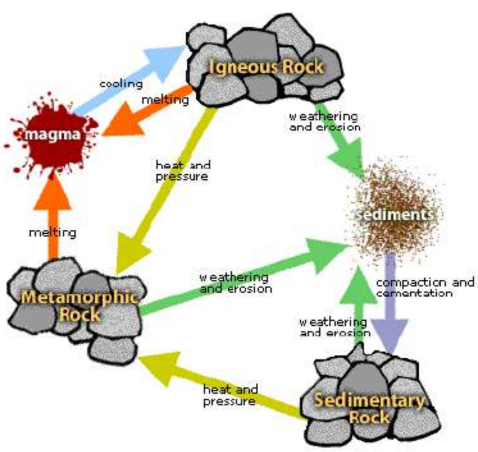
(i) There is the water that is trapped in the sediment as it became rock

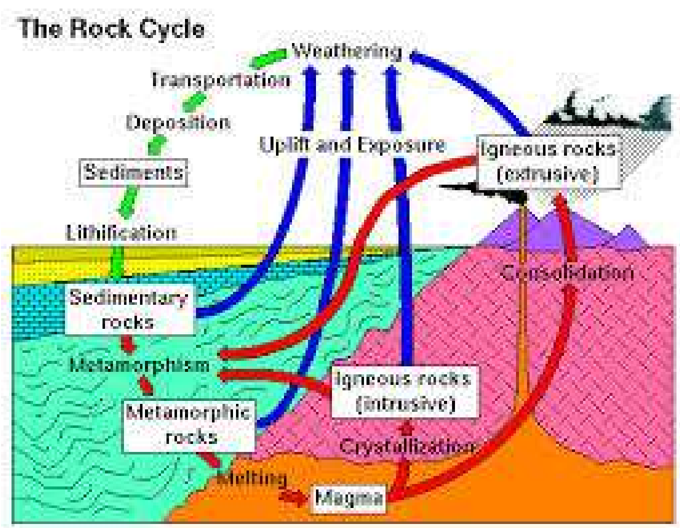
(ii) There is the water that is liberated by clay minerals as they change back to feldspar and mica→ this water can become so charged with dissolved materials that the resulting fluid is no less than a liquid mineral, it may be acidic or alkaline, full of silica, or full of sulfides or carbonates or metals in endless variety

(iii) Fluids tend to wander away from their birthplaces, interacting with rock elsewhere

(e) **Strain** refers to any change in the shape of rocks due to the force of stress, ex: movement on a fault zone

(i) Under greater heat and pressure, when metamorphic minerals such as mica and feldspar begin to form, strain orients them in layers. The presence of mineral layers, called **foliation**, is important to observe when identifying a metamorphic rock. As strain increases, the foliation becomes more intense, and the minerals sort themselves into thicker layers. The foliated rock types that form under these conditions are called schist or gneiss depending on their texture. Schist is finely foliated whereas gneiss is organized in wide bands of minerals





b) Identify Common Rock Forming Minerals Using a Table of Diagnostic Properties

Properties of Common Minerals

LUSTER	HARD-NESS	CLEAVAGE	FRACTURE	COMMON COLORS	DISTINGUISHING CHARACTERISTICS	USE(S)	MINERAL NAME	COMPOSITION*
Metallic Luster	1–2	✔		silver to gray	black streak, greasy feel	pencil lead, lubricants	**Graphite**	C
Metallic Luster	2.5	✔		metallic silver	very dense (7.6 g/cm^3), gray-black streak	ore of lead	**Galena**	PbS
Metallic Luster	5.5–6.5		✔	black to silver	attracted by magnet, black streak	ore of iron	**Magnetite**	Fe_3O_4
Metallic Luster	6.5		✔	brassy yellow	green-black streak, cubic crystals	ore of sulfur	**Pyrite**	FeS_2
Either	1–6.5		✔	metallic silver or earthy red	red-brown streak	ore of iron	**Hematite**	Fe_2O_3
Nonmetallic Luster	1	✔		white to green	greasy feel	talcum powder, soapstone	**Talc**	$Mg_3Si_4O_{10}(OH)_2$
Nonmetallic Luster	2		✔	yellow to amber	easily melted, may smell	vulcanize rubber, sulfuric acid	**Sulfur**	S
Nonmetallic Luster	2	✔		white to pink or gray	easily scratched by fingernail	plaster of paris and drywall	**Gypsum** (Selenite)	$CaSO_4 \cdot 2H_2O$
Nonmetallic Luster	2–2.5	✔		colorless to yellow	flexible in thin sheets	electrical insulator	**Muscovite Mica**	$KAl_3Si_3O_{10}(OH)_2$
Nonmetallic Luster	2.5	✔		colorless to white	cubic cleavage, salty taste	food additive, melts ice	**Halite**	NaCl
Nonmetallic Luster	2.5–3	✔		black to dark brown	flexible in thin sheets	electrical insulator	**Biotite Mica**	$K(Mg,Fe)_3AlSi_3O_{10}(OH)_2$
Nonmetallic Luster	3	✔		colorless or variable	bubbles with acid	cement, polarizing prisms	**Calcite**	$CaCO_3$
Nonmetallic Luster	3.5	✔		colorless or variable	bubbles with acid when powdered	source of magnesium	**Dolomite**	$CaMg(CO_3)_2$
Nonmetallic Luster	4	✔		colorless or variable	cleaves in 4 directions	hydrofluoric acid	**Fluorite**	CaF_2
Nonmetallic Luster	5–6	✔		black to dark green	cleaves in 2 directions at 90°	mineral collections	**Pyroxene** (commonly Augite)	$(Ca,Na)(Mg,Fe,Al)(Si,Al)_2O_6$
Nonmetallic Luster	5.5	✔		black to dark green	cleaves at 56° and 124°	mineral collections	**Amphiboles** (commonly Hornblende)	$CaNa(Mg,Fe)_4(Al,Fe,Ti)_3Si_6O_{22}(O,OH)_2$
Nonmetallic Luster	6	✔		white to pink	cleaves in 2 directions at 90°	ceramics and glass	**Potassium Feldspar** (Orthoclase)	$KAlSi_3O_8$
Nonmetallic Luster	6	✔		white to gray	cleaves in 2 directions, striations visible	ceramics and glass	**Plagioclase Feldspar** (Na-Ca Feldspar)	$(Na,Ca)AlSi_3O_8$
Nonmetallic Luster	6.5		✔	green to gray or brown	commonly light green and granular	furnace bricks and jewelry	**Olivine**	$(Fe,Mg)_2SiO_4$
Nonmetallic Luster	7		✔	colorless or variable	glassy luster, may form hexagonal crystals	glass, jewelry, and electronics	**Quartz**	SiO_2
Nonmetallic Luster	7		✔	dark red to green	glassy luster, often seen as red grains in NYS metamorphic rocks	jewelry and abrasives	**Garnet** (commonly Almandine)	$Fe_3Al_2Si_3O_{12}$

*Chemical Symbols: Al = aluminum, C = carbon, Ca = calcium, Cl = chlorine, F = fluorine, Fe = iron, H = hydrogen, K = potassium, Mg = magnesium, Na = sodium, O = oxygen, Pb = lead, S = sulfur, Si = silicon, Ti = titanium

✔ = dominant form of breakage

i) Physical properties of minerals are used by Mineralogists to help determine the identity of a specimen, some of the tests can be easily performed while other require lab equipment, the following list of tests is in a suggested order, progressing from simple experimentation and observation to more complicated either in procedure or concept

ii) **Properties of Minerals: (*= most useful properties for identification)**

(1) **Color**

(a) Most minerals have a distinctive color that can be used for identification; in opaque minerals→ color tends to be more consistent; translucent to transparent minerals have a much more varied degree of color due to the presence of trace minerals, thus color alone is not reliable as a single identifying characteristic

(2) **<u>*Streak</u>**

(a) The color of the mineral in powered form, streak shows the true color of the mineral, in large solid form trace minerals can change the color appearance of a mineral by reflecting the light in a certain way, trace minerals have little influence on the reflection of the small powdery particles of the streak

(i) The streak of metallic minerals tends to appear dark because the small particles of the streak absorb the light hitting them

(ii) Non-metallic particles tend to reflect most of the light so they appear light in color and almost white

(b) Because streak is more accurate illustration of the mineral's color streak is more reliable property of minerals than color of identification

(3) **<u>*Hardness</u>**

(a) Hardness is one of the better properties of minerals to use for identifying a mineral→ measure of the mineral's resistance to scratching

(b) <u>The Mohs scale is a set of 10 minerals whose hardness is known</u>

(i) The softest mineral, talc, has a Mohs scale rating of one, diamond is the hardest mineral and has a rating of ten

(ii) Softer minerals can be scratched by harder minerals because the forces that hold the crystals together are weaker and can be broken by the harder mineral

(c) The following is a listing of the minerals of the Mohs scale and their rating:

(i) 1. Talc, 2. Gypsum, 3. Calcite, 4. Fluorite, 5. Apatite, 6. Orthoclause Feldspar

