EARTH SCIENCE NOTES

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1. Identify the characteristics of matter.

a. Measurements have a number and a unit.

b. Matter is anything that has mass and volume.

c. Weight is a measure of the pull of gravity.

d. Length- 1m=100cm; 1cm=10mm (see ESRT p.1)

e. Mass (g) is the amount of matter in an object.

f. Volume (mL or cm3) is the amount of space an object takes up.

g. Density (g/mL or g/cm3) is the amount of mass in a specific volume of a substance (D=m/v... see ESRT p.1)

h. Usually, heating a substance makes it less dense, and cooling it makes it denser.

i. Increasing the pressure on a substance makes it denser, and decreasing the pressure makes it less dense.

j. Breaking a pure substance into smaller pieces will not change its density.

k. Most substances are most dense as solids.

l. Water is most dense as a liquid. At 3.98°C, the density of water is exactly 1g/mL (see ESRT p.1). Ice is less dense than liquid water.

m. Any measurement must contain some error (% Deviation… see formula in ESRT p.1)

2. Explain the importance of chemical bonds.

a. The internal arrangement of atoms determines what a substance is like. Salt is cubic because of the shape of its molecules.

b. Diamonds and graphite are both made of carbon. In a diamond, the carbon atoms have stronger bonds.

c. Solids, liquids and gases differ due to the speed that the atoms are vibrating (temperature) and the strength of the bonds.

3. Identify the characteristics of minerals.

a. Natural- not man-made

b. Inorganic- not alive, not from something alive, not once alive

c. Solid- not liquid, not gas

d. Definite chemical composition (ex/halite=NaCl; galena=PbS)

e. Orderly atomic arrangement (crystalline)

4. Explain how minerals form.

a. Magma is a "soup" of molten (melted) minerals under ground. Above ground, it is called lava.

b. As magma cools, some minerals crystallize (solidify) before others. This allows different minerals to form separately from each other.

5. List the physical characteristics of minerals that are influenced by their crystalline structure.

a. Color

b. Streak- color of mineral as a powder

c. Luster- how a mineral's surface reflects light (metallic or nonmetallic)

d. Hardness- Diamonds are hardest (10), talc is softest (1)

e. Density

f. Fracture- when a mineral breaks irregularly.

g. Cleavage- the way a mineral breaks along planes of weakness creating flat surfaces

h. Crystal form

i. Others- bubbles with acid, magnetism, taste

6. Identify rock-forming minerals by physical and chemical properties- see your Earth Science Reference Tables (p.16).

7. List and describe different categories of minerals: silicates & carbonates.

a. Silicates- the most common mineral group; contain Si and O; ex / quartz, feldspar, mica

b. Carbonates- contain $CaCO_3$; ex/ calcite, dolomite

c. Oxides- metal combines with oxygen; ex/ hematite, magnetite

d. Sulfides- metal combines with sulfur; ex/ pyrite

8. Compare renewable & nonrenewable resources.

a. Chemical composition and physical properties determine how humans use minerals.

b. The properties of rocks determine how they are used and also influence land usage by humans.

c. Renewable resource- a resource that can be replaced in nature at a rate close to its rate of use (oxygen, trees, food, solar energy).

d. Nonrenewable resource- a resource that is used up faster than it can be replaced in nature (iron, aluminum, sand, coal, oil, natural gas, uranium).

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9. Determine the densities of known materials.

a. Mass- triple beam balance

b. Mass of a liquid- find mass of container empty, find mass of container with fluid, subtract mass of container.

c. Volume of a regular object- V = l x w x h

d. Volume of an irregular object- graduated cylinder (displacement of water)

e. Volume of a liquid- pour it into a graduated cylinder.

f. D = m / v

10. Compare/contrast the density of continental/oceanic rock

a. Continental crust (more aluminum - felsic)= 2.7g/cm3

b. Oceanic crust (more iron and magnesium - mafic)= 3.0 g/cm3

11. Explain the difference between a mineral and a rock.

a. Minerals are the “building blocks of rocks.”

b. Rocks are mixtures of minerals. Rocks are usually made of one or more minerals.

12. Differentiate among the three major types of rocks.

a. Rocks are classified on the basis of their origin: igneous, sedimentary or metamorphic.

b. Igneous rocks form by the crystallization of molten magma or lava.

c. Most sedimentary rocks form as a result of the compression and cementing of sediments under bodies of water.

d. Metamorphic rocks form as a result of crystal growth without melting (recrystallization), usually under conditions of high temperature and pressure.

13. Distinguish between intrusive and extrusive igneous rocks and how they form.

a. Intrusive rocks have large (1mm or larger) intergrown crystals. Ex / granite, dunite, gabbro, pegmatite

b. Extrusive rocks have small (less than 1mm) intergrown crystals or none at all (glassy). Some cooled so quickly that gas bubbles got trapped within them (vesicular). Ex/ pumice, obsidian, basalt, scoria

14. Explain the relationship between crystal size and cooling time.

a. Intrusive rocks form when magma cools slowly beneath Earth's surface, allowing enough time for large crystals to grow. Ex / granite, dunite, gabbro, pegmatite

b. Extrusive rocks form when lava cools quickly above Earth's surface, not allowing enough time for large crystals to grow. Ex / pumice, obsidian, basalt, scoria

15. Understand "interlocking" crystals- There is no cement or matrix holding the individual minerals crystals together. They are intergrown.

Each crystal is touching another crystal, with nothing between them. Interlocking crystals are found in igneous rocks.

16. Distinguish among the types of sedimentary rocks and how they form.

a. Inorganic land-derived sedimentary rocks are clastic (made of fragments of other rocks cemented together).

b. Chemically formed sedimentary rocks are crystalline and usually form when water evaporates, leaving dissolved minerals behind.

c. Organically formed sedimentary rocks (bioclastic) are the result of living things. Coal is made of plant remains. Limestone is made of cemented seashells.

17. Discuss features typical of sedimentary rocks.

a. Inorganic land-derived sedimentary rocks are named by particle size.

Ex/ Shale is made of clay-sized particles cemented together. Sandstone is made of sand sized particles cemented together.

Conglomerates and breccias are made of a mixture of different particle sizes cemented together.

b. Limestone has shells cemented together.

c. Fossils are found only in sedimentary rocks.

18. Explain the processes involved in the formation of metamorphic rocks.

a. Metamorphism results in the rearrangement of atoms in existing minerals subjected to conditions of high temperature and pressure.

b. Contact metamorphism occurs when molten rock comes in contact with surrounding rocks. Transition zones from altered to unaltered rocks can be identified.

c. Regional metamorphism occurs over large areas, and is generally associated with mountain building.

The extreme pressures associated with the collision of tectonic plates (mountain building) can lead to the metamorphism of rock material.

19. Differentiate among different kinds of metamorphic rocks.

a. Add pressure to clay (sediments), and shale (a sedimentary rock) forms. Add pressure to shale, and slate forms. Add pressure to slate, and phyllite forms. Add pressure to phyllite, and schist forms.

Add pressure to schist, and gneiss forms. These are the events that turn a low-grade metamorphic rock into a high-grade metamorphic rock.

b. Metamorphic rocks often show banding or mineral alignment (foliations).

c. Metamorphic rocks often have distorted structures.

20. Learn how to use the ESRT chart for mineral and rock identification- See pages 6, 7 and 16.

21. Compare/contrast the processes in the rock cycle. (Use ESRT p.6)

a. Any one type of rock can be changed into any other type of rock.

b. Many processes of the rock cycle are the result of plate motions.

c. When one plate dives beneath another, it melts. This leads to igneous rock formation and contact metamorphism.

d. When plates collide, regional metamorphism occurs due to the great pressures exerted on large areas.

e. Down-warping of the crust leads to the creation of major depositional basins.

UNIT II: THE DYNAMIC CRUST

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1. List direct/indirect evidence of crustal movement
2. Describe evidence of continental drift
3. Define terms regarding earthquakes
4. Explain measurement of earthquake energy
5. Compare & contrast earthquake waves
6. Interpret inferred properties of earth’s interior using earthquake time/travel chart
7. Explain the cause of plate tectonics
8. Describe the types and features of plate boundaries
9. Locate and identify plate boundaries and tectonic features

1. List direct/indirect evidence of crustal movement

a. Sedimentary rocks at high elevations suggest past uplift of the crust.

b. Shallow-water marine fossils found today at both high elevations and at great ocean depths indicate changes in elevation of the crust.

c. Tilted and folded rock strata (sedimentary layers) suggest past crustal movement.

d. Rock faults, volcanoes, displaced strata, raised beaches, and changes in bench mark elevations are all indications of crustal change and movement.

2. Describe evidence of continental drift

a. Zones of frequent earthquakes and volcanic activity can be located on the Earth’s surface. ex / Ring of Fire

b. In many places the zones of crustal activity are associated with high, young mountain ranges and deep ocean trenches.

c. Igneous rock near the center of the ocean ridges is younger than the igneous rock farther from the ridges.

d. Mid-ocean ridges, the sites of sea-floor spreading, are found in all major oceans and represent more than 20 percent of Earth's surface.

These broad features are characterized by an elevated position, extensive faulting, and volcanic structures that have developed on newly formed oceanic crust.

Most of the geologic activity associated with ridges occurs along a narrow region on the ridge crest, called the rift zone, where magma from the asthenosphere moves upward to create new slivers of oceanic crust.

e. The Earth's magnetism seems to have reversed itself many times in the past.

Strips of rock parallel to the ocean ridges show patterns of reversal of magnetic polarity that match the reversals of the Earth's magnetism.

f. The shapes of the continents, combined with comparisons of rocks and minerals, mountain formations, fossils, past climates, and rock magnetism, suggest that…

… the continents were attached at one time and have since drifted apart.

3. Define terms regarding Earthquakes

a. Earthquake- the shaking of Earth's crust caused by a sudden release of energy.

b. Fault- a crack in the crust along which movement has occurred.

c. Focus- the point within the Earth where an Earthquake originates

d. Epicenter- the point on Earth’s surface directly above the focus

4. Explain measurement of Earthquake energy

a. Seismic wave- an Earthquake generated wave

b. Seismology- the study of Earthquakes

c. Seismologist- someone who studies Earthquakes

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d. Seismic station- someplace where seismic activity is being recorded

e. Seismograph- an instrument that detects and records seismic waves

f. Seismogram- the recording of an Earthquake (on paper) made by a seismograph

g. Richter scale- A scale, from 1 to 10, that measures the amount of energy (magnitude) released during an Earthquake on the basis of the amplitude (height of a wave) of the highest peak recorded on a seismogram.

It is a logarithmic scale, which means that a Richter 3 is 10 times greater than a Richter 2, and a Richter 4 is 100 times as great as a Richter 2.

Each unit increase in the Richter scale represents a 10X increase in the amplitude recorded on the seismogram and a 32X increase in energy released by the Earthquake:

1.0 = 30 pounds dynamite= Large Blast at a Construction Site

1.5 = 320 pounds dynamite

2.0 = 1 ton dynamite=
Large Quarry or Mine Blast

2.5 = 4.6 tons dynamite

3.0 = 29 tons dynamite

3.5 = 73 tons dynamite

4.0 = 1,000 tons dynamite= Small Nuclear Weapon

4.5 = 5,100 tons dynamite= Average Tornado (total energy)

5.0 = 32,000 tons dynamite

5.5 = 80,000 tons dynamite= Little Skull Mtn., NV Quake, 1992

6.0 = 1 million tons dynamite= Double Spring Flat, NV Quake, 1994

6.5 = 5 million tons dynamite= Northridge, CA Quake, 1994

7.0 = 32 million tons dynamite= Japan Quake, 1995; Largest Nuclear Weapon

7.5 = 160 million tons dynamite= Landers, CA Quake, 1992

8.0 = 1 billion tons dynamite= San Francisco, CA Quake, 1906

8.5 = 5 billion tons dynamite= Anchorage, AK Quake, 1964

9.0 = 32 billion tons dynamite= Chilean Quake, 1960

10.0 = 1 trillion tons dynamite= (San-Andreas type fault circling Earth)

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h. Mercalli scale- a scale, from I to XII (1 to 12), of Earthquake intensity (damage).

Scale I= Not felt except by a very few

Scale II= Felt only by a few persons on upper floors

Scale III = Felt indoors

Scale IV = Hanging objects swing

Scale V= Felt outdoors

Scale VI= Felt by all, many frightened & run outdoors

Scale VII= Difficult to stand

Scale VIII= Damage slight in specially designed structures

Scale IX= Damage considerable in specially designed structures

Scale X= Ground cracked, rails bent

Scale XI= Bridges destroyed, broad fissures in ground

Scale XII = Damage total

i. Earthquakes and volcanoes present geologic hazards to humans. Loss of property, personal injury, and loss of life can be reduced by effective emergency preparedness.

5. Compare & contrast Earthquake waves

a. P waves- Primary, or compressional, Earthquake waves formed by alternate compression and expansion of rock.

The vibration of the particles is parallel to the direction of travel of the waves.

P waves travel faster than any other seismic waves, and can travel through solids, liquids and gases (sound waves).

b. S waves- Secondary, or shear, Earthquake waves, which can travel through solids, but not liquids or gases. A seismic wave with a vibration that is perpendicular to the direction of wave travel.

S waves travel slower than P waves.

6. Interpret inferred properties of Earth's interior using Earthquake time/travel chart

a. Differences in travel times of seismic waves can be used to determine the distance between a seismic station and the epicenter of an Earthquake.

b. Seismograms from at least three seismic stations are needed to find the exact location of an epicenter.

c. The speed of a seismic wave varies with the physical properties of the material through which the wave is traveling. Ex / Waves travel faster through denser rock.

d. Analysis of seismic data leads to the inference that solid zones (crust, mantle, and inner core) and a liquid zone (outer core) exist within the Earth.

e. The Mohorovicic discontinuity, or Moho, is the boundary between the crust and the mantle.

f. The average thickness of the continental crust is greater than the average thickness of the oceanic crust.

g. The oceanic and continental crusts have different compositions. (Oceanic=mafic, basaltic, and high density; Continental=felsic, granitic, and low density)

h. The shadow zone is a belt around the Earth where neither P nor S waves are received from a particular Earthquake.

i. Seismic data suggest that the Earth's core is composed of iron and nickel. Denser elements sank to Earth's center.

j. The density, temperature, and pressure of the Earth's interior increase with depth.

7. Explain the cause of plate tectonics

a. The theory of plate tectonics states that the solid lithosphere (crust and rigid mantle) consists of a series of plates that “float” on the partially molten asthenosphere (plastic mantle).

b. Convection currents within the asthenosphere are thought to move the plates.

c. Why is the Earth's interior hot?

The radioactive decay of Uranium (U), Thorium (Th) and Potassium (K)

Leftover heat from Earth’s formation and meteorite impacts

Plate friction

8. Describe the types and features of plate boundaries

a. Transform plate boundary- A boundary between two lithospheric plates where the plates are sliding horizontally past one another. Ex/ San Andreas Fault in California

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b. Divergent plate boundary- A boundary where two lithospheric plates move away from each other. Ex/ Mid-Atlantic Ridge

c. Convergent plate boundary- A boundary where two lithospheric plates are coming together:

i. Oceanic-Continental Plate Boundary (Ex/ Peru-Chile Trench)

ii. Oceanic-Oceanic Plate Boundary (Ex/ Aleutian Trench)

iii. Continental-Continental Plate Boundary (Ex/ Himalayan Mountains)

d. Subduction Zones exist at convergent plate boundaries when one plate dives down beneath another plate. This process creates trenches, island arcs, and volcanic mountain ranges.

e. Hot spots- a geologic 'hot spot' is an area in the middle of a crustal plate where magma is rising. Hot spots are stationary as the plates move above them.

Magma breaks through and produces undersea volcanoes. Some of these volcanoes build up to the surface of the ocean and become islands. Over millions of years the plate may move across the 'hot spot.'

The original volcano becomes extinct but a new volcano will begin to form in the area of the 'hot spot.' A hot spot can also exist under the continental crust (Yellowstone National Park in northwestern Wyoming).

f. Hawaii’s Hot Spot- The Hawaiian islands get older to the northwest, indicating that the Pacific Plate is moving to the northwest.

The Hawaiian Ridge-Emperor Seamounts chain extends some 6,000 km from the "Big Island" of Hawaii to the Aleutian Trench off Alaska.

A sharp bend in the chain indicates that the motion of the Pacific Plate abruptly changed about 43 million years ago, as it took a more westerly turn from its earlier northerly direction.

On the seafloor to the southeast of Hawaii is an active volcanic area with periodic eruptions. This area is called Loihi and will be the site of the next Hawaiian Island more than 10,000 years from now.

9. Locate and identify plate boundaries and tectonic features- (See pages 5, 9 and 10 in your Earth Science Reference Tables.)

10. Understand that plate motions have resulted in global changes in geography, climate, and the patterns of organic evolution.

a. Earth looks very different today than it did in the past

b. Places near the equator (warm) today may have been near the poles (cold) in the past, and vice versa.

c. When the plates separated, unique life forms were able to evolve on each continent.

UNIT III/A: SURFACE PROCESSES – WEATHERING AND EROSION

UNIT III/A: SURFACE PROCESSES – WEATHERING AND EROSION

1. Explain outgassing and the water cycle
2. Explain the movement of water through the ground
3. Compare and contrast methods of physical and chemical weathering
4. List the end products of weathering
5. Explain how different climates, particle sizes and composition & exposure affect weathering processes
6. Define and list the agents of erosion
7. Understand the importance of gravity in erosional/depositional systems and give examples
8. Explain the mechanism of wind erosion /deposition
9. Explain the mechanism of erosion & deposition by ocean waves and currents
10. Recognize features of erosional/depositional systems

1. Explain outgassing and the water cycle

a. Outgassing is the release of gas (water vapor, carbon dioxide, nitrogen, and lesser amounts of other gases) from cooling molten rock or the interior of the Earth.

b. Water vapor in the atmosphere condensed to form the oceans. Earth's oceans formed as a result of precipitation over millions of years.

The presence of an early ocean is indicated by sedimentary rocks of marine origin, dating back about four billion years.

c. The water cycle is the circulation of water from the surface of the Earth into the atmosphere and back again.

d. Precipitation may infiltrate the Earth’s surface, run off, or evaporate.

e. The release of water into the atmosphere by plants is called transpiration.

f. Earth has continuously been recycling water since the outgassing of water early in its history.

