



AP BIOLOGY

Auburn University AP Summer Institute
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AP Biology

Life's beginning on Earth according to *scientific findings*

(Associated Learning Objectives: 1.9, 1.10, 1.11, 1.12, 1.27, 1.28, 1.29, 1.30, 1.31, and 1.32)

- I. The four steps necessary for life to emerge on Earth. (This is according to accepted scientific evidence.)
 - A. First: An **abiotic** (non-living) synthesis of Amino Acids and Nucleic Acids must occur.
 1. The RNA molecule is believed to have evolved first. It is not as molecularly stable as DNA though.
 2. The Nucleic Acids (DNA or RNA) are essential for *storing, retrieving, or conveying by inheritance* molecular information on constructing the components of living cells..
 3. The Amino Acids, the building blocks of proteins, are needed to construct the “work horse” molecules of a cell.
 - a. The majority of a cell or organism, in **biomass** (dry weight of an organism), is mostly protein.
 - B. Second: Monomers must be able to join together to form *more complex* polymers using energy that is obtained from the surrounding environment.
 1. Seen in monosaccharides (simple sugars) making polysaccharides (For energy storage or cell walls of plants.)
 2. Seen in the making of phospholipids for cell membranes.
 3. Seen in the making of messenger RNA used in making proteins using Amino Acids.
 4. Seen in making chromosomes out of strings of DNA molecules. (For information storage.)
 - C. Third: The RNA/DNA molecules form and gain the ability to *reproduce* and *stabilize* by using chemical bonds and complimentary bonding.
 1. Adenine with Thymine *OR* Uracil.
 2. Guanine with Cytosine.
 3. The single strands of DNA/RNA molecules are held together by covalent bonds.
 4. The two sides of the DNA double helix are held together by Hydrogen bonds. (To be discussed later in this unit.)
 - D. Fourth: The evolution of a **protobiont** (means “first life form”) membrane of phospholipids and proteins to *keep* the “cell” intact.
- II. The *scientific* supporting evidence for the above steps. (These are laboratory *testable* experiments; not “hunches” or guesses without proof.)
 - A. Step 1 - Abiotic synthesis – The Stanley Miller and Harold Urey Experiment (1953) supports this claim.
 1. The experiment took the inorganic gases hypothesized to have been in early Earth’s atmosphere, H₂, CH₄, NH₃, and water vapor and formed a variety of organic molecules, such as amino acids and oils. These organic molecules are the *building blocks of all life forms*. The energy source for the formation was an electrical spark that was to represent lightning in the early atmosphere. The gases hypothesized to be present in the early Earth’s atmosphere came from data associated with analyzing active volcanoes eruptions. Volcanoes would have been very active and present in the early Earth time period, as well as still today. These organic molecules would have accumulated in the Earth’s early oceans over millions of years and thus making possible the formation of *more complex* structures, as seen in step 2.
 - B. Step 2 –Complex polymer formation – Researchers have shown that by exposing Pyrite (fool’s gold), sand, or clay to the intense heat of sunlight, and in the presence of the tidal actions of the oceans, that complex polymers can form from the simple building blocks of amino acids and oils, from step 1, which are dissolved in water. These complex polymers would then also have accumulated in the Earth’s oceans over millions of years and then making possible the formation of more complex structures in Step 3.
 - C. Step 3 – RNA formation and reproduction – The experiments of Thomas Cech and Sidney Altman have shown that small strands of RNA molecules can act as **enzymes** (biological catalyst for chemical reactions). The enzymatic RNA molecules are called **Ribozymes**. These small strands of RNA would have been the product of step 2. RNA is great for being enzymatic; as well as *temporarily*, storing and transmitting molecular information (as seen in protein synthesis using messenger RNA). Over millions of years, a more stable and longer lasting molecule would have evolved. This molecule, DNA, would become, over millions of years, the *more stable and longer lasting* means for storing molecular information and *transferring* this important information from a cellular generation to the next in the process of binary fission/mitosis. This would “create” the ability to reproduce cells or organisms, which would come into existence with step 4.
 - D. Step 4 - **Protobiont** membrane formation – Experiments have shown that lipids and other organic molecules, from steps 1-3, can form membrane bound structures, similar to cell membranes. This formation allows for complex molecular interactions to occur in a safe, inner “environment” away from the outside “environment”. In simple terms, you have an “inside” area separated from an “outside” area by a lipid (oil) based structure referred to as a membrane. Over millions of years of evolution these *enclosed* environments would become the first Prokaryotic cells. These Prokaryotic cells would possess DNA and RNA molecules inside them. The RNA would be used to construct Ribosomes, which are needed to link Amino Acids together in the making of proteins. The DNA would be for storing that protein “making” information as well as passing it on to the next generation. Thus life could come into existence, according to science by these means over billions of years.

AP Biology
Basic Cell Structure

(Associated Learning Objectives: 1.9, 1.10, 1.11, 1.12, 1.14, 1.15, 1.16, 1.27, 1.28, 1.29, 1.30, 1.31, 2.4, 2.7, 4.5)

- I. Cells
 - A. These are considered to be the *basic unit of life*.
 - B. The cell is an example of *Emergent Properties*. If you only have organelles, nothing can happen; but if you have all the organelles together and inside a membrane “life” could emerge.
 - C. All cells are considered *Open Systems* in their natural settings because there are materials coming into the cell from the surrounding environment; as well as, materials leaving the cell and going into the surrounding environment. The cell is open to interaction with the environment.
- II. **Cytology** is the study of cells; **Cytologist** – a person who works with cells.
- III. Cell Types that exist
 - A. **Prokaryotic cells** (“pro” means “before”, “kary” means “nucleus”, “ote” means “organism”)
 1. These organisms (bacteria) would have evolved before a nucleus had evolved into existence.
 2. It is believed that the first prokaryotic cells came into existence about 3.5 Billion Years Ago (BYA).
 3. The oldest prokaryotic fossils are found on stromatolites (bacterial mounds) in Shark Bay, Australia.
 - B. **Eukaryotic cells** (“Eu” means “true”)
 1. These cells would have “truly” evolved after a nucleus had evolved, as all they possess a nucleus.
 2. The **Endosymbiotic Hypothesis** proposed by Lynn Margulis in the 1960s.
 - a. It basically hypothesized that Prokaryotes came to live together in a symbiotic relationship, the smaller living **inside** the larger, to gain a survival advantage over other prokaryotes and eventually they evolved into Eukaryotic cells over many generations that spanned hundreds of thousands of years.
 - i. Smaller organism gained protection.
 - ii. Larger organism gained energy production or faster motility.
 - iii. Over time DNA segments were “swapped” to create a more permanent existence. This “swapping” is referred to as **genetic annealing**.
 - b. Supporting pieces of evidence will be seen in the structures of the Mitochondria, Chloroplasts, and Flagella.
- IV. Surface- to- Volume Ratio is of GREAT Importance for all cells.
 - A. Cells can only be so small. (There has to be *enough* room (volume) to hold things and to perform work inside a cell using the cell membrane.)
 - B. Cells can only be so large. (Larger means more traffic going in both directions across the cell membrane.)
 - C. A cell must be large enough to contain DNA and Ribosomes for making proteins, and some cytoplasm to act as working “space”. They can only be so big because we have to be able to move enough “food” into and “waste” out of a cell efficiently. If it is too large the cell becomes inefficient at moving these things so it divides to get back to a smaller state.
 - D. Think of cells as cubes. We can find the *surface area* of a cuboidal cell by using the formula: Length X Width X 6 **OR** 6 X S². S represents “a side” and the measurement is *Squared*. (i.e. cm², mm², or m²)
 - E. We can also find the *interior volume* of a cell by the formula: Length X Width X Height **OR** S³. This measurement is *cubed*. (cm³, mm³, or m³)
 - F. The comparison is made as such: SA:V, in lowest common denominator form. For all cells, they desire a much higher surface area than volume so as to be *most efficient* in transport by diffusion across the membrane.
- V. Basic Prokaryotic Cell (Bacteria) Structure
 - A. All prokaryotes are unicellular. The cell possess inside DNA (in the **nucleoid**), ribosomes, and cytoplasm.
 - B. Three basic shapes of prokaryotes exists:
 1. Cocci (Means “round”)
 2. Bacilli (Means “rod”)
 3. Helical (Means “spiral”)
 - C. Most prokaryotes will have a **cell wall**. (This is NOT the same as a plant’s cell wall.)
 1. This structure is primarily for protection of the underlying cell membrane.
 2. It also helps prevent the prokaryotes from bursting in an aquatic environment. (The cell is hypertonic to the surrounding hypotonic water. **Remember, water travels Hypo to Hyper.**)
 3. The cell wall is mainly composed of proteins and sugars. (What are called **peptidoglycans**.)

(“peptide” refers to the proteins; “glycan” refers to the sugars.)

4. Scientists perform a Gram staining for easy, fast identification of most bacteria.
 - a. Gram + (stain blue) (They possess a THICK peptidoglycan layer.)
 - b. Gram - (stain Red) (These possess a THIN peptidoglycan layer BETWEEN phospholipid layers.)
 - c. Gram- are more dangerous to humans and are usually resistant to antibiotics.
- D. Some bacteria produce a **Capsule** that covers the cell wall. (The capsule is a sticky substance for adherence to surfaces. This capsule material is what actually makes people sick; not the bacteria.)

VI. There are three main parts to Eukaryotic Cells

- A. Plasma “cell” membrane (This holds the cell together. *Same as Prokaryotic cells*)
- B. Nucleus (This controls the activities of a cell by holding the DNA. The DNA is the “instructions”.)
 1. *Prokaryotic cells have DNA in the nucleoid.* (“oid” means “like”...like a nucleus)
- C. Cytoplasm or cytosol (This creates room for work and space for holding organelles and ribosomes.)
 1. *Same as Prokaryotic cells, EXCEPT without the organelles.*

AP Biology
Biochemistry – Chemistry Basics
(Associated Learning Objectives: 4.1, 4.2, 4.3, 4.17)

- I. CHNOPS (The most common elements in ALL life forms.) and **Trace** elements (present in **small** amounts).
- II. **Atom**
 - A. The smallest *unit of matter* that has chemical properties because of it having all the subatomic parts.
 - B. Atoms still maintain their original properties of that element, because the subatomic parts are all present.
- III. **Subatomic Particles** (Small parts that make up atoms.) (“**sub**” means “below” or “lower”)
 - A. **Proton** - These particles carry a positive charge. They are located in the nucleus of an atom.
 - 1. The number of protons never changes in an element. (This allowed the *Periodic Table* to be created.)
 - B. **Neutron** - These particles carry NO charge, which is called **neutral**. They are also located in the nucleus of an atom.
 - 1. The number of neutrons can change. (Atoms with different numbers of neutrons than the *normal amount* for that element are called **Isotopes**.)
 - C. **Electrons** - These particles carry a negative charge. They are located in the “Electron cloud”. The cloud is *created* because electrons move at the speed of light, which creates a blur around the atom. (The electrons moving, which is called **kinetic energy**, is why they are associated with energy and batteries. It is **potential energy** when they are bonded. The symbol is e-.)
 - 1. The number of electrons can change. (Atoms with different numbers of electrons than the *normal amount* for that element are called **Ions**.)
- IV. **Molecule**
 - A. Two or more *atoms* bonded together. (They maybe the same type of atom or they maybe different atoms.)
- V. **Energy** (represented by the symbol “E”)
 - A. Energy comes primarily from the rapid *movement* of electrons (e-).
 - B. **Potential Energy (PE)** – Energy of *position*. (Usually refers to electrons “locked” in a chemical bond.)
 - C. **Kinetic Energy (KE)** – Energy of *movement*. (Usually refers to electrons that can move freely.)
 - D. **E levels or e- shells** – Where the electrons or E is located within an atom or molecule.
 - E. *Adding energy* to electrons makes them move farther out; *losing energy* causes them to move inward.
 - F. **Valence Shell**- Where the *outer most electrons* are located on an atom.
 - G. **Valence e-** - Refers to the outer most electrons. (**These are the most important for chemical bonds and the chemical properties of an element or molecule.**)
 - H. **Valence** – Refers to the *bonding capacity* of an atom. (Depends on the number of valence electrons.)
- VI. **Chemical Bonds** (These occur between elements or molecules.)
 - A. These are *attempts* to fill the outer most shell (valence shell) so as to become *stable molecules*.
 - B. **Covalent Bonds**
 - 1. This type is the *strongest* type of chemical bond.
 - a. Results from *sharing electrons* between elements or molecules to fill *both* outer shells.
 - 2. They *always* create a molecule. (The size of the molecule may differ though.)
 - a. Two or more atoms together of any kind.
 - 3. **Polar molecules** carry an *electrical charge* at opposite poles (poles refers to the “ends” of the molecule) and **non-polar** molecules *do not have an electrical charge*.
 - 4. **Electronegativity**
 - a. Refers to the element’s or molecule’s *desire to acquire or release* electrons.
 - b. Hydrogen atoms (The **LEAST** electronegative biological element. **It wants to RELEASE e-**.)
 - c. Oxygen (The **MOST** electronegative biological element. **It wants to ACQUIRE e-**.)
 - C. **Structural Formula** is used to *show the shape* of the molecule.
 - D. **Molecular Formula** are used to *tell the elements, and number of atoms of each*, that make up a molecule.
 - 1. A.K.A. **Chemical Formula**
 - E. **Ionic Bonds**
 - 1. These are *fairly strong* bonds while dry – but are weak in water so they dissolve into **ions**.
 - 2. These bonds are created by *swapping electrons* between elements so that each element can fill it’s outer most shell.
 - 3. When dissolved in water, **Ions** (charged particles) are created. (Gatorade is an ion loaded drink.)
 - a. **Cations** – possess a *positive charge* because it has more protons than electrons.

- b. **Anions** – possess a *negative charge* because it has more electrons than protons.
 - c. THESE LOVE WATER. (Because water is a polar molecule too.)
 - 4. **Ionic Compounds**
 - a. A cation bonded to an anion to make a salt when dry.
- F. **Hydrogen Bonds**
 - 1. *Fairly weak* bonds. (It is “like” a magnet. A positive Hydrogen attracted to a negative “Substance”...USUALLY oxygen.)
 - 2. **THESE ARE THE MOST IMPORTANT BIOLOGICAL BONDS.**
- G. **Van der Waals Interactions**
 - 1. These are *temporary bonds*. (Usually a fraction of a second.)(Involves *enzymes* mostly.)
 - 2. These *interactions* are “created” when electrons clump on one side of an atom making that side temporarily “negative” and the other side “positive” so that charged particles can attach *momentarily* and then they unclump, because electrons are moving, and the “interaction” disappears because of loss of the charge.

AP Biology
Biochemistry (Water) – Part 1
(Associated Learning Objectives: 2.9, 4.1, 4.2, 4.3, 4.17)

- I. Water *supports life* on Earth.
 - A. Water, mainly found *inside* of cells, makes up 70 –95% of the organisms body for all life forms on earth.
 - B. Water is the *only* substance on earth to be found in all 3 states naturally, those being *solid, liquid, and gas*.
- II. **Biogeochemical Cycles** (“Bio” means “life”; “geo” means “earth”) These refer to the cycling of matter.
 - A. **Water cycle** – Water vapor is *generated* by the sun causing evaporation of the bodies of water such as oceans and lakes. This water vapor is *carried* by the winds to almost the whole world. It condenses in the air to make rain or snow (referred to as precipitation) and is returned to the land or ocean. Eventually, the water that lands back on land, makes its way to plants or rivers and streams that lead back to the oceans. Plants take in the water and use it for photosynthesis but also can lose it in the form of transpiration to the air.
- III. Water is a **Polar** Molecule.
 - A. Water’s polarity allows for it to make **HYDROGEN** bonds easily, which helps with nutrient transport.
 1. Remember, the two negative electrons from Hydrogen are “clumping” around the oxygen atom as a result of the *covalent bonding* between Hydrogen and Oxygen, so the Oxygen molecule has more electrons than normal and thus a negative charge. The Hydrogen end just has the single positive proton. One side is negative and the other is positive.
 - B. This polarity makes it possible to conduct electricity very well. (Remember, electricity is flowing electrons.)
 - C. The polarity allows for a single water molecule to bind to **4** other water molecules at a time.
- IV. **Cohesion**
 - A. This term refers to water molecules binding to *other water molecules*.
 - B. This property is made possible because of **HYDROGEN** bonds.
 - C. This is important in the Cohesion-Tension Principle that describes how water moves upward in plants xylem tissues by making water “chains”.
- V. **Adhesion**
 - A. This term refers to water molecules binding to something *other than water molecules*.
 - B. This property is made possible because of **HYDROGEN** bonds.
- VI. Water helps with **Temperature Regulation** in organisms and on the Earth.
 - A. Water can act as a huge heat “piggy” bank. (Such as when the sunlight hits the oceans and other water bodies and the water heats up SLOWLY as it absorbs the light energy.)
 - B. This property is made possible because of **HYDROGEN** bonds.
 - C. It takes tremendous amounts of E to break *all four hydrogen bonds at once* and turn liquid water to a gas.
 - D. This is an important worldly effect as it helps to keep the temperature of Earth stable (the water of the oceans absorbs the energy of sunlight but does not evaporate completely, so we don’t fry, and then releases that same energy at night, so we don’t freeze... remember, that one side of earth is always in the sun and the other side is dark so temperature is stable.)
 - E. Ice cubes and cold drinks (The hot drink molecules lose energy as they try to warm up the frozen water molecules thereby causing the drink to “cool”.)
- VII. **Evaporative Cooling** effect for plants and animals:
 - A. Putting heat E into water, causing the water to *evaporate and carry the heat E away* from the body thus providing a cooling of the organism to occur as the E leaves.
 - B. Wind *increases* the effect of cooling by carrying the water vapor away from the body. **Humidity**, water vapor in the air, decreases the effect because water can’t evaporate into the air, as it is already full of water vapor.
- VIII. Expansion of Water when it freezes.
 - A. Water condenses down to 4°C Celsius; after that, the colder it gets, the more it expands.
 - B. The **HYDROGEN** bonds move outward to 90° angles from original position of 105°. This movement “pushes” the water molecules farther apart and thus it becomes less dense.
 - C. Life was and still is able to survive under the FLOATING ice that occurs at the poles and during winter.

AP Biology
Biochemistry (Water) – Part 2
(Associated Learning Objectives: 4.1, 4.2, 4.3, 4.14, 4.15, 4.17)

- I. Water is the **Universal Solvent**.
 - A. **Solvent** – Liquid that is *doing the dissolving* of another substance.
 - B. **Solute** – Substance *being dissolved* in the solvent.
 - C. **Solution** – Substance possessing *equal distribution* of material. (Kool-aid is a good example.)
 - D. **Suspension** – *Temporary suspension* of material. (Italian Dressing herbs in a bottle are a good example.)
 - E. **Colloid** – *Extended temporary suspension* of material. (Milk is a good example.)
 - F. **HYDROGEN** bonds of water make each situation possible.
 - G. **Hydration shell** – Water *surrounding* a molecule. Substance is dissolved and “disappears”.
 - H. Oils, grease, and fat are NON-POLAR and therefore water can’t grab and dissolve. (Need salt to make a molecular bridge to dissolve... MOST dishwashing liquids are just SALTWATER with coloring.)
- II. **Hydrophobic** (“hydro” means “water”; “phobic” means “fear of”)
 - A. Water *cannot* attach to the substance because the substance is non-polar.
 - B. The substance “hates” water’s polarity.
- III. **Hydrophilic** (“philic” means “love of”)
 - A. Water *can* attach to the substance because the substance is polar.
 - B. The substance “loves” water’s polarity.
- IV. “WET” Chemistry Terminology
 - A. **Mole** (mol)
 1. Refers to a measurement of molecules that is relative to its molecular weight.
 2. Avogadro’s Number 6.02×10^{23} .
 - a. # of molecules of that particular substance present in a 1 mole.
 3. Find the molecular weight of a molecule using the Periodic Table and then weigh out that many grams of the substance and that amount is equal to 1 mole. (Sucrose = 342, so I need 342 grams.)
 - B. **Molarity**
 1. Term for telling how many moles of a substance are *dissolved* in a solution. (Usually water.)
 - C. **Dissociation**
 1. Refers to water breaking apart into H^+ (Proton) and an OH^- (Hydroxide Ion).
 2. **Acid** – a substance that gives away H^+ . (Measured on a **pH** scale.)
 - a. Scale goes from 0 to 14.
 - b. 7 neutral
 - c. ON THE pH SCALE: <7 - substance is an ACID; >7 - Substance is a BASE.
 3. **Base** – a substance that gives away OH^- . (Measured on a **pOH** scale.)
 - a. ON THE pOH SCALE: <7 - Substance is a BASE; >7 - Substance is an ACID.
 4. The scales are *inverse*.
 - D. **Buffer**
 1. A substance that *can resist changes* in pH or pOH.
 2. It can take on or gives off a H^+ or OH^- to maintain the pH or pOH concentration.
 3. Good example is Human Blood –The buffer is Bicarbonate (HCO_3^-).
 - a. Bicarbonate helps keeps blood at a pH of 7.4, ideally.
 - b. It is needed because of the food, drink, air or other substances we put into our bodies.
 - c. Blood pH is below 7.2. (This condition is called **Acidosis** and can be deadly.)
 - d. Blood pH is above 7.6. (This condition is called **Alkalosis** and can also be deadly.)
 (“sis” means “the condition of being”)
 4. The pH of the blood affects oxygen’s ability to adhere to red blood cells.
 - E. **Acid Precipitation** (Refers to Rain, Snow, Sleet, Ice, or Fog with a low pH.)
 1. Water falling in the environment that has a pH of **less** than 5.6.
 2. Mainly because of SO (Sulfur oxide) and NO (Nitrous oxide) in the air to combine with water.
 - a. Both are found in *fossil fuels* when burned. (Such as oil, gasoline, or diesel fuel.)
 3. **Leaching**
 - a. This refers to the rain *pushing nutrients away* from plant roots to deeper in the soil.
 - b. Process causes the plant to starve and the rain burns the plants leaves.
 4. Lowest recorded was about 3.2 in Ohio, West Virginia, and Pennsylvania.
 - a. During the Mid 1970’s.
 - b. This brought about massive regulation laws for industry.