(ii) 7. Quartz, 8. Topaz, 9. Corundum, 10. Diamond

(4) **<u>*Cleavage And Fracture</u>**

(a) Minerals tend to break along lines or smooth surfaces when hit sharply, different minerals break in different ways showing different types of cleavage

(b) Cleavage is defined using two sets of criteria→ the first set= describes <u>how easily the cleavage is obtained</u>

(i) Cleavage is considered perfect if it is easily obtained and the cleavage planes are easily distinguished

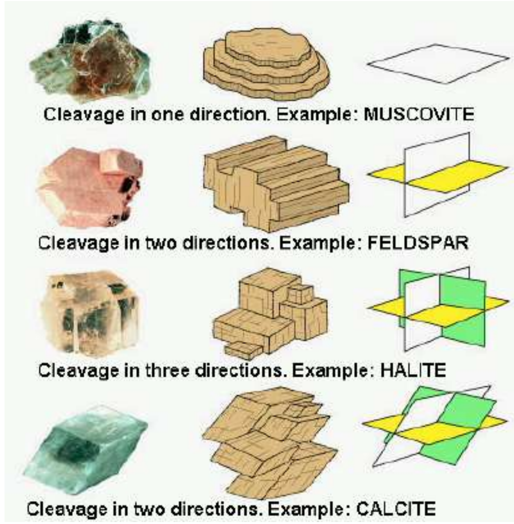
(ii) It is considered good if the cleavage is produced with some difficulty but has obvious cleavage plants

(iii) It is considered imperfect if cleavage is obtained with difficulty and some of the planes are difficult to distinguish

(c) The second set of criteria is <u>direction of the cleavage surfaces</u>

(i) The names correspond to the shape formed by the cleavage surfaces:

1. Cubic (cleaves in three directions, ex: Halite),
2. Rhombohedral (cleaves in three directions but not 90 degrees to one another, Ex: Calcite)
3. Octahedral (cleaves in four directions, Ex: Fluorite)
4. Dodecahedral (cleaves in six directions, Ex: Sphalerite)
5. Basal (cleaves in one direction, Ex: Muscovite, Gypsum, Biotite)
6. Prismatic (cleaves in two directions, ex: Feldspar)
7. These criteria are defined specifically by the angles of the cleavage lines:



(d) Fracture→ describes the quality of the cleavage surface, most minerals display either uneven or grainy fracture, conchoidal (curved, shell-like lines) fracture, or hackly (rough, jagged) fracture

(5) ***Crystalline structure**
  (a) Mineral crystals occur in various shapes and sizes, the particular shape is determined by the arrangement of the atoms, molecules, or ions that make up the crystal and how they are joined= called the Crystal Lattice
  (b) There are degrees of crystalline structure, in which fibers of the crystal become increasingly difficult or impossible to see with the naked eye or the use of hand lens
  (c) If there is no crystalline structure= called amorphous (very few of these)
  (d) Look for obvious shapes such as: cubes, sheets (called micaceous or floliated), elongated prisms with 3, 4, or 6 sides, prismatic crystals with pyramids on the end, blocks, blades (knife-life), homogenous masses (no obvious flat surface) called massive

(6) **Diaphaneity or amount of transparency**
  (a) A mineral's degree of transparency or ability to allow light to pass through it, the degree of transparency may also depend on the thickness of the mineral

(7) **Tenacity**
  (a) The characteristics that describes how the particles of a mineral hold together or resists separation

(8) **Magnetism**
  (a) The characteristic that allows a mineral to attract or repel other magnetic materials, it can be difficult to determine the differences between the various types of magnetism but it is worth knowing that there are distinctions made

(9) ***Luster**
  (a) The property of minerals that indicates how much the surface of a mineral reflects light, the luster of a mineral is affected by the brilliance of the light used to observe the mineral surface, described in the following terms:
    (i) Metallic: The mineral is opaque and reflects light as a metal would
    (ii) Sub-metallic: The mineral is opaque and dull, the mineral is dark colored
    (iii) Non-metallic: The mineral does not reflect light like a metal; are described using modifiers that refer to commonly known qualities
      1. Waxy- mineral looks like paraffin wax
      2. Vitreous- mineral looks like broken glass

3. Pearly- mineral appears iridescent, like a pearl
4. Silky- mineral looks fibrous, like silk
5. Greasy- mineral looks like oil on water
6. Resinous- mineral looks like hardened tree sap
7. Adamantine- mineral looks brilliant, like a diamond

(10) **Odor**

(a) Most minerals have no odor unless they are acted upon in one of the following ways: Moistened, Heated, Breathed upon, or rubbed

(11) **Taste**

(a) Only soluble minerals have taste (don't place in mouth or tongue)

(12) **Specific Gravity**

(a) A comparison or ratio of the weight of the mineral to the weight of an equal amount of water, the weight of the equal amount of water is found by finding the difference between the weight of the mineral in air and the weight of the mineral in water

c) Identify Common Ore Minerals as Sources of Copper, Iron, Lead, Zinc, Cement, Halite, Gypsum, Uranium

i) Certain kinds of minerals can be treated for metal extraction more easily than others= Ore Minerals (can be extracted through mining, these are then refined to extract valuable elements

ii) Often different minerals containing a particular metal occur together in a deposit and are referred to as ore forming minerals, ore minerals form as a result of special geologic processes and often occur in isolated, small, localized rock masses→ called mineral deposits= are what prospectors seek

11) Water, Carbon, and Nitrogen Cycles

a) The Water Cycle

i) **Hydrosphere**

(1) Also called the hydrologic cycle

(2) All the water on Earth is part of this, ex: oceans, rivers that flow into the oceans, water suspended in the atmosphere, water in the ground, etc

ii) The **Sun** is a very important aspect of the water cycle as it provides heat for evaporation to occur, its absence or minimized effect results in condensation

iii) **Evaporation**:

(1) Heat is necessary for this to occur

(2) Process by which water changes from a liquid to a gas or vapor

(3) Primary pathway that water moves from the liquid state back into the water cycle as atmospheric water vapor

(4) **Evapotranspiration**→ combination of evaporation from land and transpiration from plant life

(a) When water gets absorbed from the ground into the roots of plants, transported up through a plant's stem into the leaves, it is from the pores in the leave that water gets released into the atmosphere

(5) **Condensation**:

(a) The process by which water vapor in the air is changed into liquid water

(b) Important to the water cycle because it is responsible for the formation of clouds, these clouds may produce precipitation, which is primary route for water to return to Earth's surface

(c) The opposite of evaporation→ generally occurs in the atmosphere when warm air rises, cools, and looses its capacity to hold water vapor, As a result= excess water vapor condenses to form cloud droplets

(d) Responsible for ground-level fog for your glasses fogging up when you go from a cold room to the outdoors on a hot humid day, etc

(e) The upward motions that generate clouds can be produced by convection in unstable air, convergence associated with cyclones, lifting by air fronts and lifting over elevated topography such as mountains

(6) **Water is stored in the ocean**

(a) The water then heats up and turns from liquid to a gas→ gaseous particles rise up, float into the atmosphere → over time particles start to pull together and become larger and larger particles (liquid particles) and become too heavy to stay suspended in the air→ fall back to the earth (precipitation)

(7) **Precipitation**

(a) Can take the form of snow, rain, sleet, hail, etc

(b) Primary mechanism for transporting water from the atmosphere to the surface of the Earth

(i) Some places receive more precipitation than others do, these areas are usually close to oceans or large bodies of water that allow more water to evaporate and form clouds

(ii) The areas that receive less precipitation are usually far from water or near mountains→ as clouds move up and over mountains the water vapor condenses to form precipitation and freezes, snow falls on the peaks

(c) Precipitation creates runoff that travels over the ground surface and helps fill lakes and rivers, it also percolates or moves downward through openings in the soil to replenish aquifers under the ground

(d) Particles are too heavy to remain suspended and fall back to Earth, when they hit Earth's surface=