2. Explain the movement of water through the ground

a. Less than 3 percent of Earth's water is fresh, and over two thirds of that is frozen. Most usable fresh water is underground.

b. Infiltration can occur if the surface is permeable and unsaturated, and if the slope of the land is gentle enough.

c. The rate of infiltration is determined by the porosity and permeability of the soil.

d. Porosity is the percentage of open space in a sample compared with its total volume.

e. Porosity is determined by the shape of the particles, how they are packed, and whether or not they are sorted by size.

f. Size does not affect porosity. A 1000mL container full of large beads, and a 1000mL container full of small beads both have the same porosity!

g. The permeability of a material is a measure of the rate at which water can pass through it.

h. Permeability depends on pore size and on whether or not the pores are interconnected.

i. The permeability of loose materials increases with increased pore size.

j. Surface runoff can occur when rainfall exceeds the permeability rate, when the soil is saturated, or when the slope of the surface is too great to allow time for infiltration.

k. Water moves upward into tiny pore spaces by capillary action.

I. Zone of Saturation- Groundwater zone within the Earth's bedrock where all available pores spaces are filled by water; found beneath the water table.

m. Zone of Aeration- Horizontal zone that extends from the top of the water table to the ground surface; soil and rock pore spaces in this zone are not saturated with water.

n. Water Table- Top surface of groundwater; top of zone of saturation; the depth of the water table depends on the climate, season, and location.

o. For a well to be productive, it must extend down below the water table to the zone of saturation.

3. Compare and contrast methods of physical and chemical weathering

a. Weathering is the physical or chemical breakdown of rocks.

b. Weathering occurs when the lithosphere (rocks) is exposed to the atmosphere (air) and the hydrosphere (water).

c. Physical weathering causes a rock to crack or break into pieces.

d. Physical weathering may occur as the result of alternate freezing and melting of water (frost action), when plant roots widen cracks (plant action), and when the pressure of overlying material is removed (pressure unloading/exfoliation).

e. Chemical weathering changes the chemical composition of the minerals in rocks, usually weakening the rock.

f. Chemical weathering may occur when minerals react with oxygen (oxidation), carbonic acid (carbonation), and water (hydrolysis).

4. List the end products of weathering

a. Weathering breaks down rocks into particles of many sizes (clay, silt, sand, pebbles, cobbles, boulders)

b. Soil is a mixture of rock and organic material (humus).

c. Soils are the result of weathering and biological activity over long periods of time.

d. A mature soil profile shows three distinct horizons. The A-horizon (topsoil) is dark and rich in humus. The B-horizon (subsoil) is lighter in color, has more clay, and less humus.

The C-horizon is made of slightly weathered bedrock (rock fragments). Beneath the three horizons is the unweathered bedrock.

e. Soils may be residual (form from underlying bedrock) or transported (form from sediments that have been carried from some other place).

5. Explain how different climates, particle sizes and composition & exposure affect weathering processes

a. At high latitudes and high altitudes, where it is cold and humid, frost action is the major form of weathering.

b. In warm and humid climates chemical weathering is most important.

c. In dry climates, very little weathering takes place.

d. Local climatic conditions (winds, nearness to cities, etc.) can affect the rate of weathering.

e. Small rock particles will weather faster than a single large sample of the same mass because more surface area is exposed by the small particles.

f. Rocks containing more resistant minerals will weather at a slower rate.

g. Rocks that are not exposed to the atmosphere and hydrosphere will weather at the slowest rate.

6. Define and list the agents of erosion

a. Erosion is the movement of sediments from one place to another.

b. Whatever is moving sediments is an agent of erosion.

c. Most sediments on Earth are transported (have been moved).

d. Running water is by far the most important agent of erosion.

e. Minor agents are glaciers, the wind, and waves breaking against the coast.

f. Gravity may act alone as an agent of erosion.

7. Understand the importance of gravity in erosional/depositional systems and give examples

a. Gravity is the main driving force of erosion.

b. Mass Movement- General term that describes the downslope movement of sediment, soil, and rock material.

c. Landslides- a general term for the downslope movement of sediments under the influence of gravity.

d. Slumping- the downslope movement of material on a curved slip surface.

e. Hillside creep- the slow movement of sediments downslope under the influence of gravity.

8. Explain the mechanism of wind erosion /deposition

a. Erosion of sediments by wind is most common in arid climates and along shorelines.

b. Wind-generated features include dunes and sand-blasted bedrock.

c. Wind can transport sediment the size of sand or smaller.

d. Wind can create features like sand dunes in deserts and on beaches. Sand dunes are steeper on the leeward side.

e. Dunes migrate as sand from the windward side blows over to the leeward side.

f. Sediments eroded by wind are often rounded, and under magnification, have frosted surfaces.

g. Wind-deposited sediments usually consist of well-sorted, small particles in layers that may be tilted.

h. Cross-bedding may develop when sediments are deposited by the wind in leaning positions on sand dunes.

9. Explain the mechanism of erosion & deposition by ocean waves and currents

a. Wave action has erosional affects on shoreline rocks and on beaches.

b. Most waves result from winds.

c. Swash- motion of water up the beach

d. Backwash- motion of the water running back down the beach

e. Longshore current- a current that flows parallel to the shoreline, caused by waves moving towards the beach at an angle.

f. Longshore Drift- The movement and deposition of coastal sediments parallel to the beach because of longshore currents.

g. Rip currents- strong surface currents that flow away from the beach.

h. Density currents result when water in an area of the ocean has become denser than the water around it. The denser water moves beneath the less dense water forming a current.

i. Sandbar- a bar of sand formed by ocean currents depositing sand near the shore.

j. Spit- A long and narrow accumulation of sand and/or gravel that projects into a body of ocean water, attached at one end to the beach.

k. Baymouth bar- a narrow deposit of sand and/or gravel found across the mouth of a bay.

l. Hook- A spit with a curved end.

m. Barrier island- a narrow, sandy coastal island built through wave action and separated from the mainland. Such islands form a barrier that protects the shore from the open sea.

They are easily flooded during storms or high water, and are constantly in the process of being created, shifted, or destroyed by wind and waves.

10. Recognize features of erosional/depositional systems.

a. You should be able to identify the agent of erosion responsible for the formation of the features listed above (dunes, spits, etc.).

b. In certain erosional situations, loss of property, personal injury, and loss of life can be reduced by effective emergency preparedness.

UNIT III/B: SURFACE PROCESSES – EROSIONAL-DEPOSITIONAL SYSTEMS

UNIT III/B: SURFACE PROCESSES – EROSIONAL-DEPOSITIONAL SYSTEMS

1. Define and calculate gradient
2. Explain the factors that affect stream velocity and particle transport
3. Describe the stages of stream development
4. Compare & contrast factors which affect rates of deposition such as density, shape, size and energy loss
5. Describe horizontal and vertical sorting
6. Differentiate between deltas & alluvial fans
7. Explain glacier formation
8. Recognize types and parts of glaciers
9. Describe glacial motion
10. Understand the erosional & depositional effect of glaciation on landscapes
11. Recognize glacial erosional/depositional features
12. Explain the effect of the Ice Ages on NYS

1. Define and calculate gradient

a. Gradient- The steepness of a slope.

b. Field Value- Information measured at a specific location (elevation, temperature, wind speed, pressure, etc.)

c. Gradient can be calculated by dividing the change in field value (ex/ difference in elevation) by the distance between the two points where the values were measured.

d. Units such as m / km must be used.

2. Explain the factors that affect stream velocity and particle transport

a. Every steam and its branches make up a single system that collects all the runoff within a definite area called the drainage basin of the system.

b. A stream system consists of running water, the land surface it drains, the sediment it transports, and the energy used to drive it.

c. As the gradient (slope) of the stream bed increases, the average velocity of the stream increases.

d. An increase in the discharge (the volume of water flowing past a given point in a stream in a given amount of time) of a stream increases its average velocity.

e. Streams transport sediments in solution (dissolved salt), in suspension (silt and clay), by bouncing (sand), and rolling or sliding (pebbles, cobbles and boulders).

f. The size of the sediments that a stream can transport increases as the velocity increases (see ESRT p.6).

g. The total amount of sediment that a stream can transport increases as its discharge increases.

h. Sediments transported by streams tend to become rounded as a result of abrasion.

3. Describe the stages of stream development

a. Youthful streams carrying sediments down steep gradients can cut through solid bedrock.

b. When youthful, streams have V-shaped valleys.

c. In the stage of maturity the valley of a stream widens. The stream ceases to cut through bedrock.

d. In old age, the stream develops a wide flood plain, across which it wanders in a series of curves, or meanders.

e. Erosion occurs on the outer curve of a meander, where the water is faster.

f. Deposition occurs on the inner curve of a meander, where the water is slower.

g. A cutoff occurs when a meander has almost formed a complete loop, and the narrow neck of land is eroded in flood conditions, allowing the river to by-pass the bend.

h. Oxbow Lake- a crescent-shaped lake formed when a river meander gets completely cut off from the river.

4. Compare & contrast factors which affect rates of deposition such as density, shape, size and energy loss

a. The processes by which transported materials are left in new locations are called deposition (sedimentation).

b. Rock particles that are transported by erosional processes are called sediments.

c. As the velocity of a stream decreases, sediments will be deposited.

d. If all factors other than size are equal, smaller particles settle more slowly in water than larger particles.

e. Very small particles, such as clay, may remain suspended in water indefinitely.

f. If all factors other than shape are equal, flatter particles settle more slowly in water than rounded particles.

g. If all factors other than density are equal, particles of higher density settle in water faster than particles of lower density.

5. Describe horizontal and vertical sorting

a. Patterns of deposition result from a loss of energy within the transporting system and are influenced by the size, shape, and density of the transported particles.

b. When several events of deposition occur in quiet water, each involving a mixture of sediments, vertical sorting will take place and graded beds of sediment will be formed.

c. As a stream gradually slows down, it deposits the larger, rounder, denser particles first, upstream.

Smaller sediments are carried farther downstream. The smallest particles are carried the farthest, eventually to the ocean.

This separation of sediment sizes from upstream to downstream is called horizontal sorting.

6. Differentiate between deltas & alluvial fans

a. A delta is a fan-shaped deposit of sediment formed where a stream or river enters a quiet body of water, due a sudden decrease in the velocity of the water.

b. An alluvial fan is a fan-like accumulation of sediment created where a steep stream slows down rapidly as it reaches a relatively flat valley floor.

7. Explain glacier formation

a. A glacier is a large mass of snow and ice that is moving because of gravity.

b. Glaciers occur where the amount of snowfall is greater than the amount that melts over many years.

c. Glaciers are found only in polar regions and at high altitudes.

8. Recognize types and parts of glaciers

a. Valley or alpine glaciers are found in mountain areas where they usually follow valleys that were originally occupied by streams.

b. Ice sheets or continental glaciers exist on a much larger scale, covering most of Greenland and Antarctica.

c. Front- The leading edge of a glacier.

d. Crevasse- a crack in the glacial ice.

e. Tongue- At or near the coast, some glaciers flow directly into the ocean and develop floating extensions, called "glacier tongues."

9. Describe glacial motion

a. Glaciers flow slowly downhill and outward under the force of gravity.

b. Research suggests that melting ice on the bottom of a glacier lubricates movement.

c. Glaciers move fastest near the center, away from the friction of the valley walls.

10. Understand the erosional & depositional effect of glaciation on landscapes

a. Glaciers leave behind U-shaped valleys.

b. Most glaciers push, carry, and drag great quantities of sediment known as till. The glaciers that shaped New York State must have moved huge amounts of unsorted sediment.

c. Glacial deposits contain mixed (unsorted) sizes of sediments from clay to huge boulders (erratics). The great sizes of some erratics (like Indian Rock in Suffern) show the tremendous power of moving ice.

d. Glacial ice erodes solid rock by abrasion as the ice drags rocks over exposed bedrock.

e. Glacial erosion of New York's highest mountains shows that the ice was at least a mile thick.

f. Erratics traceable to bedrock exposures in the north show the general direction of ice flow. Some rock types are so distinct that their origins can be identified very confidently.

Many boulders in our area come from the Adirondacks and Canada.

g. Glacial erosion has produced characteristic features throughout New York State such as north-south valleys, and thin, rocky soils.

11. Recognize glacial erosional/depositional features

a. Esker- a long, winding ridge formed when sand and gravel were deposited in meltwater tunnels beneath a glacier.

b. Moraines- sediments deposited beneath, along the sides, and/or at the end of a glacier.

c. Kettle- a depression created by the melting of a large chunk of ice left buried in the ground by a retreating glacier. The ice prevents sediment from collecting; when the ice melts a lake or swamp may fill the depression.

d. Drumlin- a long, canoe-shaped hill made of unsorted sediments and shaped by an advancing glacier. Drumlins point in the direction of glacier movement. The steep side of a drumlin faces in the direction from which the glacier came.

e. Glacial polish- a smooth polish on bedrock created when fine particles transported at the base of a glacier abrade the bedrock.

f. Glacial striation- parallel grooves and scratches in bedrock that form as rocks are dragged along at the base of a glacier.

g. Outwash plain- a smooth plain covered by deposits from water flowing from melting glaciers.

h. Glacial Valley (Glacial trough)- a U-shaped valley formed by glacial erosion.

i. Hanging valleys- a smaller valley that enters a main valley at an elevation well above the main valley's floor. Hanging valleys are often the sites of spectacular waterfalls.

j. Cirque- a deep, steep-walled hollow on a mountainside in which an alpine glacier forms. The walls and floor of the cirque are carved by glacial ice to form a bowl shape.

k. Arête- a sharp narrow ridge between neighboring valleys.

I. Horn- a sharp, pyramid-shaped mountain peak where three or more cirques intersect near the summit. The Matterhorn of the Swiss Alps was formed in this manner.

m. Fiord (fjord)- a long, deep, narrow inlet of the sea bounded by steep walls, generally formed by submergence of a glacially eroded valley.

In the book "Roadside Geology of New York" by Bradford B. Van Diver, the author documents:

"The Hudson River has cut a narrow, 15-mile long gorge through the range between Peekskill and Newburgh that served as a channelway for ice erosion during Pleistocene glaciation.

The gorge is a true fjord, like those of the Norwegian coast, a glacially-gouged valley now invaded by the sea, and through which daily tides reach 160 miles inland to Troy!")

12. Explain the effect of the Ice Ages on NYS

a. Layer upon layer of weathered till show that there have been several major periods of glaciation in recent geologic past.

New York has been covered by thick ice repeatedly in the Pleistocene Epoch (1.6 mya). We live within a period of glacial/interglacial alternations.

b. The Ice Ages resulted in major ecological changes and very different plant and animal communities. The natural environment of New York State might have looked like the tundra of northern Canada, Alaska, and Siberia.

c. Nearly all of New York State displays evidence of glaciation. Soils covering most of New York State are composed of weathered till. Only the Allegheny region and southern Long Island may have escaped covering ice.

d. Fossil and geologic evidence indicates periodic changes in sea level coinciding with the advancing and retreating ice sheets.

Terrestrial fossils of the Pleistocene Epoch have been found on the continental shelf off Long Island.

e. Modern glaciers preserve samples of the atmosphere and dust from the distant past. Modern studies of current glaciers are used to investigate prehistoric conditions on our planet.

Air samples, pollen, dust and meteorites are regularly collected from the surface and deep within (core samples) major glaciers.

f. The Ice Ages left an abundance of sand and gravel as a natural resource. Sand and gravel are our most economically important geological resource in New York State.

g. The Finger Lakes were formed by glaciation.

UNIT IV: LANDFORMS AND TOPOGRAPHIC MAPS

UNIT IV: LANDFORMS AND TOPOGRAPHIC MAPS

1. Understand how landscapes are classified
2. Identify NYS landscape regions
3. Interpret and apply isolines on topographic maps
4. Draw profiles of topographic maps, calculate gradient and draw isolines
5. Define uplift and leveling events
6. Compare/contrast bedrock structure for mountains, plateaus and plains
7. Explain the effect of climate on landscape development
8. Identify the main watersheds/drainage basins of NYS and the USA
9. How does human population growth affect pollution
10. Discuss efforts to restore the environment

1. Understand how landscapes are classified

a. Landscapes are areas of land that are recognized by their features (rugged, rolling, mountainous, flat, high, low-lying, etc.).

b. Mountains (Highlands)- at least 300 meters above the surrounding land.

c. Plateaus (Uplands)- large areas of flat land at high elevation.

d. Plains (Lowlands)- large areas of flat land at low elevations.

e. Landforms are the result of the interaction of tectonic forces and the processes of weathering, erosion, and deposition.

2. Identify NYS landscape regions (see ESRT p.2)

a. Atlantic Coastal Plain- the low, wide plain along the east coast of North America, including Staten Island and Long Island in New York…

horizontal sedimentary rocks; near sea level; Long island consists of glacial deposits; waves and ocean currents have shaped the shoreline.

b. Newark Lowlands ("DINOSAUR COUNTRY" - HOME OF EAST RAMAPO CSD)- This region is composed of weak sedimentary rocks dating from the Age of Dinosaurs (Late Triassic-Early Jurassic).

Footprints of Coelophysis, a meat-eating dinosaur about three meters long, were found near Nyack in Rockland County. Dinosaur fossils have not been found in any other part of New York.

A volcanic intrusion called the Palisades Sill borders the Hudson River. Because of its greater resistance, it forms a cliff that ranges up to more than 150 meters above sea level.

c. Hudson Highlands- eroded roots of ancient Precambrian mountains; metamorphic rocks used to be sedimentary; part of the New England Highlands; northwestern Rockland County.

d. Manhattan Prong- the region underlain by metamorphic rocks in the New York City-Westchester County area.

e. Taconic Mountains- Highlands in eastern New York and western New England; highly folded and faulted metamorphic rocks.

f. Hudson-Mohawk Lowlands- covers most of Hudson and Mohawk River valleys; soft sedimentary rocks.

g. Alleghany Plateau- northern end of Appalachian Plateau; uplifted horizontal sedimentary rocks deposited in a warm shallow sea that covered much of New York State during the Late Silurian and Devonian.

h. Erie-Ontario Lowlands- low, flat areas north and west of the Alleghany Plateau; horizontal sedimentary rocks covered by many glacial deposits.

i. Tug Hill Plateau- resistant horizontal sedimentary rocks; one of the snowiest regions west of the Rocky Mountains; receives twenty feet of snow annually.

j. Adirondack Mountains- a circular region that is part of the Grenville Province; Precambrian mountains composed mostly of metamorphic rocks.

k. St. Lawrence and Champlain Lowlands- part of the Interior Lowlands that extend west through the Great Plains; mostly horizontal sedimentary rock.

I. The Catskills- a deeply eroded section of the Alleghany Plateau; not true mountains.

3. Interpret and apply isolines on topographic maps

a. The latitude-longitude system is a coordinate system using two sets of lines that make a grid covering Earth's surface.

b. Earth's coordinate system of latitude and longitude, with the equator and prime meridian as reference lines, is based upon Earth's rotation and our observation of the Sun and stars.

c. The east-west lines are parallels of latitude.

d. The north-south lines are meridians of longitude.

e. Latitude is a measurement of angular distance north or south of the equator.

f. Longitude is a measurement of angular distance east or west of the prime meridian.

g. A topographic or contour map is a map showing the elevations of a portion of the Earth's surface.

h. The contour lines on a contour map pass through points that have the same elevation.

i. Where contour lines are closely spaced, the gradient, or slope, of the surface is steep.

j. Where contour lines are widely spaced, the gradient or slope is gradual (gentle).

k. A perfectly flat area has no contour lines at all.