AP Biology
Biochemistry: Carbon Properties

(Associated Learning Objectives: 1.9, 1.10, 1.11, 1.12, 1.27, 1.28, 1.29, 1.30, 1.31, 1.32, 4.1, 4.2, 4.3, 4.17)

- I. Organic Chemistry
 - A. *Branch of science* dealing with the element carbon and its many properties.
 - B. It is usually associated with *all* living organisms.
 1. About 30% of an organism's *dry weight* (called **Biomass**) is Carbon in organic molecules.
 - a. Helps to make the organic molecules: *Carbohydrates, Lipids, Proteins, and Nucleic Acids.*
 - b. The *original source* for Carbon in *all life forms* is Carbon Dioxide. (CO₂ - Photosynthesis)
 - i. Also supported by the Stanley Miller experiment, as discussed below.
- II. Stanley Miller Experiment (Took place in 1953.)
 - A. He took *inorganic substances* found in Earth's early atmosphere, such as H₂O vapor, H₂, NH₃, CH₄, and created *organic* amino acids and oils. (CO₂ and CH₄ are *not* considered organic compounds, even though they contain Carbon.)
 1. There are 20 amino acids that are used to make proteins in living organisms.
 2. Early Earth? (He analyzed volcanic gases to determine what the air must have been like.)
 3. Energy source to power the chemical reactions? (Electricity replaces lightning.)
- III. Carbon's e- configuration:
 - A. Carbon has versatility in four directions because of its **Tetravalence**. ("Tetra" means "four")
 - B. The tetravalence allows carbon to act like *an intersection* in the building of an organic molecule.
 1. This allows cells to build an almost infinite number of *different* molecules.
 - C. **Covalent** bonding *capabilities* of Carbon:
 1. **Single Bond** between Carbon atoms.(Shown as: C-C)
 2. **Double Bond** between Carbon atoms. (Shown as: C=C)
 3. **Triple Bond** between Carbon atoms. (Shown as: C≡C)
- IV. **Hydrocarbons**
 - A. Molecules containing mostly Carbon and Hydrogen.
 - B. Most hydrocarbons are *energy sources*. (Some examples are: Fossil fuels, Oils, And Fats.)
 1. The more Hydrogen atoms in a molecule; the more energy there is in the molecule.
 - C. Hydrocarbons are important parts of cell membranes. (The tails of phospholipids.)
 - D. All hydrocarbons are *extremely hydrophobic* because they are nonpolar molecules. ("Afraid of" water's polarity.)
- V. **Functional Groups** Associated with *Organic Molecules*:
 - A. These are the sites of most organic molecules chemical reactions or properties. (They have a *function* to do.)
 - B. **Hydroxyl s** (-OH)
 1. This group allows molecules to act as an *alcohol* or *polar* molecule.
 2. Name usually ends with "ol".
 - C. **Carbonyls** (Only has *one double bonded* oxygen. It takes *one* stroke to make a lower case "n".)
 1. *Aldehydes* (A is at one *end* of the alphabet. Carbonyl is located on the end of the molecule.)
 2. *Ketones* (K is in the *middle* of the alphabet. Carbonyl is located in the middle of the molecule.)
 - D. **Carboxyl** (Has *two oxygens*...one double bonded and one singled. It takes *two* strokes to make an "x".)
 1. These molecules can act as an acid by *losing* a Hydrogen atom and can also possibly polar too.
 - E. **Amine** (Contains Nitrogen)
 1. Can act as bases by *picking up* free H⁺.
 - F. **Sulphydrils** (Contains Sulfur)
 1. Sulfur can make Di-Sulfide bridges for "pockets" in protein formation .
 - G. **Phosphate** (Contains Phosphorus)
 1. These molecules are usually involved in *E Transfers*, such as associated with ATP. It can also act like an *Anion*, a negative ion.

AP Biology
Biochemistry (Macromolecules) – Part 1
(Associated Learning Objectives: 2.4, 2.5, 2.10, 4.1, 4.2, 4.3, 4.17)

- I. **Macromolecules** (“Macro” means “large”)
 - A. **Polymers** (“poly” means “many”; “mer” means “unit”).
 1. These are formed from *individual units* called **monomers** “Building Blocks”.
 2. Monomers are linked together by *covalent bonds*. Organisms need these to stay intact so the strongest type of bond is used.
 - B. Macromolecules are formed by **Dehydration or Condensation Reactions**.
 1. Hydroxyl and Hydrogen must be *aligned* properly to *produce water*.
 2. This orientation of molecules and making of a bond *releases E*.
 3. *Enzymes* help *speed up* the rate of the reaction.
 - C. Macromolecules are broken apart into individual monomers by **Hydrolysis reaction**. (“lysis” means “to split.”)
 1. This process *requires E* in the bond breakage.
 2. The process *needs* water (hydroxyl and hydrogen) to fill the open bonds on the monomers.
 3. *Enzymes* speed up the rate of the reaction here too.
- II. **Carbohydrates** (“Carbo” refers to “Carbon”; “hydrate” refers to “water”.)
 - A. These macromolecules are mainly *sugars*.
 1. **Monosaccharides** - Are the monomers or “building blocks”. (“sacch” means “sugar”).
 2. **Polysaccharides** - Are the polymers.
 - B. The chemical composition is: Carbon = Oxygen; 2X as much Hydrogen is also present.
 - C. The names usually end with “ose”. (Such as Fructose, Glucose, Sucrose.)
 - D. These are *primary E sources* for cells.
 - E. Carbohydrates serve as the raw building materials for the other 3 Organic Molecules.
 - F. The covalent bond between monomers is called a Glycosidic Linkage. (It means “Sugar Bond”).
 - G. Carbohydrates can also be sources of *stored E* in cells or organisms.
 1. **Starch** - E storage molecule in plants.
 2. **Glycogen** – E storage molecule in Animals.
 3. **Cellulose** – Structural component of plant cell walls.
 - a. Cellulose is the most abundant organic compound on Earth.
 4. **Chitin** – This is the exoskeleton of some animals and also Fungi cell walls.
- III. **Lipids**
 - A. These macromolecules are *fats, oils, waxes, and steroids*.
 - B. Most lipids are *hydrophobic* molecules. (“Hydro” means “water”; “phobic” means “fear of”).
 - C. Lipids are mainly composed of *Hydrocarbons* (All the Hydrogens means lipids have 2x The E of Carbs.)
 - D. Two Main parts:
 1. **Fatty Acid** (It is a Hydrocarbon.)(Number of Carbons will be a multiple of 2 if it is made by living cells.)
 2. 3 Carbon **Glycerol molecule** (alcohol) to *hold the whole molecule together*.
 3. Lipids use a *covalent bond* called an **Ester Linkage** to hold the fatty acid and glycerol together.
 4. An Ester linkage is a *Carboxyl of the Fatty Acid* paired with a *hydroxyl of the glycerol* molecule.
 - E. Major Types of lipids:
 1. **Triglycerols or Triglycerides** (These are your basic fat or oil.)
 - a. There are **saturated fats**. These fatty acids are saturated with Hydrogen atoms. The molecule has *no open bonds* to put any more Hydrogen on. (These are *solid at room temp* and they usually are *associated with animals*. These are the *bad types of fat* when it comes to our diet.)
 - b. There are **unsaturated fats**. These have *double or triple bonds* that “could be broken” to add more Hydrogen to the fatty acid. (These are *liquids at room temp*. and they usually are *associated with plants*, such as vegetable oil, sunflower oil, or peanut oil. The “good” fats.)
 - c. There are also **polyunsaturated fats**. These have *numerous double or triple bonds* in the fatty acid portion. (These are also liquids at room temp. and they are also usually from plants.)
 - d. **Hydrogenated or Trans fats**. These are *oils turned solid* by **adding Hydrogen** and by *breaking the double or triple bonds* so in order to **TRANSFORM** it into a saturated fat.
 2. **Phospholipids**
 - a. These molecules *replace* a single fatty acid with a single Phosphate ion. (This part of the molecule is **Hydrophilic**. [“philic” means “lover of”] It loves water because the Phosphate

carries a *negative* charge. Remember, water is polar, so the negative Phosphate will be *attracted to* the positive Hydrogen portion of water.)

- b. They still have 2 Fatty Acid tails. (These are the Hydrophobic portions of the molecule. They carry a neutral charge. Therefore, they are not attracted to water.)
- c. Phospholipid Bi-layers (having 2 layers) are common for *cell and organelle membranes*.

3. Waxes

- a. These are made by combining *alcohols with unsaturated oils*. (Such as girls lipsticks, which also have coloring, added to make the different shades.)

4. Steroids, Hormones, and Cholesterol

- a. A steroid has *4 carbon rings with the top ring looking like a house*.
- b. What make them different are the *attached functional groups*. These functional groups help determine the *function* of the steroid.
- c. Cholesterol is also a steroid molecule, but it helps with *cell membrane flexibility*. All membranes need to have some cholesterol to remain flexible. Cholesterol IN EXCESS is bad for your health though.

F. Lipids are *stored in adipose tissue* in animals.

AP Biology
Biochemistry (Macromolecules) – Part 2
(Associated Learning Objectives: 2.8, 2.9, 4.1, 4.2, 4.3, 4.5, 4.10, 4.15, 4.17)

- I. **Proteins** (A. K.A. **Polypeptides**) and Enzymes (Enzymes are a TYPE of protein.)
- A. These macromolecules make up greater than 50% of an organisms dry weight, called *biomass*.
 - B. Names usually end with the suffix “lin” (i.e. Insulin) for proteins and “ase” for enzymes (i.e. Sucrase)
 - C. The *monomer “building blocks”* are called **Amino Acids** (There are 20 different Amino Acids that can be involved in making proteins. Proteins and enzymes usually have hundreds to thousands of Amino acids in their structure.)
 - D. **Amino Acids** have 4 different parts to them:
 - 1. **Carboxyl end** (COOH) – This part *acts as the acid* because it can give off the Hydrogen.
 - 2. **Amine end** (NH₂) – The end *can act as a base* by accepting a third Hydrogen.
 - 3. **Alpha (α) Carbon** – This is the *central Carbon* that holds the whole molecule together.
 - 4. **R group** - This is the *most important part* as it gives each amino acid its distinctly different property. (Notice all 20 amino acids have a different R group.)
 - E. Individual Amino Acids (monomers) are bonded together by a *covalent* bond called a **peptide bond**. An *amine end* of one amino acid is positioned to combine with the *Hydroxyl* on the Carboxyl end of the second amino acid. The open bonds left behind, by removing to make water in the *dehydration reaction*, allows for a bond between the Carbon and Nitrogen to be created. When we put **many** amino acids together, we get a **POLYPEPTIDE** or protein.
 - F. *Arrangement and Quantity* of Amino acids affect the structure and function of that protein or enzyme. (Structure = Function)
 - 1. **Primary Structure** (Represented by the symbol - 1')
 - a. This refers to the **sequence of bonded Amino Acids**. (THINK “SEQUENCE” for Primary structure.)
 - b. **Primary Sequence is REALLY IMPORTANT!** Just look at the difference between Sickle-Cell Disease and normal red blood cells. Just changing the SIXTH amino acid in the primary sequence creates this horrible condition.
 - 2. **Secondary Structure** (2')
 - a. **HYDROGEN** bonds allow for overlapping and coiling to occur in the “folding” of the protein into that 3-D shape. **All proteins must be “folded” in order to work**. (THINK “FOLDS AND COILS” for secondary structure.)
 - b. Coiling – Is referred to as an **Alpha (α) helix**.
 - c. Overlapping – Is referred to as a **Beta (β) pleat sheets**.
 - 3. **Tertiary Structure** (3') (“Tert” means “third”)
 - a. Di-sulfide bridges help *stabilize* the proteins folded structure.
 - b. To make the Di-Sulfide bridge, the Amino Acid Cystein is needed.
 - 4. **Quaternary Structure** (4')
 - a. This is when two or more polypeptides are woven together.
 - b. **Hemoglobin** - Red Blood Cells [RBCs] have four proteins woven together to make it. (THINK “MULTIPLE WOVEN TOGETHER” for Quaternary structure.)
 - G. **Denaturation** (Enzyme “unfolding”.)
 - 1. The “unraveling” of a protein or enzyme causing it not to function.
 - 2. Denaturing can be caused by *ph changes, salt concentration changes, and temperature changes*.
 - H. **Chaperonins**
 - 1. **Protective structures** that allows proteins to fold inside *without water being present*.
 - 2. A “Chaperone” is a person who **watches over a function** or date to make sure nothing terrible happens.
 - I. **Nitrogen Cycle** - The majority of Nitrogen is removed from the air by water. Remember, water is the universal solvent, so the gas is dissolved in the rain or snow. The Nitrogen in the water mainly is consumed by **Nitrogen Fixing bacteria**, in the soil, that convert it into Ammonium (NH₄). This process is referred to as **Nitrogen Fixation**. The Ammonium can then be absorbed by plants to help make proteins and DNA or RNA. Some Ammonium (NH₄) in the soil is also consumed by **Nitrifying Bacteria**, and converted to Nitrite (NO₂) first and then ultimately into Nitrate (NO₃). This process is called **Nitrification**. The Nitrates are also absorbed by the plants, just as was the Ammonium. (The plants **ate** the **Nitrates and Ammonium**, but not the Nitrites.) Some other bacteria in the soil can also eat the Nitrates. These are called **Denitrifying Bacteria**. They consume the Nitrates and break it

down into Oxygen gas (O_2) and Nitrogen gas (N_2) and both are returned to the air to be used again. This process is called **Denitrification**. As plants are eaten by animals, the Nitrogen travels through the food chain. When all life forms die, the bodies decompose and create Ammonia (NH_3), which is why they stink. The Ammonia is converted by bacteria into Ammonium to be used again by plants and bacteria. This conversion is called **Ammonification**. Some Nitrogen is also released by animals in their urine. It too undergoes Ammonification.

AP Biology
Biochemistry (Macromolecules) – Part 3
(Associated Learning Objectives: 2.8, 2.9, 4.1, 4.2, 4.3, 4.5, 4.10, 4.15, 4.17)

- I. **Nucleic Acids**
 - A. *Monomers* are called **Nucleotides**.
 - B. *Polymers* are called **DNA or RNA**- It depends on the 5 Carbon sugar present in the monomer.
 - 1. DNA has *Deoxyribose* for the 5 Carbon sugar.
 - 2. RNA has *Ribose* for the 5 Carbon sugar.
 - C. These are the *source of genes and hereditary information* primarily.
 - D. Two Types:
 - 1. **DNA** – This polymer is the “Master Million Dollar Blueprint”. It is kept “safe” in the nucleus. (Nucleus is like a vault to keep the DNA in.)
 - 2. **RNA** – This polymer is like a “cheap 10 cent copy” of the “Master Million Dollar Blueprint”. It is disposable/recyclable. It makes messenger RNA and other RNA molecules.
 - E. **Pyrimidines** (C, T, U)
 - 1. Big name small molecule. (These have 1 Carbon ring in the Nitrogen base.)
 - 2. “Counting steps Takes you Up the **Pyramid**” is the easy way to remember them.
 - F. **Purines** (A, G,)
 - 1. Small name big molecule. (These have 2 Carbon rings in the Nitrogen base.)
 - 2. “Alabama is **Purely** Greater than Auburn” or “Auburn is **Purely** Greater than Alabama” is an easy way to remember. It just depends on who you like more.
 - G. *It is Always* a pyrimidine paired with a purine.
 - H. Individual nucleotides joined by a *covalent bond* called a **Phosphodiester bond**. The *phosphate* of one nucleotide is joined with the 5 *Carbon Sugar* of the previous nucleotide.
 - I. **THE SEQUENCE DETERMINES WHAT PROTEIN OR ENZYME IS MADE!**
 - 1. Structure = Function and Emergent Properties are themes related to Nucleic Acids too.
 - 2. That is why it is the “BLUEPRINT”.
- II. DNA Double Helix Structure
 - A. James Watson and Francis Crick make the model in 1953.
 - B. The two sides of DNA strands are said to be **complementary**. (They fit together perfectly.)
 - C. One side has information to make proteins and enzymes (The Million Dollar Blueprint); other side is a *protective cap* for the Million Dollar Blueprint. It protects the **SEQUENCE** of nucleotides. The sides *alternate* on each strand.
- III. Genes and Evolution
 - A. The more Nucleotide sequence “genes” in common; the *more closely related* the organisms are.
 - B. The fewer Nucleotide sequence “genes” in common: the *more distantly related* they are.
- IV. **Phosphorus Cycle** - The Phosphorus is initially a component of rock. As the rock breaks down over time, called **weathering**, the Phosphorus is released into the soil. Some dissolves into the water as the rains pass through the soil. This Phosphorus makes its way into bodies of water, such as lakes and oceans, and is available for producers (phytoplankton) to use to help make organic compounds such as phospholipids and DNA or RNA. Plants (also producers) can also retrieve the Phosphorus from the soil and use it to make organic compounds too. When organisms die, decomposers break down the bodies and return the Phosphorus back to the soil to be reused.