(i) Earth is porous enough to absorb the water→ becomes ground water

(ii) Earth isn't porous enough, already saturated with water, water does not get absorbed and it runs off= surface runoff→ occurs if the ground cannot absorb the water, will most likely act as an agent for transporting sediment

b) Photosynthesis and Respiration (Reservoirs of Carbon and Oxygen)

i) **Complementary reactions of respiration and photosynthesis**

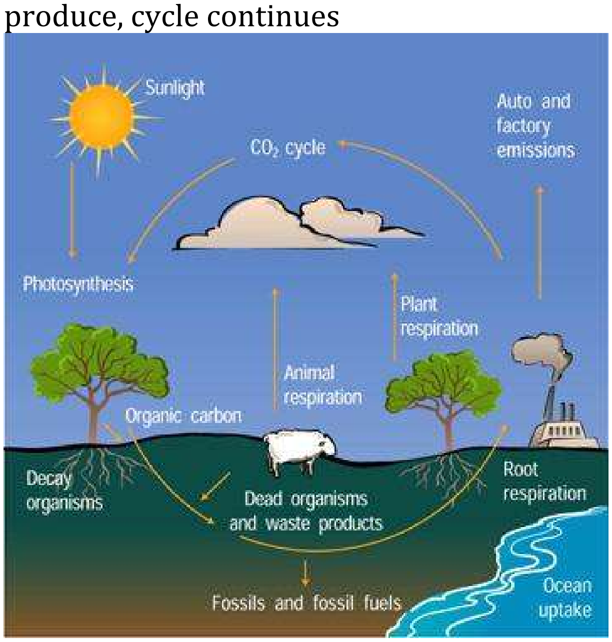
(1) Respiration takes sugar and oxygen and combines them to produce CO2, water and energy
(2) Photosynthesis takes CO2 and water and produces sugars and oxygen
(3) The outputs of respiration are the inputs of photosynthesis, the outputs of photosynthesis are the inputs of respiration
(a) The reactions are also complementary in the way they deal with energy= photosynthesis takes energy from the sun and stores it in the carbon-carbon bonds of carbohydrates and respiration releases that energy

ii) Both plants and animals carry on respiration but only plants (and other producers) can carry on photosynthesis

iii) Plants and animals are reservoirs that store Carbon as carbohydrates, fats, DNA, and other molecules
(1) Carbon and oxygen moves between reservoirs via processes such as photosynthesis and respiration

iv) **Photosynthesis**:
(1) CO2 + water + sunlight→ organic material (sugar) + O2
(2) Carried out by the primary produces and uses CO2, water, and sunlight to create organic carbon and nitrogen based compounds using phosphate groups as energy
(a) In this way CO2 is **removed** from the atmosphere and stored in the structure of plants
(3) Plants take in CO2 and build carbohydrates→ release O2 as a waste product
(4) Carbohydrates are passed along food webs to animals and other consumers

v) **Respiration**:
(1) Reverse of photosynthesis: organic material + O2→ CO2 + water + energy
(2) Carried out by both producers and consumer→ O2 is consumed and CO2 is expelled
(3) Plants release O2 as a waste product when they convert carbohydrates to chemical energy
(4) Animals eat carbon contained in animal and plant tissues and release CO2 as a waste produce, cycle continues



c) Carbon Reservoirs/ Movement of Carbon Among Reservoirs

i) The movement of carbon as it is recycled and reused throughout the biosphere→ Biogeochemical cycle by which carbon is exchanged among the biosphere, pedosphere, geosphere, hydrosphere, and atmosphere of Earth

ii) The global carbon budget is the balance of the exchanges (incomes and losses) of carbon between the carbon reservoirs or between once specific loop (ex: atmosphere→ biosphere) of the carbon cycle

iii) The carbon exchanges between the following reservoirs occur as the result of various chemical, physical, and biological processes; the ocean contains the largest active pool of carbon near the surface of the Earth; the carbon flowing between all these reservoirs would be fairly stable without human influence

(1) **Carbon moves from the atmosphere to plants**

(a) Carbon in the Earth's atmosphere exists in two main forms: CO_2 and methane

(b) Both of these gases retain heat in the atmosphere and are partially responsible for the greenhouse effect

(c) CO_2 leaves the atmosphere through photosynthesis thus entering the terrestrial and oceanic biospheres; also dissolves directly from the atmosphere into bodies of water (oceans, lakes, etc), also dissolving in precipitation as raindrops fall through the atmosphere

(2) **Carbon moves from plants to animals**

(a) Through food chains the carbon that is in plants moves to the animals that eat them, animals that eat other animals get the carbon from their food too

(b) Autotrophs extract carbon from the air in the form of CO_2 converting it into organic carbon while heterotrophs receive carbon by consuming other organisms

(3) **Carbon moves from plants and animals to the ground**

(a) When plants and animals die their bodies, wood, and leaves decay bringing carbon into the ground

(b) Some become buried miles underground and will become fossil fuels in millions and millions of years

(4) **Carbon moves from living things to the atmosphere**

(a) Each time you exhale you are releasing CO_2 into the atmosphere, animals and plants get rid of carbon dioxide gas through respiration

(5) **Carbon moves from fossil fuels to the atmosphere when fuels are burned**

(a) When humans burn fossil fuels to power factories, power plants, cars, and trucks→ most of the carbon quickly enters the atmosphere as carbon dioxide gas

(b) Of the huge amount of carbon that is released from fuels, 3.3 billion tons enters the atmosphere and most of the rest becomes dissolved in seawater

(6) **Carbon moves from the atmosphere to the oceans**

(a) The oceans and other bodies of water soak up some carbon from the atmosphere

iv) **Major reservoirs:**

(1) **Atmosphere** (see above)

(2) **Terrestrial biosphere**

(a) Includes the organic carbon in all land-living organisms (plants and other organisms), both alive and dead, as well as carbon stored in soils

(b) Carbon leaves this reservoir in several ways on different time scales:

(i) The combustion or respiration of organic carbon releases it rapidly into the atmosphere

(ii) It can be exported into the oceans through rivers or remain sequestered in soils in the form of inert carbon→ soil respiration

(3) **Oceans (including dissolved inorganic carbon and living and non-living marine biota)**

(a) Oceans contain the greatest quantity of actively cycled carbon in the world and are second only to the lithosphere in the amount of carbon they store

(b) Oceans surface layer holds large amount of dissolved organic carbon that's exchanged rapidly with the atmosphere
   (i) Carbon enters ocean mainly through the dissolution of atmospheric carbon dioxide
(c) Carbon can enter the oceans through rivers as dissolved organic carbon
(d) Carbon is converted by organisms into organic carbon through photosynthesis and can either be exchanged throughout the food chain or precipitated into the oceans deeper, more carbon rich layers as dead soft tissue or in shells as calcium carbonate
   (i) Circulates in this layer for long periods of time before either being deposited as sediment, or eventually returned to the surface waters
(e) Deep layer's concentration of dissolved inorganic carbon is about 15% higher than that of the surface layer→ stored in the deep layer for long periods
(f) One of the most important forms of carbon sequestering limiting the human-caused rise of CO2 in the atmosphere

(4) **Geological Carbon Cycle**
   (a) **Sediments (including fossil fuels, fresh water systems, non-living organic material)**
   (b) **The Earth's interior, carbon from the Earth's mantle and crust**
      (i) Geological component of the carbon cycle operates slowly in comparison to other parts of the global carbon cycle→ one of the most important determinants of the amount of carbon in the atmosphere (thus global temperatures)
      (ii) Most of the Earth's carbon is stored inertly in the lithosphere, much of the carbon stored in the Earth's mantle was stored there when the Earth formed
      (iii) Can leave in several ways:
         1. CO2 is released during the metamorphosis of carbonate rocks when they are subducted into the Earth's mantle→ this CO2 can be released into the atmosphere and oceans through volcanoes and hotspots
         2. Can also be removed by humans through the direct extraction of fossil fuels→ after extraction fossil fuels are burned to release energy thus emitting carbon they store into the atmosphere

d) Nitrogen Cycle

i) Nitrogen is an element, its found in living things like the air above and the dirt below, atoms of nitrogen move slowly between living things, dead, things, the air, soil and water→ these movements make up the Nitrogen Cycle
ii) Nitrogen is necessary for all known forms of life on Earth, component of all amino acids, proteins, and is present in the bases that make up nucleic acids (DNA, RNA); also present in plants and the atmosphere
iii) Process by which nitrogen is converted between its various chemical forms, this transformation can be carried out through both biological and physical processes
   (1) Important processes in the nitrogen cycle include→ fixation, ammonification, nitrification, and denitrification
   (2) The majority of earth's atmosphere is nitrogen= 78%
      (a) Atmospheric nitrogen has limited availability for biological use
iv) Nitrogen availability can affect the rate of key ecosystem processes (including primary production and decomposition)

(1) Human activities such as fossil fuel combustion, use of artificial nitrogen fertilizers, and release of nitrogen in wastewater have dramatically altered the global nitrogen cycle

v) **The Process of the Nitrogen Cycle:**

(1) Present in the environment in a wide variety of chemical forms:

(a) Organic nitrogen (may be in the form of a living organism, humus, or the intermediate products of organic matter decomposition), Ammonium, Nitrite, Nitrate, Nitrous Oxide, Nitric Oxide, or inorganic nitrogen gas

(2) The processes of the nitrogen cycle transform nitrogen from on form to another; many of those processes are carried out by microbes→ in their effort to either harvest energy or to accumulate nitrogen in a form needed for growth

(3) **Nitrogen Fixation (cycle in the soil):**

(a) Some fixation occurs in lightning strikes, but most fixation is done by free-living bacteria

(i) Lightening provides enough energy to "burn" the nitrogen and fix it in the form of nitrate, which is nitrogen with three oxygens attached, this process is replicated in fertilizer factories to produce nitrogen fertilizers

(b) Atmospheric nitrogen must be processed, or "fixed," to be used by plants

(i) Nitrogen fixing bacteria use special enzymes instead of the massive amount of energy found in the lightening to fix nitrogen