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I. The contour interval is the change in elevation between neighboring contour lines.

m. Every contour line encloses a definite area. There are no loose or free ends dangling in mid-air.

n. When you approach a closed contour from the outside, you are going uphill.

o. When you leave an area enclosed by a contour line, you are going downhill.

p. A contour line never crosses itself or any other contour lines. They may appear to touch on a vertical slope, cliff, or overhang.

q. Depressions in the land are shown by hachured contour lines. The hachure lines point toward the inside of the hole. A depression contour line always has the same elevation as the lower of the neighboring contour lines.

r. Contour lines point upstream when they cross a stream or river. If the V is sharp, the river valley has steep walls.

4. Draw profiles of topographic maps, calculate gradient and draw isolines

a. A profile shows the changes in elevation (ups and downs) of a line across any part of a contour map.

b. Place the edge of a sheet of paper along the line to be followed.

c. At each point where the line crosses a contour, make a mark on the edge of the paper.

d. Record the height of the contour next to its mark on the paper.

e. When all points are marked, use the vertical scale to raise each point to its proper height on the graph or lined paper.

f. Finally, draw a smooth curve connecting the points.

g. Gradient (ESRT p. 1) can be calculated by dividing the difference in elevation by the distance between the two points where the elevations were measured. (Unit=m/km)

h. Contour lines (isolines connecting points of equal elevation) can be drawn on a map by following the contour line rules above (3.g.-3.q.)

5. Define uplift and leveling events

a. Leveling or Destructional Forces- forces of weathering, erosion, and deposition, which are reducing slopes and making the surface horizontal. These forces are acting constantly to bring the land down to a uniform, flat surface.

b. Uplifting or Constructional Forces- forces, operating beneath the surface, that undo the work of leveling forces. Uplifting tends to increase elevations and also to roughen, or increase the relief of, the surface.

Ex / volcanic activity, isostasy (the vertical readjustment of the surface of the Earth due to the addition or removal of weight; the lithosphere floats on the asthenosphere as an iceberg floats on water), …

… Earthquakes, seafloor spreading and continental drift.

c. In a particular landscape, one of these forces may be dominant (occurring at a faster rate).

d. In some places, the rates of uplift and leveling may be approximately equal, and the landscape will be in a state of dynamic equilibrium…

Dynamic equilibrium is a situation in which changes are occurring, but a balance among the changes keeps the overall conditions the same.

6. Compare/contrast bedrock structure for mountains, plateaus and plains

a. Mountains usually have folded or faulted rock structure due to crustal movements.

b. Plateaus usually have horizontal rock structure that was uplifted.

c. Plains are usually formed by the deposition of sediments in horizontal layers at or below sea level.

7. Explain the effect of climate on landscape development

a. Arid (dry) landscapes- steep slopes, sharp and angular landscape features; little vegetation to hold sediments in place.

b. Humid landscapes- smoother and more rounded landscape features; sediments are better held in place by vegetation.

8. Identify the main watersheds/drainage basins of NYS and the USA

a. The land area where precipitation runs off into streams, rivers, lakes, and reservoirs is called a watershed, or drainage basin.

b. Watersheds can be identified by tracing a line along the highest elevations between two areas on a map, often a ridge.

c. Drainage basins come in all sizes, from the size of a book (think about a little depression that collects water after a rain) to thousands of square miles (the area into which water that falls drains into the Mississippi River). The Mississippi River basin covers 48% of mainland United States.

d. Divide- The ridge that separates drainage basins.

e. Continental Divide- An imaginary boundary line that runs north-south along the crest of the Rocky Mountains, separating river and drainage basins that flow west to the Pacific Ocean from those that flow east to the Atlantic Ocean.

f. New York has many watersheds: Long Island Sound Basin, Delaware River Basin, Hudson-Mohawk River Basin, Lake Champlain River Basin, St. Lawrence River Basin, Lake Ontario Basin,

… Lake Ontario Basin, Lake Erie / Niagara River Basin, Susquehanna-Chesapeake River Basin, Allegheny-Ohio River Basin (part of The Mississippi River Basin: Water from here eventually flows to the Gulf of Mexico!), etc.

g. Drainage Pattern- the geometric pattern that a stream's channels take in the landscape. These patterns are controlled by factors such as slope, climate, vegetation, and bedrock resistance to erosion.

h. Dendritic Drainage Pattern- resembles the pattern of a branching tree; forms on horizontal strata.

i. Radial Drainage Pattern- a system of streams running in all directions away from a central elevated structure, such as a volcano.

j. Trellis Drainage Pattern- nearly parallel streams occupy valleys cut in folded strata.

k. Rectangular Drainage Pattern- numerous right angle bends that develop on faulted strata.

9. How does human population growth affect pollution

a. Typically, higher populations result in more pollution.

b. The results of human activities may be beneficial at first, but the long-term affects are often harmful.

c. Excavation and agriculture often expose the surface to agents of erosion and introduce pollutants to the environment.

d. Highway construction can disrupt groundwater flow and surface drainage.

e. Man-made chemicals commonly pollute groundwater and streams.

10. Discuss efforts to restore the environment

a. Certain measures, like contour farming (each crop row is planted across, rather than up and down, the slope, following the contours of the land)…

crop rotation (alternating, every year, which crops will grow in a certain area)...

terracing (shaping a slope with a series of “steps”. The steps allow for planting on level areas and reduce the potential for erosion across a steep slope)…

windbreaks (wind barriers of living trees and shrubs planted to block wind flow, reducing soil erosion)...

and strip cropping (a crop that leaves bare ground between rows is alternated with a crop that completely covers the ground), help minimize erosion.

b. Wastewater treatment facilities can help reclaim or protect water quality.

c. Groundwater levels can be maintained and surface runoff controlled and conserved through the use of such devices as recharge basins, dams, and stream bank protectors.

d. Sanitary landfill methods can help reduce the negative effects of solid-waste disposal, and can be used to reclaim unusable areas for recreational purposes.

UNIT V: EARTH'S HISTORY

UNIT V: EARTH'S HISTORY

1. Learn to sequence and correlate rocks using such rules as superposition, original horizontality, cross cutting relationships, included fragments, etc.
2. Recognize unconformities, their formation and significance.
3. Describe the processes of fossil formation.
4. Understand how to interpret paleoclimate and environment from fossil evidence.
5. Locate and interpret the fossil record and geologic history of New York State using the ESRT.
6. Understand that geologic time is determined by the fossil record.
7. Understand that fossils reveal the process of evolution.
8. Explain the significance of index fossils and volcanic ash in correlation.
9. Understand that unconformities reveal an incomplete rock record.
10. Understand that subsidence/ submergence leads to deposition; uplift/emergence leads to erosion.
11. Explain how radioactive decay causes heating in the earth's interior.
12. Using the ESRT, understand half-life as a tool for measuring actual age.
13. Explain how the age of the earth has been determined.
14. Know the evidence of past tectonic activity and interpret the sequence of plate motions using the ESRT.

1. Learn to sequence and correlate rocks using such rules as superposition, original horizontality, cross cutting relationships, included fragments, etc.

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a. Relative dating is an attempt to put geologic events or structures into proper chronological order.

b. The Principal of Uniformitarianism states that the geologic processes that occurred in the past are basically the same as those that are occurring now.

c. Original Horizontality- sedimentary rocks generally form in horizontal layers, with new layers forming on top of existing layers.

d. The Principle of Superposition states that the bottom layer of a series of sedimentary layers is oldest, unless the series has been overturned or has had older rock thrust over it.

e. Rock layers are older than igneous intrusions that cut through them or igneous extrusions that are above them.

f. Rocks are older than faults, joints, folds, or veins that appear in them.

g. Fragments of unmelted material occurring within a rock are older than the rock.

h. In sedimentary rocks, the sediments are older than the cements (matrix) that bind them and the rock formation itself.

i. Correlation is the process of showing that rocks or geologic events occurring at different locations are of the same age.

j. In correlation, rock layers may be traced from one location to another directly by “walking the outcrop,” thus showing the continuity of layers.

k. Rocks may be correlated on the basis of similarities in appearance, composition, and position in relation to other layers.

2. Recognize unconformities, their formation and significance.

a. An unconformity is a buried erosional surface.

b. Where the surface has been eroded away, there is a gap, in the rock layer.

3. Describe the processes of fossil formation.

a. Fossils are the remains or impressions of ancient plants and animals.

b. Petrification- the process of turning plant material into stone by infiltration with water carrying mineral particles without changing the original shape; ex / petrified wood

c. Carbonization- the weight of the sediments squeezes out the water and gas from plant matter and leaves an imprint of carbon.

d. Impressions- molds; ex/ indentations left behind in mud

e. Casts- a replica of an organism created when minerals use the organism as a mold to create the replica. For example, a shell fills with minerals, the shell dissolves away and the cast (inside of the shell) is left behind.

f. Preservation in amber- a hard, translucent, yellow, orange, or brownish-yellow fossil resin.

Formed from hardened sap, resin, or gum from conifers (ex/pine trees); amber is a valuable fossil record of ancient plants and animals - many species have been found trapped inside amber chunks dating over hundred of millions yrs old.

g. Tracks- ex/ footprints

h. Burrows- tunnels or holes that small animals dig in the ground; an excellent last name.

i. Fossils are found in sedimentary rocks.

j. The special conditions that favor preservation are rapid burial and the possession of hard parts such as shells, bones, or teeth.

4. Understand how to interpret paleoclimate and environment from fossil evidence.

a. Fossils in rocks provide information about the environment in which they formed.

b. Animals and plants that live in the ocean are very different from those that live on land. The same is true for fossils of ancient life forms.

c. The presence of marine fossils at high elevations indicates that uplift has occurred.

d. The presence of shallow water marine fossils at great depths indicates that subsidence has occurred.

e. The presence of fossil coral indicates that there was once a shallow tropical sea. Coral needs warm, shallow, clear, salty water to live (not too salty).

5. Locate and interpret the fossil record and geologic history of New York State using the ESRT (pages 2,3,8 and 9).

a. You should be able to determine the age the rocks at any location in NY.

b. You should be able to determine where specific fossils may be found in NY.

c. You should be able to determine when important geologic events occurred in NY.

6. Understand that geologic time is determined by the fossil record.

a. Long before geologists had the means to recognize and express time in numbers of years before the present, they developed the geologic time scale.

b. Geologists have divided the Earth's history into time units based upon the fossil record. These units of time often begin and end with major extinctions.

c. The geologic time scale is commonly presented in chart form, with the oldest time and event at the bottom and the youngest at the top.

d. Units of time, from largest to smallest: Eons, Eras, Periods, Epochs.

e. The largest units of the geologic time scale are called eons. Together, the Archean (Greek “ancient”) and Proterozoic (Greek “earlier life”) are commonly referred to as the Precambrian. The Phanerozoic (Greek “visible life") began about 544 million years ago.

f. The Phanerozoic eon is divided into the following eras: Paleozoic ("ancient life"), Mesozoic ("middle life" – Age of Reptiles), and Cenozoic ("recent life").

g. Periods:

Quaternary Period and Tertiary Period- The several geologic eras were originally named Primary, Secondary, Tertiary, and Quaternary.

The first two names are no longer used. Tertiary and Quaternary have been retained but used as period designations.

Neogene- An Age of Grasses

Paleogene- The Early Age of Mammals

Cretaceous- New Dinosaurs - Flowering Plants - Derived from Latin word for chalk (creta) and first applied to extensive deposits that form white cliffs along the English Channel.

Jurassic Period- The Triumph of the Dinosaurs- Named for the Jura Mountains, located between France and Switzerland, where rocks of this age were first studied

Triassic Period- Taken from the word “trias” in recognition of the three distinct layers within these rocks in Germany.

Permian Period- Named after the province of Perm, Russia, where these rocks were first studied.

Carboniferous- means "coal bearing." It is the age of great forests.

Pennsylvanian Period- Named for the State of Pennsylvania where these rocks have produced much coal.

Mississippian Period- Named for the Mississippi River Valley where these rocks are well exposed.

Devonian Period- "the age of fishes" Named after Devonshire, England, where these rocks were first studied.

Silurian and Ordovician Periods- Named after Celtic tribes, the Silures and the Ordovices that lived in Wales during the Roman Conquest.

Cambrian Period- Taken from the Roman name for Wales (Cambria) where rocks containing the earliest evidence of complex forms of life were first studied.

h. If you pretend that Earth's history took place in a single day, each minute on this twenty-four hour clock would represent about 3 million years:

Midnight (4.6 billion years ago) — Earth forms from cosmic dust

3:20 A.M. (3.96 billion years ago) — age of oldest rock ever found

9:23 P.M. (500 million years ago) — first animals with backbones

11:00 P.M. (190 million years ago) — age of the dinosaurs

11:35 P.M. (80 million years ago) — Rocky Mountains start to form

11:58 P.M. (6 million years ago) — small stream begins carving Grand Canyon

11:59 P.M. and 26 sec.
(1.8 million years ago) —
earliest humans appear

11:59 P.M. and 45 sec.
(750 thousand years ago)
— humans begin using fire

11:59 P.M. and 59 sec. (20 thousand years ago) — last Ice Age

i. You should be able to date rocks based upon the fossils within them using the ESRT.

7. Understand that fossils reveal the process of evolution.

a. If we begin at the present and examine older and older layers of rock, we will come to a level where no fossils of humans are present.

b. If we continue backwards in time, we will successively come to levels where no fossils of flowering plants are present, no birds, no mammals, no reptiles, no four-footed vertebrates, no land plants, no fishes, no shells, and no animals.

c. Evolution- the process by which all forms of plant and animal life change slowly over time because of slight variations in the genes that one generation passes down to the next…

Living beings have changed through time and older species are ancestors of younger ones.

d. The pattern of evolution of life-forms on Earth is at least partially preserved in the rock record.

e. Fossil evidence indicates that a wide variety of life-forms has existed in the past and that most of these forms have become extinct.

f. Human existence has been very brief compared to the expanse of geologic time.

8. Explain the significance of index fossils and volcanic ash in correlation.

a. Index fossils are the remains or imprints of organisms that existed for a relatively short period of time, but were widely distributed over the Earth. They identify and date the layers in which they are found.

b. Layers of volcanic ash in rock can be useful in correlation because they were deposited over a large area in a very short period of time.

c. An excess of the element iridium, discovered in a layer of rocks formed at the end of the Cretaceous period 65 million years ago, suggests that an asteroid struck the Earth at that time.

The consequences of the impact may have played a role in the Cretaceous extinctions. This layer, called the K-T Boundary, can be used to correlate rock layers.

9. Understand that unconformities reveal an incomplete rock record.

a. If rock layers are eroded away, there is a gap in the rock record.

b. Information is missing where unconformities are found.

10. Understand that subsidence/ submergence leads to deposition; uplift/emergence leads to erosion.

a. When land subsides (lowers) or submerges (drops under water), deposited sediments usually begin to build up.

b. The presence of sedimentary rocks indicates that subsidence or submergence has occurred in the past.

c. When rocks are uplifted out of the water (emergence), they are exposed to the agents of weathering and erosion.

d. The presence of erosion or an unconformity indicates that the crust uplifted/emerged in the past.

11. Explain how radioactive decay causes heating in the Earth's interior.

a. Most of Earth's internal heat is created by the decay of radioactive elements that were trapped in the interior when the Earth first formed.

These elements (for example Uranium, Thorium, Cesium and many others) spontaneously split apart into smaller elements and release energetic particles in a nuclear process called fission.

The energetic particles released by fission collide with other atoms and produce heat.

b. The Earth can be thought of as a giant fission battery that is slowly running down as it uses up its original charge of radioactive elements.

Eventually (in a couple of billion years), the Earth's interior will cool and the planet will become geologically dead - as the Moon is today.

12. Using the ESRT, understand half-life as a tool for measuring actual age. (see ESRT p.1)

a. Some rocks contain elements with atomic nuclei that undergo spontaneous decay (decrease of a radioactive substance).

b. An unstable radioactive isotope, called the parent, will decay and form stable daughter products.

c. The length of time for one-half of the nuclei of a radioactive isotope to decay is called the half-life of the isotope.

d. If the half-life of the isotope is known, and the parent/daughter ratio can be measured, the age of a sample can be calculated. A table of half-lives of commonly used radioisotopes is in the Reference Tables.

e. The absolute age of a rock can be determined from the relative amounts of a radioisotope and its decay product.

f. Each radioactive isotope has unique properties and uses. Carbon-14, the radioactive isotope of carbon that is absorbed by living matter, is used to date very recent events. It can only be used to date thing that were once living, recently.

g. Other elements occur in igneous and metamorphic rocks.

h. Since sedimentary rocks contain pieces of other rocks, they are difficult to date radioactively.

13. Explain how the age of the Earth has been determined.

a. The oldest known rocks on Earth have been dated radiometrically at 3.96 billion years, and the oldest individual crystals at 4.3 billion years.

b. Scientists believe that the Earth is older than this, but that more ancient rocks did not survive the molten conditions that prevailed after the planet's birth.

c. The oldest Moon rocks have been dated at about 4.5 billion years, and the oldest meteorites at 4.5 to 4.6 billion years.

d. On the basis of these results, along with calculations concerning radioisotopes in meteorites and in the Earth, scientists have concluded that the entire Solar System, including Earth and all the other planets, formed about 4.6 billion years ago.

14. Know the evidence of past tectonic activity and interpret the sequence of plate motions using the ESRT. (ESRT p.9)

UNIT VI/A: METEOROLOGY – ATMOSPHERIC VARIABLES

UNIT VI/A: METEOROLOGY – ATMOSPHERIC VARIABLES

1. Explain how outgassing formed the earth's original atmosphere and how it evolved through time.
2. Describe the various temperature zones of the atmosphere and be able to interpret the ESRT chart/graph on the atmosphere.
3. Understand and interpret the various temperature scales using the ESRT.
4. Understand that the sun is the earth's main energy source.
5. Understand how a barometer measures air pressure.
6. Describe how temperature, humidity and altitude affect air pressure.
7. Explain the relationship between uneven heating, density differences and convection.
8. Explain that winds blow from high to low pressure and how the earth's rotation/coriolis effect affects the motion of winds.
9. Explain how pressure gradient affects wind speed.
10. Explain the function of an anemometer and a wind vane.
11. Explain how evaporating water affects humidity.
12. Use a sling psychrometer and the ESRT to determine relative humidity and dew point.
13. Explain how changes in humidity affect air pressure.
14. Define condensation and understand the concept of saturation.
15. Explain the factors cloud formation.
16. Compare and contrast the formation of clouds, fog, dew and frost.
17. Construct and interpret isotherms, isobars and station models.