AP Biology

Membrane Structure and Transport of Molecules – Part 1

(Associated Learning Objectives: 2.6, 2.7, 2.8, 2.9, 2.10, 2.11, 2.12, 2.13, 2.15, 4.4, 4.5, 4.6, 4.14, 4.16)

- I. Selectively Permeable
 - A. The cell “selects” what materials *enter or exit* the cell through the membrane.
- II. Membrane Structure
 - A. Phospholipids make up the *majority* of the cell membrane and also organelle membranes.
 1. These are **Amphipathic** Molecule. (It means there is a *hydrophilic and hydrophobic* component.)
 2. These molecules create the bi-layer and the structure is held intact by the *presence of water* outside and inside the cell. The *negatively* charged Phosphorus line up to make a barrier preventing water from forming **hydration shells**, water surrounding a molecule, around the phospholipids and thereby dissolving the membrane.
 - B. Proteins
 1. These are *also* **Amphipathic** molecules. (This is due to proteins folding into a 3-D structure and that proteins are composed of *amino acids*, of which some are *polar* and some are *non-polar*.)
 2. Two types of proteins are present on membranes:
 - a. **Integral** – These *run completely through the bi-layer* from the outside to the inside.
 - i. These function in the transport of molecules and *foundation*. (Help to maintain the INTEGRITY of the structure.)
 - b. **Peripheral** – These are located *on one side* of the membrane. (They do not extend into the bi-layer of the membrane.)
 - i. These act as sites for *attachment* of the Cytoskeleton on the inside of the cell and the attachment of the **Extra Cellular Matrix**, ECM, (like armor for the fragile cell) on the outside of the cell.
 3. The proteins of the cell membrane can have several functions:
 - a. *Molecule transport* (Helps move food, water, or something across the membrane.)
 - b. *Act as enzymes* (To control metabolic processes.)
 - c. *Cell to cell communication and recognition* (So that cells can work together in tissues.)
 - d. *Signal Receptors* (To catch hormones or other molecules circulating in the blood.)
 - e. *Intercellular junctions* (For “stitching” cells together to make tissues.)
 - f. *Attachment points* for the cytoskeleton and ECM.
 - C. Cholesterol
 1. This molecule helps keeps the cell *membrane flexible* to some degree.
 2. It also helps to keep the cell membrane of plant cells from freezing solid in very cold temperatures, like the Tundra.
 - D. The membrane is described as a **Fluid-Mosaic model** because it looks like a *moving* (Fluid) *puzzle* (mosaic). All the pieces can move *laterally*, like students moving from seat to seat. The proteins moving in this sea of phospholipids would be like the teacher moving around the student desks. Imagine the ceiling and floor are water molecules. They keep you from moving up and down to some extent by their presence.
 1. **Scientific Model**
 - a. These are used to represent what is difficult to actually see. (Like a model of the solar system. or the model of DNA or a cell membrane.)
- III. The Importance of *Surface Area* to *Cell Volume* relationship:
 - A. All cells are considered *Open Systems* in their natural settings because there are materials coming into the cell from the surrounding environment; as well as, materials leaving the cell and going into the surrounding environment. The cell is open to interaction with the environment.
 - B. Remember, cells can only be so small. (There has to be ENOUGH room [volume] to hold things and to perform work inside a cell using the cell membrane.)
 - C. Cells can only be so large. (Larger means more traffic going in both directions across the cell membrane)
 - D. A cell must be large enough to contain DNA and Ribosomes for making proteins, and some cytoplasm to act as working “space”. They can only be so big because we have to be able to move enough “food” into and “waste” out of a cell efficiently. If it is too large the cell becomes inefficient at moving these things so it divides to get back to a smaller state.
 - E. How do you increase surface area WITHOUT increasing cell volume significantly?

ANSWER: Folding of the membrane. Look at the following examples:

 1. Your lungs and other respiratory surfaces.
 - a. The surface of the cells needs to stay wet for gas exchanges to occur; but notice the increased surface area by folding. This allows for the transport of the *massive* amounts of Oxygen (O₂) that organisms need to live AS WELL AS the CO₂ out as a waste product.

(Your lungs have the surface area *equal to a tennis court*, all jammed into your chest.)

2. Your and other animal intestines. Look at the folding at the organ and at the cellular levels. This allows your body to take in the massive amounts of food we eat. After all, you have a trillion cells to feed and they need food all day and night long.
 - a. This section of intestine has finger-like projections, called **villi**, which increase surface area.
 - i. Smaller finger-like membrane projections, called **microvilli**, are located on the cells covering the villi; this too increases surface area again.
(THE TOTAL SURFACE AREA IS EQUAL TO THE SIZE OF A FOOTBALL FIELD!!!!)
3. Your and other animals' excretory systems. Thousands of cells all try to help purify the liquid component of blood by performing selective molecule transport. The buildup of Nitrogen containing Ammonia (NH_3) comes from our cells utilizing proteins for energy production. Our excretory system gets rid of the Ammonia either as straight Ammonia (In the case of fish), as Urea (as in most land animals, including humans), or as Uric acid (for birds and reptiles) ALSO, notice that Urea and Uric acid get rid of an additional waste product... CO_2 . (Remember, this is part of the Nitrogen cycle.)

AP Biology
Membrane Structure and Transport of Molecules – Part 2
(Associated Learning Objectives: 2.6, 2.7, 2.8, 2.9, 2.10, 2.11, 2.12, 2.13, 2.15, 2.17, 4.4, 4.5, 4.6, 4.14, 4.16)

I. Material Transport

- A. CO₂ and O₂ (both gases) diffuse across the *wet bi-layer* because they are *neutrally* charged particles.
- B. Ions and water move through the proteins because of *particle charge*. (Hence the name Transport proteins.)
 - a. Some proteins are “tunnels” and some are “grabbers”.

II. Types of **Passive Transport** (NO E required for this process.)

A. **Diffusion**

- 1. This process operates upon an *established concentration [] gradient*.
- 2. Materials flow from high [] to low [] until equilibrium is achieved.
- 3. This is how the majority of materials are transported in cells. (Because it requires no E expenditure by the cell...which saves E for maintaining homeostasis, repair, and reproduction.)

B. **Osmosis** (The diffusion of Water.)

- 1. **Water ALWAYS flows from Hypotonic to Hypertonic until Isotonic**, provided there is no pressure being applied.
 - a. Terms refer to the **material dissolved in the water, NOT the water itself**. (That is **tonic**.)
 - b. Water flows one way and the materials dissolved in the water flow the *opposite* direction.
 - c. Plants and Fungus have cell walls that *may* affect water movement, see below.
- 2. This process is crucial for *all* cells to control.
 - a. **Osmoregulation** (This term refers to water control.)
 - b. Pure water vs. normal water. Pure water is ALWAYS the **HYPO**.
 - c. **Turgid** – This refers to a condition when there is *plenty of water* in the plant cell, so the cells are rigid and the plant is stiff.
 - d. **Flaccid** – This refers to a condition when there is *not enough water* in the plant cell, so the cells are limp and the plant is wilted.
 - e. **Plasmolysis** – This is when the cell membrane *rips away* from the cell wall killing the plant cell. (“Plasmo” refers to the “plasma membrane”; “lysis” means “the process of tearing”)
- 3. **Water Potential** (Represented by the Greek letter psi – Ψ ...after Poseidon’s Trident.)
 - a. It is basically water’s *ability to perform work* while passing through the cell membrane.
 - b. It flows from High Ψ to Low Ψ . (It can be affected by the pressure of a plant cell wall.)
 - c. **Pressure Potential** (Represented by Ψ_P .)
 - i. *Pushing* is *positive pressure* being exerted on the cell. (+ Ψ_P)
 - ii. *Pulling away* from is *negative pressure* (- Ψ_P) being exerted on a cell. (Important when you consider a plant is having water pulled out of it by transpiration at the stomata and pushed in to the xylem vascular cylinder in the root. (Referred to as Root pressure.)
 - d. **Solute Potential** (Represented by the symbol Ψ_S .)
 - i. $\Psi_S = -iCRT$
 - ii. $-i$ is the *ionization constant* for a molecule (Basically, the number of ion *types* present. For example Na⁺ and Cl in water would be a constant of 2.)
 - It is *always negative*, because you *decreased* pure waters ability.
 - iii. C is the *molar concentration*.
 - iv. R is the pressure constant. ($R = 0.0831 \text{ literbars/mole-K}$)
 - v. T is the temperature in Kelvin. ($273 + ^\circ\text{C}$...Room temp is 298K.)
 - e. **Total Water Potential** (Represented by Ψ_T)
 - i. $\Psi_T = \Psi_S + \Psi_P$

C. **Facilitated Diffusion**

- 1. This transport of molecules requires the *help* of a Transport Protein.
- 2. **Aquaporins**- These help move water (because it is a polar molecule) across a membrane.
- 3. Gated-ion channels are also examples.

III. **Active Transport** (This process **REQUIRES ENERGY**.)

- A. This process is moving material against the [] gradient. (Like pushing a car up a hill...it will require energy.)
 - 1. Na⁺/K⁺ Pump of the nervous system, is an example.
 - a. Energy from ATP by **Phosphorylation** (Attaching a phosphate ion to a structure to make it work.) **activates** the protein to grab and move molecules.

IV. Membrane **Potential**

- A. This is the ability for a cell membrane *to do work* involving transport of molecules.
- B. **Voltage Gradient** (This gradient works on + and – Ions.)
 - 1. The inside of a cell is *negative* because of *anions in excess*, mostly DNA; the outside of a cell is *positive* because of *cations in excess*, mostly Na⁺. (A [] gradient or “hill” is created. So now we have the “potential” to perform work moving molecules.)
 - 2. A.K.A. Electrochemical gradient (“electro” referring to “charge”; “chemical” referring to “the ion”)
- C. **Electrogenic Pump** (A.K.A. **Proton [H⁺] Pump**)
 - 1. This is the *most important active transport protein for all life forms*. They are important in processes involved in the electron transport chain of photosynthesis and cellular respiration.
 - 2. Hydrogen ions, H⁺, move out of the cell to create a gradient. (Outside is + and inside is -.) Diffusion can now occur based on charges into and out of cell.
 - 3. **Co-transport**
 - a. Protons (H⁺) acts like party invitations. (Very little energy is required to send them out of the cell. They then bring in INVITED guests only.)
 - b. This is very important in helping cells of plants and animals to be able to take up glucose or sucrose by active transport.

V. Large Molecule Transport (These molecules are TOO big for proteins to transport.)

- A. **Exocytosis** – This is the process of moving materials *out of a cell*. (“Exo” means “out”; “cyto” means “cell”; “sis” means “process of”)
 - 1. This would be like Pancreas cells releasing the hormone Insulin into the blood stream to help regulate blood glucose levels.
- B. **Endocytosis** – This is the process of moving materials *into a cell*. (“Endo” means “in”)
 - 1. **Phagocytosis** – This process is “cell eating”. (“Phage” means “to eat”)
 - 2. **Pinocytosis** – This process is “cell drinking”. (“Pino” means “to drink”)
- C. **Receptor-Mediated Endocytosis**
 - 1. **Ligand** (This refers to *the molecule* to be transported.) attaches to a receptor protein (like the blind man’s hands) on the cell membrane... (The cell can tell what the molecule is by its shape basically.) (“mediated” means the ligand must be present to make the process occur)
 - 2. The molecule in the cell’s “hand” (receptor protein) triggers endocytosis to occur.
 - 3. Familial Hypercholesterolemia is an example. (A Genetic Disease that is inherited.)
 - a. No LDL cholesterol receptor proteins on the cell membranes of the individual.
 - b. LDL stays in the blood to clog the arteries.

AP Biology
Eukaryotic Cell Components – Part 1
(Associated Objectives: 1.14, 1.15, 2.9, 2.13, 2.14, 4.4, 4.5, 4.6, 4.8, 4.9)

- I. There are three main parts to Eukaryotic Cells:
 - A. Plasma “cell” membrane (This holds the cell together.)
 - B. Nucleus (This *controls the activities* of a cell by holding the DNA. The DNA is the “instructions”.)
 - C. Cytoplasm or cytosol (This *creates room for work and space for holding organelles and ribosomes.*)
- II. **Nucleus** (Membrane Bound Structure)
 - A. This acts as a *control center for all activities* performed by the cell. (Like the principal’s office for a school.)
 - B. It is the source of genetic information (DNA). (It “acts as the vault for the million dollar blueprint of a cell”.)
 - C. **Nuclear Envelope** (This acts as the actual “vault” to protect the DNA that is inside.)
 1. It is made mainly of a bi- layer of phospholipids.
 2. It also contains pores (tunnels) composed from *proteins* for *charged* molecules to travel through, such as nucleotides (from our food) to make messenger RNA. The messenger RNA leaves to help make proteins in the cytoplasmic “construction site”.
 - D. DNA (This is the “Million Dollar Blueprint”.)
 1. **Chromatin phase** (“The DNA is *loose*”. It would look like a bowl of plain spaghetti noodles.)
 - a. A cell can move the DNA around to find the gene of importance.
 2. **Chromosome phase** (“The DNA is *tightly wrapped up*.” This phase is used for separating the DNA *equally* during cell division. This way we hopefully get two equal sets. One set for each new daughter cell.)
 - E. **Nucleolus** (This structure acts like a photocopier in your school.)
 1. This is the site of RNA synthesis. (“Synthe” means “to make”; “sis” means “the process of”) This is the making a cheap, *disposable COPY* of DNA. We can make “messenger” RNA, mRNA, and send it to the cytoplasmic “construction site”.
 - a. It is also responsible for helping to make ribosomes, which are mostly RNA structures.
 - b. It also makes mRNA and other types of RNA molecules.
- III. **Ribosomes**
 - A. These are CELL PARTICLES made of ribosomal RNA, rRNA, and proteins. (These are NOT organelles... as *ALL CELL TYPES*, Prokaryotes and Eukaryotes, have them so that all cells can make proteins and enzymes.)
 - B. These are the site of Protein Synthesis. (These are like an actual “construction site” for a building, except they make proteins and not buildings.)
 1. Normal proteins and enzymes are ALL made here.
 - C. Two types of ribosomes exist based on location:
 1. **Free Ribosomes**– These float “freely” in the cytoplasm of a cell. (They are found in ALL TYPES of cells.)
 - a. These ribosomes make proteins that will stay *inside* the cell for use by the cell, like enzymes associated with metabolism or DNA replication.
 2. **Bound Ribosomes** – These are attached to the endoplasmic reticulum organelle (RER). (These are ONLY found in Eukaryotes ONLY because they have the organelle.)
 - a. These make proteins that will *leave* the cell to be used elsewhere. (Most are for communication between cells, such as antibodies for fighting infection.)
- IV. **Endomembrane system** (“Endo” means “inside”; “system” means “multiple parts”)
 - A. Pathway found *inside* of membrane bound *organelles* that are involved in making proteins that will be *leaving* a cell. (RER → Golgi → Membrane for release.)
 - B. Membrane bound organelles also create *separate, specialized environments* within the cell to carryout isolated, complex chemical reactions without interference from other components in the cytoplasm.
- V. **Endoplasmic Reticulum (ER)** (Membrane Bound Structure)
 - A. It is composed of a network of small tubes called cisternae. (“cisternae” means “tubes”)
 - B. They are ALWAYS found just outside and around the nucleus.
 - C. Two types of ER can exist inside EUKARYOTIC cells:
 1. **Smooth Endoplasmic Reticulum (SER)**
 - a. This structure helps with the *synthesis* of lipids, phospholipids, and steroids.
 - b. Helps with carbohydrate *breakdown*. (Glycogen “stored sugar” to glucose “usable sugar”).
 - c. Helps to *detoxify* the blood. (Liver cells are loaded with SER.)
 - d. It also helps store Ca⁺⁺, needed for *muscle contraction*. (Muscle cells have lots of SER.)

2. Rough Endoplasmic Reticulum (RER)

- a. This structure helps with *protein synthesis*. (Provides a safe area for protein folding.)
- b. Ribosomes are bound to the outside of the organelle and depositing the protein *inside* as it is made by the ribosome. Inside the structure, the protein can fold up into the specific 3-D structure needed to function.

VI. Golgi Apparatus (Membrane Bound Structure)

- A. This structure *modifies* proteins by attaching sugars to them. (What are called Glycoproteins.)
 1. It is like “Gift Wrapping” to disguise the protein for export through the cell membrane.
- B. They are composed of flattened tubes also called cisternae. (These tubes look like a stack of pancakes.)

VII. Lysosomes - These act like a “stomach” for the cell. (Membrane Bound Structure)

- A. They are involved in *digestion and recycling (autophagy)* of molecules.
- B. They are full of digestive enzymes. (Lysozyme is the name of the enzyme.)

VIII. Vacuoles and Vesicles - These act as “Closets” for storage of materials. (Membrane Bound Structures)

- A. *Storage structures* for various products needed by the cell.
- B. Various types can exist: Food, Contractile, Central.

AP Biology
Eukaryotic Cell Components – Part 2

(Associated Learning Objectives: 1.9, 1.10, 1.11, 1.14, 1.15, 1.16, 2.4, 2.5, 2.9, 2.13, 2.14, 4.4, 4.5, 4.6, 4.8, 4.9)

I. Mitochondria - Nicknamed the “Power House”. (Membrane Bound Structure)

- A. This organelle is involved in *making energy* by performing the process of *cellular respiration* inside it.
- B. This organelle has it’s own DNA, ribosomes, enzymes inside it; it can even reproduce by binary fission.
- C. It has a “small room within a larger room” appearance.
 - 1. **Cristae** – the folded inner membrane. (The folding increases *surface area* for making energy.)
- D. Evolutionary Significance? (They were believed to have been *purple bacteria*. Remember, bacteria are prokaryotes. They entered into a symbiotic relationship with a larger prokaryote that could provide protection in return for extra energy. Together they would have an evolutionary advantage over other bacteria. The advantage allowed them to survive and reproduce and eventually lead to Eukaryotic cells.)

II. Chloroplasts (Membrane Bound Structure)

- A. These organelles are the site of *Photosynthesis* in plants and algae.
- B. They are a type of **Plastid**. (Plastid is a Pigment Container. These contain the green pigment **chlorophyll**.) (“phyll” means “pigment”)
- C. Has it’s own DNA, ribosomes, and enzymes too! Reproduces by binary fission too!
- D. It has a “small room within a larger room” appearance too!
 - 1. **Thylakoid** – looks like a “green cookie rooms”. (Site of the light reaction of photosynthesis.)
 - 2. **Grana**- is a stack of “green cookies” or thylakoids.
 - 3. **Stroma**- This is mostly watery space in between the thylakoids and outer membrane.
- E. Evolutionary Significance? (They too were believed to have been blue-green bacteria that entered into a symbiotic relationship for protection in return for energy.)

III. Endosymbiont Hypothesis, remember, tries to *scientifically* explain these relationships.

- A. This hypothesis was proposed by Lynn Margulis in the 1960’s.
- B. It basically hypothesized that Prokaryotes came to live together in a symbiotic relationship, the smaller living *inside* the larger, to gain a survival advantage over other prokaryotes and eventually they evolved into Eukaryotic cells over many generations that spanned hundreds of thousands of years.
 - 1. Smaller organism gained protection.
 - 2. Larger organism gained energy production or faster motility.

IV. Cytoskeleton

- A. These structures help support and protect the cell. (Much like your skeleton does for you.)
- B. It also helps to keep inner organelles organized. (Much like your skeleton does for you.)
- C. It also helps in cell motility or cell organelle movement. (Much like your skeleton helps you move.)
- D. The cytoskeleton is composed of various sized protein fibers. (Your skeleton has different sized structures too. Largest – bones, middle – Ligament and tendons, smallest- muscle fibers.)
 - 1. **Microtubules** (These are the *largest* structures in the cytoskeleton.)
 - 1. These are large, *hollow tubes*.
 - 2. They are composed of Tubulin protein.
 - 3. Their main function is support or movement of the cell or organelle.
 - 4. Important structures made of microtubules within a cell:
 - i. **Centrosomes/Centrioles** - These act as anchors during cell division.
 - ii. **Spindle Fibers** - These act as guides or “tow ropes” for chromosomes during division.
 - iii. **Cilia**
 - These help with cell movement. Cells usually have a lot and they are small in length.
 - iv. **Flagella**
 - These are also for movement. Usually few on a cell and they are very long in length.
 - 2. **Microfilaments** (These are the *smallest* structures in the cytoskeleton.)
 - 1. These are *solid rods*.
 - 2. Composed of Actin or Myosin protein.
 - 3. They provide a **pulling** force.
 - i. They are abundant in muscle tissue cells in animals.
 - 3. **Intermediate Filaments** (These are *medium* sized structures.) (“inter” means “between”)
 - 1. These are permanent, *solid rods*.
 - 2. They are mostly composed of keratin protein.
 - 3. They help to reinforce and brace the large microtubules.

V. Protective or weight bearing structures for cells:

A. **Cell Wall** of Plant Cells (It is composed of the carbohydrate cellulose primarily.)

B. **Cell Walls** of Fungus (Composed of the carbohydrate called *Chitin*.)

C. **Extra Cellular Matrix (ECM)**

1. This is the *outer protective* “skeleton” of the cell plasma membrane in animal cells. (“extra” means “outside of”; “matrix” means “skeleton”)
2. It also functions in *communication* with other cells.

VI. **A CELL IS THE SUM OF IT’S PARTS!** It is the *basic unit of life* only when all the parts work together to make “LIFE” possible.