(ii) All of these fix nitrogen, either in the form of nitrate or in the form of ammonia

1. These nitrogen fixing bacteria come in three forms: Some are free-living in the soil; Some form symbiotic, mutualistic with the roots of bean plants and other legumes; Some are photosynthetic cyanobacteria (blue-green algae) which are most commonly found in water

(4) Most plants can take up nitrate and convert it to amino acids, animals acquire all of their amino acids when they eat plants (or other animals)

(5) When plants or animals die (or release waste) the nitrogen is returned to the soil, the usual form of nitrogen returned to the soil in animal wastes or in the output of the decomposers is ammonia

(a) Ammonia is toxic but fortunately there are nitrite bacteria in the soil and in the water which take up ammonia and convert it to nitrite (nitrogen with two oxygen)

(i) Nitrite is also somewhat toxic but another type of bacteria, nitrate bacteria, will take nitrite and convert it to nitrate which can be taken up by plants to continue the cycle

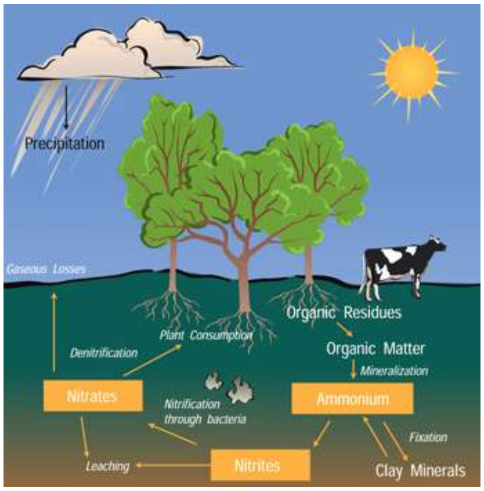
(6) In order for the nitrogen to return to the air= denitrifying bacteria→ take the nitrate and combine the nitrogen back into nitrogen gas

vi) **Pollution:**

(1) When too much nitrogen (through activities such as the addition of artificial fertilizers) and phosphorus enter the environment (usually form a wide range of human activities) the air and water can become polluted

(a) Results in serious environmental and human health issues→ harm water quality, food resources, habitats, decrease the oxygen that fish and other aquatic life need to survive; harmful to humans because they produce elevated toxins and bacterial growth that can make people sick if they come into contact with polluted water, consume tainted fish or shellfish, or drink the water

(b) Causes algae to grow faster than ecosystems can handle= called algal blooms and can severely reduce or eliminate oxygen in the water, leading to illness in fish and death of large numbers of fish



<u>California Geology: understanding symbols on topographic maps (http://www.map-reading.com/ch10-6.php http://www.princeton.edu/~oa/manual/mapcompass.shtml)</u>

12) <u>Tectonic Evolution</u>

a) Geologic Maps/ Understanding Tectonic Evolution of California in Terms of Plate Margins

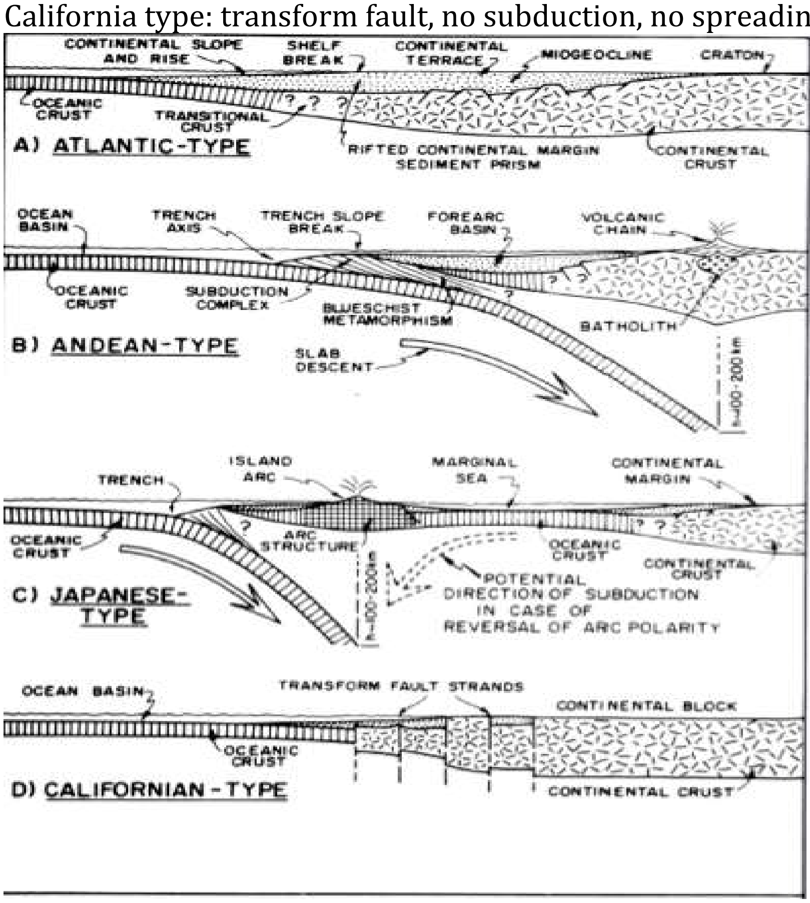
i) There are four recognized types of ocean-continent margin= California has been all four, at various times in the past billion years

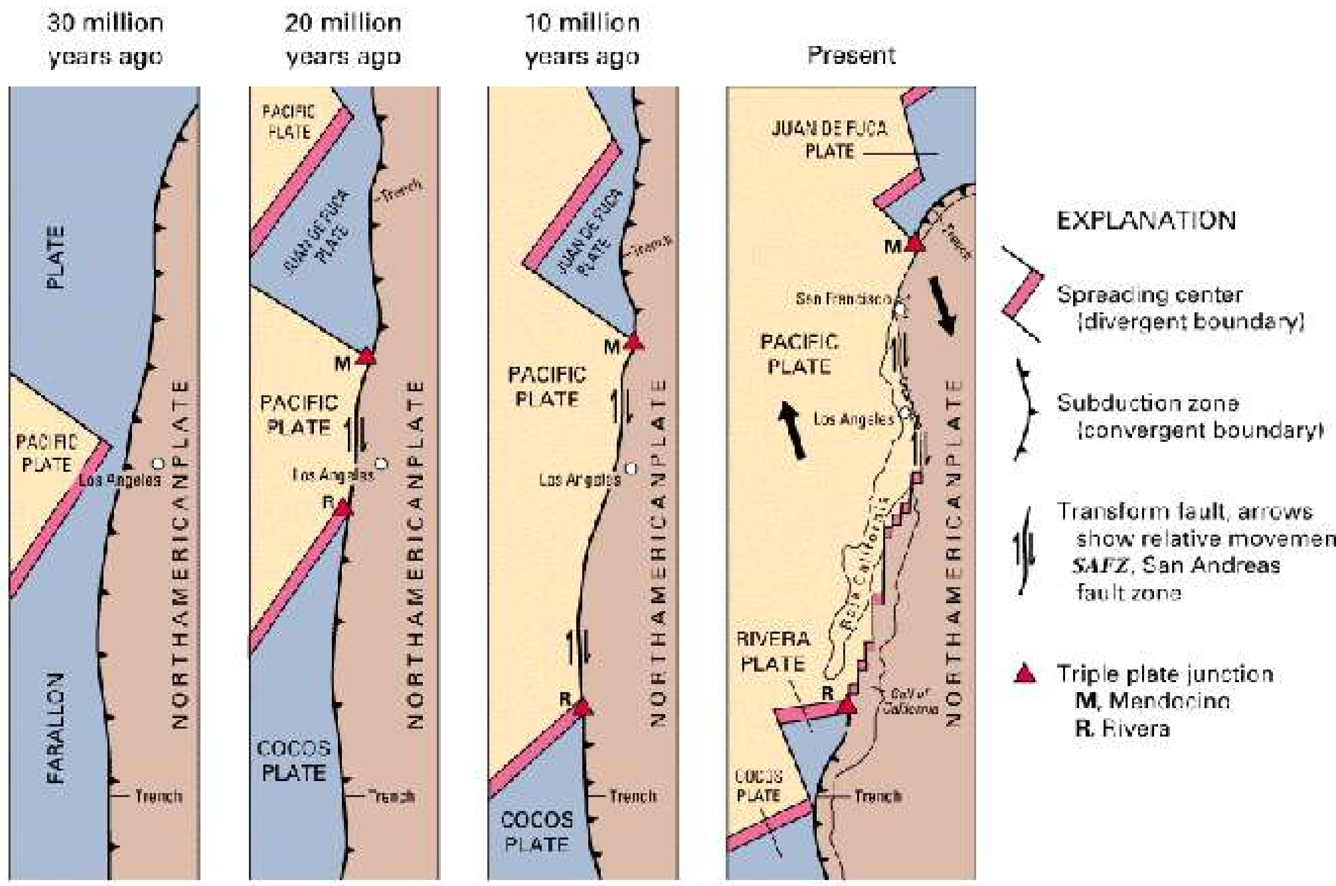
(1) Atlantic type: a passive margin, not a plate boundary