1. Explain how outgassing formed the Earth's original atmosphere and how it evolved through time.

a. Earth's primitive atmosphere probably consisted of such gases as water vapor, carbon dioxide, nitrogen, and several trace gases that were released in volcanic emissions, a process called outgassing.

b. The first life forms on Earth, probably anaerobic bacteria, did not require oxygen.

c. As life evolved, plants, through the process of photosynthesis, used carbon dioxide and water and released oxygen into the atmosphere.

d. Once the available iron on Earth was oxidized (combined with oxygen), substantial quantities of oxygen accumulated in the atmosphere.

e. About 4 billion years into Earth's existence, the fossil record reveals abundant ocean-dwelling organisms that require oxygen to live.

2. Describe the various temperature zones of the atmosphere and be able to interpret the ESRT chart/graph on the atmosphere.

a. Weather is the state of the atmosphere at a particular place for a short period of time.

b. Climate, on the other hand, is a generalization of the weather conditions of a place over a long period of time.

c. The most important elements, those quantities or properties that are measured regularly, of weather and climate are…

1) air temperature, 2) humidity, 3) type and amount of cloudiness, 4) type and amount of precipitation, 5) air pressure, and 6) the speed and direction of the wind.

d. If water vapor, dust, ozone, and other variable components of the atmosphere were removed, clean, dry air would be composed almost entirely of nitrogen (N_2), about 78% of the atmosphere by volume, and oxygen (O_2), about 21%.

e. Carbon dioxide (CO_2), although present in minute amounts (0.036%), is important because it has the ability to absorb heat radiated by Earth, thus aiding atmospheric warming.

f. Among the variable components of air, water vapor is very important because it is the source of all clouds and precipitation and, like carbon dioxide, it is also a heat absorber.

g. Ozone (O_3), the triatomic form of oxygen, is concentrated in the 10- to 50-kilometer altitude range (Stratosphere) of the atmosphere, and…

is important to life because of its ability to absorb potentially harmful ultraviolet radiation from the Sun.

h. Because the atmosphere gradually thins with increasing altitude, it has no sharp upper boundary but simply blends into outer space.

i. Based on temperature, the atmosphere is divided vertically into four layers.

j. The troposphere is the lowermost layer. In the troposphere, temperature usually decreases with increasing altitude. The rate is variable, but averages about 6.5°C per kilometer (3.5°F per 1000 feet).

Essentially all important weather phenomena occur in the troposphere.

k. Above the troposphere is the stratosphere, which exhibits warming because of absorption of ultraviolet radiation by ozone.

l. In the mesosphere, temperatures again decrease.

m. Upward from the mesosphere is the thermosphere, a layer with only a minute fraction of the atmosphere's mass and no well-defined upper limit.

n. The boundaries or zones of transition between the layers are the tropopause, stratopause, and mesopause.

o. You should be able to determine the altitude, temperature, atmospheric pressure, and water vapor concentration within the layers of the atmosphere (ESRT p. 14).

3. Understand and interpret the various temperature scales using the ESRT (p.13).

a. Fahrenheit (°F)- A temperature scale on which water freezes at 32°F and water boils at 212°F at sea level;

$$°F = (°C \times 1.8) + 32$$

b. Celsius (°C)- A temperature scale having the freezing point of pure water at 0°C and the boiling point at 100°C at sea level

$$°C = (°F - 32) \div 1.8$$

c. Kelvin (K)- A temperature scale used in science to measure extremely cold temperatures.

The Kelvin temperature scale is just like the Celsius scale except that the freezing point of water, zero degrees Celsius, is equal to 273 K.

Absolute zero, the coldest known temperature, is reached at 0 K. There is no degree (°) symbol used with the Kelvin scale.

$$K = °C + 273$$

4. Understand that the Sun is the Earth's main energy source.

a. Radiation from the Sun is the chief source of energy for the atmosphere.

b. When energy from the Sun reaches Earth's surface, the energy is absorbed, heating the surface.

c. The Earth's surface then reradiates the energy into the atmosphere, heating it.

d. The general drop in temperature with increasing altitude in the troposphere supports the fact that the atmosphere is heated from the ground up.

5. Understand how a barometer measures air pressure.

a. Barometric pressure is the pressure exerted by the atmosphere (weight of the atmosphere) at a given point. Its measurement can be expressed in millibars (mb), or in inches of mercury. Also known as atmospheric pressure.

b. A barometer is an instrument used to measure atmospheric pressure.

c. A standard mercury barometer has a glass column about 30 inches long, closed at one end, with a mercury-filled reservoir.

Mercury in the tube adjusts until the weight of the mercury column balances the atmospheric force exerted on the reservoir.

High atmospheric pressure forces the mercury higher in the column. Low pressure allows the mercury to drop to a lower level in the column.

d. An aneroid barometer uses a small, flexible metal box called an aneroid cell. The box is tightly sealed after some of the air is removed, so that small changes in external air pressure cause the cell to expand or contract.

e. Decreasing air pressure often brings warm and unsettled or rainy weather. The movement of low pressure into an area can be associated with overcast skies and possible precipitation.

f. If pressure is rising, the weather is clearing up.

6. Describe how temperature, humidity and altitude affect air pressure.

a. As air cools down, it contracts. The air molecules move closer together, and the air becomes denser. Therefore, cooler air is heavier and causes higher air pressure. COLD AIR SINKS.

b. As air heats up, it expands. The air molecules move farther apart, and the air becomes less dense. Therefore, warmer air is lighter and causes lower air pressure. WARM AIR RISES.

c. Since moist air is less dense (lighter) than dry air, an increase in humidity generally results in lower air pressure.

(A water molecule has an atomic mass of 18. An air molecule has an atomic mass of approximately 28. When a water molecule replaces an air molecule, the air becomes lighter.)

d. As you move higher into the atmosphere, air pressure decreases. Although the weight of the air pulls it down, the pressure of the atmosphere is exerted in all directions.

7. Explain the relationship between uneven heating, density differences and convection.

a. Dark and rough surfaces are excellent absorbers of energy, and heat up more quickly than lighter, smoother surfaces that reflect sunlight.

b. The land heats up and cools down much more quickly than water.

c. Specific heat- the amount of heat (number of calories) required to raise the temperature of one gram of substance one degree Celsius (see ESRT p.1). A calorie is a unit of heat energy.

To raise the temperature of one gram of water one degree Celsius, one calorie of heat must be added to the water. The unit for specific heat is (calories / gram x C°).

Water gains energy during melting (+80 calories/gram) and evaporation (+540 calories/gram), and releases energy during freezing (-80 calories/gram) and condensation (-540 calories/gram).

d. Water (as a liquid) has a higher specific heat than land. This means that it takes more energy to raise the temperature of water. Water heats up slowly.

e. Air is heated mostly by the surface beneath it. Most sunlight passes through the air without changing its temperature much.

f. Air over the land will heat up faster during the day, and cool faster during the night.

g. Air over the water will heat up slowly during the day, and cool slowly at night.

h. Warm (lower density) air rises. Cool (higher density) air sinks. This is due to the difference in their densities. Oil floats on water since oil is less dense.

i. Convection- the transfer of heat through a liquid or gas by the actual movement of the liquid or gas; updrafts (warm air rising) and downdrafts (cool air sinking) occur due to convection in an unstable atmosphere.

8. Explain that winds blow from high to low pressure and how the Earth's rotation/coriolis effect affects the motion of winds.

a. Wind is the horizontal movement of air over Earth's surface.

b. Winds are named by where they are coming from.

c. If you poke a hole in a new bottle of soda, the soda squirts out of the bottle, from an area of high pressure (inside) to an area of lower pressure (outside). Once the pressure inside the bottle is equal to the pressure outside the bottle, the soda stops squirting.

d. If a window in a high-flying airplane is broken, air rushes out of the airplane, from an area of high pressure (inside) to an area of lower pressure (outside).

e. Wind always blows from regions of higher pressure to regions of lower pressure. “Winds blow from high to low.”

f. Coriolis Effect- the effect of the Earth's rotation on the atmosphere and on all objects on the Earth's surface including bodies of water.

In the northern hemisphere it causes moving objects and currents to be deflected to the right; in the southern hemisphere it causes deflection to the left.

g. Example- Imagine a spinning disk (like a CD or DVD). If you scratched a line from the center to the edge while the disk was spinning, the resulting line would be curved.

h. Example- A missile is launched from the North Pole. As it heads south, the Earth turns to the east, causing the missile to appear to deflect to the west as viewed by an Earthbound observer.

9. Explain how pressure gradient affects wind speed.

a. Pressure gradient- the change in atmospheric pressure between two points. The greater the change (the larger the difference) in pressure between these two points, the stronger the pressure gradient and the stronger the wind.

b. Strong pressure gradient: If city A has very high pressure, and city B has very low pressure, the wind will blow very quickly from city A to city B.

c. Weak (gentle) pressure gradient: If the air pressure at city A is just a little greater than the air pressure at city B, the wind will blow from city A to city B slowly.

10. Explain the function of an anemometer and a wind vane.

a. Anemometer- An instrument used to measure wind speed. An anemometer usually has four cups placed at the ends of two intersecting rods. As the wind blows, the cups catch the wind and cause the cups to spin.

The faster the wind is blowing, the greater the spinning of the anemometer. Wind speed is measured in miles per hour and knots (nautical miles per hour).

One knot equals 1.15 mi/hr (ESRT p.13).

by Charles A. Burrows

b. Wind vane- an instrument that determines the direction from which a wind is blowing. The part of the vane that turns into the wind is usually shaped like an arrow. The other end is wide so it will catch the smallest breeze.

The breeze turns the arrow until it catches both sides of the wide end equally. The arrow always points into the wind. The arrow tells you the direction from which the wind is coming.

11. Explain how evaporating water affects humidity.

a. Evaporation- liquid changes to gas

b. Condensation- gas changes to liquid

c. Melting- solid changes to liquid

d. Freezing- liquid changes to solid

e. Sublimation- solid changes directly to gas

f. Deposition (or sublimation)- gas changes directly to solid

g. Humidity is the general term used to describe the amount of water vapor in the air.

h. Relative humidity- how "full" the air is with water vapor; the ratio (expressed as a percent) of the air's water vapor content to its water vapor capacity at a given temperature; the most familiar term used to describe humidity.

i. The water vapor capacity (how much it can hold) of air depends on temperature, with warm air having a much greater capacity than cold air.

Antarctica is the biggest desert because the air is so cold, and therefore, so dry. If the air is hot, like daytime in the Sahara Desert, it CAN hold a lot of moisture, but may not be holding much at all.

j. Relative humidity can be changed in two ways. One is by adding (evaporation) or subtracting (condensation) water vapor to or from the air.

k. The second is by changing the air's temperature. When air is cooled, its relative humidity increases. Cooling air often leads to condensation, which creates clouds and fog.

This is why air conditioners drip.

Heating air has the opposite effect. When air is heated, relative humidity decreases. This is why the air can get so dry indoors during the winter.

l. Air is said to be saturated when it contains the maximum quantity of water vapor that it can hold at any given temperature and pressure. When air is saturated, relative humidity is 100%.

m. Dewpoint is the temperature to which air would have to be cooled in order to reach saturation (100% relative humidity).

12. Use a sling psychrometer and the ESRT to determine relative humidity and dewpoint.

a. Sling psychrometer- an instrument used to measure the water vapor content of the atmosphere, in which wet and dry bulb thermometers are mounted on a frame connected to a handle at one end.

The psychrometer is whirled by hand to provide the necessary ventilation to evaporate water from the wet bulb.

b. Dry bulb- a normal thermometer that measures air temperature.

c. Wet bulb- a thermometer, with the thermometer bulb wrapped in cloth, which is kept wet.

The evaporation of water from the thermometer has a cooling effect, so the temperature indicated by the wet bulb thermometer is less than the temperature indicated by a dry-bulb thermometer.

d. The rate of evaporation from the wet-bulb thermometer depends on the humidity of the air - evaporation is slower when the air is already full of water vapor.

For this reason, the difference in the temperatures indicated by the two thermometers gives a measure of atmospheric humidity.

e. If the air is completely saturated with water vapor (100% relative humidity), no water will evaporate from the wet-bulb, and the two temperatures (wet- and dry- bulb) will be the same.

f. Don’t ignore the word “DIFFERENCE” on the charts on page 12 in the ESRT! These charts can be used to determine relative humidity and dewpoint.

To use the charts, find the difference on top, and the dry-bulb temperature on the left. Go down from the difference and across from the dry-bulb temperature to where the column meets the row. There should be ONE number where they meet.

13. Explain the factors cloud formation.

a. For condensation to occur, air must be saturated.

b. Saturation takes place either when air is cooled to its dewpoint, which most commonly happens, or when water vapor is added to the air.

c. There must also be a surface on which the water vapor may condense. In cloud and fog formation, tiny particles called condensation nuclei (microscopic particles of dust, smoke or salt) serve this purpose.

d. The cooling of air as it rises and expands is the basic cloud-forming process.

e. If air rises high enough, it will cool sufficiently to cause condensation and form a cloud.

f. The condensing water vapor releases heat, thereby reducing the rate at which the air cools.

g. Four ways that clouds can form from rising air:

Orographic lifting- occurs when elevated terrains, such as mountains, act as barriers to the flow of air. As air blows up the side of a mountain, it cools, reaching the dewpoint and forming clouds.

Frontal wedging- when cool air acts as a barrier over which warmer, less dense air rises. A warm air mass always rises up and over a cooler air mass. The warm air cools and reaches the dewpoint, forming clouds.

Convergence- when air flows together and a general upward movement of air occurs. The rising air cools to the dewpoint, forming clouds.

Convection- when unequal surface heating causes localized pockets of air to rise. The rising air cools to the dewpoint, forming clouds.

14. Explain how precipitation occurs.

a. For precipitation to form, millions of cloud droplets must somehow join together (coalesce) into large drops.

b. In clouds where the temperatures are below freezing, ice crystals form and fall as snowflakes. At lower altitudes the snowflakes melt and become raindrops before they reach the ground.

c. Large droplets form in warm clouds that contain large condensation nuclei, such as salt particles. As these big droplets descend, they collide and join with smaller water droplets. After many collisions the droplets are large enough to fall to the ground as rain.

d. Precipitation cleans the atmosphere by bringing down condensation nuclei and other suspended material.

e. Precipitation gauge- an instrument used to measure the amount of rain that has fallen. Measurement is often done in hundredths of inches (0.01").

f. Rain- Precipitation in the form of liquid water droplets greater than 0.5 mm.

g. Drizzle- Small, slowly falling water droplets, with diameters less than 0.5 mm.

h. Snow- precipitation falling from clouds in the form of ice crystals. A snowflake forms first as a very tiny crystal, that grows to become a larger six-sided hexagonal crystal.

i. Sleet- Raindrops that freeze into ice pellets before reaching the ground. It forms when snow enters a warm layer of air above the surface and melts and then enters a deep layer of sub-freezing air near the surface and refreezes.

j. Hail- falling ice in roughly round shapes. Hail comes from thunderstorms and is larger than sleet. Hailstones form when upward moving air (updrafts) in a thunderstorm keeps pieces of ice from falling.

Drops of supercooled water hit and freeze to the falling ice, causing it to grow.

If the currents are strong enough, a hailstone will fall and rise many times, causing several layers of ice to build up until the hailstone is heavy enough to fall from the cloud.

15. Compare and contrast the formation of clouds, fog, dew and frost.

a. Cloud- a visible group of tiny water and/or ice particles in the atmosphere.

b. Fog- a cloud on the ground. Fog is composed of billions of tiny water droplets floating in the air.

c. Smog- air pollution by a mixture of smoke and fog.

d. Dew- condensation in the form of small water drops that forms on grass and other small objects near the ground when the temperature has fallen to the dewpoint, generally during the nighttime hours.

e. Frost- Deposits of white ice crystals or frozen dew drops on objects on or near the ground. Formed when the surface temperature falls below freezing (0°C).

16. Construct and interpret isotherms, isobars and station models.

a. Weather map- a map showing the weather at a given time in a region.

b. Weather station- a location where meteorological observations are measured.

c. Station model- the listing of many different weather observations around the location of a weather station on a weather map (see ESRT p.13).

d. Isoline- a line on a map connecting points with equal value or common characteristics (e.g., rainfall intensity, temperature, barometric pressure, etc.).

e. Isotherm- an isoline connecting points of equal air temperature on a weather map.

f. Isobar- an isoline connecting points of equal air pressure on a weather map.

g. Weather variables can be represented in a variety of formats including radar and satellite images, weather maps (including station models, isobars, and fronts), atmospheric cross-sections, and computer models.

UNIT VI/B: METEOROLOGY – WEATHER MAPS, ENERGY EXCHANGES, FORCASTS

UNIT VI/B: METEOROLOGY – WEATHER MAPS, ENERGY EXCHANGES, FORCASTS

1. Explain how source regions influence air mass characteristics.
2. Identify air mass symbols on a weather map using the ESRT and explain how air masses move.
3. Understand that fronts form where air masses meet.
4. Compare and contrast the characteristics of cold, warm, stationary and occluded fronts.
5. Compare and contrast movement of air in regions of high and low pressure.
6. Recognize the patterns of isobars and isotherms in highs and lows.
7. Describe the arrangement of fronts and air masses in a typical low pressure system.
8. Describe the frontal weather and patterns of movement.
9. Predict future weather for any location within a mid-latitude cyclone.
10. Explain the seasonal nature of hurricane formation.
11. Explain the role of condensation/latent heat in hurricane sustenance.
12. Explain how hurricanes lose and gain energy.
13. Understand storm tracks of hurricanes.
14. Compare and contrast hurricanes and tornadoes.

1. Explain how source regions influence air mass characteristics.

a. An air mass is a large body of air, usually 1600 kilometers (1000 miles) or more across, which is characterized by a sameness of temperature and moisture at any given altitude.

b. When this air moves out of its region of origin, called the source region, it will carry these temperatures and moisture conditions elsewhere, perhaps eventually affecting a large portion of a continent.

c. Air masses are classified according to:

1) the nature of the surface (water or land) in the source region.

2) the latitude of the source region.

d. Continental (c) designates an air mass of land origin, with the air likely to be dry; whereas a maritime (m) air mass originates over water, and therefore will be relatively humid.

e. Tropical (T) air masses form in low latitudes and are warm. Polar (P) air masses originate in high latitudes and are cold. Arctic (A) air masses originate in the Polar Regions and are very cold.

f. According to this classification scheme, the five basic types of air masses are continental polar (cP), continental arctic (cA), continental tropical (cT), maritime polar (mP), and maritime tropical (mT).

g. Continental polar (cP) air masses from Canada, and maritime tropical (mT) air masses from the Gulf of Mexico influence the weather of North America most.

h. Maritime tropical air is the source of much, if not most, of the precipitation received in the eastern two-thirds of the United States.

i. You should be able to identify air mass symbols on a weather map (ESRT p.13).

j. Arctic and polar air masses usually move southeast over America.

k. Tropical air masses usually move northeast over America.