AP Biology
Living Metabolism - Part 1
(Associated Learning Objectives: 1.14, 1.15, 1.16, 2.1, 2.2, 2.4, 2.5, 4.1, 4.14, 4.17)

IMPORTANT Concepts from Previous Unit:

- 1) There are essentially two types of energy associated with electrons and chemical bonds – Potential and Kinetic.
- 2) To make the four macromolecules of life releases energy and dehydration synthesis reactions. To break them apart requires energy and requires hydrolysis.
- 3) The four macromolecules serve specific main processes - Carbohydrates (Immediate Energy), Lipids (Stored Energy and membranes), Proteins (Workhorse functions) Nucleic Acids (Information Storage and Inheritance).

I. Metabolism

- A. The sum of all the chemical reactions occurring in an organism.
- B. The collective process has two separate phases:
 1. **Catabolism** – This refers to the *breaking down* (hydrolysis) of a molecule.
 - a. This process releases “potential” E found in the chemical bond between monomers.
 - b. This is an **exergonic** reaction because it *releases heat to the environment*. (Think **Catastrophe**; breaking up things. Like digestion in your body.)
 2. **Anabolism** – This is the assembly (synthesis) of molecules.
 - a. This process requires “Kinetic” E to position molecules in away so as to create a chemical bond between monomers.
 - b. This is an **endergonic** reaction because it *absorbs energy from the environment*. (Think **Anabolic** steroids; these BUILD muscle.)
- C. This is a great example of **Energy Coupling** – two different processes united by common energy.

II. Energy (represented by “E”) (This is previous unit information.)

- A. Has the ability to facilitate transformation (“perform work”).
- B. There are two types of E mainly, as ALL living organisms are concerned:
 1. **Kinetic E** (represented as “KE”) - This is the energy of movement. This energy usually refers to the *movement* of electrons or protons in Biology.
 2. **Potential E** (represented as “PE”) – This is the energy of position. This energy usually is referring to the *chemical bonds* associated with those electrons and protons.
- C. For living organisms, the chemical E of life is found in chemical bonds.
 1. The processes of Cellular Respiration and Digestion releases the E for use by cells.
 2. Source of all E for Earth? It is the sun. The process of photosynthesis allows plants to transform and store this solar energy in the form of chemical energy (sugar).

III. Thermodynamics

- A. The study of Heat E (“Thermo”) and its properties (“dynamics”).
- B. **First Law of Thermodynamics** (It is also called the **Principle of the Conservation of Energy.**)
 1. Energy cannot be created nor destroyed *ONLY* transformed or transferred.
- C. **Second Law of Thermodynamics**
 1. Every Energy transfer *increases* the entropy of the universe.
 - a. **Entropy**- means “disorder”; *unable to do work* because it is in a LOW state of order.
 2. Sunlight (high quality E) going in and heat (low quality E) coming out; it can’t do work.
 3. Conception to birth to death is how life relates to the second law.
 - a. You are at your most organized state as a single cell; as you “progress” you go/move toward a state of entropy (death).

IV. Unstable State “It is Living” (*Spontaneous* movement) → **Stable “It is Dead”** (*Non-Spontaneous* – no movement).

- A. You are unstable because metabolism is constantly occurring in your body or cell; unless it or you are dead.

V. Gibbs Free E (represented as “G”)

- A. It is referred to as “free” because E is *available to perform work*. It is mainly for helping to make ATP or GTP in a cell. (These are the molecules capable of doing work with in cells, remember.)
- B. $\Delta G = \Delta H - T\Delta S$ (This is the formula for calculating Free E.)
 1. **G**- Free E (This amount goes from positive to negative as *catabolism* of food occurs.)
 2. **H**- Total usable E in the system. (Starts large, but becomes smaller as food is broken down.)
 - a. Total Useable energy in the system is referred to as **Enthalpy**.
 3. **T**- Temperature constant (Measured in Kelvin, °C +273.)
 4. **S**- Amount of Entropy (Starts at 0 but becomes larger as the reaction continues to produce heat and the highly organized food molecules are broken apart more and more.)

- C. *Not all* energy is available. (Some is lost as waste...like when we defecate...same goes for cells too.)
 - 1. *MOST* energy is lost as Heat, as a byproduct of the bonds being broken.
- D. $\Delta G = G(f) - G(i)$... The change in free E is equal to the final amount minus the initial amount.
- E. **If ΔG is negative, then there is E available “free” to perform work.** (It is *Spontaneous*. It is *Exergonic*.)
 - 1. This is the result of Cellular Respiration and Digestion. It is a Catabolic processes that releases free E.
- F. **If ΔG is positive, then there is E that is not available because it is “locked up”** and can *NOT* perform work. (It is *Non-Spontaneous*. It is *Endergonic*.)
 - 1. Photosynthesis is a good example. The process is an Anabolic processes that stores free E.
- G. Chemical Equilibrium = Death (Organism is stable... therefore, there is no metabolism occurring.)
- H. Disequilibrium = Life (Organism is unstable...therefore there is metabolism occurring.)
 - 1. Energy coupling *the entire time* is occurring, if the organism is *living*.

VI. Types of work performed by *living* cells:

- A. **Mechanical** – work outside or inside of the cell. (Usually movement of something or movement of the cell.)
 - 1. Such as moving organelles or chromosomes during mitosis or meiosis.
- B. **Transport** across the membrane of molecules.
- C. **Metabolic processes** – Catabolism and Anabolism as discussed previously.

VII. **ATP** (Adenosine Tri-Phosphate)

- A. Made from *Ribose* sugar and the *Nitrogen base Adenine*.
- B. It has 3 *NEGATIVE* phosphates linked together which makes it *HIGHLY* unstable like a “COMPRESSED SPRING”. (Unstable, means it has the capacity do perform work, remember.)
 - 1. Remember, phosphates are a functional group that was associated with energy.
 - 2. The *three* phosphates gives this molecule *several* times more energy capability than an electron.
- C. ATP undergoing *hydrolysis* to ADP has a $\Delta G = -13J$ (*releases* energy); ADP undergoing *dehydration synthesis* to ATP has a $\Delta G = 13J$ (*requires* energy). The energy needed to make this bond comes from the “free” e in our food as it is broken down. ADP is *recycled* back to ATP.
- D. **Phosphorylation**
 - 1. The *attaching of an unstable phosphorus* ion to another molecule to make it unstable and thereby able to perform work. Take the phosphorus off and it quits working.
- D. **Phosphorus Cycle** (This is also previous unit information.)

The Phosphorus is initially a component of rock. As the rock breaks down over time, called **weathering**, the Phosphorus is released into the soil. Some dissolves into the water as the rains pass through the soil. This Phosphorus makes its way into bodies of water, such as lakes and oceans, and is available for producers (phytoplankton) to use to help make organic compounds such as phospholipids and DNA or RNA. Plants (also producers) can also retrieve the Phosphorus from the soil and use it to make organic compounds too. When organisms die, decomposers break down the bodies and return the Phosphorus back to the soil to be reused.

AP Biology
Living Metabolism- Part 2

(Associated Learning Objectives: 1.14, 1.15, 1.16, 2.1, 2.2, 2.4, 2.5, 2.15, 2.16, 2.18, 4.1, 4.17)

Important Concepts from Previous Unit:

- 1) Proteins are the workhorses of cells. Every major process with in ALL cells requires proteins.
- 2) Protein functions are determined by the *sequence* of amino acids.
- 3) Protein function is also dependent upon the different levels of protein folding and the chemical bonds that help.

I. Enzymes

- A. These molecules are Biological *Catalysts*.
 1. Most are proteins that *speed up and control the rate* of a chemical reaction.
 2. They are *mostly* composed of Amino acids, some are also pieces of RNA (Ribozymes).
- B. They are *reactivated*; therefore, they are not consumed by the reaction. They remain present, essentially.
- C. Enzymes are *selective* in what they will work with. We used to say they had a “lock and key fit” (old term); we now say it “fits like a glove or has an *induced fit*”. (New term)
 1. This is like putting on a latex glove... it stretches to conform to the shape of your hand.
 2. The hydrogen bonds of secondary structure enable this property of enzymes.
- D. Enzyme names usually end with “ase”.
- E. They are involved in just about every process that a cell can perform.

II. Free E of Activation

- A. This refers to the Free E used to start a *chemical reaction in motion*. (Essentially, it is the energy for getting the molecules moving and positioned so that it is possible to combine or be torn apart.)
- B. The energy of activation is lowered by the action of enzymes. (Enzymes reduce by GRABBING the molecule and positioning it correctly... we don't have to WAIT for nature to do it.)
 1. Enzymes also *replace the need for heat* in most chemical reactions (Remember, heat can make molecules move faster.) so that organisms don't burn up during metabolism.

III. Substrate

- A. This refers to the molecule that is being *affected by the enzyme*. (It is what the enzyme is grabbing and working on.)

IV. Active Site

- A. This refers to the *location* where the chemical reaction(s) is taking place between the enzyme and substrate.
- B. It is an “Induced Fit” which creates the **Enzyme-Substrate Complex**. (“Complex” meaning “more than one piece in the unit”).
- C. The two parts are mainly held together by weak *Hydrogen bonds*, *Ionic bonds*, or *Van der Waals Interactions*. (Remember, temporary polarity qualities because of electron clumping on one side of an atom.)
- D. The **R-Groups** of the Amino Acids (building blocks of proteins) perform all the work of the *reaction*. (The “**R**” is for reactive.)

V. Factors that can affect enzymes ability to work **optimally:** (“optimal” means “best” or “Fastest”)

- A. *Temperature* – freeze/cold (cold things don't move quickly) or too much heat can denature proteins.
- B. *pH or pOH* of the environment. (Affects the Hydrogen bonds...pH...pHydrogen.)
- C. *Salt* concentrations. (Salts in water dissociate into ions. The charges can affect the Hydrogen bonding.)
- D. ALL of these factors mainly affect the SECONDARY folding of proteins, by altering the Hydrogen bonds. They may sometimes be affected at the disulfide bonds of tertiary structure.
(Remember, when proteins “unwind” that is **denature**. Enzymes will not function when this occurs.)
- E. The **Optimal Conditions** for most human enzymes:
 1. 98.6°F (35 - 40°C)
 2. pH usually between 6 – 8. (The human body's pH of blood is an average of 7.4.)
 3. Remember, this is an unstable (dynamic) environment. There is an upper limit and a lower limit for enzymes. Beyond the limits, bad things begin to happen. So it is basically, trying to stay between the limits, as concentrations of molecules rise and fall. The limits of “life”.

VI. Inhibitors

- A. The name implies that these molecules *negatively* affect an enzymes ability to work optimally. These *slow down or stop* the rate of the chemical reaction.

- B. Two types of Inhibitors exist, based on the location of the enzyme that is affected:
1. **Competitive** - These molecules *compete* for the active site. (This is because of similar shape.)
 - a. These molecules *slow down the reaction rate*. (These molecules will be removed.)
 2. **Non-competitive** –These molecules attach somewhere *other than the active site* and thereby causing the shape of the active site to change so the substrate can't fit into it.
 - a. These molecules cause the reaction *to stop* completely. (These molecules may affect the enzyme permanently or maybe temporarily in the case of an Allosteric connection.)

VII. **Allosteric Site**

- A. This site, on the enzyme, *acts as an "on/off switch"* for that enzyme.
- B. It is a way to *control* the enzyme's being used at any given time. (It is like a light switch that controls when there is light in a room.)
- C. An **Inhibitor molecule** – This turns the enzyme "**off**" by *closing* the active site.
- D. An **Activator molecule**– turns the enzyme "**on**" by *opening* the active site.

VIII. **Feedback Inhibition**

- A. A *product* IN EXCESS shuts down the reaction that is taking place at an *earlier point* in the pathway.
 1. The excess product molecule of the reaction combines with the **allosteric site**.
- B. Prevents "waste" of precious materials and energy by not making more of what is not needed at that time.
- C. Most enzymes are *controlled* using this form of regulation.
- D. This is also considered a component of a **negative feedback loop**.
 1. This refers to *stopping* a process that is *already occurring* (Production); and starting the consuming of the product.

IX. **Cooperativity**

- A. One Active site helps or cooperates with another active site on the same molecule.
- B. Red Blood Cells carrying Oxygen. (One of the four parts is filled, that filled part then turns on the second part so it can fill and so forth until the whole molecule is full. Once one part is emptied, that part will cause the next part to begin to empty. IT ALL ALLOWS FOR MAXIMUM SYSTEMIC DISTRIBUTION OF OXYGEN BY A RED BLOOD CELL.) This is an example of Regulation (control).

AP Biology
Photosynthesis – Part 1

(Associated Learning Objectives: 1.16, 2.2, 2.4, 2.5, 2.8, 2.13, 2.14, 2.22, 4.2, 4.5, 4.17)

Important concepts from previous unit:

- 1) Electrons are a source of energy, either Kinetic or Potential.
- 2) Carbohydrates are generated from H₂O and CO₂ by the chloroplast in Eukaryotes.
- 3) The amount of energy in a molecule is directly related to the amount of Hydrogen atoms in the molecule.

I. **Autotrophs** – Organisms that can “produce” their own food. (“Auto” means “self”; “trophe” means “feeding”)

II. **Heterotrophs** – Organisms that “consume” other organisms (living or dead). (“Hetero” means “different”)

III. **Chlorophyll** – Green light reflecting, light-absorbing protein pigment found in plants, algae, and blue-green bacteria.
 (“phyll” means “pigment”; “chloro” means “green”)

IV. **Chloroplast** structure (“plast” means “container”) Remember, these are organelles in some Eukaryotic cells.

A. **Thylakoid** – Little green discus shaped, membranous structures that actually contain the pigment chlorophyll.

1. Site of the *light reaction* of photosynthesis. (The Thylakoid membrane contains the photosystems.)

a. **PRIMARY PURPOSE IS TO HELP MAKE ATP AND NADPH. (CHEMICAL ENERGY MOLECULES.)**

B. **Grana** – A stack of Thylakoids. These are necessary to *create more surface area* for making energy molecules.

C. **Stroma** – The *watery* space surrounding the Thylakoids. (It holds the water needed for photosynthesis.)

1. Site of the *light – independent* reaction (a.k.a. the Calvin Cycle) of photosynthesis.

a. **PRIMARY PURPOSE IS TO USE THE ATP AND NADPH TO MAKE SUGAR USING CO₂.**

V. Photosynthesis Chemical Reaction

A. Starts by taking radiant *electromagnetic* energy (sunlight) and *converting* it into the chemical energy molecules ATP & NADPH.

1. Then takes the *chemical* energy (ATP and NADPH) and *uses* that chemical energy to *power the production* of sugar. (A chemical energy storage (potential energy) molecule created by **catabolism**.)

B. $6\text{ CO}_2 + 6\text{ H}_2\text{O}$ (in the presence of sunlight) $\rightarrow \text{C}_6\text{H}_{12}\text{O}_6 + 6\text{ O}_2 + \text{Heat}$ (KEY NUMBER IS 6 in balancing.)

C. **H₂O SPLITS** using the *energy of sunlight*; **CO₂ does not split** in this process.

E. There are two processes involved in the conversion of sunlight energy to sugar:

1. **Light reaction** (light dependent) – It *converts* sunlight into ATP and NADPH. (Usable chemical energy.)
2. **Calvin cycle** (light independent or Calvin cycle) – Makes sugar using CO₂ and Energy. (Carbon fixation.)
 - a. Melvin Calvin discovered the working process.

VI. Sunlight (It is electromagnetic energy.) It is also *HIGH QUALITY ENERGY*. High quality means it *can perform work*.

A. Sunlight travels in *waves* with different *wavelengths*. The **Electromagnetic spectrum** shows all the wavelengths found in sunlight.

1. Red Light– Has the *longest* wavelength. (It also has the *least* energy of “white light”.)
2. Blue Light– Has the *shortest* wavelength. (It has the *most* energy of “white light”.)

B. Visible “white” light – ROY G. BIV (red, orange, yellow, green, blue, indigo, violet) are the colors within.

C. Light travels in *units of energy* called **Photons**.

D. Absorption vs. Reflection

1. **Absorbed** – These colors are *usable* light energy.
 - a. Plants *use* the reds and blues; BUT NOT the green.
 - b. **Chlorophyll A** – Main protein pigment found in all plants and algae.
(It has a structure that looks like a Mg spider in carbon ring web.)
 - c. **Chlorophyll B** – *Helps* Chlorophyll A *receive* sunlight energy. (B *funnels* energy to A.)
 - d. **Carotenoids** – These are *accessory* pigments that *help* Chlorophyll A. (They *funnel* energy to A too.) (These are red, orange, or yellow light *absorbing* protein pigments.)
 - e. **Photosystem** – *Group* of light absorbing pigments in the thylakoid membrane. Chlorophyll A would be in the reaction center. (“system” means “group of”)
 - i. Photosystem I – It is *responsible* for ATP **and** NADPH production.
 - ii. Photosystem II – It is *responsible* for ATP production only.
3. **Reflection** – These colors are *not usable*. (They provide the COLOR of an object.)
 - a. This is why plants are green. Green light is *reflected* back toward *your* eyes.

AP Biology
Photosynthesis – Part 2

(Associated Learning Objectives: 1.15, 1.16, 2.2, 2.5, 2.13, 4.4, 4.5, 4.17)

Important Concepts from previous unit:

- 1) Surface area of membranes is important to *all* cells, prokaryotic or eukaryotic.
- 2) Valence shell electrons are the important electrons when considering *bonds* and *energy*.
- 3) Energy *absorbed* by electrons causes them to move *farther away* from the nucleus, maybe even escape.

I. Light Reaction of Photosynthesis

A. This process is used for turning *sunlight* into *usable chemical* energy. Those molecules are: **ATP** and **NADPH**.

B. The process has *two* parts:

1. **Non-cyclic electron flow** – This part makes ATP (by non-cyclic *photophosphorylation*) and NADPH.

- a. These electrons *start out* in water. Then they are released to Photosystem II as water *lyses*. The electrons then make their way to Photosystem I by way of the primary *electron transport chain*, and then *ultimately* end up going to NADPH. This is referred to as non-cyclic because the starting point for the electrons is different from the ending point.

2. **Cyclic electron flow** – This part makes extra ATP. (By cyclic *photophosphorylation*.)

- a. These electrons *start out* at Photosystem I and then go down the secondary *electron transport chain* to Fd (Ferredoxin), but then are *transferred* over to the other path by going to **Cytochrome C**. They then make their way back to their starting point, Photosystem I, by way of the primary *electron transport chain*. Hence the term cyclic, the starting point and ending point are *the same*.

C. These two parts are occurring, in the presence of sunlight, *at the same time* on the **Thylakoid membranes**.

D. There are thousands of these Photosystems (I and II) on *each* Thylakoid membrane. (Surface Area? It's important again. More surface → more photosystems → more energy production.)

II. The major steps to the light reaction of Photosynthesis:

Step 1: *Sunlight* hits the water in the stroma and also hits the Photosystems I and II at the *same time*.

- A. The water in the stroma, using the *high quality E* of sunlight, lyses into O gas (a waste product), 2 H⁺ **ions** (these stay in the stroma), and 2 *free* electrons. (These will be used to *replace* the 2 “excited” electrons lost from the **Mg** atom of **Chlorophyll A** in Photosystem II.)
- B. The Photosystem II **Mg** atom *loses* two electrons, due to *absorbing* all the E being *funneled* into **Chlorophyll A** from **Chlorophyll B** and the **Carotenoids**. (These 2 excited electrons are collected by a primary acceptor protein, also in the Thylakoid membrane, and moved toward Photosystem I along the primary *electron transport chain*. They will be *replaced* by the 2 electrons from water lysing. This *keeps the process going*.)
- C. The Photosystem I **Mg** *also* loses two electrons due to *absorbing* all the E from the **Chlorophylls** and **carotenoid** molecules. (These are *also* collected by another primary acceptor protein and moved toward **NADP⁺** along the secondary *electron transport chain*. These *will be replaced* by the 2 electrons coming down the chain from Photosystem II in the primary electron transport chain.)

Step 2: *Excited* electrons travel down the *electron transport chains*. (This is a series of **Redox reactions**. A redox reaction is basically two molecules *exchanging* electrons. One molecule **receives** them [called **Reduction**] and the other molecule **loses** them [called **Oxidation**]. Hence the combined name of Redox.) This is associated with the **Law of Conservation of Mass**... “Mass is neither created nor destroyed; only *transferred* and transformed.”

As the *excited* electrons go down the electron transport chain, by going through these series of Redox reactions,

their excited **kinetic E** (also called **Free E**) is being used *to power* the proteins called **Proton pumps**. As the electrons go down their transport chain, their excited kinetic E *decreases*.