(2) Andean type: Subduction close to shore, arc volcanoes built on continental basement

(3) Japanese type: Subduction offshore with a marginal sea between the ac and the mainland

(4) California type: transform fault, no subduction, no spreading





(5) The major events affecting the tectonic evolution of California (see ppt: Califonia Geology for slides, check out other ppt for other pictures):

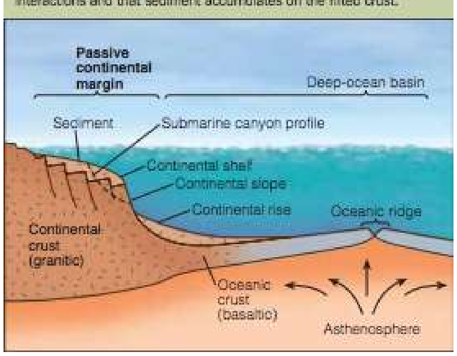
(6) **<u>Late Precambrian-Paleozoic:</u>**

(a) North America was part of a great supercontinent known as Rodinia

(b) About 750 mya=

(i) Rodinia began breaking apart into several different continental fragments, the core of N. American was isolated as an ancient continent name Laurentia→ as rifting progressed the southwestern edge of Laurentia evolved into a **passive continental margin** (it existed within a single plate, in the absence of any plate tectonic interactions passive continental margins generally have no active volcanoes and minimal seismic activity)

Figure SC.9 A passive continental margin similar to southeastern California in the early Paleozoic era. Note that there are no plate interactions and that sediment accumulates on the rifted crust.



(ii) Farther west= a severed continental fragment now in east Antarctica steadily moved away, there was no land where California now stands in the late Precambrian

(7) Prior 700 million years:
  (a) Proterozoic= west coast of North America was attached to some other continent
  (b) Beginning around 800 mya this continent rifted away and established a stepped western boundary of the continent (slide 6)

(8) 700-400 million years ago: Atlantic-type passive margin
  (a) Through the mid-Devonian time= remained a stable passive continental margin (Atlantic type) and deposition of clastic and carbonate sediments up to several km thick (slide 7)

(9) 300 mya= Laurentia began to change→ continental masses formed during the fragmentation of Rodinia had started to reassemble into Pangea
  (a) Early stages of this process involved collisions between Laurentia and several plates to the east to create larger continental masses
    (i) When Laurentia collided with the Eurasian plate (Laurasia)= shifted from a passive to an active continental margin

(10) 400-250 million years ago: Japanese-type offshore subduction
  (a) The ocean offshore widened and aged until it become unstable to subduction zone
  (b) The situation like Japan today, where subduction is occurring on both sides of the arc, with the Pacific plate and the Japan sea both subducting under Japan
  (c) In the late Devonian this offshore arc ran up against the North American margin in the Antler orogeny
    (i) The arc ended up connected to the continent overlying the miogeocline
  (d) The early Triassic Sonoma orogeny bringing in a new sequence of oceanic rocks on top of the migoeocline and the Antler rocks

(11) See slides 11-21 for the rest

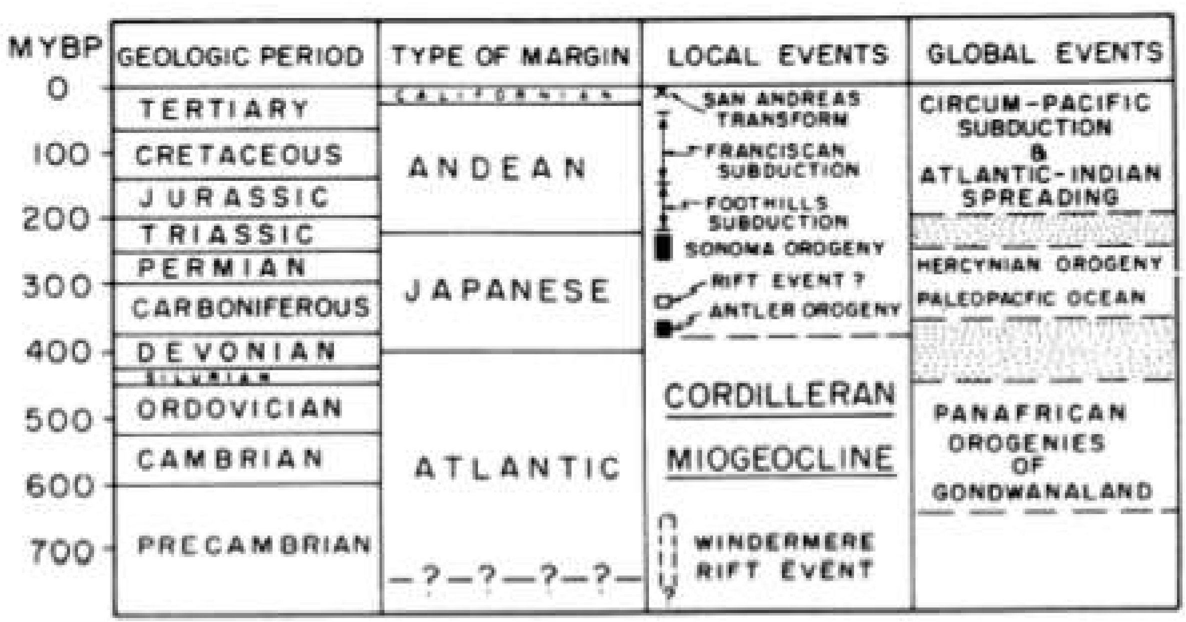
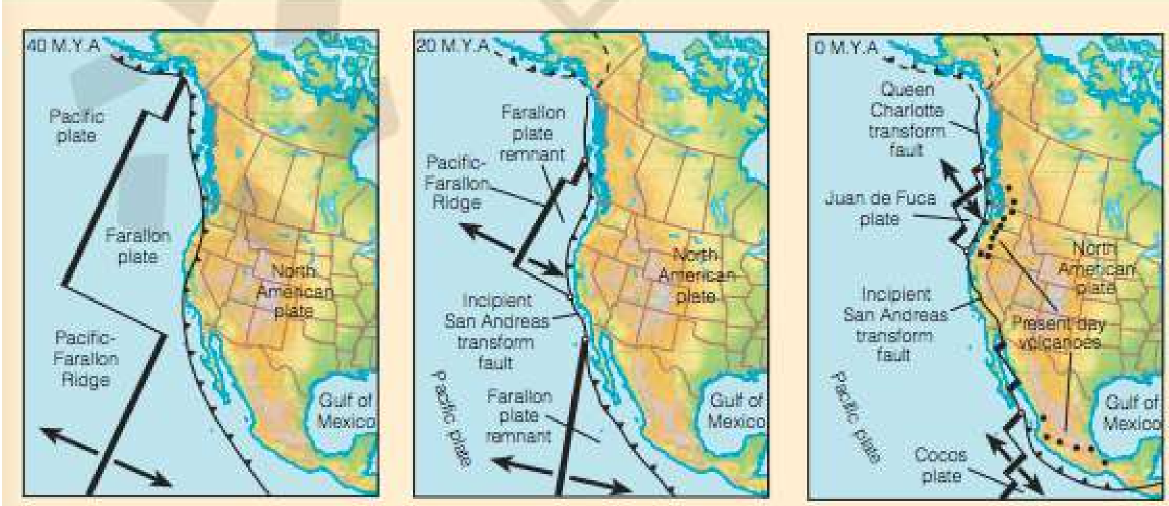


Figure SC.12 The origin of the modern transform boundary between the Pacific and North American plates.



ii) **<u>Formation of the San Andreas Fault System:</u>**

Figure SC.13 The San Andreas fault zone marks the transform boundary between the Pacific and North American plates. Los Angeles, and much of adjacent southern California, is attached to the Pacific plate.

iii) http://www.geologycafe.com/class/chapter3.html

iv) http://www.grossmont.edu/garyjacobson/Naural%20History%20150/Geology%20of%20Southern%20California.pdf

13) <u>Major Economic Earth Resources</u>

a) Importance of Water to Society, Origins of California's Fresh Water, Statewide Water Distribution, Environmental and Economic Impact of Water Redistribution

i) **<u>Importance of Water to Society</u>**

(1) Clean fresh drinking water is essential to human and other life forms, there is a clear correlation between access to safe water and GDP per capita

(2) Water plays an important role in the world economy, as it functions as a solvent for a wide variety of chemical substances and facilitates industrial cooling and transportation,

(3) The biggest consumer of water= agriculture, approximately 70% of freshwater is consumed by agriculture, most of the water is used for irrigation and once this water has been used it often evaporates into the atmosphere instead of draining back into the natural waterway= as a result some major rivers have been slowed to a trickle

ii) **Origins of California's Fresh Water**

(1) Water supply comes from two main sources: surface water, (ex: rivers, streams, lakes), groundwater (water that is pumped out from the ground)