I. Air masses move in the direction of the planetary winds and jet streams (ESRT p.14).

m. Jetstream- An area of strong winds that are concentrated in a relatively narrow belt in the upper troposphere of the Northern and Southern Hemispheres.

Jetstreams flow in a band around the globe from west to east. Jetstreams form the dividing lines between warm tropical air masses and cold polar air masses, and they steer global weather systems.

2. Understand that fronts form where air masses meet.

a. Front- the leading edge of an advancing air mass.

b. When a cold air mass (cP, cA, or mP) moves towards a warm air mass (mT or cT), the warm air mass is forced to rise.

c. When a warm air mass moves towards a cold air mass, the warm air mass is forced to rise up and over the cold air mass.

d. Cold air is denser, so the warm air mass is always the one forced up and over colder air.

3. Compare and contrast the characteristics of cold, warm, stationary and occluded fronts (ESRT p.13).

a. Cold front- The leading edge of a quickly (averaging 30 mph) advancing cold air mass that is moving under, and displacing, the warmer air in its path.

Generally, with the passage of a cold front, the temperature and humidity decrease. Showers, thunderstorms, and sometimes hail generally occur at and/or behind the front.

b. Squall line- a line of sudden, sometimes violent thunderstorms that develop along the leading edge of a cold front, often hundreds of kilometers long.

c. Warm front- the leading edge of a slowly (averaging 15 mph) advancing warm air mass that is rising up and over a retreating relatively colder air mass.

Generally, with the passage of a warm front, the temperature and humidity increase. Precipitation, in the form of light rain, snow, or drizzle, is generally found ahead of the front, and may last for one to two days.

d. Stationary front- the boundary between two air masses that are not moving (moving less than 6 mph).

Also: two air masses are sliding past each other, in parallel paths, and the boundary between them is not moving. May last for several days.

e. Occluded front: when a cold front catches up with a warm front. It develops when three different air masses come together: A warm air mass is pinched between a cold and a cool air mass. The warm air mass is lifted completely off of the ground.

f. Thunderstorms are caused by the upward movement of warm, moist, unstable air, associated with frontal lifting.

g. Often, with the passage of a front, the pressure will decrease then increase, and there will be a sharp change in the wind direction.

4. Compare and contrast movement of air in regions of high and low pressure.

a. High pressure: cool, sinking air, diverging (moving away from the center) at Earth’s surface, rotating clockwise north of the equator.

b. Low pressure: warm, rising air, converging (moving towards the center) at Earth's surface, rotating counterclockwise.

5. Recognize the patterns of isobars and isotherms.

a. Isobar values increase towards the center of a high. Pressure is greatest at the center of a high.

b. Isobar values decrease towards the center of a low. Pressure is lowest at the center of a low.

c. Isotherms generally increase in value towards lower latitudes. Earth is warmest near the equator.

d. Isotherms generally decrease in value towards higher latitudes. Earth is coldest near the poles.

6. Describe the arrangement of fronts and air masses in a typical low pressure system.

a. The primary weather producers in the middle latitudes are large centers of low pressure that generally travel from west to east, called middle-latitude cyclones.

b. These bearers of stormy weather, which last from a few days to a week, have a counterclockwise circulation pattern in the Northern Hemisphere, with an inward flow of air toward their centers.

c. Most middle-latitude cyclones have a cold front extending to the south and a warm front extending to the east from the central area of low pressure.

d. As the cold front catches up with the warm front, an occluded front forms.

e. A typical low pressure system has a cold air mass moving eastward towards a warm air mass. The warm air mass typically moves northward towards a cooler air mass.

The warm air mass gets pinched between the cold and cool air masses, and is forced aloft.

7. Predict future weather for any location within a mid-latitude cyclone.

a. Since most mid-latitude cyclones move from west to east, locations east of the cyclone will usually experience stormy weather in the future.

b. As the different fronts approach an area, the weather will change accordingly (see 4a-f).

c. Locations near the fronts experience the stormiest weather.

d. Weather patterns become apparent when weather variables are observed, measured, and recorded.

These variables include air temperature, air pressure, moisture (relative humidity and dewpoint), precipitation (rain, snow, hail, sleet, etc.), wind speed and direction, and cloud cover.

e. Atmospheric moisture, temperature and pressure distributions; jet streams, wind; air masses and frontal boundaries; and the movement of cyclonic systems and associated tornadoes, thunderstorms, and hurricanes occur in observable patterns.

f. Loss of property, personal injury, and loss of life can be reduced by effective emergency preparedness.

8. Describe hurricanes.

a. Hurricanes, the greatest storms on Earth, are tropical cyclones with wind speeds in excess of 119 kilometers (74 miles) per hour.

b. They have diameters of 250 to 500 miles, and a calm central “eye” where air is sinking.

c. These complex tropical disturbances develop over tropical ocean waters and are fueled by the heat released when huge quantities of water vapor condense.

d. Hurricanes form most often in late summer when ocean-surface temperatures reach 27°C (80°F) or higher and thus are able to provide the necessary heat and moisture to the air.

e. Hurricanes diminish in intensity whenever they move over cool ocean water that cannot supply adequate heat and moisture, or move onto land.

f. Hurricanes usually cause the most damage where they first move over land.

g. Hurricane damage is of three types:

1) storm surge (the dome of water that builds up as a hurricane moves over water. As this water comes ashore with the storm, it causes flooding that is usually a hurricane's biggest killer

2) wind damage, and

3) inland flooding.

9. Understand storm tracks of hurricanes.

a. The hurricanes that affect us originate in the eastern tropical Atlantic Ocean near the shores of Africa.

b. They are driven westward towards the Caribbean Islands, south of America, by easterly trade winds in the tropics.

c. Eventually, these storms turn northwestward and migrate into higher latitudes.

d. As a result, the Gulf of Mexico and East Coast of the United States are at risk to experience one or more hurricanes each year.

10. Describe tornadoes.

a. Tornadoes, destructive, local storms of short duration, are violent windstorms associated with severe thunderstorms that take the form of a rotating funnel of air that extends downward from a storm cloud.

b. Tornadoes most often occur during the spring months.

c. They are most frequent in the United States, in the area between the Rockies and the Appalachians. Cold Canadian air moves southward, and meets warm Gulf air moving northward. The warm air is forced to rise very rapidly, causing tornadoes.

d. Hail is commonly produced by tornadoes.

UNIT VII: CLIMATE AND INSOLATION

UNIT VII: CLIMATE AND INSOLATION

1. Define climate.
2. Understand that global wind circulation is the result of uneven heating, density differences and the coriolis effect.
3. Identify convergent and divergent belts and planetary winds using the ESRT.
4. Define specific heat and explain the moderating effect of a nearby large body of water.
5. Explain how land breezes, sea breezes and monsoons affect climate.
6. Understand that density differences, wind and the coriolis effect cause ocean currents.
7. Explain the climate affects of warm/cold currents (El Nino, Gulf Stream).
8. Compare/contrast climate changes with altitude and latitude.
9. Explain the differences between windward and leeward climate.
10. Compare/contrast inland and coastal climates at the same latitude.
11. Define insolation and explain how its intensity and duration affects temperature.
12. Describe how daily/seasonal temperature cycles are affected by insolational variations.
13. Understand that insolation variations change with latitude.
14. Compare/contrast conduction, convection and radiation.
15. Explain why cloudy days are cool and cloudy nights are warm.
16. Compare/ contrast surfaces that absorb or reflect insolation.
17. Understand that good absorbers are good radiators.
18. Interpret the electromagnetic spectrum in the ESRT/
19. Understand that visible light is the most intense form of energy radiated by the sun.
20. List the greenhouse gases and explain their affect on global warming.
21. Understand the greenhouse affect of the absorption, conversion and reflection of insolation.

1. Define climate.

a. Climate- the average weather (usually taken over a 30-year time period) for a particular region and time period.

b. Climate is not the same as weather, but rather, it is the average pattern of weather for a particular region. (Weather describes the short-term state of the atmosphere.)

c. Climates are often described by amounts of precipitation and temperature. A location's climate is influenced by latitude, proximity to large bodies of water, ocean currents, prevailing winds, vegetative cover, elevation, and mountain ranges.

d. Temperature and precipitation patterns are altered by:

natural events such as El Niño and volcanic eruptions human influences including deforestation, urbanization, and the production of greenhouse gases such as carbon dioxide and methane.

2. Understand that global wind circulation is the result of uneven heating, density differences and the Coriolis effect.

a. Within the troposphere are six major convection cells (ESRT p.14) located at latitudes between:

0° and 30° (one north and one south)

30° and 60° (one north and one south)

60° and 90° (one north and one south)

b. Warm (low density) air at the equator rises to the top of the troposphere. This creates a band of low air pressure, centered on the equator. As the rising air cools to the dewpoint, clouds and precipitation form. This is why the tropics have so much rain.

c. At a height of about 14 km, the air begins to move horizontally to the north and south, away from the equator.

Eventually, this cooled air sinks at 30° north and south of the equator, creating two bands of high pressure. The sinking air heats up, creating very dry conditions. Most major deserts are located at these latitudes.

d. When this sinking air reaches the surface, it travels in two directions, towards the equator or towards 60° latitude. The Coriolis effect causes these surface winds to curve to the right (north of equator) or to the left (south of the equator).

e. When sinking (cold and dense) air at the poles reaches the surface, it moves away from the poles, towards 60° latitude, also curving due to the Coriolis effect.

f. At 60° latitude, surface winds from the poles and from 30° latitude converge. They are forced to rise, creating two more bands of low pressure with wet climates.

3. Identify convergent and divergent belts and planetary winds using the ESRT (p.14).

a. Zones of convergence exist on the surface at the equator and 60°. Here, the winds are coming together.

b. Zones of divergence exist on the surface at the poles and 30°. Here, the winds are moving apart.

c. Remember:

North of the equator, surface winds curve to the right. If they are blowing north, they will curve east. If they are blowing south, they will curve west.

South of the equator, surface winds curve to the left. If they are blowing north, they will curve to the west. If they are blowing south, they will curve to the east.

4. Define specific heat and explain the moderating effect of a nearby large body of water.

a. The land heats up and cools down much more quickly than water.

b. Specific heat- the amount of heat (number of calories) required to raise the temperature of one gram of substance one degree Celsius (see ESRT p.1).

c. Water (as a liquid) has a higher specific heat than land. This means that it takes more energy to raise the temperature of water. Water heats up slowly.

d. Throughout the year, the temperature of the ocean does not change as much as the temperature of the land.

e. Locations near large bodies of water usually have cooler summers and warmer winters.

f. Locations far from large bodies of water are usually hotter during the summer and colder during the winter.

5. Explain how land breezes, sea breezes and monsoons affect climate.

a. Air is heated mostly by the surface beneath it. Most Sunlight passes through the air without changing its temperature much.

b. Air over the water will heat up slowly during the day, and cool slowly at night.

c. Air over the land will heat up faster during the day, and cool faster during the night.

d. Warm (low density) air rises. Cold (dense) air sinks.

e. Convection- the transfer of heat energy within the atmosphere, the hydrosphere, and Earth's interior results in the formation of regions of different densities. These density differences result in motion.

f. Sea breeze- a local wind blowing from the sea to the shore. Cooler air from over the sea flows onto the shore to replace the warm air rising over the land.

On Sunny days the land heats up more quickly than the sea. The air in contact with the land warms and rises causing convection. During the day, clouds often form over the land where the warm air is rising and cooling to the dew point.

g. Land breeze- a local wind blowing from the land to the sea, opposite of a sea breeze.

During the night, the sea is warmer than the land. Cooler air from over the land flows out to sea to replace the warm air rising over the water. During the night, clouds often form over the sea where the warm air is rising and cooling to the dew point.

h. Monsoons are caused by a seasonal change in wind direction. Winds usually blow from land to sea in winter, while in the summer this reverses, bringing heavy precipitation.

During the winter, the land cools down quickly, causing a large area of high pressure. During the summer, the land heats up quickly, causing a large area of low pressure. Winds always blow from high to low pressure.

i. Monsoons are most typical in India and southern Asia.

For Arizona, the monsoon results in westerly winds shifting to southerly or southeasterly (winds are named by where they come from); this shift brings considerable moisture into the state from the Gulf of California and the Gulf of Mexico.

6. Understand that density differences, wind and the Coriolis effect cause ocean currents.

a. Ocean currents are basically rivers in the ocean. They move around 4 miles an hour.

b. Surface ocean currents are parts of huge, slowly moving, circular whirls, or gyres (pronounced “jires,” like tires), that begin near the equator in each ocean.

c. Currents moving away from the equator are warm. Currents moving away from the poles are cold.

d. Wind is the driving force for the ocean's surface currents. Where wind is in contact with the ocean, it passes energy to the water through friction and causes the surface layer to move.

e. The most significant factor other than wind that influences the movement of surface ocean currents is the Coriolis Effect, which causes wind (and therefore ocean currents) to be deflected to the right in the Northern Hemisphere and to the left in the Southern Hemisphere.

f. Because of the Coriolis Effect, surface currents flow clockwise in the Northern Hemisphere and counterclockwise in the Southern Hemisphere.

g. The world's oceans also have significant currents that flow beneath the surface. In contrast to surface currents, deep-ocean circulation is controlled by gravity and driven by density differences.

h. Cold water is very dense, and sinks.

i. Cold, dense water near Antarctica sinks and travels along the seafloor towards the equator, where it will eventually (500 to 2000 years) return to the sea surface.

j. Salty water is very dense, and sinks. Both the evaporation and freezing of sea water leave behind salt, increasing salinity levels and water density.

k. In the summer the Mediterranean Sea loses more water by evaporation than it gets back as rain. The salinity and density of the Mediterranean Sea increase.

As a result, deep currents of dense water flow along the sea bottom from the Mediterranean into the Atlantic Ocean. At the same time, the less salty water of the Atlantic Ocean flows into the Mediterranean at the water's surface.

7. Explain the climate affects of warm/cold currents (El Niño, Gulf Stream).

a. Ocean currents are important in navigation and travel and for the effect that they have on climates.

b. Cold currents, like the Labrador, California, and Falkland Currents, decrease air temperatures of nearby land and cause increased fog.

c. Warm currents, like the Gulf Stream, the North Atlantic, and the Kuroshio Current, warm the climates of nearby land.

d. El Niño- The term El Niño refers to a warm ocean current that typically appears around late December and lasts for several months, but may persist into May or June.

e. Starting up an El Niño event: The western Pacific Ocean warms and cools in cycles. Normally, east-to-west winds pile up warm water in the western Pacific, while cold water from deep in the ocean rises to the surface along the South American Coast.

Every few years, the trade winds change, allowing the pool of warm water to move to the east where it blocks the rising cold water. These changes help trigger the global weather changes associated with El Niño.

A strong El Niño has very noticeable effects on the USA's weather, which can range from a stormy winter along the West Coast, a wet winter across the South, and a warmer-than average winter for parts of the North.

f. La Niña- condition opposite of an El Niño. In a La Niña, the tropical Pacific trade winds become very strong and an abnormal accumulation of cold water occurs in the central and eastern Pacific Ocean.

During a La Niña year, winter temperatures are warmer than normal in the Southeast and cooler than normal in the Northwest.

g. El Niño and La Niña events tend to alternate about every three to seven years. However, the time from one event to the next can vary from one to ten years.

8. Compare/contrast climate changes with altitude and latitude.

a. Places at low latitudes (near the equator) are warm due to the high angle of insolation (incoming solar radiation).

b. Places at high latitudes (near the poles) are cold due to the low angle of insolation.

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c. Locations at high altitudes are cool. Quito, Ecuador, is a city near the equator. It has a very cool climate because it is located high in the Andes Mountains.

d. Locations at low altitudes are warm. Death Valley, California, and the Dead Sea, between Israel and Jordan, are extremely hot and dry since they are both below sea level.

9. Explain the differences between windward and leeward climate.

a. The windward side of a mountain is the side that the wind is blowing against.

b. The leeward side of a mountain is the side facing away from the wind, opposite from the windward side.

c. When wind blows towards mountains, such as the Washington Cascades, it is forced to rise.

d. When the rising air expands and cools, condensation occurs, and it rains on locations situated on the windward slopes, like Seattle, Washington.

e. When the wind blows down the leeward side of the mountain, like at Spokane, Washington, it is compressed, warming and drying it out.

f. This sinking, contracting, dry air produces a rain shadow, or area in the leeward of a mountain with less rain and cloud cover.

10. Define insolation and explain how its intensity and duration affects temperature.

a. Insolation- “IN”-coming “SOL”-ar radi-“ATION”

b. The higher the Sun is in the sky, the stronger (more intense) the sunlight is.

c. Places near the equator receive the most intense insolation.

d. At places near the poles, the Sun never rises high in the sky, so the sunlight is always weak. The Polar Regions receive the least intense insolation.

e. During the summer months, the duration, angle, and intensity of insolation are greatest.

f. Day= hot; Night= cold (no insolation)

g. Summer= hot; Winter= cold

11. Compare/contrast conduction, convection and radiation.

a. Conduction- the transfer of heat from one substance to another by direct contact (touching); the transfer is always from warmer to colder substances.

b. Convection- the transfer of heat in a fluid (such as air, water, or magma), where a warm current rises into a cool area, and a cool current descends to take its place.

Convection is driven by gravity -- warm fluids are usually lighter than denser cold fluids, and gravity drags the densest material to the bottom.

c. Radiation- the transfer of energy in the form of electromagnetic waves that can travel through the vacuum of empty space, or through anything that is transparent (air, glass, water, etc.).

electromagnetic waves: radio, microwave, infrared (heat), visible or ultraviolet, x rays or gamma rays

d. The transfer of heat energy within the atmosphere, the hydrosphere, and Earth's surface occurs as the result of radiation, convection, and conduction.

e. Heating of Earth's surface and atmosphere by the Sun drives convection within the atmosphere and oceans, producing winds and ocean currents.

12. Explain why cloudy days are cool and cloudy nights are warm.

a. Clouds block the Sunlight. Much of the solar radiation hitting the cloud is reflected back to space. When this happens, less solar radiation reaches the Earth. This makes the Earth cooler than expected.

When the daily high temperature is lower than forecasted, unexpected low thick clouds may have been the result.

b. Clear skies allow more solar radiation to reach the surface. This is why desert climates are so hot during the day. The lack of moisture results in the lack of clouds.

c. On a cloudy night, the clouds will absorb most of the infrared radiation that the surface is attempting to reradiate back into space.

They will then radiate a significant amount of this energy back to the surface. The heat is trapped in the lower atmosphere, making it warmer.

d. On clear nights there are few clouds to absorb and reradiate radiation back to the surface.

Infrared energy (heat) escapes very quickly from the atmosphere with the lack of cloud cover resulting in a cool night. (This is why desert nights are often very cold.)