A. Photosystem II electrons (P.A. → Pq → cyto C → Pc → Photosystem I)

1. **Free E** of the **electrons** is used to **actively transport** H⁺ ions (a.k.a. called protons) into the inner thylakoid space. The H⁺ ion concentration [H⁺] goes up inside the space. This causes the **pH** to decrease and become *more acidic*. The [H⁺] goes down in the stroma. The stroma becomes *more basic*. As this is occurring a **concentration gradient** is *created*. A concentration gradient is a source of Potential E now. (It would be like blowing air into a balloon. The pressure builds as more air is blown inside the balloon. This is also an example of Potential E.)

B. Photosystem I electrons (P.A. → Fd → NADP⁺) (**Reduction** occurs to create NADPH from NADP⁺.) (This is the ending point for **non-cyclic electron flow**.)

OR

(P.A. → Fd → Cyto C → Pc → Photosystem I) This would be for **cyclic electron flow**.

Remember, this makes *extra* ATP.

C. **Cytochrome C** is an important molecule as ALL organisms possess it in their membrane that is used for *energy production*. This supports *common ancestry* among ALL organisms.

1. Mitochondria and Chloroplast INNER membranes in eukaryotic organelles.
2. The plasma membrane of Prokaryotic cells.

Step 3: The trapped H⁺ ions, *inside* the Thylakoid, are *released* through the **ATP Synthetase Complex**. This is a group of enzymes in the Thylakoid membrane that helps make ATP, by **Anabolic Phosphorylation**. (Just look at the enzymes name.) This *release* of kinetic H⁺ ions *powers* the **phosphorylation** of ADP → ATP. (This would be like the air coming out of the blown up balloon and turning a pinwheel.)

A. This *Kinetic movement* of H⁺ ions produces a **LARGE AMOUNT OF ATP**. (ADP + P = ATP.)

B. This is an example of **Energy Coupling** (**Two** processes **working together** and involving energy.) The first process was **Active transport** to *pump* the H⁺ ions *into* the *confined space* of the Thylakoid, using the **Proton pump** proteins, to make the *concentration gradient*. The second process is *diffusion*, The H⁺ ions going from high [] to low []. The kinetic movement of the H⁺ *fuels the production of ATP*.

1. This form of **energy coupling**, for making ATP, is referred to as **Chemiosmosis**.

Step 4: **ATP** and **NADPH** will now *be used to power* the fixing of CO₂ into sugar in Calvin Cycle.

AP Biology
Photosynthesis – Part 3

(Associated Learning Objectives: 1.15, 1.16, 2.2, 2.3, 2.5, 2.13, 2.22, 2.25, 2.27, 4.4, 4.5, 4.17)

Important Concepts from previous unit:

- 1) Matter is neither created, nor destroyed; just *transferred* and *transformed*. (Law of *Conservation* of Mass.)
- 2) The macromolecule Carbohydrate is an energy storage molecule that is intended for *quick* release of energy.
- 3) Carbon is an important molecule in making macromolecules. The *primary* source is from CO₂ in the air.

I. Calvin Cycle (A.K.A Light *Independent* reaction)

- A. This part uses the **ATP** and **NADPH**, of light reaction, to perform **Carbon fixation** - making sugar using CO₂.
- B. It has three steps:

Step 1: CO₂ molecules enter the leaf through the *open stomata*. Then the CO₂ molecules *diffuse* into the cells by crossing the phospholipid portion of the plasma membrane. Once inside the cell, the CO₂ molecules *diffuse* across the phospholipid portion of the chloroplast membrane. Once in the stroma of the chloroplasts, 3 molecules of CO₂ *combine* with 3 RuBP molecules using the *enzyme Rubisco*. (RuBP is a 5 Carbon molecule.)

- A. The resulting three 6 carbon molecules are *unstable* and break into two 3 carbon molecules of 3 phosphoglycerate. (Six total carbon molecules still exist, just in two groups of three.)

Step 2: Use **6 ATP** and **6 NADPH** (1 ATP and 1 NADPH /molecule of 3 phosphoglycerate) to “*bend*” each molecule *twice* into a **G3P molecule**. (G3P is half of a Glucose molecule.)

Step 3: Take out 1 **G3P** and *recycle* the other 5 G3Ps *back into* the original 3 RuBPs using 3 extra **ATP**. (Remember, from the *cyclic electron flow*.) This process basically takes 1 Carbon away from two G3Ps (Remember, there are 5 G3P left.) and thus creating 2 two carbon molecules. Then one of the two 2 carbon molecules is paired with one of the three remaining three Carbon molecules. (3 + 2 = 5) The two single Carbons are added to the last G3P molecule to have 5 carbons again. (3 + 1 + 1 = 5) So we end up with 3 five Carbon molecules of RuBP again. Thus, we have started and ended at the same point... a cycle.

- a. 1 G3P is used to make Glucose. (So the cycle must go around TWICE to make 1 Glucose molecule. So repeat steps 1-3 to make the second half.)

- C. **Total Numbers** needed: For each turn of the cycle – **9 ATP** and **6 NADPH** are needed.
: To make 1 glucose molecule (2 turns) – **18 ATP** and **12 NADPH** are needed.
- D. These sugars will be needed to feed the whole plant or algae. Or they will be stored in the form of starch, a complex carbohydrate. The sugars will be *consumed* in the process of **cellular respiration**. They could also be *utilized* in the making of plant cell walls.

II. Photorespiration – This is using oxygen, *instead* of CO₂, to perform carbon fixation in the Calvin Cycle.

- A. This is a *last resort*, in an attempt to try and stay alive because of the stomata being *closed* to *conserve* H₂O. If the stomata are *closed*, then *no* CO₂ can enter the plant. Also, no O₂ can *leave* the plant.
- B. In **C3 plants** – RuBPs are broken down to make G3Ps like normal. (This can eventually cause death to the plant because there *will not be enough* Carbons to *recreate* the necessary RuBPs if they are slowly being taken out to make sugar. (It would go 15C → 12C → 9C → 6C → 3C → Death.) The plant *needs* the 3 CO₂ to *replace* the THREE Carbons in G3P that were taken out to make sugar.)
- C. **C4 plants** - These plants like dry climates. These are plants like corn and cotton.
 1. **Bundle Sheath cells** *prevent photorespiration* from occurring. The oxygen is *limited* in entering the bundle sheath cells, where the Calvin Cycle occurs. CO₂ can enter, BUT AFTER it has been *modified*.

2. PEP combines with CO₂ using the PEP Carboxylase *enzyme* in the mesophyll cell to make Oxaloacetate. O₂ *won't fit* the enzymes **active site**. (Remember, that enzymes are *substrate specific*.)
3. Oxaloacetate is too big to enter **bundle sheath cells** so it must be converted to Malate to enter.
4. Malate will then release the CO₂ to the Calvin Cycle, *inside* the **bundle sheath cell**. The molecule that remains is Pyruvate. It will be *converted* back to PEP to *be reused* upon reentering the mesophyll cell.
5. "Sheath" means "surrounding" (These cells *surround* the vascular bundle of xylem and phloem.)

D. **CAM plants** (Crassulacean Acid Metabolism) - These are desert plants.

1. The stomata open at *night* to take in CO₂ and release O₂. (CO₂ is *stored* as Crassulacean Acid.)
2. Crassulacean acid is broken down *during the day*, when the stomata are closed, to release the CO₂ for *use* in the Calvin cycle. This process *helps to decrease water loss* through **transpiration**.
 - a. **Transpiration** is water *loss* through the stomata.
 - b. **Transpiration** is *very* important in determining the amount of energy that will be *available* in an *ecosystem* and the *food webs* in that area. Deserts have *very little energy available* because of transpiration is a big problem. Tropical rainforests, on the other hand, have *abundant energy* because of transpiration not being a problem. The more energy that can be produced, the *greater* the size of the food web.

III. COMPETITION and EVOLUTION? Each type of plant has its own *unique niche* (role within an ecosystem) and this *helps reduce competition* for vital resources. Reducing competition *conserves necessary energy*. The *more* energy that can be conserved; the *more reproduction* can occur by an organism. The more reproduction that can occur; the more that species of organism *dominates that environment* and *helps guide* the path of evolution.

AP Biology
Photosynthesis – Part 4
(Associated Learning Objectives: 2.1, 2.2, 2.3, 2.9, 2.22, 2.24, 4.1)

Important Content from previous unit:

- 1) **Law of Conservation of Matter** – Matter is neither created, nor destroyed; only *transferred* and *transformed*. Matter is *recycled* within the environment using **anabolic** and **catabolic** processes.
- 2) **Second Law of Thermodynamics** - All energy starts out as high quality usable energy in the form of sunlight and all energy leaves Earth in a state of **entropy**, low quality energy *incapable* of work.
- 3) Carbon is the main *source* for making the four macromolecules – Carbohydrates, Lipids, Proteins, and Nucleic Acids.

I. **Carbon Cycle** - CO₂ is removed from the air by photosynthesizing organisms such as plants, phytoplankton and bacteria. The CO₂ is used in the development of sugars during **photosynthesis**. These sugars, which contain the Carbon (C₆H₁₂O₆) are then passed from organism to organism through the food chain. All organisms then release the Carbon, in the form of CO₂, by performing the process of **cellular respiration** in their cells. The burning of plant materials, natural gas and fossil fuels, which are the remains of dead life forms such as dinosaurs and pre-historic forests, puts CO₂ back into the air as well.

II. **Ecosystems** – Refers to all the *interacting* communities within a given area **plus** the abiotic (non-living) factors affecting it.

A. Abiotic factors mainly deal with energy flow, nutrient cycling, temperature, and water.

III. **Trophic Structure** - These are *feeding* relationships (“Troph” means “to feed”)

- a. **Energy Flow** - Sunlight enters Earth, is received by plants and made into *chemical energy* (sugars). Then, the sugars are *passed from organism to the next organism* by consuming the previous organism. Eventually all energy becomes *heat*, with each transfer and **metabolism**. The heat energy then leaves Earth. This demonstrates the **Second Law of Thermodynamics**...All Energy proceeds towards a state of Entropy which each transfer.
- b. **Matter Flow** - Matter is neither created, nor destroyed; just transferred and transformed – **Law of Conservation of Matter**. Essentially, the matter that organisms are composed of is cycling through continual food chains and food webs. This is seen in the Biogeochemical cycles that you have studied so far – Water cycle, Phosphorus cycle, Carbon Cycle and Nitrogen Cycle.
- c. **Food chains** – This tries to demonstrate an *orderly flow* of who eats who. (Producers eaten by consumers, consumers and producers broken down by decomposers.)
 - i. Most food chains only have four to six trophic levels in them, because you *run out of energy to transfer* and support life.
 - ii. **Energetic Hypothesis** – Basically states why we have short food chains due to the **10 % rule of Energy** (90 % of all energy is *lost as heat/waste* by metabolism of that organism; 10 % of the energy is *passed on* to next trophic level each time.)

For example:

10 joules of E (Snake) – END HERE

100 joules of E (Bird)

1000 joules of E (Grasshopper)

10,000 joules of E (Grass... producers) – START HERE

Each time only 10% of the energy gets *passed on to the next higher level* in the chain. 90% is *lost*, as heat/waste, from the metabolism maintaining the life of that organism before it is eaten.

- d. **Food web** – A model showing *all possible feeding relationships* that could exist within an area. (A food web is essentially *interacting food chains*.)

IV. **Primary Production** –Refers to the *total amount* of solar energy *converted* to chemical energy by the process of photosynthesis occurring in *producers*.

A. **Global E budget** -This refers to the amount of energy used on Earth for the process of photosynthesis.

1. ONLY 1% of solar energy is used to power photosynthesis, but it *makes* **170 BILLION tons of sugar/year**.
2. 99% of solar energy is *absorbed* by water or *reflected back* into space/atmosphere by water/ice.
3. Reflected energy contributes to the Greenhouse effect and is helping the average temperature of Earth, as a *whole*, rise.
4. The *absorbed* energy by water will be *released at night* to help keep the unlighted side of Earth warm.

B. **Gross Primary Production (GPP)** – This is the amount of chemical energy **produced** *before any use* by those autotrophic organisms that made it *over a certain period of time*.

C. **Net Primary Production (NPP)**

1. This is the amount of **energy left** *after self preservation (R)* of those autotrophs occurs.
 - a. Self- preservation includes processes such as Cellular Respiration, Homeostasis, growth, and repair.
 - b. **NPP** is the energy that will be *available to the next trophic level*; usually 10 %.
(**The 10% rule.**)
2. Calculated as: **$NPP = GPP - R$**

AP Biology
Cellular Respiration – Part 1

(Associated Learning Objectives: 1.15, 1.16, 2.2, 2.4, 2.5, 2.13, 2.14, 2.22, 4.1, 4.4, 4.17)

Important Content from previous topics:

- 1) The electron transport chain is a series of redox reactions, occurring on a *membrane*, intended to create a concentration gradient that is a *source of Potential Energy*.
- 2) Redox reactions are just the *transferring* of electrons from one molecule to another molecule.
- 3) Carbohydrates, sugar, are *primary energy molecules* made in photosynthesis. G3P is *half* of a sugar Glucose molecule.

I. Cellular Respiration

- A. This is the process of *releasing energy* contained in organic molecules (mainly sugar) *to do work*. (This is an example of **catabolism**.)
 1. The process is for *making ATP using Oxygen gas (O₂)*, if available.
 2. The process *releases* heat (Remember, heat is *low quality energy*.) and free electrons. (Remember, that free electrons are a *source of Kinetic Energy*.)
- B. With O₂ present in the cell – Cellular Respiration can occur in the mitochondria.
- C. Without O₂ present in the cell – Fermentation will occur in the cytoplasm of the cell.
- D. $6 \text{ O}_2 + \text{C}_6\text{H}_{12}\text{O}_6 \rightarrow 6 \text{ CO}_2 + 6 \text{ H}_2\text{O} + \text{Free E} + \text{Heat E}$
 1. $\Delta G = -686 \text{ k/cal per mol Glucose}$ (A *negative* ΔG means **Free E** is *available*, from breaking down Glucose, to do work. In this case, the work is *making ATP* by **phosphorylation**.)
 - a. The **Free E** is used to make ATP from ADP by **phosphorylation**.

II. Redox Reactions (This is the *transfer* of electrons.) Electrons can be represented by the symbol **e⁻**.

- | | | |
|---|---|---|
| A. Oxidation (loss of electrons) | } | These two are <i>processes</i> . (“tion” means “process”) |
| B. Reduction (gaining of electrons) | | |
| C. Reducing Agent (electron seller) | } | These two refer to actual <i>molecules or elements</i> . |
| D. Oxidation Agent (buyer for electrons) | | |
- *Always together (The Law of Conservation of Matter)

III. Electronegativity

- A. Think of this as the *desire to acquire electrons*. (Look at a molecule's valence shell.)
- B. Oxygen—Has the *most desire biologically*; Hydrogen—Has the *least desire*. (It *wants* to get rid of its one electron.)
- C. **Electron Transport Chain** is a series of “transferring of electrons” or Redox reactions. Just look at the name. We are moving electrons from one molecule to the next. So one is receiving electrons (called reduction) and one is losing them (called oxidation) all the way down the line.
 1. **Free E** is *released from each transfer* between the molecules in the chain.
 2. **NAD⁺ and FAD⁺** (These are *electron carriers*. They take the released electrons, from the breakdown of organic molecules, to the chain for *release* into the chain.)
 - a. Oxidizing Agents (These carriers are accepting 2 e⁻, so they are **Oxidizing agents**.)
 - b. **NADH or FADH₂** (The 2 negative electrons combine with the carrier. The *first* negative electron *cancels* the carrier's *positive charge*. The *second* negative electron *makes the carrier negative*. This causes a positive H⁺ ion to attach to become NADH or FADH₂.)
 - i. 2 e⁻ are carried at a time to the chain.
 3. The Electron Transport Chain is ALWAYS in a membrane.
 - a. For Bacteria- It is the plasma membrane.
 - b. For Eukaryotes – It is the Mitochondrial inner membrane or Thylakoid membrane.
 4. The WHOLE process is a **controlled** release of energy.
 5. **Oxygen** is at *end* of the chain to *receive* the two electrons. (Remember, Oxygen is the *most Electronegative* element in living organisms. The Oxygen atom takes the 2 negative electrons from the chain. This gives it a negative 2 charge, so two positive H⁺ ions attach to make water.
 - a. Forming water *keeps the chain open* so that we can *keep feeding it electrons* at the top. If the chain stops, we *lose* the ability to make energy. (This is what Cyanide does! It prevents Oxygen from taking the electrons out of the chain, so it backs up and quits working.)

- IV. Cellular Respiration is a **Three Step Process**:
- A. Step 1: **Glycolysis** - This is the *breaking* of Glucose into 2 molecules of G3P. *All organisms* can do this process as it occurs in the *cytoplasm of a cell*.)
 - B. Step 2: **Kreb's Cycle** (This is all about *making electron carriers* in the continued breakdown of food molecules.)
 - C. Step 3: **e- Transport Chain** - This is where the **Free E** of the electrons is used to **help make ATP**.)
 - 1. This is referred to as **Oxidative Phosphorylation** (makes 90% of ATP) because it will *need Oxygen to be present*.
 - D. **Substrate-Level Phosphorylation** (makes 10% of ATP) uses *another SUBSTance* to help make ATP.
 - E. The whole process yields a **maximum of 38 ATP**/ 95% of time only 36 produced though.
- V. The Process of **Glycolysis** ("Breaking of Glucose")
- A. In this process, Glucose ($C_6H_{12}O_6$) will be *broken apart into 2 molecules* of G3P. *Each molecule* of G3P will then be *converted* to a molecule of **Pyruvate**. At the *end of the process*, the cell will have 2 molecules of **Pyruvate** that can be put into the mitochondria, if Oxygen is present and it is a Eukaryotic Cell.
 - 1. Glucose is said to be **oxidized**, as it is *losing electrons* in the breakdown.
 - B. There are two parts to Glycolysis:
 - 1. **E Investment Phase**
 - a. Glucose is *broken into 2 molecules* of G3P.
 - b. To break it in half **requires 2 ATP** be used. (One phosphate is put on EACH side of the Glucose molecule. This makes it *unstable* and Glucose breaks in half to make 2 G3P molecules. The enzyme, **Phosphofructokinase**, puts the SECOND phosphate on the Glucose molecule; it is the "ON/OFF Switch" for the WHOLE process. If it does NOT put the second phosphate on the Glucose molecule, the Glucose WILL NOT break in half.)
 - 2. **E Payoff Phase**
 - a. The 2 molecules of G3P will then be *converted* to 2 molecules of **Pyruvate**.
 - b. This phase will yield 4 ATP + 2 NADH total. (2 ATP and 1 NADH per molecule.) The cell *pays back* the two it *used* for the first part. This leaves the cell with a *payoff* of two ATP. (What we refer to as **NET Gain**.)
 - C. Remember, this process occurs *with or without O_2 present* in the cell.
 - D. **ALL** organisms can do it, as it occurs in the *cytoplasm of a cell*. Therefore, this process *must* have been one of the earliest processes to evolve within organisms to harvest energy from molecules present within the Earth's earliest environments. Even *before free Oxygen gas was present* in the atmosphere.