(2) Constructed infrastructure of dams, water diversions, aqueducts, canals and water storage reservoirs make distribution of water across California possible

(3) California has an abundance of fresh water= statewide precipitation produces about 200 million acre-feet of water each year, ex: it is supplied by the precipitation and melting of the snow up in the Sierra Nevada and other mountain ranges

(4) Main water systems supplying water to California:

(a) Groundwater, the Los Angeles Aqueduct, the Hetch Hetchy Aqueduct, the Mokelumne Aqueduct, **the Colorado River**, the Central Valley Project, the State Water Project, **the Sacramento-San Joaquin Delta** (also known as the Bay-Delta)

iii) **Statewide Distribution**

(1) California State Water Project (SWP)→ a state water management project, collects water from rivers in Northern California and redistributes it to the water-scarce but populous south through a network of aqueducts, pumping stations and power plants

(2) Where your water comes from depends upon where you live→ some areas have abundant local sources, while other areas rely on imported water for most or even all of the year

(3) Fundamental controversy surrounding California's water is one of distribution, over both distance and time, combined with conflicts between competing interests over the use of available supplies

(a) Besides satisfying the needs of a growing population→ demands for more water also come from the agricultural industry, businesses, manufactures, and developers

(b) These needs must be balanced against demands for protecting water quality and for protecting fisheries, wildlife, and recreational interests

(4) Water is not distributed evenly as Northern California receives much more rainfall and snow melt than Southern California= About 75% of water supply originates in the northern third of the state or north of Sacramento, while 80% of the demand occurs in the southern 2/3 of the state, this water is transported through pipes and canals

(5) In an average year= urban use was 11%, agricultural was 34%, and 48% was left in streams and rivers for the environment

iv) **Environmental and Economic Impact of Water Redistribution**

(1) SWP expansion has been opposed because water rates could be raised; additionally agricultural users pay far less than their urban counterparts for SWP water

(2) California's transformation from a sparsely populated region into one of the world's leading agricultural and food production regions is due to the development of the area's natural resources, especially water

(3) Water development, storage and distribution projects have transformed deserts into farmland→ make California a leading agricultural producer, major manufacturing center

(a) But not without consequences= fish populations have been depleted (especially salmon and steelhead trout), wetlands have been drained, and dams and levees have altered natural water flow patters, invasive plants and species are changing ecosystems and altering native habitat, species of many native plants and wildlife have declined or become extinct, water quality has been impaired by agricultural, mining and urban sources

(b) Due to environmental problems and water use problems= CALFED Bay-Delta Program was created

b) Resources of Major Economic Importance in California/ Relation to California's Geology

i) In the Central Valley's basin, a major economic importance is agriculture, oil, and natural gas. These are due to the deposition of sediments in the valley (the central valley was created when the Farallon Plate subducted. Later, the valley was surrounded by the Sierra Nevada and the Coastal Ranges when faulting took place). At one point, CA was covered by an epieric sea→ resulted in dead marine life filling the ocean floor and was compacted= Over the years, their remains eventually turned into petroleum or natural gas

ii) **Gold** in California is produced through plate tectonics

(1) Gold in the Mother Lode belt of the Sierra Nevada occurs primarily in the quartz veins associated with Mesozoic metamorphic rocks, most of the gold probably originated from hot fluids circulating through fractures and faults in the metamorphic rocks when magma bodies intruded the Mother Lode region during the Mesozoic Era

iii) **OIL:**

(1) San Joaquin Valley→ location of the largest oil fields in California and the US, petroleum in the SJV originates primarily in deep-water marine shale of the late Mesozoic through mid-Cenozoic age, organic matter, mostly the remains of planktonic organisms, was trapped in the Cenozoic and Mesozoic marine deposits, this material has evolved into petroleum under the elevated temperatures and pressures that exist in the subsurface, once fluid hydrocarbon compounds formed, they migrated into porous subsurface rock bodies or into fractured zones associated with faults and folds

iv) **Open space, soil, arable land:**

(1) California has a fair amount of fertile land and ranks first in agricultural production in the US→ agricultural production in California totals $20B each year contributing a significant amount to the state's income

(2) This land (mainly in central California) is thought to have originated below sea level as an offshore area depressed by subduction of the Farallon Plate into a trench further offshore, the San Joaquin Fault is a notable seismic feature in the Central Valley, the valley was later enclosed by the uplift of the Coast Ranges, over the millennia the valley was filled by the sediments of these same ranges as well as the rising Sierra Nevada to the east, that filling eventually created an extraordinary flatness just barely above sea level

14) Surface Processes

a) Assessment of Mechanisms by which Tectonics, Geologic Structures, and Rock Properties influence Surface Properties

i)

b) Factors Controlling the Influence of Water in Modifying the Landscape

i) **(See below)**

c) Factors Controlling Erosion, Deposition, Transport in Superficial Processes

i) **Water:**

(1) Observing the Grand Canyon= visible evidence of the strong and powerful forces that water has on shaping Earth's landscape, with each rainfall each tiny droplet acts like a bomb, spewing soil fragments in all direction, when the ground becomes saturated then the flow of water lifts and transports loose rock fragments (sediments) down slope, these sediments can also act abrasively on rocks, wearing them down

(**weathering**) as it is transported, when water moves sediments by thin sheets of water, then the process is called sheet **erosion**; on slopes with no vegetation sheet flows often forms small rills, which eventually evolve into larger gullies, once the volume has increased then it becomes a stream

(2) Rivers and streams have important roles in the formation of our landscape, these systems erode channels in which they flow, transport sediments and materials, and shape the landform

(3) Within each river system there are three parts: a zone of erosion, a zone of sediment transport, and a zone of sediment deposition

  (a) In a river system erosion is the dominant processes in upstream areas, where streams erode the channel through which they flow and carry sediments and other materials that was broken down by weathering or mass wasting

(4) All streams regardless of size are able to transport some sediments

  (a) Streams sort sediments as they are transported, the finer lighter sediments are carried further than the lager heavier sediments

  (b) Sediments are carried by streams in three different ways:

    (i) **Dissolved load:** <u>Sediments dissolved in the stream</u>/ material that is chemically carried in the water, the amount of dissolved sediments that a stream will carry varies, depends on geological factors and climate, the sediment was brought to the stream through groundwater, this dissolved load will continue to flow with the stream, regardless of the stream's velocity or stream flow, <u>the dissolved load will only precipitate out when the chemistry of the stream changes</u>

    (ii) **Suspended Load:** When <u>sediments are suspended in the stream</u>, the most common portion of the stream's load consists of particles sizes of fine sand, silt, and clay, the type and amount of sediments and material that can be suspended in a stream depends on its velocity, the settling velocity of the sediment grains, the settling velocity means that larger sediments will settle to the floor more rapidly than smaller ones, the shape size, and density of the sediments also affects its settling velocity, flat grains settle out more slowly than spherical grains, dense grains settle out more rapidly than less dense ones, the longer sediments stay suspended the further it will travel

    (iii) **Bed Load:** Sediments that are too large to be carried in suspension moves along the floor of the stream, called a bed load. Because the bed load is rolling and sliding along the bed floor, it is grinding the floor down. Sediments that aren't too heavy may experience saltation, where it is moved upward by the current and pulled back down by gravity

(5) Where the zone of deposition takes place is generally where a river enters a large body of water (a place where change in velocity takes place), accumulation of sediments may form a delta, or other coastal features

ii) **<u>Wind:</u>**

(1) Not as strong erosional force as water or glacier is. Wind erosion has much more effect in arid regions= in humid regions particles are held together and the vegetation helps hold soil together, for <u>wind to be an effective erosional force the region needs to be dry and have little vegetation</u>

(2) Deflation (the act of lifting and removing loose material) is one way that wind erodes sediments. Some areas begin to develop a shallow depression as a result of deflation called a blowout

(3) Wind can also erode through abrasion when windblown sand polishes rock surfaces

(4) Wind, in general, doesn't not produce erosional landforms as sand doesn't travel more than a meter above the Earth's surface, so sandblasting effect is limited to an extent above the surface

(5) Wind is able to create great depositional landforms. These features are especially evident in dry regions and along sandy coasts. There are different types of wind deposits:

(a) **Dunes:** dunes are mounds and ridges made up of sand that is deposited from the wind's bed load

(b) Just like streams and rivers, wind also carries sediments in suspension and will drop sediments when wind's velocity drops→ sand is able to accumulate in a region that causes wind to drop its velocity. As sand drops in this region, the sand begins to build up. This accumulation of sand becomes an even better barrier to wind and is able to trap more and more sand. Eventually, if wind continues to drop sand in this region, then it grows large enough to become a dune. There are many different kinds of dunes, but many are asymmetrical, leeward steep slope, and windward gentle slope. Through the process of saltation, sand particles are moved up the windward slope, and when the velocity of the wind drops, it collects at this region, steepening the crest of the dune. Once enough sand is piled on, some of it slides down as a result of gravity. The leeward slope of the dune, called slipface, cycle continues and results in a slow movement of dunes being created in the direction of wind movement. The windward side of dunes are called cross beds, name cross beds comes from the fact that as sand is deposited, layers are formed at an incline in the direction that the wind is moving in. These layers become buried and become part of the sedimentary rock layer