13. Compare/ contrast surfaces that absorb or reflect insolation.

a. Dark and rough surfaces are excellent absorbers of insolation.

b. Light and smooth surfaces reflect more Sunlight.

c. Clouds and snow can reflect much Sunlight.

d. Albedo- the amount of light reflected from a surface.

14. Understand that good absorbers are good radiators.

a. Anything that heats up quickly cools down quickly.

b. Anything that heats up slowly cools down slowly.

15. Interpret the electromagnetic spectrum in the ESRT (p.14).

a. Electromagnetic Spectrum- the entire range of wavelengths of electromagnetic radiation extending from short gamma rays to the longest radio waves and including visible light.

b. Wavelength- the distance between two crests (high points) or troughs (low points) of a wave.

c. Short wavelength = High energy = Dangerous

d. All forms of electromagnetic energy radiate at the same speed, the speed of light: 300,000 km/s (186,000 miles per second). At the speed of light, an object could travel around the Earth almost eight times in one second.

e. Types of electromagnetic energy:

Gamma rays- a form of electromagnetic radiation with a large amount of energy. They have a large penetrating and destructive power.

X rays- wavelengths between ultraviolet and gamma rays; X-radiation can go through human skin tissue but is stopped by dense bones. This property makes X-rays valuable in medicine.

Ultraviolet- a wavelength just too small to see; light that is so blue humans can't see it; A band of the electromagnetic spectrum between the visible and the X-ray; known to damage eyes and cause skin cancer.

Visible light- visible light is the most intense form of energy radiated by the Sun. It is electromagnetic radiation at wavelengths that the human eye can see. We perceive this radiation as colors.

The Sun emits most of its radiation as visible light, which is probably why our eyes can see it. From longest to shortest: red, orange, yellow, green, blue, indigo, violet (ROY G. BIV)

Infrared- heat energy; a wavelength just too long to see; light that is so red humans can’t see it; a band of the electromagnetic spectrum between the visible and the microwave.

Microwaves- wavelength between radio waves and infrared radiation; very short radio waves. A microwave oven uses microwaves to heat food. They are absorbed by water, fats and sugars, and converted directly into atomic motion – high temperatures.

Radio waves- longest wavelength (lowest energy) electromagnetic radiation; used on Earth to communicate over large distances.

16. List the greenhouse gases and explain their affect on global warming.

a. Some greenhouse gases occur naturally in the atmosphere, while others result from human activities.

b. Naturally occurring greenhouse gases include water vapor, carbon dioxide, methane, nitrous oxide, and ozone.

c. Certain human activities, however, add to the levels of most of these naturally occurring gases:

Carbon dioxide is released to the atmosphere when solid waste, fossil fuels (oil, natural gas, and coal), and wood and wood products are burned.

Methane is emitted during the production and transport of coal, natural gas, and oil. Methane emissions also result from the decomposition of organic wastes in municipal solid waste landfills, and the raising of livestock.

Nitrous oxide is emitted during agricultural and industrial activities, as well as during combustion of solid waste and fossil fuels.

Very powerful greenhouse gases that are not naturally occurring include hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6), which are generated in a variety of industrial processes.

d. Each greenhouse gas differs in its ability to absorb heat in the atmosphere. HFCs and PFCs are the most heat-absorbent.

Methane traps over 21 times more heat per molecule than carbon dioxide, and nitrous oxide absorbs 270 times more heat per molecule than carbon dioxide.

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17. Understand the greenhouse affect of the absorption, conversion and reflection of insolation.

a. The solar energy, primarily in the form of the shorter wavelengths (visible light), which penetrates through the atmosphere, is ultimately absorbed at Earth's surface.

b. Earth releases the absorbed radiation (reradiation) in the form of long-wave radiation (infrared radiation).

c. The atmospheric absorption of this long-wave terrestrial radiation by greenhouse gases (primarily by water vapor and carbon dioxide) is responsible for heating the atmosphere.

d. This very important phenomenon has been termed the greenhouse effect.

UNIT VIII/A: THE EARTH IN SPACE – THE SOLAR SYSTEM

UNIT VIII/A: THE EARTH IN SPACE – THE SOLAR SYSTEM

1. Identify the seasonal changes in the Sun's noon altitude, positions of sunrise/sunset, and amount of daylight.
2. Recognize the path of the sun during each season at different latitudes.
3. Explain the annual migration of the sun's vertical ray as a result of revolution, tilt, and parallelism.
4. Compare and contrast the evidences of revolution and rotation.
5. Relate Earth's rate of rotation to time keeping and longitude.
6. Locate zenith, horizon, and compass directions on a celestial sphere model.
7. Locate Polaris using the Big Dipper.
8. Use the angle of Polaris to determine the observer's latitude at different locations.
9. Explain how Polaris is used as a navigational tool.
10. Explain how the Moon's rotation and revolution affects its appearance.
11. Describe the changing phases of the moon.
12. Explain why eclipses are rare events.
13. Compare and contrast solar and lunar eclipses.
14. Describe how the Moon and the Sun cause the tides.
15. Understand the size, scale, and arrangement of the members of the solar system.
16. Compare/contrast the geocentric and heliocentric models.
17. Compare/contrast terrestrial and Jovian planets.
18. Explain Newton's Law of Gravitation with respect to mass and distance.
19. Explain how distance from the Sun affects a planet's orbital velocity (Kepler's Laws).
20. Diagram elliptical orbits and analyze their eccentricities (Kepler's Laws).
21. Understand that the apparent size of the Sun changes seasonally due to the Earth's elliptical orbit.
22. Describe meteors, their origin, and cratering as an early geologic activity.
23. Describe comets, the eccentricity of their orbits, and the Oort cloud.
24. Describe the location of the asteroids and their past influence on the Earth.
25. Describe other planetary satellites/rings

1. Identify the seasonal changes in the Sun's noon altitude, positions of Sunrise/Sunset, and amount of daylight.

a. Most objects in the solar system are in regular and predictable motion.

b. These motions explain such phenomena as the day, the year, seasons, phases of the moon, eclipses, and tides.

c. Gravity influences the motions of celestial objects. The force of gravity between two objects in the universe depends on their masses and the distance between them.

d. The two principal motions of Earth are:

Rotation- the spinning of Earth about its axis, which produces the daily cycle of daylight and darkness.

Revolution- the movement of Earth in its orbit around the Sun.

e. Several factors act together to cause the seasons (The seasons ARE NOT caused by the distance between the Earth and the Sun!!!):

Earth revolves around the Sun.

Earth's axis is tilted 23.5° degrees (from the perpendicular to the plane of its orbit around the Sun).

Parallelism- The axis remains pointed in the same direction (toward the North Star) as Earth journeys around the Sun. The axis is parallel to itself at any position in Earth's orbit.

f. As a result, Earth's orientation to the Sun continually changes. Sometime the North Pole is tilted toward the Sun, and sometimes it is tilted away.

g. The yearly changes in the angle of the Sun and length of daylight brought about by Earth's changing orientation to the Sun cause seasons.

h. Summer Solstice- June 20 or 21. The Earth’s axis is tilted at its most towards the Sun, and marks the longest day and the beginning of summer (in the southern hemisphere this is the winter solstice). The Sun is directly overhead at the Tropic of Cancer (23.5°N) at noon.

i. Winter Solstice- December 21 or 22. The planet's axis is tilted at its most away from the Sun, and marks the shortest day and the beginning of winter (in the southern hemisphere this is the summer solstice). The Sun is directly overhead at the Tropic of Capricorn (23.5°S) at noon.

j. Spring (Vernal) Equinox- March 20 or 21. The first day of spring (in the southern hemisphere this is the first day of fall.) There are 12 hours of daylight and 12 hours of darkness. The Sun is directly overhead at the Equator (0°N) at noon.

k. Fall (Autumnal) Equinox- September 22 or 23. The first day of fall (in the southern hemisphere this is the first day of spring.) There are 12 hours of daylight and 12 hours of darkness. The Sun is directly overhead at the Equator (0°N) at noon.

I. Seasonal changes can be explained using concepts of density and heat energy. These changes include the shifting of global temperature zones, the shifting of planetary wind and ocean current patterns, the occurrence of monsoons, hurricanes, flooding, and severe weather.

2. Recognize the path of the Sun during each season at different latitudes.

a. Insolation (incoming solar radiation) heats Earth’s surface and atmosphere unequally due to variations in:

The intensity caused by differences in atmospheric transparency and the angle of insolation, which vary with time of day, latitude, and season.

Characteristics of the materials absorbing the energy such as color, texture, transparency, state of matter, and specific heat.

Duration, which varies with seasons and latitude.

b. The Sun’s apparent path through the sky varies with latitude and season.

c. North of the equator, the Sun always rises in the east, travels through the southern sky, and sets in the west. (South of the equator, it rises in the east, travels through the northern sky, and sets in the west.)

d. Altitude (ALT)- number of degrees above horizon. Straight up is 90°. The horizon is 0°.

e. Azimuth (AZ)- A way of using degrees to state a compass direction:

North = 0°

East = 90°

South = 180°

West = 270°

f. The path of the Sun at Spring Valley, New York (41°N latitude):

Summer Solstice- the Sun rises in the northeast (AZ=58°), travels highest in the sky (ALT=72.5°), and sets in the northwest (AZ=302°).

Winter Solstice- the Sun rises in the southeast (AZ=121°), travels lowest in the sky (ALT=25.5°), and sets in the southwest (AZ=239°).

Both Equinoxes- the Sun rises exactly in the east (AZ=90°), rises to its average height (ALT=49°), and sets exactly in the west (AZ=270°).

g. At the Equator: day and night are each always 12 hours long. The Sun always travels in a path perpendicular (at a 90° angle) to the plane of the horizon.

Only on the equinoxes, the Sun rises exactly east and sets exactly west, traveling directly overhead, through the zenith at noon. The noon Sun is never lower than 66.5° altitude.

h. At the Poles: on the equinoxes, the Sun moves along the horizon, never quite rising or setting. At the North Pole the Sun “rises” on March 21st and “sets” on September 22.

The situation is reversed for the South Pole. During the summer, the Sun never sets. During the winter, the Sun never rises. The Sun, when up, always travels in a circle through the sky, parallel to the horizon. The Sun never rises more than 23.5° above the horizon.

i. The Sun can only be directly overhead, at the zenith, at locations between the Tropics of Cancer (23.5°N) and Capricorn (23.5°S). The Sun is NEVER at the zenith in New York!

3. Explain the annual migration of the Sun's vertical ray as a result of revolution, tilt, and parallelism.

a. The Sun's rays are vertical when the Sunlight is hitting Earth at a 90° angle.

b. Dates and locations of Sun's vertical rays:

Summer solstice – Tropic of Cancer

Fall equinox - Equator

Winter solstice – Tropic of Capricorn

Spring equinox – Equator

c. Throughout the course of one year, the Sun’s vertical rays migrate back and forth between the Tropics of Cancer and Capricorn.

4. Compare and contrast the evidences of revolution and rotation.

a. Two pieces of evidence for Earth's Rotation:

Foucault Pendulum- Each hour the pendulum shifts approximately 11 degrees in a clockwise direction knocking over all the pins that surround it. The shift is caused by Earth's rotation.

If the Earth did not rotate only 2 pins (in a straight line from each other) will be knocked down. At the north pole the apparent rotation would be a full circle of 360° each 24-hour day, or about 15° per hour.

The further south you go, the slower the apparent rotation gets, and at the equator there is no rotation at all. Below the equator the apparent rotation begins again, but in the opposite direction.

Coriolis Effect- Earth's rotation causes winds and any other freely moving objects to curve in their paths.

b. 2 pieces of evidence for Earth's Revolution:

Parallax Effect- The apparent shift in a star's position that occurs because Earth has moved in its orbit. Parallax refers to the apparent shifting of an object when viewed at different angles.

If you view the same object from two different angles, the perspective will change. Hold your thumb out in front of you at arm's length and view it first with your right eye (left eye closed), and then with your left eye (right eye closed). Your thumb appears to move.

Astronomers view stars from one side of the Earth's orbit and then from the other side to attempt to detect parallax.

Seasonal changes in constellations- During the summer, certain constellations are visible in the nighttime sky. During the winter, when the Earth is on the opposite side of the Sun, the nighttime sky faces the opposite side of the universe, so we see different constellations.

c. Computing the speed of Earth's rotation (at the equator):

Circumference of Earth = 40,000 kilometers

Time for one rotation = 24 hours

Speed of rotation = Distance/Time = 40,000 km / 24 hr = 1,670 km/hr (1,038 mi/hr)

d. Computing the speed of Earth's rotation (at the Spring Valley, NY):

Circumference of Earth at 41°N latitude = 30,289 kilometers

Time for one rotation = 24 hours

Speed of rotation = Distance/Time = 30,289 km / 24 hr = 1,262 km/hr (784 mi/hr)

Every second, the Earth's rotational motion carries you 351 meters, or about 1,150 feet, through space.

e. Computing the speed of Earth's revolution around the Sun:

Circumference of Earth's orbit = 940,000,000 kilometers

Time for one revolution = 365 1/4 days = 8766 hours

Speed of revolution = Distance/Time = 940,000,000 km / 8766 hr = 107,000 km/hr = 30 km/sec (66,490 mi/hr)

Every second, the Earth's orbital motion carries you 30 kilometers, or about 18 miles, through space.

5. Relate Earth's rate of rotation to time keeping and longitude.

a. Earth rotates 360° every 24 hours.

b. Earth rotates 15° per hour. (360°/24hr=15°/hr)

c. Earth is divided into twenty-four time zones, each 15° wide.

d. If you move 15° west, your time decreases by one hour.

e. If you move 15° east, your time increases by one hour.

f. Greenwich Mean Time (GMT)- The time at the Prime Meridian (0° longitude).

g. Chronometer- a very accurate clock that can keep time in all weather; used in navigation.

h. Longitude may be determined by calculating the time difference between the location a person is in and Greenwich Mean Time (GMT). So if the time zone a person is in is three hours ahead of GMT then that person is at 45° longitude (3 hours x 15° per hour = 45°).

In order to perform this calculation, however, a person needs to have a chronometer set to GMT and needs to determine local time by solar observation or astronomical observation.

i. California is three hours earlier than New York. Its longitude must be 45° west of New York.

j. London, England is five hours later than New York. Its longitude must be 75° east of New York.

k. If you are on a ship, your local time is 2pm, and your chronometer reads 8pm, your longitude must be 60°W. [(8-2)x15=60]

l. If you are on a ship, your local time is 11am, and your chronometer reads 9am, you longitude must be 30°E. [(11-9)x15=30]

m. International Date Line- imaginary line on the Earth's surface, generally following the 180° meridian of longitude, where, by international agreement, travelers change dates. Traveling eastward across the line, one subtracts one calendar day; traveling westward, one adds a day.

6. Locate zenith, horizon, and compass directions on a celestial sphere model.

a. Zenith- the point on the celestial sphere directly above the observer.

b. Horizon- where the sky meets the Earth in the distance.

c. Looking at a map with north at the top, south is down, east is right, and west is left.

7. Locate Polaris using the Big Dipper.

a. Polaris, or the North Star, is located at the end of the handle of the LITTLE DIPPER.

b. To find Polaris, use the Big Dipper. The two stars on the side of the cup opposite the handle are called the “pointer stars.” Draw an arrow from the bottom star through the top star, and it will point to Polaris.

8. Use the angle of Polaris to determine the observer's latitude at different locations.

a. The altitude of Polaris = latitude.

b. An astrolabe (sextant) is an ancient scientific instrument that the Greeks used in the second century B.C. to determine the latitude at which they were located.

c. The astrolabe, which allows the user to measure vertical angles, was very important to sailors in ancient times.

d. Determining the angle between your position on Earth and Polaris determines your latitude.

e. A person standing at the North Pole will find Polaris straight overhead (90°), which is her latitude.

f. A person standing at the equator will find Polaris at the horizon (0°), also her latitude. Polaris is not visible below the Equator.

g. To build an astrolabe:

You need these materials:

Protractor

Tape

Straw

12" of string

A weight (such as a washer, nut, or paper clip)

Directions:

Turn your protractor upside down so the rounded part is facing the ground

Tape the string on the center of the straight edge.

Tie the weight on the end of the string.

Tape the straw on the straight edge of the protractor.

h. To use your astrolabe, look at an object (Polaris) through the straw, the sight, letting the string hang down the front of the protractor.

When the object is in the center of the sight, hold the string tightly against the protractor. While you are still holding the string against the protractor look at the measure of the angle. This angle is your latitude!

9. Explain how Polaris is used as a navigational tool.

a. Traveling north, Polaris rises in the sky.

b. Traveling south, Polaris lowers in the sky.

c. Traveling east or west, the altitude of Polaris stays the same.

10. Explain how the Moon's rotation and revolution affects its appearance.

a. Earth is orbited by one moon and many artificial satellites.

b. When we watch the Moon during the course of a month, it looks like it is changing shape. What we are really seeing is Sunlight reflected from the moon's surface as it moves around the Earth.

c. The Sun always shines on half of the moon, but we cannot always see the entire half that is lit up. The phases are the parts of the lit half that we can see.

d. It takes about one month (moonth) for the Moon to complete one cycle of phases.

e. The shape varies from a full Moon (when the Earth is between the Sun and the moon) to a new Moon (when the Moon is between the Sun and the Earth).

f. The phases of the Moon in order: new, waxing crescent, first quarter, waxing gibbous, full, waning gibbous, last (third) quarter, waning crescent, new, etc.

g. Waxing= getting brighter

h. Waning= getting darker

i. Crescent= banana shape

j. Gibbous= more than half lit, less than full.

k. When the Right side is lit, it is getting Rounder.

I. When the Left side is lit, it is in its Last phases.

m. Looking at the shapes of the phases in order, can you see the word, “DOC”?

D = first quarter

O = full moon

C = waning crescent

n. At the time of the new moon, the Moon rises at about the same time the Sun rises, and it sets at about the same time the Sun sets.

As the days go by (as it waxes to become a crescent moon, a half moon, and a gibbous moon, on the way to a full moon), the Moon rises during the daytime (after the Sun rises), rising later each day, and it sets at nighttime, setting later and later each night.

o. At the full moon, the times of moonrise and moonset have advanced so that the Moon rises about the same time the Sun sets, and the Moon sets at about the same time the Sun rises.

As the Moon wanes (becoming a half Moon and a crescent moon, on the way to a new moon), the Moon rises during the night, after sunset, rising later each night. It then sets in the daytime, after the Sun rises.

Eventually, the Moon rises so late at night that it's actually rising around sunrise, and it's setting around sunset. That's when it's a new Moon once again.