AP Biology
Cellular Respiration – Part 2

(Associated Learning Objectives: 1.15, 1.16, 2.2, 2.4, 2.5, 2.13, 2.14, 2.22, 4.1, 4.4, 4.17)

Important concepts from previous topics:

- 1) *Surface area* of membranes is important to *all* cells, prokaryotic or eukaryotic.
 - 2) An existing *concentration gradient* is also a source of *Potential Energy*.
 - 3) The *amount of energy* in a molecule is directly related to the amount of *Hydrogen atoms* in the molecule.
- I. If Oxygen gas is *present within the Eukaryotic cell* (“Aerobic” means “with Oxygen”), the cell can perform the other two parts of Cellular Respiration – Krebs’s Cycle and Electron Transport Chain.
- A. In order to enter the *inner* mitochondrial space, where the Krebs’s cycle occurs, Pyruvate *must be converted* to Acetyl Coenzyme A. This is referred to as the **Pyruvate conversion**. It occurs in the space *between* the outer membrane and the inner membrane of the mitochondria.
1. This Pyruvate Conversion involves three steps:
 - a. Step 1: Removal of CO₂ from *each* molecule of Pyruvate. (Remember, there are 2.)
 - b. Step 2: NAD⁺ **or** FAD⁺ (Both can perform this act as they are both electron carriers.) becomes **reduced** by *accepting* the 2 e⁻ from the *broken bond*. This allows for a H⁺ ion to attach and make NADH or FADH₂. (Remember, these are **Oxidizing Agents** because they are *receiving* electrons.)
 - c. Step 3: To the open bond, Coenzyme A is attached using Sulfur as the connecting link.
 2. The *final* product is **Acetyl Coenzyme A**. (**EACH** molecule is now located in the *inner* mitochondrial space.) (“acetyl” means “two carbons”)
- B. **Krebs’s cycle** (This occurs in the inner mitochondrial space where there is *room* to work.)
Remember, the *main purpose* of the Krebs’s cycle is *to make electron carriers*. See how many it makes per Acetyl Coenzyme A put into the cycle.
1. **EACH** Acetyl Coenzyme A that goes through the cycle will produce:
 - a. **3 NADH** (electron carrier) → So 2 molecules X 3 = **6 NADH electron carriers**.
 - b. **1 FADH₂** (electron carrier) → So 2 molecules X 1 = **2 FADH₂ electron carriers**.
 - c. **1 ATP** → So 2 molecules X 1 = **2 ATP**.
 - d. **2 CO₂** (A waste product.) → So 2 molecules X 2 = **4 CO₂** that diffuse out of the cell.
- C. **Electron Transport Chain**
- a. This occurs on the *inner mitochondrial membrane*.
 - i. This membrane is *folded* (**THE FOLDS INCREASES SURFACE AREA; MORE ATP CAN BE PRODUCED AS THERE IS ROOM FOR MORE ELECTRON TRANSPORT CHAINS.**)
 - b. Electrons move by a series of Redox reactions using increasing **electronegativity**.
 - i. Move 2 at a time **DOWN** the chain toward **OXYGEN**, *making H₂O at end*.
 - c. **NADH** drops its two electrons off at FMN “first molecule at top of chain”. (In doing so, the pair of electrons *will pass through 3 protein Proton Pumps*. So three protons, H⁺ ions, are pumped into the space **BETWEEN** the membranes; *3 ATP will be able to be produced.*)
 - d. **FADH₂** drops its two electrons off at Q, which is a lipid.
(These pairs of electrons *will only pass through two Proton pumps*; therefore only 2 protons, H⁺, will be pumped into the space between the membranes and thereby *only 2 ATP will be able to be produced.*)
 - e. Remember, the **Cytochromes** indicated *common ancestry* for **ALL** organisms, as **ALL** electron transport chains will possess these proteins.
 - f. Cyanide kills by replacing Oxygen at the chain and stopping the flow of electrons.
 - g. **Free Energy**, from the electrons, fuels the **active transport** of H⁺ ions *into* the inner mitochondrial space *between the membranes*. (Chemiosmosis **AGAIN**.)
 - i. H⁺ (ions/protons) are *pumped* into the *confined* space between the membranes using the **Free E released from electrons** as they go down the chain.
 - ii. The concentration of H⁺ ions *builds inside the space* (like blowing up a balloon) to *create a concentration gradient*. High [] in between and low [] in the center.
 - iii. The H⁺ ions *are released* using **ATP Synthesizing Complex**. (It would be like pulling the cork in the sink.)

- iv. The H^+ ions rush out (going from High [] $\rightarrow$ Low []) allowing the **ATP Synthesizing Complex** to *use the Kinetic E* to turn $ADP \rightarrow ATP$ in large amounts by **phosphorylation**.
- v. This is another example of **Energy Coupling** – two processes *working together and involving energy*. (Same as it was in Photosynthesis.) One process is **active transport** and the other is **diffusion**.
- vi. This type of **energy coupling**, for making ATP, is referred to as **Chemiosmosis**.
- vii. The Electron Transport Chain can make **34 or 32 ATP**. *It depends on which electron carrier showed up in the Pyruvate conversion*. If it was NAD^+ , the process makes 34. If it was FAD^+ , the process makes 32. FAD^+ usually shows up because NAD^+ is *too busy* in the Krebs' cycle.)

D. ADD IT ALL UP NOW:

2 Net ATP From Glycolysis

2 Net ATP from the Krebs' cycle

34 OR 32 Net ATP from the Electron Transport Chain *using all the $NADH$ and $FADH_2$* .

38 Maximum OR 36 Normal

AP Biology
Cellular Respiration – Part 3

(Associated Learning Objectives: 1.15, 1.16, 2.2, 2.4, 2.5, 2.14, 2.16, 2.18, 2.22, 4.1, 4.4, 4.17)

Important concepts from previous topics:

- 1) *All cells*, prokaryotic and eukaryotic, can perform **Glycolysis** in the cells *cytoplasm*.
- 2) Since *all organisms* can perform Glycolysis, they must have unity by *common ancestry*.
- 3) Enzymes control most processes within cells; therefore they must be *regulated* (controlled). Most are *controlled* at the **allosteric site** using **inhibitors** and **activators**.

I. If **NO OXYGEN** is present *within* the cell (“Anaerobic” means “without oxygen”):

A. **Fermentation** will occur to *free up the electron carriers* to keep at least **Glycolysis** going making ATP.

1. Two types of fermentation can occur. It depends on the *organism* doing it.

a. **Alcohol Fermentation** (This occurs in bacteria and Yeast – a fungus.)

i. They convert the two Pyruvate molecules to 2 molecules of Ethanol by cutting off CO₂ and filling the open bond with H from the electron carriers. This frees up the electron carrier to *keep Glycolysis going* and thereby *making some* ATP which is needed to stay alive.

ii. Beer, wine, and bread are made by this type of fermentation.

b. **Lactic Acid fermentation** (This occurs in animals mainly.)

i. Converts Pyruvate into Lactic Acid by breaking the ketone, the double bonded Oxygen in the middle, and adding H. The H comes from the electron carrier. Here again keeping the process of Glycolysis going to make *a little amount of* ATP to keep the cells alive in the absence of Oxygen.

ii. Cheese, yogurt, and muscle cramps (These force you STOP exercising.) are all created by this type of fermentation.

II. **Facultative Anaerobes**

A. These organisms *can perform both* Aerobic and Anaerobic Respiration, but prefer to use Oxygen – because it produces *more* ATP than by using fermentation.

III. Evolutionary *Significance* of Glycolysis

A. Early Earth had no free Oxygen gas (O₂) – Since Glycolysis doesn’t need Oxygen to occur it **and all organisms** can perform the process; it most likely would have been the first energy making process to evolve.

1. Remember, there was no free Oxygen gas in the Miller/Urey experiment.

B. Common Ancestry – All living organisms continue to use the process *because it works effectively!*

C. **Endosymbiant Hypothesis** – mitochondria are found in *all* eukaryotic cells because they are *effective* at getting *more energy* from the pyruvate by breaking it down further!

IV. Versatility of Respiration

A. **Amino Acid Utilization** (These must undergo **Deamination** to be used in the Krebs’s cycle.)

1. Cut off the Amine group (Hence DE amination) and put on Coenzyme A using a Sulfur molecule to the remaining 2 carbon skeleton (“acetyl”) from the Amino Acid. Then feed Acetyl Coenzyme A into the Krebs’s cycle to make energy. The resulting NH₃ (Ammonia) is put into the blood stream for disposal by the kidneys using water in the form of Urea (mammals) or Uric acid (birds and reptiles). Fish release the NH₃ directly into the water.

B. **Lipid Utilization** (These undergo **Beta Oxidation**. Beta is the *second* letter of Greek Alphabet.)

1. Cut the Fatty acid tails of the lipid molecules up into 2 carbon skeletons and attach Coenzyme A using a Sulfur molecule to each 2 Carbon skeleton (Acetyl). Then feed the Acetyl Coenzyme A molecules into the Krebs’s cycle to make energy.

V. **Biosynthesis** – This is using food building blocks to make self. (Basically it is **Anabolism**. It *requires* ATP.)

VI. **Feedback Inhibition** – The enzyme **Phosphofructokinase** acts as the “on/off switch” for the *whole* process in **Glycolysis**. When there is *plenty* of ATP in a cell, the excess ATP and Citrate, from the Krebs’s cycle, work together as co-inhibitors, attaching at the **allosteric site**, to shut down the whole process *until energy is needed* again by the cell.

AP Biology
Cell Cycle – Part 1
(Associated Learning Objectives: 1.14, 1.15, 1.16, 3.1, 3.7, 3.8, 3.9, 3.11)

Important concepts from previous units:

- 1) RNA molecules can act as enzymes; as well as deliver molecular information.
- 2) DNA is more stable and longer lasting than RNA; therefore it is the principle molecule of inheritance.
- 3) All organisms must be able to reproduce to keep life going on Earth.

- I. ALL cells undergo *three basic processes* associated with reproduction.
 - A. *Replication of the DNA* within the parent cell. This occurs in what is referred to as the “S phase”. (“s” stands for **synthesis** which means “to make”.) We need a copy of DNA for each *new* cell that is created.
 - B. *Replication* of any items that are in the cytoplasm, such as ribosomes and organelles, if it is a eukaryotic cell.
 - C. *Division* of the cytoplasm and cell membrane. This is referred to as **cytokinesis**; which means “movement of the cytoplasm”.
- II. **Binary Fission** in Prokaryotes
 - A. This is the process of *Reproduction/Replication* in prokaryotes (bacteria).
 - B. DNA replication (S phase) starts at the “origin” and works around the entire single, circular chromosome. This results in two identical circular chromosomes in the **nucleoid** region. (Discovered by John Cairns in the 1960’s. He referred to it as Circular or Theta replication. The Greek symbol for the letter Theta is: Θ .)
 - C. This is followed by producing a cleavage furrow in the cell membrane (cytokinesis) to produce 2 new cells, that are referred to as **clones**.
 1. The cleavage furrow is produced using actin and myosin microfilaments of the cytoskeleton.
 2. They are called clones because they possess 100% identical DNA strands.
 - D. How is Binary Fission related to Mitosis, as seen in Eukaryotes, in terms of evolution? Binary Fission would have *evolved into* Mitosis as the DNA content of cells increased dramatically and also, as the endosymbiont hypothesis states, “organelles” came into existence. The *two major steps* are the same: synthesis and division.
- III. Reproduction by Eukaryotic cells
 - A. This is a part of the **Cell Cycle**. (A Cell “Life History” basically.)
 1. Cell Division, by a **parent cell**, results in 2 *genetically identical daughter cells* (offspring).
 - a. The daughter cells are genetically identical to each other and the previous parent cell.
 2. **Maturation** occurs after division. The cells are growing and being able to perform its *adult* functions.
 - B. This process is also necessary for normal growth (such as in size of organs) and repair of existing structures.
 - C. The process *requires* that DNA reproduction take place.
 1. DNA could be thought of as the “Million Dollar Blue Prints” for making items required by cells.
 2. **Genome** – This is the *entire* genetic material (DNA) for an organism or cell.
 - a. The genomes “Blue Prints” vary from species to species.
 - b. In humans, the genome length is about 2 m or 7 ft. per cell.
 - c. DNA has two different *appearances (states)* within a cell and it depends on what is happening within the cell.
 - i. **Chromatin** – this is the *loose* state of DNA. (It is like looking at a bowl of spaghetti noodles [without the sauce]. The DNA “noodles” can be moved around to *find* the gene segment of interest for Transcription.)
 - ii. **Chromosomes** – this is the *tightly coiled* state of DNA. (It looks like a cork screw shaped pasta noodle. These are for *dividing equally* and easily. [Have you ever tried to divide a bowl of spaghetti noodles 100% equally?])
- IV. **Somatic cells** (“soma” means body) - These are your normal body cells.
 - A. These are the cells that make up the majority of an organism.
 - B. Their chromosomal content is **2n or diploid**. (They get half “n” from the “mother”; half “n” from the “father”.)
 1. Half, in terms of chromosomal content, is referred to as **“haploid or n”**.
 - C. For humans cells, our **diploid** number is 46 chromosomes = 2n. (n= 23 in the egg; n=23 in the sperm.)
- V. **Germ cells** (“germ” means beginning) - These cells will undergo **meiosis** to become **haploid “n”**.
 - A. **Meiosis** is the process of making haploid sperm or eggs that are intended for contributing DNA to sexual reproduction.
 - B. A.K.A. gametes or sex cells.
 - C. **Meiosis** results in sperm for males **OR** eggs for females. They are “n” or haploid and have 23 chromosomes.

VI. **Histones**

- A. These are the proteins that help DNA *coil up* “condense” to form the chromosomes needed for division.
- B. When DNA is wrapped around these histones, the *whole* combined structure is referred to as a **nucleosome**.

VII. **Sister Chromatids** (“tid” means “portion”) A portion of the whole “duplicated” chromosome.

- A. This term refers to half of a *duplicated* chromosome. *Duplicated* chromosomes look like an “X”.
- B. The two halves are held together at the **centromere** (means “center unit”), which is a group of proteins in a constricted portion of the chromosome.

VIII. Mitosis vs. Meiosis

- A. **Mitosis** – This process refers to **ordinary cell division**. (Parent cell and daughter cells are exactly alike genetically.)
 - 1. Involves only **ONE** division after replication occurs in the S phase.
- B. **Meiosis** – This is the process of **forming haploid gametes**. (Gametes have **half** the genetic material as the parent cell and they are NOT genetically identical to each other or the parent.)
 - 1. Involves **TWO** divisions after replication in the S phase.

AP Biology
Cell Cycle – Part 2

(Associated Learning Objectives: 1.14, 1.15, 1.15, 2.31, 2.32, 2.33, 2.35, 2.36, 2.37, 3.1, 3.3, 3.7, 3.8, 3.9, 3.11, 4.4, 4.5)

Important concepts from previous units:

- 1) Centrioles are protein components of the cytoskeleton that are composed of microtubules.
- 2) Microtubules, also proteins, compose the spindle fibers of mitosis and meiosis.
- 3) Proteins are the work horses of cells. They help move things within cells.

I. The Cell Cycle Phases for Eukaryotic Cells are:

A. **Interphase**

1. Cells spend 90% of their existence in this phase.
2. This phase consists of three parts:
 - a. **G1** (Primary or “first” growth)
 - i. This is ordinary, *everyday* growth, activity, or repair of the cell.
 - ii. Organelles begin replicating.
 - iii. First checkpoint (called “Point of no return”) is the barrier to the rest of the cycle.
 - b. **S** (synthesis)
 - i. The DNA replicates or is *synthesized* during this phase.
 - ii. In humans, we go from 46 Chromosomes “2n” to 46 chromosomes “2n” + the replicates. (Still considered 46 chromosomes...even with replicates.)
 - c. **G2** (Secondary or “second” growth)
 - i. The *organelles* mainly enlarge or complete replication.
 - ii. The newly synthesized DNA is checked for errors.
 - iii. Second checkpoint occurs after this “part”. (Do we have everything for **TWO** cells? If yes, then proceed to dividing; if no, then make what is missing.)

B. **Mitosis** (means “nucleus division”) - First divide the DNA; then secondly the cytoplasm.

1. This process has four parts:
 - a. **Prophase** (“pro” means “first”)
 - i. Nuclear envelope is broken down and *rearranged* to make the spindle apparatus.
 - ii. The **chromatin** *condenses* to form “X” shaped **chromosomes**. (*Two* chromatids.)
 - iii. Centrioles move toward the poles. (In animal cells only...plants use the cell wall.)
 - b. **Metaphase** (“meta” means “middle”)
 - i. All chromosomes line up on the metaphase plate. (Middle of cell.)
 - ii. The spindle apparatus attaches to the **kinetochore** (a part of the centromere) AND centrioles (the anchors).
 - iii. Third checkpoint occurs here. (Are all the chromosomes attached and lined up and ready to “divide/separate” or “segregate”?)
 - c. **Anaphase** (“ana” means “separate”)
 - i. Chromosome pairs are *pulled apart* and each chromosome moves toward opposite poles (ends) of the cell.
 - ii. The spindle apparatus is being *broken down* as the two sister chromosomes are “walked” toward the poles by the motor protein using ATP.
 - d. **Telophase** (“telo” means “last”)
 - i. The nuclear envelope is *rebuilt* by using broken down spindle apparatus pieces.
 - ii. The chromosomes begin to *decondense* back to their chromatin state.
 - iii. A cleavage furrow begins to form using actin and myosin microfilaments.

C. **Cytokinesis** (“Cleavage” means “split”) - This is the division of the cytoplasm.

1. The cytoplasm and cell organelles are separated to produce two **daughter cells**.

D. **G0** (Zero growth phase)

1. The cells may take a brief break and rest or they stop adult development.

II. **Spindle Apparatus**

- A. These structures are formed from the broken down cytoskeleton and nuclear envelope. (**They are recycled.**)
- B. The construction starts at the centrosome (where the centrioles are) and works toward the chromosomes.
- C. They attach to the **kinetochore** on the centromere of the replicated chromosomes.
- D. **Motor Protein** “walks” the chromosomes/sister chromatids toward the opposite poles (ends) using **ATP by phosphorylation**.
- E. Non-kinetochore spindles are used to “push” the poles farther apart to help produce the cleavage furrow.

III. **Cell Plate**

- A. Remember, Plant cells **DO NOT** have centrioles because they have cell walls to anchor to.
- B. The NEW cell wall “Plate” develops, using small segments of cellulose, instead of a cleavage furrow.

IV. **Regulation** “control” of the Cell Cycle.

- A. Regulation is crucial for **normal** growth and development.
- B. Regulation varies for each different type of cell.
- C. The regulation is controlled by protein molecules called **Cyclins**. (They control the cell **CYCLE**.)
- D. Three checkpoints exist: (Checkpoints are “stopping points to make sure everything is correct before going on to the next phase.”)
 - 1. First – It is at the end of G1. (Called the Restriction point. “Point of no return”)
 - 2. Second – It is at the End of G2. (Do we have 2 sets of DNA and 2 sets of organelles?)
 - 3. Third – It is at the End of Metaphase. (Are all the chromosomes in the middle of the cell and are they ALL attached to the spindle fibers?)

V. What is the difference between a theta (circular) chromosome and Eukaryotic chromosomes (linear):

- A. More genes are present on Eukaryotic chromosomes than on theta chromosomes.
 - 1. This means there exists more genetic *variation* exists in Eukaryotic organisms.
 - 2. There also exist more possible genetic combinations that can be inherited.
- B. There exists more genetic stability in eukaryotic chromosomes.
 - 1. Offspring receive the same number of chromosomes most of the time.
 - 2. Important *linked genes* tend to be inherited together.
- C. Allows for diploid cells to exist, as a result of sexual reproduction and one half of the DNA to come from each parent.
 - 1. Also increases *variation* among a species.

AP Biology
Cell Cycle – Part 3

(Associated Learning Objectives: 2.15, 2.16, 2.17, 2.19, 2.20, 2.22, 2.23, 2.24, 2.28, 2.31, 2.32, 2.33, 2.35, 2.36, 2.37, 3.34, 3.35)

Important concept from previous units:

- 1) Enzymes are proteins that catalyze and regulate cellular processes.

I. Cyclin Production

- A. This protein's concentration ("amount") increases from S phase until Anaphase occurs.
- B. Cyclin must combine with Cyclin dependent **Kinase** (CdK) to become active.
 1. **Kinases** are enzymes that "turn on" processes within cells.
 2. Remember, enzymes *are not used up* so concentration of CdK remains constant.
 3. Together they make Maturation Promoting Factor (MPF). This is the process the cell wants "on".
 - a. MPF causes the cell to *undergo* Mitosis when levels are *high* within a cell.
 - b. Concentration levels must reach checkpoint level to begin.
 - c. Cyclin starts being produced in the S phase and keeps being produced until Anaphase begins.
 4. After checkpoint, **Phosphorylation** of cytoskeleton and nuclear envelope occurs to start breaking down for conversion into the spindle apparatus.
- C. Cyclin *degrades* after Mitosis leaving only CdK behind, as enzymes are *recycled*.

II. Kinetochore Signal

- A. This signal occurs at the third checkpoint - End of Metaphase.
- B. As the chromosomes' kinetochores *connect* with the spindle apparatus, enzymes are "turned on".
 1. The enzymes are called **Anaphase Promoting Complexes**. (**APC**)
 2. When concentration levels of APC reach the checkpoint level, Anaphase begins.
 3. When ALL the chromosomes have attached to the spindle apparatus, we are ready to start Anaphase.
("Promote" means "to start"; "complexes" means "several molecules working together")

III. Density- dependent Inhibition

- A. Basically, means "A cell *stops* dividing when *contact* with other cells is made."
(Seen in repair. Once the wound is healed, cells back in contact, they stop dividing to "fix" the wound.)