(c) **Loess:** these are blankets of silt that were carried in suspension

iii) **Glacial:** Glaciers have the ability to carry huge blocks of debris that no other erosional force could handle. The debris that is carried by the glacial ice eventually drops out when the glacier melts and retreats. The deposition of sediments can help to shape the landscape. Glacial drift is the term used to describe sediments that were deposited due to glaciers, no matter how, where or in what shape the sediments that were deposited were in. There are different types of landforms created by glacial drift:

(1) **Till:** Unlike moving water or wind, glacial ice sheets are not able to sort sediments. When the glacier deposits its sediments, there is a mixture of many different particle sizes. This is a pretty good indicator that if you stumble into a mound that consists of unsorted debris, that it was a result of glacier activity. If you were to examine the sediments closely, you would see that many of them have scratches and are polished. Large boulders that differ in composition and size from the surrounding rocks are called glacial erratics, sometimes the source of these boulders can be figured out by looking at the mineral composition and texture and direction the boulder and other nearby glacial erratics came from, also helps track the path of the glacial ice

(2) **Moraine:** Two types of moraines:

(a) Lateral moraines are formed when glacial ice is moving down a valley. As it moves down, it erodes the sides of the valley, quite efficiently. The sediments produced are added to the sides of the glacier. When the ice melts and begins to retreat, the debris that accumulated drops next to the valley walls. This forms lateral moraines that run alongside the valley

(b) Medial moraine forms when two alpine glaciers combine to form a single ice stream. The lateral moraines that have been carried along the sides of the alpine glacier now combine together. As the ice moves down, you can see single dark stripes. Some glacier ice sheets may have several strips throughout

(c) **Terminal Moraine:** These types of moraines drop off sediments at the end of the glacier. Glaciers act like a conveyor belt in which the sediments are moving through the glacier to the end as the ice melts. The end moraine continues to grow as long as the ice front remains stable. Meaning, the rate of melting that is taking place equals the forward movement of the glacier. So, as long as this equilibrium stays the same, then sediments will constantly be dropped off. The longer this equilibrium stays stable, the larger the moraine will be. Eventually, the evaporation of ice (ablation) becomes greater than the forward movement of the glacier. The glacier begins to retreat, still dropping off sediments. These form ground moraine land features

(d) **Ground Moraine:** These are produced when glacial ice sheets are retreating. As it melts away, it drops layers of till. These deposits create gently rolling layer of tills. Ground moraines change the landscape= cause clogging streams and changing drainage systems

(e) **Recessional Moraine:** Sometimes, as glaciers retreat, a balance of evaporation and forward movement is archived again. Thus, new terminal moraines may form again. This cycle of creating terminal moraines and ground moraines may take place several times. Terminal moraines that were created when ice retreated and then stabilized are called recessional moraines. Terminal and recessional moraines are alike. The difference is that terminal moraines were created when glacial ice sheets retreated and then achieved equilibrium again

(3) **Drumlins:** These are large hills composted of till. Drumlins are found in clusters called drumlin fields. Their actual formation is still being studied, however it is thought that they form over previously deposited drift

iv) Glaciers scrape and scour rocks from the floor and walls of valley as it moves downward. Glacial erosion is not as widespread as it was during the last ice age. Glaciers erode by plucking or abrasion→

(1) **Plucking:** As a glacier moves over rocks, the water moves in through the cracks and freezes. The ice expands and acts as leverage, pushing the rock loose. The glacier lifts these blocks of rock (plucking) and the rock mass becomes a part of the glacier load**.**

(2) **Abrasion:** The rocks that have become incorporated in the glacier load and moves along with the glacier. As it does so, the rocks scrape (glacial striations), grind, or polish as it moves over the bedrock. Rock fragments produced by this action are called rock flour. So much rock flour may be produced that when meltwater moves through the glacier, it has a grayish color. Glacial striations give us clues as to the glacier's direction. The rate of glacier erosion is based on several different factors: rate of glacier movement; thickness of the ice sheet; shape, hardness of the rock fragments found in the glacier load; and the material below the glacier sheet and it's erodibility

d) Desert Environments/Water Resource Needs for Habitation

i) Plants and animals living in the desert need special adaptations to survive in the harsh environment

ii) Plants tend to be tough and wiry with small or no leaves, water-resistant cuticles and often spines to deter herbivores, some annual plants germinate, bloom and die in the course of a few weeks after rainfall while other long-lived plants survive for years and have deep root systems able to tap underground moisture

iii) Animals need to keep cool and find enough food and water to survive, many are nocturnal and stay in the shade or underground during the heat of the day= tend to be efficient at conserving water, extracting most of their needs from their food and concentrating their urine, some animals remain in a state of dormancy for long periods, ready to become active again when the rare rains fall, they then reproduce rapidly while conditions are favorable before returning to dormancy

iv) One of the driest places on Earth is the Atacama Desert, it is virtually devoid of life because it is blocked from receiving precipitation by the Andes mountains to the east and the Chilean Coast Range to the west

(1) When rain falls in deserts it is often with great violence, the desert surface is evidence of this with dry stream channels known as arroyos or wadis meandering across its surface, these can experience flash floods becoming raging torrents with surprising rapidity after a storm

15) **<u>Natural Hazards</u>**

a) Analyze Published Geologic Hazard Maps of California/ How to use maps to identify evidence of geologic events of the past and to predict the likelihood of Geologic Changes in the Future

i) Natural disaster is a natural even with catastrophic consequences for living things in the vicinity, the human death toll resulting from natural disasters depends on many factors which are not natural

ii) Natural disasters in California:

(1) Landslides, volcano eruption, river flooding, earthquakes, wildfires, drought

iii) With the present state of technology most geologic events cannot be prevented or even predicted with any precision (except most landslides)

iv) Areas prone to such events can be identified as earthquake fault zones, active volcanoes, and coastal areas susceptible to tsunamis

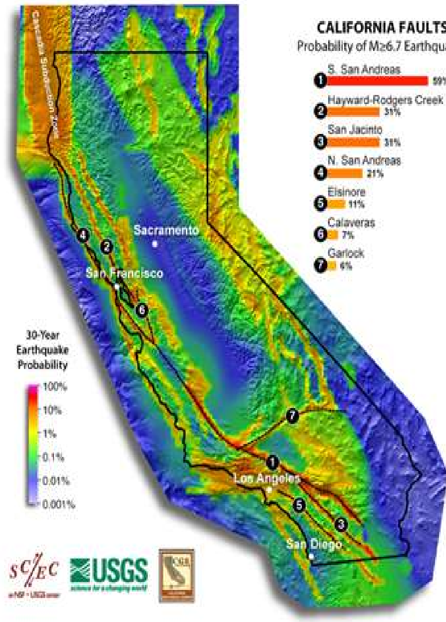
v) http://www.consrv.ca.gov/cgs/rghm/psha/ofr9608/Pages/Index.aspx

vi) http://www.consrv.ca.gov/cgs/rghm/psha/Pages/sp_203.aspx

vii) **Earthquakes** occur at tectonic boundaries, California has three tectonic plates that come together: Pacific Plate (west section of California, SF to Imperial), North American Plate (East Part of California), Gorda Plate (northern part of California)

(1) **Faults** are fractures along plates where movement occurs

(a) Well known faults in California: San Andreas Fault, Ellsinore, San Jacinto, Hayward Fault, Calaveras Fault



viii) California has several active and potential active **Volcanoes**

(1) Northern California- Cascade Range (Mt Shasta and Lassen Peak)

(2) Eastern Sierra- Long Valley

ix) **Floods**: stage at which rivers or dams overflow, California levees are in critical condition and need repair

x) **Wildfires**: common in California, following a fire usually flooding, erosion, and landslides

xi) **Landslides**: the down slope movement of soil and/or rock, an abrupt movement of soil and bedrock downhill in response to gravity, can be triggered by an earthquake or other natural causes

16) **Geologic Mapping**

a) **How to Find Position Using a Topographic Map**

i) http://www.princeton.edu/~oa/manual/mapcompass3.shtml

ii) http://mapzone.ordnancesurvey.co.uk/mapzone/PagesHomeworkHelp/docs/mapabilitycompassbearings.pdf

iii) You can determine your position on a map by using a compass to triangulate between three points

iv) Pick three topographic features that you can see and can identify on your map (mountains are ideal)

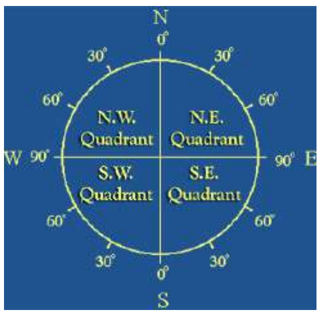
v) State with the first feature chosen and determine the bearing between you and it