11. Explain why eclipses are rare events.

a. During a new moon, when the Moon is between the Earth and the Sun, the Moon usually doesn’t block the Sun.

b. During a full moon, when the Earth is between the Sun and the moon, the Earth's shadow usually doesn't fall on the moon.

c. The Moon's orbit is tipped by 5 degrees with respect to the Earth's orbit. Therefore, eclipses do not occur every month.

d. The three objects (Sun, Moon, Earth) are rarely lined up perfectly.

12. Compare and contrast solar and lunar eclipses.

a. Eclipses, be they solar or lunar, occur when the Earth, Sun and Moon are in a line.

b. If the Moon is in between the Earth and the Sun, it blocks the view of the Sun from some parts of the Earth, and this produces a solar eclipse.

c. If the Earth is in between the Sun and Moon, then the Earth will block the light from the Sun before it can get to the Moon. Since moonlight is just the light the Moon reflects from the Sun, this will darken the Moon, and we get a lunar eclipse.

d. Whether it is the Moon between the Earth and Sun, or the other way around, the phenomenon is basically the same: the body in the middle casts a cone of shadow, and if the outer body happens to move into this cone, we have an eclipse.

e. It is important to notice that the shadow is more complicated than just a cone: it actually consists of a darker cone, or umbra, where no Sunlight reaches, and a lighter region, the penumbra, where only some of the Sunlight is blocked.

Whether you will be able to observe a total or partial eclipse will depend on which of the two regions you are located in.

13. Describe how the Moon and the Sun cause the tides.

a. Tides- The rise and fall of the surface of oceans, seas, bays, rivers, and other water bodies caused by the gravitational attraction of the Moon and Sun occurring unequally on different parts of the Earth.

b. Approximately 70 percent of Earth's surface is covered by a relatively thin layer of water, which responds to the gravitational attraction of the moon and the Sun with a daily cycle of high and low tides.

c. The moon's gravity pulls on the Earth, and pulls the water towards it. The water moves up into a slight bulge on the side of the Earth that faces the moon.

d. At the same time, there is a force pulling water out in the opposite direction of the moon. To understand this force, you need to picture the Earth and the Moon as one unit.

Picture two unequal balls on the ends of a stick. If you spin this stick around, you can imagine the force that a particle might feel if it were on the far end of either the Moon or the Earth. It would feel a force outward, away from the center of the spin. This is called the centrifugal force.

The water on the far end of the Earth, away from the Moon, is always being pulled out from the center of the spinning Earth-moon unit, like a person being whirled around on a carnival ride.

e. In one rotation (one day), a point on Earth travels from an area of high tide (where there is a force pulling water outward), through an area of low tide, through an area of high tide again (the opposite pull), and through another area of low tide, before it returns to the point of origin at high tide.

This results in two high tides and two low tides in a day (called semidiurnal tides).

f. The tides are caused mainly by the gravitational attraction of the Moon and the Earth, but there is also a gravitational attraction between the Earth and the Sun.

The effect of the Sun upon the tides is not as significant as the moon's effects. Basically, the Sun's pull can heighten the moon's effects or counteract them, depending on where the Moon is in relation to the Sun.

g. Spring tides- especially high high tides and low low tides that occur during full and new moons, when the Sun and the Moon are lined up with the Earth.

h. Neap tides- especially low high tides and high low tides that occur during quarter moons, when the gravitational forces of the Moon and the Sun are perpendicular to one another with respect to the Earth.

14. Understand the size, scale, and arrangement of the members of the Solar System (ESRT p.15).

a. The Solar System consists of the Sun (our star), the nine planets, more than 130 satellites (moons) of the planets, and a large number of small bodies (the comets and asteroids). (There are probably also many more planetary satellites that have not yet been discovered.)

b. The inner Solar System contains the Sun, Mercury, Venus, Earth and Mars.

c. The asteroid belt lies between the orbits of Mars and Jupiter, separating the inner planets from the outer planets.

d. The planets of the outer Solar System are Jupiter, Saturn, Uranus, Neptune and Pluto.

e. The Solar System is mostly empty space. The planets are very small compared to the space between them.

f. The Sun contains 99.85% of all the matter in the Solar System.

g. The planets contain only 0.135% of the mass of the Solar System.

h. Jupiter contains more than twice the matter of all the other planets combined.

i. Satellites of the planets, comets, asteroids, meteoroids, and the interplanetary medium constitute the remaining 0.015%.

j. If the Sun had an equatorial diameter of 25cm (ESRT p.1 and 15), the planets would be this big:

25 cm / 1,392,000 km = ? cm / (actual planet diameter) km

*****CROSS MULTIPLY!**

Mercury - 0.8mm

Venus - 2.1mm

Earth - 2.2mm

Mars - 1.2mm

Jupiter - 25mm (2.5cm)

Saturn - 20.9mm (2.1cm)

Uranus - 8.4mm

Neptune - 8.1mm

Pluto - 0.4mm

k. If the distance from the Sun to Pluto is 25cm, the distance from the planets to the Sun would be:

25 cm / 5,900,000,000 km = ? cm / (actual planet distance) km

***CROSS MULTIPLY!

Mercury - 2mm (0.2cm)

Venus - 4mm (0.4cm)

Earth - 6mm (0.6cm)

Mars - 9mm (0.9cm)

Jupiter - 32mm (3.2cm)

Saturn - 60mm (6cm)

Uranus - 121mm (12.1cm)

Neptune - 190mm (19cm)

Pluto - 250mm (25cm)

15. Compare/contrast the geocentric and heliocentric models.

a. Geocentric model- model of the universe with the Earth at the center and all other objects moving around it.

b. Heliocentric model- model of the universe with the Sun at the center and all other objects moving around it.

c. The following is a summary of major achievements in astronomy.

Among the first people known to have kept astronomical records were the Akkadians who lived some 4,500 years ago in northern Babylonia. The Babylonians accumulated records of astronomical observations for many centuries.

The records enabled them to see repeated patterns in the motions of the celestial objects. They used the patterns to predict the positions of the Moon and planets.

The first record of an eclipse of the Sun was made in China (2136 B.C.). The first calendars were made in China (1300 B.C.). The Chinese recorded sightings of many comets, including Halley's comet (466 B.C.)

The Mayans built many monuments and buildings, which were aligned to the position of Sunrise and Sunset at the equinoxes and solstices. Their calendars kept track of the Sun, Moon and Venus, as well as solar and lunar eclipses (1000-2000 years ago).

Early Greeks held the geocentric ("Earth-centered") view of the universe, believing that Earth was a sphere that stayed motionless at the center of the universe

Orbiting Earth were the seven wanderers (planetai in Greek), which included the Moon, Sun, and the known planets—Mercury, Venus, Mars, Jupiter, and Saturn. To the early Greeks, the stars traveled daily around Earth on a transparent, hollow sphere called the celestial sphere.

In A.D. 141, Claudius Ptolemy presented the geocentric outlook of the Greeks in its most complicated form in a model that became known as the Ptolemaic system. The Ptolemaic model had the planets moving in circular orbits around a motionless Earth.

To explain the retrograde motion of planets (the apparent westward, or opposite motion planets exhibit for a period of time as Earth overtakes and passes them) Ptolemy proposed that the planets orbited in small circles (epicycles), revolving along large circles (deferents).

In the fifth century B.C., the Greek Anaxagoras reasoned that the Moon shines by reflected Sunlight, and because it is a sphere, only half is illuminated at one time. Aristotle (384-322 B.C.) concluded that Earth is spherical.

The first Greek to acknowledge a Sun-centered, or heliocentric, universe was Aristarchus (312-230 B.C.). The first successful attempt to establish the size of Earth is credited to Eratosthenes (276-194 B.C.).

The greatest of the early Greek astronomers was Hipparchus (second century B.C.), best known for his star catalog.

Modern astronomy evolved through the work of many dedicated individuals during the 1500s and 1600s.

by Charles A. Burrows

Nicolaus Copernicus (1473-1543) reconstructed the Solar System with the Sun at the center and the planets orbiting around it, but mistakenly continued to use circles to represent the orbits of planets.

Tycho Brahe's (1546-1601) observations were far more precise than any made previously.

Johannes Kepler (1571-1630) ushered in the new astronomy with his three laws of planetary motion.

After constructing his own telescope, Galileo Galilei (1564-1642) made many important discoveries that supported the Copernican view of a Sun-centered Solar System.

Sir Isaac Newton (1643-1727) was the first to formulate and test the law of universal gravitation, develop the laws of motion, and prove that the force of gravity, combined with the tendency of an object to move in a straight line (inertia), results in the elliptical orbits discovered by Kepler.

16. Compare/contrast terrestrial and Jovian planets.

a. The terrestrial planets are the four innermost planets in the Solar System, Mercury, Venus, Earth and Mars. They are called terrestrial because they have a compact, rocky surface like the Earth's. The planets, Venus, Earth, and Mars have significant atmospheres while Mercury has almost none.

b. Jupiter, Saturn, Uranus, and Neptune are known as the Jovian (Jupiter-like) planets, because they are all gigantic compared with Earth, and they have a gaseous nature like Jupiter's. The Jovian planets are also referred to as the gas giants, although some or all of them might have small solid cores.

c. Mercury is a small, dense planet that has no atmosphere and exhibits the greatest temperature extremes of any planet. Its surface is covered by craters, like our Moon.

d. Venus, the brightest planet in the sky, has a thick, heavy atmosphere composed of 97 percent carbon dioxide, a surface of relatively subdued plains and inactive volcanic features, ...

... a surface atmospheric pressure ninety times that of Earth's, and surface temperatures of 475°C (900°F) due to a runaway greenhouse effect.

e. Mars, the "Red Planet," has a carbon dioxide atmosphere only 1 percent as dense as Earth's, extensive dust storms, numerous inactive volcanoes, many large canyons, and several valleys of debatable origin exhibiting drainage patterns similar to stream valleys on Earth.

Mars is red due to the presence of iron oxide (rust) on the surface.

f. Jupiter, the largest planet, rotates rapidly, has a banded appearance caused by huge convection currents driven by the planet's interior heat, a Great Red Spot (bigger than Earth) that varies in size, a thin ring system, and at least sixteen moons (one of the moons, Io, is a volcanically active body).

g. Saturn is best known for its system of rings. It also has a dynamic atmosphere with winds up to 930 miles per hour and "storms" similar to Jupiter's Great Red Spot.

h. Uranus and Neptune are often called "the twins" because of similar structure and composition. A unique feature of Uranus is the fact that it rotates "on its side."

Neptune has thin, white, wispy clouds above its main cloud deck and an Earth-sized Great Dark Spot, assumed to be a large rotating storm similar to Jupiter's Great Red Spot.

i. Pluto, a small frozen world with one Moon (Charon), may have once been a satellite of Neptune. Pluto's noticeably elongated orbit causes it to occasionally travel inside the orbit of Neptune, but with no chance of collision.

17. Explain Newton’s Law of Gravitation with respect to mass and distance.

a. The more mass an object has, the more gravity it has.

b. All objects are attracted to each other by gravity.

c. The closer two objects are to each other, the greater the gravitational attraction between them.

18. Explain how distance from the Sun affects a planet's orbital velocity (Kepler's Laws).

a. The closer a planet is to the Sun, the faster it moves.

b. Mercury is the fastest planet.

c. Pluto is the slowest planet.

d. The orbits of all planets are NOT perfect circles. When a planet is closest to the Sun, it moves fastest.

e. Earth moves fastest during the winter, when it is closest to the Sun.

f. A line connecting a planet to the Sun will sweep out equal areas in equal times.

19. Diagram elliptical orbits and analyze their eccentricities (Kepler's Laws).

a. The orbits of all planets are ellipses, with the Sun at one focus.

b. Ellipse- A closed curve resembling a flattened circle (oval).

c. Focus- one of two special points along the major (long) axis of an ellipse. A focus is not at the center of an ellipse unless the ellipse is perfectly circular. Plural = foci (“foe-sigh”).

d. Eccentricity- Eccentricity is a measure of how circular an ellipse is.

e. For a perfectly circular orbit the eccentricity is zero; elliptical orbits have eccentricities between zero and one. The higher the eccentricity, the more "squashed" the orbit is. A line segment has an eccentricity of one.

f. Eccentricity of an ellipse (ESRT p.1) = the distance between the foci divided by the length of the major axis.

g. The sum of the distances from any point on the curve to the two foci is a constant (always the same).

h. Here’s how to draw a perfect ellipse. You'll need:

A flat board, made of any material into which pins or nails can easily be pushed

Two pins or nails

A loop of thread or string

A pen or pencil

Paper

Place a piece of paper on the board, and stick in the two pins (not too close together). Loop the thread around the pins and pull tight with the tip of the pen. Now move the pen around, always keeping the loop of thread tight. As the pen rotates around the two pins it will trace out an ellipse.

i. If you move the pins closer together, the ellipse becomes more circular (eccentricity decreases).

j. If you move the pins farther apart, the ellipse becomes less circular (eccentricity increases).

k. If you leave the pins in the same place, but use a longer piece of string, the ellipse will become more circular (less eccentric).

l. If you leave the pins in the same place, but use shorter string, the ellipse will become less circular (more eccentric).

20. Understand that the apparent size of the Sun changes seasonally due to the Earth’s elliptical orbit.

a. During the winter, when Earth is closest to the Sun, the Sun appears largest in the sky.

b. During the summer, the Sun appears smallest.

21. Describe meteors, their origin, and cratering as an early geologic activity.

a. Meteoroid- a rock in space.

b. Meteor- a meteoroid that has entered Earth's atmosphere.

c. Meteorite- a meteor that has landed on Earth's surface.

d. A meteor occurs when a meteoroid enters the Earth's atmosphere and vaporizes, heating itself and atmospheric gases so that they glow. Most meteoroids are no more than 1 cm in diameter.

e. High meteor rates occur during meteor showers, when the Earth runs into a swarm of meteoroids. Showers take place on or close to the same date each year, when the Earth crosses the common orbit of the meteoroids.

f. The number of recovered meteorites has risen dramatically with the discovery that Antarctic ice fields collect and preserve meteorites for millions of years.

g. Meteorites are classed as stones, irons, and stony-irons. Stones resemble Earth rocks and are the most common meteorites. Carbonaceous chondrites are a type of stony meteorite and may represent unaltered material from early in the history of the Solar System.

Iron meteorites contain of iron and nickel and stony-iron meteorites are mixtures of stone and metal.

h. The radioactive elements in meteorites show that most of them solidified at almost the same time as the oldest Moon rocks, about 4.6 billion years ago (the age of the Solar System).

i. The large number of craters on the Moon and other Solar System objects indicates that they experienced an early period of intense bombardment.

j. Impact craters can be identified in Earth's crust.

22. Describe comets, the eccentricity of their orbits, and the Oort cloud.

a. Comets are chunks of ice and dust. When they come close to the Sun, however, the nucleus is warmed enough by Sunlight to release gas and dust. These flow away from the nucleus to produce the tail of the comet, which always points away from the Sun.

b. The Sun is surrounded by the Oort cloud, a swarm of comets beyond the orbit of Pluto. There may be as many as 1 trillion comets in the Oort cloud.

Passing stars alter the orbits of Oort cloud comets, causing some of them to enter the planetary system and become visible as new comets. Other comets are thought to come from the Kuiper belt, a disk of comets just beyond the orbit of Neptune.

c. A comet loses icy material each time it passes the Sun. Eventually, the ice is entirely eroded. The dust particles left behind form meteoroid swarms that produce meteor showers. Some comet nuclei may have rock cores that become asteroids once the surrounding ice is gone.

d. If a large meteoroid or comet struck the Earth, there would be serious local and global consequences. The global consequences might include darkness for weeks or months, very acidic rain, and temporary heating of the atmosphere.

23. Describe the location of the asteroids and their past influence on the Earth.

a. Most of the known asteroids orbit in a belt located between the orbits of Mars and Jupiter. These asteroids are very widely spread out.

b. Many asteroids are not found in the asteroid belt. The Trojan asteroids, for example, either follow or go before Jupiter in its orbit around the Sun. In addition, the asteroids Hidalgo and Chiron have orbits larger than Jupiter's.

c. Many asteroids have orbits that carry them inside the orbit of the Earth. Within tens of millions of years, these asteroids are likely to be destroyed by striking the Earth.

d. Many asteroids are fragments of larger asteroids that were shattered by impacts. Most of the small asteroids are the eroded cores of much larger bodies.

e. An excess of the element iridium, discovered in rocks formed at the end of the Cretaceous period 65 million years ago, suggests that an asteroid struck the Earth at that time. The consequences of the impact may have played a role in the Cretaceous extinctions.

24. Describe other planetary satellites/rings

a. Our Moon's surface is covered with craters from impacts with meteoroids.

b. The rotation period of the Moon is the same as the period of its revolution about the Earth. This arrangement keeps the same face of the Moon turned toward the Earth.

c. Phobos and Deimos, the satellites of Mars, are believed to be captured asteroids.

d. The intense tidal heating of Jupiter’s moon, Io, makes it the most volcanically active body in the Solar System. Volcanic material is deposited so rapidly on Io's surface that all evidence of impact cratering has been covered up.

e. Jupiter’s moon, Europa, has a very smooth, icy surface even though it is made mostly of rock. Europa's surface has been smoothed by glacier-like flows and, probably, by flows of water from the interior. A thick ocean of water probably exists below its icy crust.

f. Saturn's largest satellite is Titan. Its atmosphere contains mostly nitrogen and is thicker than the Earth's. Titan is cold enough that atmospheric ethane can condense to liquid form. In fact, Titan may have ethane rain and lakes or oceans of ethane.

g. Triton orbits Neptune in a retrograde direction and is slowly spiraling inward. Triton probably formed elsewhere and was captured into a retrograde orbit.

h. The rings of Jupiter, Saturn, Uranus and Neptune are very thin and consist of many individually orbiting particles (rock and ice).

i. The 32 Largest Objects in Solar System

Rank Object Diameter Year of Discovery Comment

1 Sun 1,392,000 km

Star

2 Jupiter 142,800 km

Planet

3 Saturn 120,000 km

Planet

4 Uranus 51,800 km

1781 Planet

5 Neptune 49,500 km
1846 Planet

6 Earth 12,756 km
Planet

7 Venus 12,104 km

Planet

8 Mars 6,787 km Planet

9 Ganymede 5,260 km

1610 Moon of Jupiter

10 Titan 5,150 km

1655 Moon of Saturn

11 Mercury 4,880 km Planet

12 Callisto 4,800 km

1610 Moon of Jupiter

13 Io 3,630 km 1610

Moon of Jupiter

14 Moon

3,476 km
Moon of Earth

15 Europa 3,140 km

1610 Moon of Jupiter

16 Triton 2,700 km
1846 Moon of
Neptune

17 Pluto 2,300 km

1930 Planet?

18 Sedna 2003

1,700 km Inner Oort Cloud

19 2004DW 1,600 km
2004 Kuiper Belt

20 Titania 1,580 km

1787 Moon of Uranus

21 Rhea 1,530 km

1672 Moon of Saturn

22 Oberon 1,520 km

1787 Moon of Uranus

23 Iapetus 1,440 km

1671 Moon of Saturn

24 Quaoar 1,300 km

2002 Kuiper Belt

25 Charon 1,200 km

1978 Moon of Pluto

26 Umbriel 1,170 km

1851 Moon of Uranus

27 Ariel **1,160 km**

1851 **Moon of Uranus**

28 Dione 1,120 km

1684 Moon of Saturn

29 Tethys 1,050 km

1684 Moon of Saturn

30 Ixion 1,055 km
2001 Kuiper Belt

31 Ceres 910 km 1801 Asteroid

32 Varuna 900 km 2000

Kuiper Belt

UNIT VIII/B: THE EARTH IN SPACE – STARS AND GALAXIES

UNIT VIII/B: THE EARTH IN SPACE – STARS AND GALAXIES

1. Define and describe “galaxy”.
2. Locate the sun’s position in the Milky Way Galaxy
3. Understand why light years are used to measure distances in space.
4. Explain the composition of the sun and other stars and the process of fusion.
5. Explain the equilibrium between the inward pull of gravity and the outward pull of fusion.
6. Describe the structure, color and temperature of the sun and other stars.
7. Compare/contrast the temperature, color, mass and luminosity of the sun to other stars.
8. Explain the how stars are plotted on the Temperature/ Luminosity Diagram (H-R Diagram).
9. Locate the position and give characteristics of the Sun on the Temperature/ Luminosity Diagram.
10. Describe the evolution of the Sun and different kinds of stars.
11. Explain why larger/hotter stars burn their fuel faster and live shorter lives than the Sun.
12. Explain why stars are considered to be “factories” which create elements needed for future stellar generation.
13. Explain the importance of the electromagnetic spectrum in identifying some objects in the universe.
14. Describe the Big Bang theory of the origin of the universe.
15. Explain how red-shift (the Doppler Effect) and background radiation are evidence for an expanding universe.
16. Understand that scientists are searching for invisible mass that will explain continued expansion, implosion (Big Crunch), or oscillation of the universe.
17. Describe how the Sun/solar system formed 4.6 billion years ago from the gas and dust (nebula) left behind by a previous star’s supernova.
18. Explain how the planets were formed by accretion.
19. Explain the theories of the origin of the moon.
20. Explain why astronomers say, “we are made of star dust.”