IV. Anchorage Dependence

- A. Basically, means "Cells must be connected to the connective tissue base to divide."
(Wound severity is key. If a "hunk" of flesh is cut off, it won't be connected "anchored" and able to get nutrients, so it dies.)

V. Cancer (ABNORMAL cell growth) The prefix "onco" means "cancer".

- A. Cancer "creates" *abnormally high* Cyclin production within cells.
- B. *No checkpoints exist* within cancerous cells, so there is **no density-dependent inhibition**.
- C. Cancer cells are considered "immortal" so long as *oxygenated blood* is available.
 1. **Angiogenesis** occurs – means "creation of new blood vessels" to "feed" the tumor.
(**HeLa** cells prove this. Named after Henrietta Lacks. They have been "growing" since 1951.)
 2. **Telomerase** enzyme present. This enzyme is fueling the abnormal production of Cyclin.
 - a. Everyone *has* the *ability* to make this enzyme because it is needed during development in the womb to make the organism develop quickly. Once the organism is developed, it gets turned off normally. It is turned back on by cancer causing substances, called **carcinogens**.
(Cigarette smoke is an example of a carcinogen.)
- D. Normal cells divide between 1 and 100X –It depends on the *cell type*.
 1. If no telomeres are present, the cell will not be able to continue dividing.
- E. Cancer starts with *Transformation* of the DNA in a cell. (Transformation of telomerase to the "on" setting).
 1. Things that can cause this to occur: weak genetic history, trauma, or viral insert such with HPV- **Human Papilloma Virus**). and repeated carcinogen exposure.
- F. **Tumor** – means "Abnormal growth"
- G. Two main types of cancer are:
 1. **Benign** (It is *encapsulated* – like a tennis ball. This kind is *non-invasive*).
 - a. Usually not deadly – easy to **CURE by removal**.

2. **Malignant** (means “the CRAB”) - It is *Invasive*. It grows *between* cells destroying the tissue.
 - a. It **CAN** be deadly.
 - b. Normally **TREATED** with chemotherapy, radiation, or surgery.

H. **Metastasis**

1. This is the *movement* of cancer cells from the site of origin to another site within the body.
2. Cancer cells can travel through the blood vessels or lymph tract.
3. Heart? (The heart is the **ONLY** structure that cancer cannot grow in. It is too hard, and blood moves too quickly through it.)

I. Two MAIN genes that are affected to cause cancer in humans:

1. **RAS gene** (30% of all cancers are the result of this gene *mutation*.)
 - a. A G-protein mutated. These are involved in normal cell-to-cell communication. (A faulty signal transduction pathway occurs.)
 - b. The cell **CANNOT** shutdown the signal to grow going to nucleus; so it reproduces very quickly and constantly.
2. **p53 gene** (A.K.A the Guardian Angel gene.) 50% of all cancers are the result of this mutating.
 - a. This affects a tumor-suppressing gene.
 - b. A cell cannot commit suicide when it becomes damaged beyond repair. This mutation prevents cell cycle shut down because Cyclin becomes constantly produced by the damaged cell. This leads to more defective cells being produced.

J. **CANCER IS AN ACCUMULATION OF MUTATIONS OVER A LIFE TIME.**

3. Life style vs. Genetic Predisposition. We **ALL** have oncogenes in our genome. Some individuals have stronger control mechanisms that resist mutations; some have weaker. Our **CHOICE** in life style determines **HOW** much or **WHAT** kinds of carcinogens or mutagens we expose our bodies to.

AP Biology
Cell Communication Part 1

(Associated Learning Objectives: 1.14, 1.15, 1.16, 3.31, 3.32, 3.33, 3.34, 3.35, 3.36, 3.37, 3.38, 3.39, 4.5)

Important concepts from previous unit:

- 1) Chemical molecules have distinct shapes and densities based upon the number of each subatomic unit.
- 2) Cell membranes interact with the surrounding environment.
- 3) The Extra Cellular Matrix (ECM) is involved in cell communication.

I. Cell-to-Cell Communication

- A. It is absolutely *essential* for multi-cellular organisms to survive and function properly.
- B. Communication is accomplished mainly by *chemical* means.

II. *Types of signaling* that can occur between cells or organisms:

A. **Direct**

1. Involves *physical contact* between cells or organisms.
2. Could also involve passage from plant cell to another plant cell through the plasmodesmata (holes) in the cell wall of *adjacent* cells.

B. **Local**

1. Growth factors that are released into a *localized area*. (Usually for normal growth or repair.)
2. Another example is at the synapses of neurons. (Not direct contact because of the synaptic cleft.)
3. Another example, a teacher speaking to a class of students.

C. **Long Distance**

1. **Hormones** - They are released in one part of the body to travel to another part of the body.
2. **Pheromones** - Chemical “mate attractants” released into the environment.

III. **Signal Transduction Pathway** (It is *analogous* to talking on the phone.)

- A. Earl Sutherland won the Nobel Prize in 1971 for this discovery. He worked at Vanderbilt University.

B. Three parts to the pathway:

1. **Reception** - Molecule *binding* to membrane receptor protein. (It is like the phone ringing. I don't know anything about the actual call. I only know the phone is ringing. I will need to change the ringing into something I can understand.)
2. **Transduction** (means “to change or carry through”) (It is like answering the phone.)
 - a. This is a *series of steps in the changing of the signal* to something the cell can understand at the nucleus or in the cytoplasm.
(It would be this series of steps: Pick the phone up, move the phone to your mouth, say hello, and wait for the conversation to begin. Now that the conversation is occurring, I can understand what the message is that was initiated by the ringing of the phone.)
3. **Response** - This usually involves making something or turning on/off an enzymatic process.
 - a. Usually involves DNA transcription and translation or enzymes **INSIDE** the cell.
(Now that I know what the phone message was for; I hang up the phone and do what I was asked to do. The pathway is now complete and the action/response has occurred.)

IV. **Ligand** - This refers to the *actual signal molecule*.

- A. The ligand *binds* to the receptor protein (which are like cell “hands”) on the cell membrane or inside the cell. (Think of cells like a blind, deaf, and mute individual. They could effectively still communicate and understand their environment by using their hands to touch and feel.)
- B. The attachment causes a *conformational shape change* in the receptor protein that sets in motion the transduction pathway.
- C. *Different* ligands can initiate *different response*, this is important when considering chemical based medicines.

AP Biology
Cell Communication Part 2

(Associated Learning Objectives: 1.14, 1.15, 1.16, 3.31, 3.32, 3.33, 3.34, 3.35, 3.36, 4.4, 4.5, 4.22)

Important concepts from previous units:

- 1) **Phosphorylation** occurs by the hydrolysis of a phosphate ion from ATP and attaching it to a molecule.
- 2) **Enzymes** are proteins whose names usually end in “ase”.
- 3) **Enzymes** control cellular processes by feedback (negative or positive) mechanisms.

I. The most important receptor protein pathways in cells:

A. **G- Protein Pathway** - This is the *most* common pathway used by cells.

1. **G- Protein Linked Receptor**

- a. This protein serves as the *attachment point* for the **Ligand**. It is found in the plasma membrane of a cell. (This acts like the “hands” for the cell.)
 - b. It *will change shape* upon attachment of the *proper* ligand.
 - c. ALL cells possess G protein receptors. This allows them to interact with and respond to the environment around them.
2. **G- Protein** - This protein or enzyme acts as a relay protein, carrying the message to the appropriate location.
- a. **Phosphorylation** is possible due to the shape change that occurred with the receptor protein. This process will “*turn on*” the G-protein.
 - b. The activated G-protein then *travels to* the appropriate enzyme or protein to phosphorylate it. (It is usually GTPase.)
 - c. The GTPase will then “turn on or off” the necessary process in the cytoplasm or nucleus. (Mostly the process of transcription/translation.)

B. **Tyrosine- Kinase Pathway** - This pathway is involved with *growth/emergency repair* most of the time.

1. It has the ability to act like a *catalyst* for rapidly activating several relay proteins. (6 at one time.) (This is a great example of structure = function. In repair, you need to get *multiple processes* going quickly to prevent possible cell or tissue death.)

C. **Ion Channel Receptors** (Such as found at synapses of neurons.)

1. A.K.A. **Ligand-gated Ion Channels**.
2. These act as a *control* of a particular signal. Like letting sodium into a post-synaptic neuron. The “gate” is opened by the attaching of the neurotransmitter (the ligand) to the receptor protein. Once the gate is opened now the charged sodium ions can enter the cell to start depolarizing that cell.

D. **INTRACellular Receptors**

1. These receptors are mostly for *receiving hormones and steroids*. Since these molecules are lipids, they don’t need receptor proteins on the cell membrane. They travel into the cell by diffusing across the phospholipid bi-layer.
- a. A.K.A. **Transcription Factors** – the usually start the making of mRNA within the nucleus.

II. **Secondary Messengers** - These are relay molecules within the cell’s cytoplasm.

A. Usually they are *ion-based* molecules *within* a cell. These can MOVE about inside the cell.

B. Most common types:

1. **Cyclic AMP (cAMP)**

- a. Made by Adenylyl Cyclase from ATP.

2. **Ca⁺⁺ (Calmodulin) and IP₃ (Inositol Triphosphate)**

- a. These are mainly involved in helping to create and control muscle contraction.
- b. The ligand (first messenger) for a muscle contraction comes to the cell. It combines with the membrane bound receptor protein. A shape change occurs in the receptor protein. The shape change allows for the inactive G protein to attach to the receptor protein and become phosphorylated by ATP. The activated G-protein will then travel to the inactive PIP₂. The g-protein will break a bond in the PIP₂ to convert it to an active state molecule called IP₃. The IP₃ will travel to the endoplasmic reticulum of the muscle cell. The endoplasmic reticulum is like a storage place for Calcium ions. To open the storage facility you need a key. The key here is the secondary messenger IP₃. The IP₃ binds to a receptor protein on the endoplasmic reticulum. This causes a shape change to occur in the receptor protein. The shape change now allows the calcium ions (in the form of Calmodulin) to come out into the cytoplasm. The calmodulin (a secondary messenger too) will go and attach to the myosin microfilaments and thereby initiate a muscle contraction using the sliding filament theory.

AP Biology
Cell Communication Part 3

(Associated Learning Objectives: 1.15, 1.16, 3.31, 3.32, 3.33, 3.36, 3.37, 3.38, 3.39, 4.17, 4.22)

Important concepts from previous units:

- 1) **Enzymes** regulate (control) cell processes.
- 2) **Phosphorylation** is the binding of a phosphate to a molecule with the intent of making it “work”.
- 3) **ATP** is the molecule cells use for cellular “work”.

I. Cellular Response

- A. The end product of the pathway is about the regulation of some cell process.
 1. The responses are usually protein synthesis or product synthesis. (Turning them on/off.)

II. Protein **Kinase Cascades**

- A. KINASES turn **ON** processes by *phosphorylating* the molecule.
- B. The point of the cascade is to *amplify* the signal. (It keeps cells from making excess ligand signals. We only need **one** molecule to activate a process in that cell.)
- C. Each step in the cascade can amplify a signal; but it can also *control the reaction rate* of the process.

III. Protein **Phosphatase Cascades**

- A. Turn **OFF** processes by *removing a phosphate* ion from the molecule.
- B. Same as “B” and “C” above.

IV. **Amplification** of the Signal

- A. Only need a *very small amount* of the ligand to convey the message. (This conserves E and materials.)
- B. The cascades *amplify the signal* at each step. (1 becomes 2, 2 becomes 4, 4 becomes 8, and so forth.)

V. Structure = Function

- A. Different kinds of cells have different kinds and numbers of protein receptors. Each controls a different process.

VI. **Scaffolding Proteins**

- A. This allows for *direct* contact stimulation of multiple relay proteins at one time. (Similar to a Tyrosine-Kinase receptor protein. (Can you see how the scaffolding proteins might have evolved into the “one” half of a Tyrosine- Kinase protein over time? Then putting two next to each other over time?)

AP Biology
Nervous Systems – Part 1

(Associated Learning Objectives: 1.15, 1.16, 2.21, 3.43, 3.44, 3.46, 3.47, 3.48, 3.50)

Important concepts from previous units:

- 1) The parts to the Signal Transduction Pathway – Reception, Transduction, Response.
- 2) **Ligand** is a term referring to a signal molecule.
- 3) Energy can be in the form of charged particles, called **ions**.

I. The evolution of a Nervous System in animals:

- A. Starts with the evolution of an organism *wide* **Nerve Net** in Cnidarians (Jellyfish) to help “control” movement.
- B. Evolution of a brain (a mass of neurons) leads to *greater control* of the system. It utilizes a nerve cord to *span* the body.
- C. The evolution of other sensory organs in the *head region*, called **Cephalization**, allows for reception and response to *various types* of stimuli from the environment.

II. Overview of the Nervous System:

- A. **Sensory Input** - Sending information *into* the brain or spinal cord neurons in the body.
 1. Sensory Receptors *receive* a stimulus from the environment. A **stimulus** is a *form of energy* such as electromagnetic (light), mechanical (pressure), or sound waves.
- B. **Integration**
 1. This is the *interpretation* of the energy by the **Central Nervous System (CNS)**. (Basically “thinking” about the stimulus.)
 2. This interpretation of the stimulus leads to a *determination of the appropriate response*.
- C. **Motor Output** – Sending *out* of impulses from the brain or spinal cord to glands or muscles to “create” a *response*.
 1. The response is carried out by **Effector Cells**.
 - a. Effectors are Muscles or Glands. (These structures can have an *effect* on your body.)
- D. **Peripheral Nervous System (PNS)**
 1. This includes the Sensory receptors and Motor Nerves found in the body.

IV. **Neuron** (Nerve cell) structure:

- A. **Cell Body** - This takes stimuli from *different* dendrites and *compiles the energy* into one signal, like a funnel for fluids.
- B. **Dendrites** - These collect and carry stimulus energy **IN** to the cell body. They cover a *large area*.
- C. **Axon** - This *one* arm carries the one compiled signal **AWAY toward the next** neuron or effector cell.
 1. **Axon Hillock** - This is the swelling around the connection between the cell body and the axon.
- D. **Myelin Sheath** - This is a lipid layer of *insulation* around the axon created by **Schwann Cells**. It *prevents* the electrical energy of the neuron from burning the overlying muscle tissue. (It is analogous to the rubber covering on electrical wires.)
- E. **Synaptic Terminal** - At the end of the axon. (“terminal” means “end”)
- F. **Synapse** - This is the *gap* between neurons or between a neuron and an effector cell.
 1. **Neurotransmitter** - This is the chemical, produced by the **neuron**, used to *transmit* the signal *across* the gap.
 - a. The most common neurotransmitter is **Acetylcholine**.
 2. The neurotransmitter is released from the **Presynaptic cell**. (A neuron)
 3. The neurotransmitter travels to the **Postsynaptic cell**. (A neuron or effector cell.)

V. **Ganglia** - This term refers to a bundle of neurons in the PNS.

VI. **Nuclei** – This term refers to a bundle of neurons in the CNS. The “brain” is a collection of nuclei

VII. Types of accessory (helping) cells:

- A. **Glial Cells** - These are *supporting* cells for neurons to “hang” onto. (They are analogous to the frame for a house.)
 1. They help to maintain the integrity (functioning) of system.
- B. **Oligodendrocytes** - This term refers to the **Schwann cells** of the **CNS**. Same *type* of cells; just in a *different* location.
Schwann Cells - This term refers to the insulating cells in the **PNS**.
 1. Each acts as insulation around an Axon.
 2. These cells produce **Myelin** - a “Lipid” based substance that is a poor conductor of electricity.
 3. **Multiple Sclerosis (MS)** – This disease is where the Schwann cells in the CNS and PNS begin to die. The electricity traveling through the nerves then burns the muscles into permanent painful contractions until death.

AP Biology
Nervous Systems – Part 2

(Associated Learning Objectives: 2.10, 2.11, 2.21, 2.28, 3.36, 3.37, 3.38, 3.43, 3.44, 3.45, 3.47, 3.48, 3.49)

Important concepts from previous units:

- 1) Energy can be associated with *charged* particles, called ions.
- 2) *Established* concentration gradients can be a source of energy.
- 3) Active transport *requires* a transport protein, in the cell membrane, and an *energy source*.

I. Membrane Potential - The ability for the membrane to *potentially* do work.

A. This is “created” by *electrical charge gradients* across the membrane.

1. **Ion** Concentrations on *each side* of the membrane create the *charge gradient*.
 2. (-) **Anions** (Inside)
 3. (+) **Cations** (Outside)
- } Polarity exists

II. Resting Potential - This term refers to an *unstimulated* neuron. The electrochemical gradient *is* established.

A. **Na⁺ / K⁺ Pump** - This is a cell membrane bound protein. It *controls* the movement of the *charged* particles of Na⁺ and K⁺. Remember, these molecules can also be called **ligands**.

1. This protein requires energy (ATP or stimulus) to work. (This is an example of **active transport**.)
2. It is responsible for *generating* a Nerve Impulsive. (A.K.A. Electrical Impulse.)

B. **Gated Ion Channels** – These proteins *help* the Na⁺/K⁺ pump generate a nerve impulse *quickly*.

1. **Chemically—Gated Ion Channels** - These respond to chemically *charged ligands* in the cellular fluids.
2. **Voltage—Gated Ion Channels** - These respond to the “charge” concentrations because of the **ligands**.

C. **Depolarization**

1. This phase refers to the *flood of Na⁺ into* the cell. (This “*destroys*” the polarity.)
2. **Graded Potentials** - This term refers to “how much” Na⁺ entered? (Like your tests have different levels...grades.)
 - a. **Threshold Potential** – This term refers to the *minimum that must enter* to generate a nerve impulse within a neuron. It is considered an *all-or-none event*. It either generates a nerve impulse or it does not.
 - b. **Action Potential “Spike”** – Term refers to the electrical generated impulse in a nerve. (Action can now occur... a nerve impulse that can be relayed to the next cell.)

D. **Repolarization**

1. This phase refers to the *pumping out of K⁺* from the neuron in an attempt to *return to a resting potential* state. (The cell is trying to *re-establish* polarity.)

E. **Hyperpolarization**

1. This phase refers to the *excess pumping out of K⁺* from the cell; so the cell will pull some back in.
2. This is necessary to *re-establish a Resting Potential*; when the electrochemical concentration gradient exists.
3. No generation of a “spike” is possible until polarity is re-established.
4. **Refractory Period** - This term refers to the period of time when a neuron *cannot* make a new impulse.

III. Propagation - This term refers to the impulsive traveling down an axon. (It is like a cup overflowing into the next empty cup. Then when it gets full, it flows over into the next empty cup in the line.) This *overflow* of Na⁺ causes the voltage gates to open in the next segment, causing Na⁺ to *flood* into that segment.

IV. Saltatory Conduction – This term refers to the “hopping” of the impulse over the Schwann cells. This makes for *extremely quick* travel down an axon. The impulse must “jump” from node to node. This is because ion exchange can *only* occur at *exposed* membranes... where the Na⁺/K⁺ pumps are located. When you stub your toe, how long does it take for signal to get to your brain?

VI. Reflex Arc (The simplest neural pathway.)

- A. A *stimulus energy* is *detected* by a **Sensory Neuron**. The neuron carries the energy signal to the spinal cord.
- B. An **Interneuron** (of the CNS – spinal cord) *relays* the energy back out to the motor nerve instead of to the brain. (“inter” means “go between”... between the sensory and motor neurons.)
- C. The energy is carried out of the CNS by the **Motor Neuron**. It carries the energy to an **effector** cell, usually a muscle.
- D. This is why you do not think about a reflex, it just happens. The stimulus never made it to the brain for integration.

AP Biology
Nervous Systems – Part 3

(Associated Learning Objectives: 2.10, 2.11, 2.28, 3.34, 3.35, 3.36, 3.37, 3.38, 3.39, 3.43, 3.45, 3.47, 3.49)

Important concepts from previous units:

- 1) **Diffusion** is *movement* of a molecule from *high* concentration to *low* concentration *without energy usage*.
- 2) **Ligands** can cause *conformational shape changes* in receptor proteins.
- 3) *Different ligands* cause *different responses* in target cells.