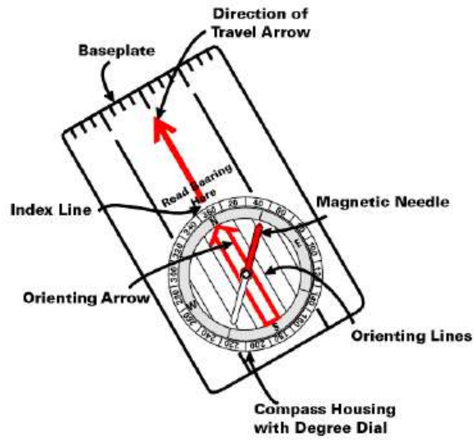
(1) **Determining bearing:**

(a) Bearing= a measurement of direction between two points, given in one of two formats=

(i) Azimuth bearing: uses all 360 degrees of a compass to indicate direction, the compass is numbered clockwise with north as 0, east 90, south 180, west 270; a bearing of 42 would be northeast and a bearing of 200 would be southwest

(ii) Quadrant bearing: compass is divided into four sections, each 90 degrees, given in the format of N 40 degrees E, S 26 degrees W





(b) Place the compass on the map so that one side of the base plate points toward the landmark

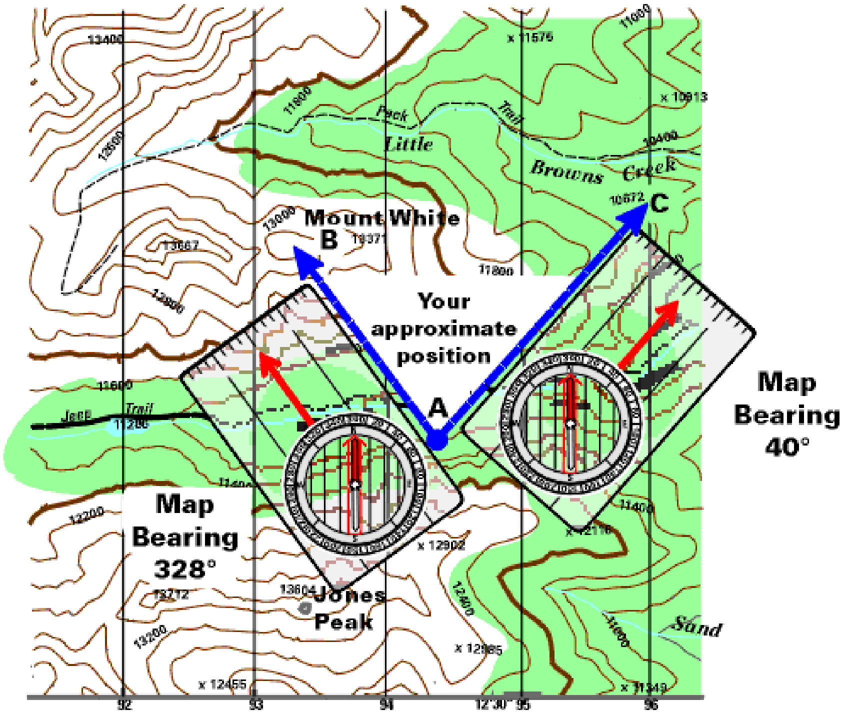
(c) Keep the edge of the base plate on the symbol, turn the entire compass on the map until the orienting arrow and the compass needle point to north on the map

(d) Draw a line on the map along the edge of the base plate, intersecting the prominent land mark symbol, your position is somewhere along this line

(e) Repeat this procedure for the other prominent land mark, the second landmark should be as close to 90 degrees from the first as possible, your approximate position is where the two lines intersect

(f) You can repeat this process a third time to show an area bounded by three lines= you are located within this triangle

(g) If you are located on a prominent feature marked on the map such as a ridge, stream, or road= one calculation from a prominent land mark should be necessary, your position will be approximately where the drawn line intersects this linear feature



b) How to Make a Geologic Map showing Faults, Structural Data, and Contacts between Formation

i) http://www.nature.nps.gov/geology/usgsnps/gmap/gmap1.html

ii) http://www.cavalrypilot.com/fm21-26/Ch10.htm

iii) All geologic maps have several features in common: colored areas and letter symbols to represent the kind of rock unit at the surface in any given area, lines to show the type and location of contacts and faults, and strike and dip symbols to show which way layers are tilted

iv) **Colored Areas**

(1) Each color represents a different geologic unit→ a volume of a certain kind of rock given an age range, area of a given color is the area where the geologic unit is the one at the surface

(2) Ex: A sandstone of one age might be colored bright orange while sandstone of a different age might be colored pale brown

v) **Letter Symbols**

(1) Each geologic unit is assigned a set of letters to symbolize it on the map, usually the symbol is the combination of an initial capital letter followed by one or more small letters, the capital letter represents the age of the geologic unit, the small letters indicate either the name of the unit (if it has one) or the type of rock

(a) The most common division of time used in letter symbols on the geologic map is Period

(i) Ex: J (Jurassic), K (Cretaceous), T (Tertiary), Q (Quaternary)

(ii) Ex: Kjm= symbol for the Joaquin Miller sandstone formed in the Cretaceous Period

vi) **Lines on a Map**

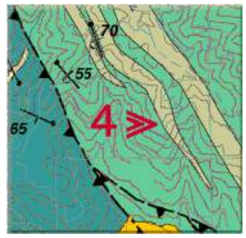
(1) **Contact Lines**

(a) The place where two different geologic units are found next to each other is called a contact, that is represented by different kinds of lines on the geologic map

(b) The two main types of contacts shown on most maps= **depositional contacts** and **faults**

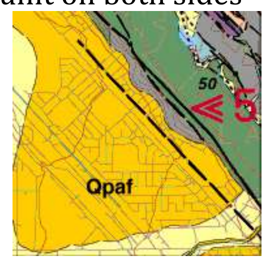
(c) All geologic units are formed over, under, or beside other geologic units

(i) Ex: Lava from a volcano flows over the landscape and when lava hardens into rock the place where the lava-rock rests on the rocks underneath is a depositional contact, where the original depositional contact between the geologic units is preserved= shown on the geologic map as a thin line (#4)



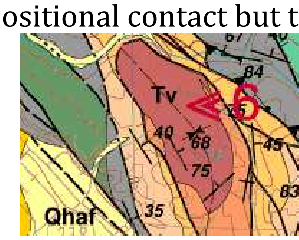
(2) **<u>Faults</u>**

(a) Geologic units tend to be broken up and moved along faults, when different geologic units have been moved next to one another after they were formed the contact is a fault contact which is shown on the map by a thick line (#5), faults can cut through a single geologic unit= shown with the same thick line on the map but have the same geologic unit on both sides



(3) **<u>Folds</u>**

(a) Another kind of long= fold axis→ geologic units can be bent and warped by the same forces into round wavelike shapes called folds, a line that follows the crest or trough of the fold is called the fold axis= marked on a geologic map with a line a little thicker than a depositional contact but thinner than a fault location



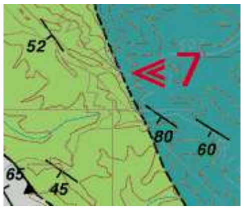
(4) **<u>Solid, dashed, or dotted lines</u>**

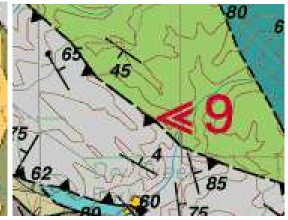
(a) Often contacts are obscured by soil, vegetation, or human construction= places where the line is precisely located is shown as a solid line, but where it is uncertain it is a dashed line (#7)

(b) The shorter the dash= the more uncertain the location, a dotted line is the most uncertain of all because it is covered by a geologic unit so no amount of searching at the surface could ever locate it (#8)

(c) Lines on the map may also be modified by other symbols on the line (triangles, small tic marks, arrows, etc) which give more info about the line

(i) Ex: Faults with triangles on them (#9) show that the side with the triangles has been thrust up and over the side without the triangles (a reserves or thrust fault)





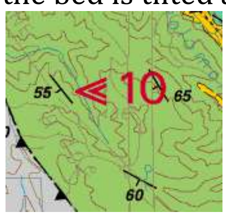
(5) **<u>Strike and Dip</u>**

(a) Many kinds of rocks form in broad, flat layers called beds that stack up like the layers of a cake→ in places like California near active plate boundaries the forces that make earthquakes don't leave the beds flat for long but bend and tilt them

(b) Tilted beds are shown on a geological map with a strike and dip symbol (#10)

(i) The symbol consists of three parts: a long line, a short line, and a number

1. Long line= the strike line, shows the direction in the bed that is still horizontal, any tilted surface has a direction that is horizontal
2. Short line= dip line, shows which way the bed is tilted
3. Number= the dip, shows how much the bed is tilted in degrees from flat, the higher the number the steeper the tilting of the bed all the way up to 90 degrees if the bed is tilted all the way onto its side



c) How to Interpret Geologic History and Processes from a Geologic Map (see above)