1. Define and describe “galaxy”.

a. A galaxy is a very large cluster of stars (tens of millions to trillions of stars) gravitationally bound together.

b. There are billions of galaxies in the observable universe.

c. The various types of galaxies include:

Spiral galaxies, which are typically disk-shaped with a somewhat greater concentration of stars near their centers, often containing arms of stars extending from their central nucleus

Barred spiral galaxies, a type of spiral galaxy that has the stars arranged in the shape of a bar, which rotates as a rigid system

Elliptical galaxies, the most abundant type, which have an elliptical shape that ranges to nearly spherical, and lack spiral arms

Irregular galaxies, which lack symmetry and account for only 10 percent of the known galaxies.

d. Galaxies are not randomly distributed throughout the universe. They are grouped in galactic clusters, some containing thousands of galaxies. Our own, called the Local Group, contains at least 28 galaxies.

2. Locate the Sun's position in the Milky Way Galaxy.

a. The Sun is one of the 200 billion stars that make up the Milky Way galaxy.

b. The Milky Way galaxy is a large, disk-shaped, spiral galaxy about 100,000 light-years wide and about 10,000 light-years thick at the center (central "bulge").

c. There are three distinct spiral arms of stars.

d. The Sun is positioned in one of these arms about two-thirds of the way from the galactic center, at a distance of about 30,000 light-years.

e. Scientists suspect that a super massive black hole – an immensely dense area of space that sucks up matter and light – lies at the galaxy's center

f. It takes about 200 million years for the Sun to revolve around the galactic center.

g. Surrounding the galactic disk is a nearly spherical halo made of gas and numerous globular clusters (nearly spherically shaped groups of densely packed stars).

h. We see the Milky Way as a bright band of stars across the sky. It looks like spilled milk!

i. Most of the points of light in the night sky are stars in the Milky Way

3. Understand why light years are used to measure distances in space.

a. A light-year is a unit of distance (NOT TIME!!!). It is the distance that light can travel in one year.

b. Light moves at a velocity of about 300,000 km each second (in a vacuum). So in one year, it can travel about 10 trillion km. More precisely, one light-year is equal to 9,460,500,000,000 kilometers (5,880,000,000,000 miles).

c. Why would you want such a big unit of distance?

In the Universe, the kilometer is just too small to be useful. For example, the distance to the next nearest big galaxy, the Andromeda Galaxy, is 21 quintillion km. That is 21,000,000,000,000,000,000 km.

This is a number so large that it becomes hard to write and hard to interpret. So astronomers use other units of distance.

d. In our solar system, we tend to describe distances in terms of the Astronomical Unit (AU). The AU is defined as the average distance between the Earth and the Sun.

It is approximately 150 million km (93 million miles). Mercury can be said to be about 1/3 of an AU from the Sun and Pluto averages about 40 AU from the Sun.

The AU, however, is not big enough of a unit when we start talking about distances to objects outside our solar system.

e. For distances to other parts of the Milky Way Galaxy (or even further), astronomers use the light-year. Using the light-year, we can say that:

The Milky Way Galaxy is about 150,000 light-years across.

The Andromeda Galaxy (one of our nearest neighboring galaxies) is 2.3 million light-years away.

Proxima Centauri, the closest star, is 4.24 light years away.

Sirius the "dog star" (the brightest star in the sky) is 8.6 light years away.

Center of the galaxy is approximately 30,000 light years away.

The most distant galaxies observed are more than 12 billion light years away.

f. Light minute- the distance light travels in a vacuum in one minute, approximately 18 million kilometers. The Sun is 8.3 light-minutes away.

g. Light second- the distance light travels in a vacuum in one second, approximately 300,000 kilometers. The Moon is about 1.3 light-seconds away.

h. When we look up, we see the Moon and sun, not as they are now, but as they were 1.3 seconds and 8.3 minutes ago.

i. Since it takes light time to reach us, the further out we look into space, the farther back we see into time.

4. Explain the composition of the Sun and other stars and the process of fusion.

a. The Sun is actually a star of about medium size. It appears larger than the other stars because it is closer to the earth.

b. By mass, the Sun is 73% hydrogen and 25% helium.

c. The Sun can be divided into four parts 1) the solar interior, 2) the photosphere (visible surface), and the two layers of its atmosphere, 3) the chromosphere and 4) corona.

d. The photosphere radiates most of the light we see. Unlike most surfaces, it consists of a layer of glowing gas less than 500 kilometers (300 miles) thick with a grainy texture consisting of numerous, relatively small, bright markings called granules.

e. Just above the photosphere lies the chromosphere, a relatively thin layer of hot, glowing gases a few thousand kilometers thick.

f. At the edge of the uppermost portion of the solar atmosphere, called the corona, gases (mostly protons and electrons; plasma) escape the gravitational pull of the Sun and stream toward Earth at high speeds producing the solar wind.

g. Numerous features have been identified on the active Sun. Sunspots are dark blemishes with a black center, the umbra, which is rimmed by a lighter region, the penumbra.

The number of sunspots observable on the solar disk varies in an 11-year cycle. Sunspots are dark because they are cooler than the surrounding areas.

h. Prominences, huge cloudlike structures best observed when they are on the edge, or limb, of the Sun, are produced by gases trapped by magnetic fields that extend from regions of intense solar activity.

i. The most explosive events associated with sunspots are solar flares. Flares are brief outbursts that release enormous quantities of energy that appear as a sudden brightening of the region above sunspot clusters.

During the event, radiation and fast-moving atomic particles are ejected, causing the solar wind to intensify. When the ejected particles reach Earth and disturb the atmosphere, radio communication is disrupted and the auroras, also called the northern and southern lights, occur.

j. The source of the Sun's energy is nuclear fusion. Deep in the solar interior, at a temperature of 15 million K, nuclear fusion converts four hydrogen atoms into one helium atom. During the reaction some of the matter is converted to the energy of the Sun.

The weight of four hydrogen atoms is slightly greater than the weight of one helium atom. This “missing weight” is converted to energy, making the Sun shine!

k. A star the size of the Sun can exist in its present stable state for 10 billion years. Since the Sun is already 4.6 billion years old, it is a "middle-aged" star.

5. Explain the how stars are plotted on the Temperature/ Luminosity Diagram (H-R Diagram).

a. This diagram (ESRT p.15) is a graph of stars plotted with luminosity and mass along the vertical axis and temperature (decreasing) and color along the horizontal axis.

b. Its real name is the H-R (Hertzsprung-Russell) Diagram.

c. The stars differ from each other in size, temperature, and age.

d. Luminosity = Brightness

e. The Sun has a luminosity of 1. A star with a luminosity of 100 is 100 times brighter than the Sun, etc.

f. More massive stars are usually brighter.

g. Hot stars are blue. Cool stars are red.

h. Typically, as a star gets hotter, it gets brighter. These stars are the Main Sequence stars.

i. A Red Giant is a cool star, but it is bright because it is so big.

j. A White Dwarf is a hot star, but it is dim because it is small.

k. The Sun is an average size star. It is located near the center of the graph. Its surface is 5,500°C, which makes it yellow.

I. Plotting stars on this graph causes certain types and ages of stars to cluster together.

6. Describe the evolution of the Sun and different kinds of stars.

a. A typical star (one like the Sun) lives (produces nuclear energy) for about 10 billion years. This incredible length of time is greater than 100 million human lifetimes.

b. A cloud of dust in space (a nebula) begins to contract due to gravity.

c. As it contracts, pressure and temperature increase inside this “protostar.”

d. When the temperature gets hot enough, fusion begins, and a main sequence star is born.

e. A star loses mass during fusion as energy is released. This decreases the star's gravity.

f. A star will expand, becoming a red giant, when the outward force of fusion is greater than the inward force of gravity.

g. As fuel runs out in a star, fusion slows down. When the outward force of fusion is less than the inward force of gravity, the star will shrink in size, becoming a white dwarf.

h. A star like the Sun will run out of fuel, and die, becoming a black dwarf.

i. Supernova- An explosion that marks the end of a very massive star's life. When it occurs, the exploding star can outshine all of the other stars in the galaxy in total for several days and may leave behind only a crushed core (perhaps a neutron star or black hole).

All of the heavy elements (heavier than iron) were created in supernova explosions.

j. A larger, more massive star will collapse violently, becoming a neutron star.

k. Neutron star- an imploded core of an exploded star made up almost entirely of neutrons. A teaspoonful of their material would weigh more than all the automobiles in the United States put together.

I. The largest stars collapse so violently that they become black holes.

m. Black hole- the remains of the death and collapse of an extremely massive star. The gravitational pull of a black hole is so strong that light itself cannot escape.

7. Explain why larger/hotter stars burn their fuel faster and live shorter lives than the Sun.

a. Large, more massive stars have much more gravity than the sun.

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b. The great internal pressures, due to the higher gravity, cause the fusion reaction to occur more quickly.

c. This causes the largest stars to burn their fuel, and eventually run out, much more quickly.

d. Larger stars live shorter lives.

e. Bigger stars are brighter and hotter due to the rapid rate of fusion.

8. Explain why stars are considered to be “factories” which create elements needed for future stellar generation.

a. Stars of all masses spend the majority of their lives their lives fusing hydrogen into helium: we call this stage the main sequence.

b. When all of the hydrogen in the central regions of a star is converted into helium, the star will begin to "burn" helium into carbon.

c. However, the helium in the stellar core will eventually run out as well; so in order to survive, a star must be hot enough to fuse increasingly heavier elements, as the lighter ones become used up one by one.

d. Stars heavier than about 5 times the mass of the Sun can do this with no problem: they burn hydrogen, and then helium, and then carbon, oxygen, silicon, and so on… until they attempt to fuse iron.

e. Iron is special in that it is the lightest element in the periodic table that doesn't release energy when you attempt to fuse it together. In fact, instead of giving you energy, you end up with less energy than you started with!

This means that instead of generating additional pressure to hold up the now extended outer layers of the aging star, the iron fusion actually takes thermal energy from the stellar core.

Thus, there is nothing left to combat the ever-present force of gravity from these outer layers. The result: **collapse!**

f. The lack of outward pressure generated by the iron-fusing core causes the outer layers to fall towards the center of the star. This implosion happens very, very quickly: it takes about 15 seconds to complete.

During the collapse, the nuclei in the outer parts of the star are pushed very close together, so close that elements heavier than iron are formed.

9. Explain the importance of the electromagnetic spectrum in identifying some objects in the universe.

a. We have only recently been able to look at the Universe over the entire electromagnetic spectrum. Our Universe contains objects that produce a vast range of radiation with wavelengths either too short or too long for our eyes to see.

b. Some astronomical objects emit mostly infrared radiation, others mostly visible light, and still others mostly ultraviolet radiation. Temperature determines the type of electromagnetic radiation emitted by astronomical objects.

c. Type of radiation radiated by objects and typical sources:

Gamma-rays: accretion disks around black holes

X-rays: gas in clusters of galaxies; supernova remnants; stellar corona

Ultraviolet: supernova remnants; very hot stars

Visible: planets, stars, some satellites

Infrared: cool clouds of dust and gas; planets

Microwaves: Sun, comets, planets, molecular clouds, galaxies, quasars and the cosmic background radiation

Radio: radio emission produced by electrons moving in magnetic fields

10. Describe the Big Bang theory of the origin of the universe.

a. The Big Bang Theory is the leading scientific theory about the origin of the universe.

b. According to the Big Bang, the universe was created around 15 billion years ago from a cosmic explosion that hurled matter and energy in all directions.

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c. The universe was originally a single tiny dense sphere of hydrogen that exploded into a gigantic expanding cloud that eventually condensed into separate galaxies.

d. After the Big Bang, matter, energy, space and time came into being.

e. By "running the film backward'' (theorizing the galaxies' motions backward in time) astronomers can estimate when the universe was born.

11. Explain how red shift (the Doppler Effect) and background radiation are evidence for an expanding universe.

a. The Big Bang was initially suggested because it explains why distant galaxies are traveling away from us at great speeds.

b. Red shift- the lengthening (or "stretching") of light waves coming from a source moving away from us.

c. If a source of light is moving toward us, the opposite effect — called a "Blue Shift" — takes place.

d. Light from ALL galaxies outside our Local Group is "red-shifted," indicating that they are moving away from us (and from each other).

e. Actually, it is the space that is expanding, carrying the galaxies along with it! This phenomenon is called the "expansion of the universe.''

f. Spectral lines are red-shifted from distant galaxies, indicating that the galaxies are moving away from us due to the expansion of the Universe.

g. The Big Bang Theory also predicts the existence of cosmic background radiation (the glow left over from the explosion itself).

h. The Big Bang Theory received its strongest confirmation when Arno Penzias and Robert Wilson, who later won the Nobel Prize for this discovery, discovered this radiation in 1964.

They detected background noise using a special low noise antenna. The strange thing about the noise was that it was coming from every direction and did not seem to vary in intensity much at all.

If this static were from something on our world, like radio transmissions from a nearby airport control tower, it would only come from one direction, not everywhere.

The scientists soon realized they had discovered the cosmic microwave background radiation. This radiation, which fills the entire Universe, is believed to be a clue to it's beginning: The Big Bang.

12. Understand that scientists are searching for invisible mass that will explain continued expansion, implosion (Big Crunch), or oscillation of the universe.

a. The fate of the universe depends upon the balance between the outward force of expansion, and the inward pull of gravity.

b. The inward pull of gravity depends on the total amount of matter in the universe. More matter has more mass and greater gravity.

c. If there is not enough matter in the universe, the outward force of expansion will be greater, and the universe will expand forever. It will get colder and darker.

d. The “Big Crunch,” the opposite of a big bang, will occur if there is enough matter (and therefore gravity) in the Universe to slow down and reverse its present expansion. Everything will come back together again.

e. Dark matter is material that is believed to make up more than 90% of the mass of the universe, but is not readily visible because it neither emits nor reflects electromagnetic radiation, such as light or radio signals.

Its composition is unknown. It can be detected by its gravitational effect on objects in space.

f. If we can determine the amount of matter in the universe, we can predict its future.

g. The universe may oscillate. This means that it may go through cycles of Big Bangs and Big Crunches, over and over again (almost like the universe is breathing!).

13. Describe how the Sun/Solar System formed 4.6 billion years ago from the gas and dust (nebula) left behind by a previous star's supernova.

a. The nebular hypothesis describes the formation of the solar system.

b. The planets and Sun began forming about 4.6 billion years ago from a large cloud of dust and gases composed of hydrogen and helium, with only a small percentage of all the other heavier elements.

c. As the cloud contracted, it began to rotate and assume a disk shape.

d. Material that was gravitationally pulled toward the center became the protosun.

e. Within the rotating disk, small centers, called protoplanets, swept up more and more of the cloud's debris.

f. The characteristics of the planets of the solar system are affected by each planet's location in relationship to the Sun.

g. The inner planets are denser. The lighter elements were blown, by the solar wind, to the outer planets, making them less dense. Heavier substances like metals, oxides and silicates stayed near the Sun, forming the inner planets.

14. Explain how the planets were formed by accretion.

a. The concept of planetary development by accretion is a theory that cosmic dust lumped together (gravity) to form particles, particles became gravel, gravel became small balls, then big balls, then tiny planets, or planetesimals, and, finally, dust became the size of the moon.

b. As the planetesimals became larger, their numbers decreased, and the number of collisions between planetesimals, or meteorites, decreased.

c. Fewer items available for accretion meant that it took a long time to build up a large planet. One calculation suggests that about 100 million years would pass between the formation of an object measuring 10 kilometers in diameter and an object the size of the Earth.

15. Explain the theories of the origin of the moon.

a. Most scientists believe that the Moon was formed from the ejected material after the Earth collided with a Mars-sized object.

b. This ejected material clumped together to form the moon, orbiting around the Earth.

c. This catastrophic collision occurred about 4.3 billion years ago. The age of the Moon is determined by the radioactive dating of Moon rocks.

d. Another theory is that the Moon was captured by Earth’s gravity.

16. Explain why astronomers say, “we are made of star dust.”

a. The atoms that make up your body come from the Earth itself. (You are what you eat!)

b. The atoms that make up the Earth came from the cloud of dust (nebula) in space that formed our Solar System.

c. Where did this cloud come from?

d. The fact that there are many heavy elements here on Earth is evidence that a supernova occurred in the past. (Remember: any elements heavier than iron can only form during a supernova, when a massive star explodes.)

e. This indicates that a different star once existed that ended its life with a bang (supernova) leaving behind a cloud of dust in space.

f. The dust, from a star that exploded in the past, is where the atoms in your body came from.

g. YOU ARE MADE OF STAR DUST!