I. **Synapses** – These are the *gaps* between neurons or between neuron and effector cells.

A. There are two types of synapses that exist:

1. **Electrical** – These require *direct contact* of cells for *continuous* electrical flow from cell to cell.
2. **Chemical** – These are the most common in animals.
 - a. These *require* a **neurotransmitter** (chemical ligand) to deliver the message across the synapse.
 - b. The signal goes Electrical Energy → Chemical Energy → Electrical Energy.

II. Steps involved in the Nerve Impulse conversion: (This is *one way flow*.)

- Step 1: **Depolarization** of axon terminal membrane. (The nerve impulse *hits* terminal cell membrane.)
- Step 2: **Voltage-gated ion channels** *open up* behind the terminus to allow Ca⁺⁺ to *rush into* the cell because of the terminal membrane getting hit by the electrical impulse.
- Step 3: Ca⁺⁺ *push* the **synaptic vesicles**, containing the **neurotransmitter**, *toward* the cell membrane.
- Step 4: The **vesicles** *fuse* with the cell membrane and *release* the **neurotransmitter** into the **synapse**.
- Step 5: The **neurotransmitter** *diffuses across* the **synapse**.
- Step 6: The **neurotransmitter** *binds* with protein receptors on the **post – synaptic neuron** or **effector** cell membrane.
- Step 7: The binding causes the receptor proteins (which may be a Na⁺ chemical gated channels) to *change shape and open*.
- Step 8: The Na⁺ *floods in* causing **depolarization** in the **post-synaptic neuron**.
- Step 9: **Cholinesterase** will *break down* the **Acetylcholine** causing the receptor proteins to *close back*.

III. **EPSP** – Excitatory Post Synaptic Potential - This refers to the *ability* to generate a nerve impulse. (Turn on.)

IV. **IPSP** – Inhibitory Post Synaptic Potential - This refers to the *inability* to generate a nerve impulse. (Turn off.)

V. **Summation** – this term refers to the *adding of dendrite stimuli together* to reach the **threshold potential** in the cell body.
(Think of the funnel example, it condenses into one area.)

VI. Neurotransmitters (ligands) in the human body:

A. **Acetylcholine**

1. Most common – This is mostly for making muscles of the PNS contract.
2. In the CNS – It can be excitatory **OR** inhibitory.

B. **Biogenic Amines** - These are *large* amino acid chains.

1. **Epinephrine** – *speeds up* body functions. (Such as breathing, metabolism, heart rate)*
2. **Norepinephrine** – *also assists with speeding up* body functions.*

* These two together are called your **“fight or flight response”**.

3. **Dopamine** – This is your happy neurotransmitter. #

4. **Serotonin** – This is your sleep neurotransmitter. #

These are *out of balance* in ADD, Schizophrenia. LSD and Xstasy *mimic* these neurotransmitters.

C. **Amino Acids** - These are *small* amino acid chains.

1. **GABA's** – These are *inhibitory*. (Think... PLEASE stop gabbing to me.)

2. **Neuropeptides**

a. **Substance P** – Relays *pain* stimulus.

b. **Endorphins** – These *block* substance P. They are responsible for your “second wind”.

i. Morphine/heroin drugs *mimics* these neurotransmitters.

D. **Gases** – these work by diffusion in a general area.

1. **Nitric oxide (NO)** – *Inhibits* muscle contraction and nerve signaling; therefore no pain. (A.K.A. Laughing gas.)

2. **Carbon Monoxide (CO)** - *Inhibitory*

AP Biology
Nervous Systems – Part 4

(Associated Learning Objectives: 1.15, 1.16, 2.11, 2.21, 2.28, 3.43, 3.44, 3.45, 3.46, 3.47, 3.48, 3.50, 4.8, 4.9, 4.10)

Important concepts from previous units:

- 1) There are various different types of energy in nature.
- 2) A ligand causes a conformational shape change in a receptor protein.
- 3) In the signal transduction pathway, a stimulus is converted and amplified during the transduction phase.

I. **Sensation** – This term refers to an **action potential** that has *reached* the brain and “sensed” the nerve impulse.

II. **Perception** – This term refers to the *integration* (“thinking about it”) of a received action potential.

III. **Sensory Reception** – This term refers to the *detection of a stimulus* by sensory receptors (dendrites of special neurons).

A. **Stimuli** are *forms of Energy* that cause a *transformational shape change* in a receptor structure or protein.

1. Sensory Transduction Process:

- a. A receptor **threshold potential** is achieved. (**Summation** leads to threshold causing **depolarization** to occur.)
- b. *Amplification* can occur on the way to the CNS of the electrical signal.
- c. *Transmission* along the axons is achieved by **saltatory conduction**.
- d. Integration by the CNS into perception occurs to determine the *appropriate response*.
 - i. **Sensory adaptation** – This is a *decrease in a continuous stimulus* coming into the CNS.
(This is what your brain does with regards to the constant detection of the clothing on your body.)

B. Types of sensory receptors:

1. **Interoceptors** – These receptor cells detect *internal* stimuli such as: pressure, balance, and homeostasis.
2. **Exteroceptors** – These receptor cells detect *external environmental* stimuli.
 - a. **Mechanoreceptors** - These detect bending or stretching of membranes or hairs.
 - b. **Nociceptors** - These detect pain using substance P.
 - c. **Thermoreceptors** - These detect heat or the lack of heat “cold”.
 - d. **Chemoreceptors** - These detect certain chemicals. (osmo-water; gustatory – taste; olfactory – smell)
 - e. **Electromagnetic receptors** (photo – light; electro – electrical; magno – magnetic)

IV. Sensation of **Hearing**

A. This sensation is accomplished by **mechanoreceptors** located in the *Inner* ear. (Sound is basically hairs bending.)

B. **Cochlea** “snail shell shaped” (This organ is located in the temporal bone of the skull.)

1. It is filled with a fluid called perilymph. (This fluid is used to make ripples.)
2. The **Vestibular Canal** runs on top of the Cochlear duct. (A “vestibule” is a covering.)
3. The **Tympanic Canal** runs on the bottom of the Cochlear duct.
4. The **Cochlear Duct** contains the **Organ of Corti** (Where the hairs are located.)
 - a. **Basilar membrane** (This contains the mechanoreceptor hairs.)
 - b. **Tectorial Membrane** (This bends the hairs as the ripple energy passes over top.)
 - c. Hairs *bend* causing **depolarization** in the membranes of the auditory nerves to create an **action potential** (electrical energy) because of the traveling ripple of **perilymph** in the canal.

V. Sensation of **Balance** and **Motion**

A. These are accomplished by **mechanoreceptors** (hairs bending again) in the *Inner* Ear.

B. **Semi-circular canals** (There are 3 on each side of head. These are the actual organs that detect these sensations.)

1. The canals are filled with perilymph fluid.
2. 3 canals: (90° - detects up/down; 45° - detects horizontal/vertical; 0° - detects left lean/right lean)
3. **Ampulla** - This is the swelling located at the end of a canal. This swelling contains the cupula.
4. **Cupula** – This structure contains the embedded **mechanoreceptors**. (Hairs that bend.)

- a. Movement of the body causes the perilymph to “flow” through the canals and bend the cupula hairs.
- b. **Cupula bends** the embedded hairs causing **depolarization** in neurons.
- c. Energy of motion is *converted* to electrical energy.

VI. Sensation of **Taste**

- A. This is accomplished using **Chemoreceptors** in the nose (**olfactory** – means “smell”) and mouth (**gustatory** – means “taste”).
- B. Chemicals cause **depolarization** of different neurons upon contact.
 - 1. The five taste senses are: sweet, sour, bitter, salty, and umami (means “savory” ... applies to meat taste.)
- C. Taste is 80 % smell and 20 % taste. (Think of when you have a cold? Food seems tasteless.)

VII. Other organism’s stimuli detection structures:

- A. **Lateral line system** - These act as “ears” for aquatic animals like fish.
 - 1. Water vibrations flowing through the system bend the cupula hairs.
- B. **Otolithes** or **Statocysts** - These detect balance and gravity.
- C. **Insect hairs** - These are for detecting taste and air currents.
- D. **Tympanum** - The “ear drum” of amphibians and insects. They are located on the sides of the body near the head.

AP Biology
Nervous System – Part 5

(Associated Learning Objectives: 1.15, 1.16, 2.11, 3.34, 3.35, 3.43, 3.44, 3.47, 3.48, 4.8, 4.9, 4.10)

Important concepts from previous units:

- 1) Conformational shape change *triggers* a transduction pathway leading to response.
- 2) Actin and myosin microfilaments are part of the cytoskeleton.
- 3) Calcium ions, referred to as calmodulin, is a secondary messenger within muscle cells.

I. Sensation of Sight (The eyes are a collection of photoreceptors.)

A. Structures in animals for detecting light energy.

1. **Oscilli** – As seen in Cnidarians (Jellyfish) and Bi-valves (Clams and oysters).
2. **Eye cup** – As seen in Platyhelminthes (Flatworms).
3. Eyes *with a lens* as seen in most other animals.
 - a. **Compound Eye** – Found in invertebrates, such as insects.
 - i. This produces *multiple pictures* of the same object.
 - ii. This type of eye is great for detecting *movement*.
 - b. **Single Eye** – Found mollusks and vertebrates. These are good for detecting *definition*.

B. **Retina** – This *layer of the eye* is the site of the **photoreceptors**.

1. **Rods** - These **photoreceptor** cells are for seeing black, white, and shades of grey.
 - a. They are the most abundant in all animals having these structures.
 - b. They possess **Rhodopsin Pigment**. (It is a combination of retinal [Vitamin A] and opsin proteins.)
 - i. A *shape change* allows for **depolarization** to occur in neuron.
2. **Cones** - These **photoreceptor** cells are used for seeing color.
 - a. They are outnumbered 20:1 by the rods.
 - b. They are found in vertebrates: but not all.
 - c. They possess **Photopsin Pigments**. (red, blue, green)

II. Locomotion – (A.K.A movement.) This term refers to *active* movement of an organism or object.

A. This process is the *second largest consumer of ATP* energy within an organism because:

1. Organism has to overcoming the *force of gravity* AND
2. Overcoming the *force of friction* (resistance).

B. Types of environments dealing with locomotion:

1. Water (Organisms are swimming or floating.)
 - a. *Little* gravity to overcome because of buoyancy; but *much* friction (water resistance).
 - i. Having a **fusiform** (means “torpedo shaped”) body lessens friction.
2. Land (Organisms are standing/walking/running.)
 - a. *Much* gravity to overcome; but *little* friction (air resistance).
 - i. Organisms have strong muscular limbs to overcome gravity.
3. Air (Organisms are flying or gliding.)
 - a. *Much* gravity to overcome and *much* friction to overcome (air resistance).
 - i. These require massive amounts of energy be consumed to overcome.

III. Muscle function and structure:

A. The main function of muscle is to provide movement using a *pulling force*.

B. **Motor unit** – This term refers to a muscle and corresponding motor nerve.

1. **Muscle contraction** process: (How a muscle contraction is accomplished.)

- Step 1: The neurotransmitter **Acetylcholine** attaches to receptor proteins on the muscle cell membrane.
- Step 2: **Depolarization**, Na⁺ flooding in, of the membrane occurs to generate an action potential. (This is electrical energy.)
- Step 3: The action potential travels along the membrane to a **T tubule**.
- Step 4: The action potential travels down the T tubule *into* the cell.

Step 5; The action potential “hits” the **Sarcoplasmic Reticulum** causing it to release Calcium ions, Ca^{++} , into the cytoplasm of muscle cell.

Step 6: The calcium ions, **secondary messengers**, bind with **the Troponin complex**.

Step 7: The calcium binding causes the **Tropomyosin thread** to “roll off” of the **Myosin binding sites** “holes” on the Actin myofibril.

Step 8: ATP is used to **phosphorylate** the **myosin heads** “Hands”.

Step 9: The Myosin heads “hands” grab the “holes” and pull “slide” the actin over.

a. This is referred to as the **Sliding Filament Theory**.

2. **Muscle relaxation** process: (How a muscle relaxes is accomplished.)

Step 1: **Acetylcholine esterase** *destroys* the **Acetylcholine** molecules on the membrane.

Step 2: The Phosphorus is taken off the “hands” and actin slides back to its original position.

Step 3: The Sarcoplasmic Reticulum reabsorbs all the Calcium ions.

AP Biology
Immune System – Part 1

(Associated Learning Objectives: 2.28, 2.29, 2.30, 3.34, 3.35, 4.8, 4.10)

Important concepts from previous units;

- 1) Ligand is a signal molecule that binds to a receptor protein on a cell membrane.
- 2) The glycolipids and glycoproteins of the ECM are involved in cellular communication.

I. Innate Immunity (A.K.A. non-specific immunity.) in animals

- A. This is immunity you are “born” with at birth. It helps protect against *most* organisms and environmental hazards.
- B. This includes your skin and mucous membranes. These are considered your *first line* of defense against disease.
- C. It also includes sweat. Sweat has a pH of 3 -5. It is salt mainly; but there is some urea to help kill bacteria.
- D. It also includes your *normal flora*. This means the good bacteria that live on your skin and inside your digestive tract.
- E. It also includes saliva, tears, pepsin of the stomach. Saliva, sweat and tears contain **lysozyme** – an antibiotic.
- F. **Phagocytes** - These are WBC’s that eat pathogens. They act as your *second-line* of defense against disease.
 1. Most phagocytes are neutrophils. (These are like your general infantry.) “phago” means “eater”
 2. Large phagocytes are called **Monocytes** (when they are in the *blood*) or **Macrophages** (when in the *tissues*).
 3. Phagocytes move by **positive chemotaxis** (towards chemicals) and **pseudopodial movement** (“oozing”).
 4. Eaten pathogens are broken down using Lysosomes or peroxisomes.

II. Inflammatory response - This is what happens when the body is attacked or injured.

- A. Capillaries dilate (open) and venules constrict (close) to *trap blood* in that location.
 1. *Redness, swelling (edema), heat, and pain* occur with an inflammatory response.
 2. The inflammatory response is initiated by the release of **Histamine** when cells get injured.
 - a. It is aided by **chemokines**. These are chemicals that *attract* phagocytes to the infected area.
 3. Neutrophils follow the chemical trail to the site of infection to fight.
 4. Macrophages come in after the fight to clean up the pus. Pus is a combination of dead cells and debris.

III. Pyrogens (means “Fire proteins”) from WBC’s

- A. These *proteins* carry out a **systemic** (entire body) response by turning up the heat, by increasing cellular respiration within the cells of your body. (What we call a “fever”.)

VI. Interferons – These are chemicals released from damaged, invaded cells that are used to *warn* other cells of incoming danger.

- A. It allows other cells to *increase their defenses* to *interfere* with the ability to be attacked. (“SAVE YOURSELF” proteins.)

VIII. Major Histocompatibility Complexes (MHC’s) – These membrane proteins are “special hands” on regular cells and WBCs.

- A. Two types exist:
 1. **Class I** – All cells other than WBC’s possess these. These are for *telling WBC’s that a cell is infected* when they are put out on the surface holding an **antigen** (antibody generating particle) in the hand.
 - a. The WBC *knows* to kill that cell because it *is infected* by the pathogen.
 2. **Class II** – All WBC’s possess these. They show *other WBC’s* what to look for and kill. (They are like trophy hands. “Come see what I have killed so that you too may seek and kill it.”)

IX. Plant general defenses against herbivory (Plants being eaten by animals.)

- A. Thorns - These are just modified leaves.
- B. **Cork** (Dead cells) that protect the exterior of trees and shrubs.
- C. Distasteful substances/poisons - These are called **canavines** or **tannins**.
- D. Predatory attractants.
- D. Sirens – such as **Jasmonic Acid**. The injury causes release of Jasmonic acid to other plant cells – this causes non-affected cells to increase cell defenses. Works similar to Interferon in your Immune System.

AP Biology
Immune System – Part 2

(Associated Learning Objectives: 2.28, 2.29, 3.34, 3.35, 4.1, 4.2, 4.3, 4.8, 4.9, 4.10, 4.22)

Important concepts from previous units:

- 1) Three parts to the Signal Transduction Pathway – Reception, Transduction, Response.
- 2) Glycoproteins and Glycolipids of the ECM are important in cellular communication.

I. Antigens and Immune Response

- A. An **Antigen** is a surface protein on a *pathogen* that causes antibodies to be generated by WBC's.
- B. **Antigen receptors** – These are “recognition hands” on lymphocytes. (The glycoproteins or glycolipids of the ECM.)
 1. When a pathogen is “identified” that triggers **Clonal Selection** in that Lymphocyte.
 - a. Clonal selection makes **effector cells** (fighters) and **memory cells** (for future fights).
 - b. **Primary Immune Response** (This refers to the *first encounter* with a pathogen.)
 - i. It generally takes 10 – 17 days to find right DNA sequence and make antibodies for fighting.
 - c. **Secondary Immune Response** (This is a *second, third, etc. encounter* with that *same* pathogen.)
 - i. It takes only 2 – 7 days to get better because of **memory cells**.

II. Specific Immune Responses - Using Lymphocytes to fight infections

- A. This immunity is the attack of *specific pathogens* using the **Lymphocyte WBC**. (These are like specialized assassins.)
 1. **B (bursa) Lymphocytes** – These “kill” by producing *antibodies*. Antibodies are like protein “tongs”.
 2. **T (thymus) Lymphocytes** – These “kill” by using *chemicals* to kill *infected* cells.
 - a. **Cytotoxic T cells** – These actually kill infected cells. (“toxic” means “deadly”)
 - b. **Helper T cells** – These *help turn “on”* B cells to make antibodies and Cytotoxic T cells to kill.
(These are the cells that are infected, and rendered useless by the AIDS virus.)
- B. **Humoral Immunity** -refers to clearing the *fluids*, such as blood, using antibodies from B cells. (“Humoral” means “fluids”)
 1. B-cells *mature* to become **plasma cells** that can make antibodies to fight pathogens.
 2. B-cell activation is initiated by:
 - a. **Interleukin 2 (IL-2)** released from a T-Helper cell. (Means “second message between WBCs”.)
 - b. Plasma cells secrete about 2,000 antibodies per second.
- C. **Cell – mediated Immunity** -refers to the use of T cells to “kill” other *infected* cells.
 1. Cytotoxic T-cells mature to fight and kill infected cells.
 2. T-helper cells initiate the two types of specific immunity.
 - a. T-helper connects to the macrophage displaying a MHC type II. It is attracted to the macrophage by **Interleukin -1 (IL1)**. This allows the T- helper to “analyze” the antigen so it can tell the other lymphocytes what to “look for”. (Means “first message between WBCs”... First message being “Come see what I have killed so that you may kill it too.”)
 - b. Cytokines (**Interleukine-2, IL-2**) are then released by T-helper cells to *relay message* to B-cells and Cytotoxic T cells.
 3. Cytotoxic T- cells
 - a. They are activated by an MHC class 1 or IL-2.
 - b. They kill *infected* cells by releasing **perforin**. (These are protein “bullets” essentially.)
 - c. Antibodies mark the pathogen parts for disposal by macrophages.
- C. Both types of lymphocytes will undergo Clonal Selection to make effectors (fighters) and memory cells.

III. Antibodies (A.K.A. Immunoglobulins –Ig’s) (Means “globular protein of the immune system”.)

- A. Structure of an antibody:
 1. **Heavy chains** and **light chains** – These are linked by **disulfide bridges** using the *Cysteine amino acid*.
 - a. This is an example of Tertiary and Quaternary structure of proteins.
 2. **Variable region** – This area *changes to match* the pathogen’s antigen. (It acts like hands on tongs.)
 3. **Constant region** – This area of the protein *never changes* in making the “handle on the tongs”.
 - a. This is the part of the antibody that the macrophage can safely grab.

AP Biology
Immune Systems – Part 3

(Associated Learning Objectives: 2.28, 2.29, 2.30, 3.34, 3.35, 4.8, 4.9, 4.10)

Important concepts from previous units:

- 1) Direct contact is a type of cell-to-cell communication.
- 2) Local (**paracrine**) and long distance communication between cells is accomplished by *chemical means*.

I. Self-tolerance situations:

- A. Recognition of normal body cells and WBCs.
- B. ABO blood groups and WBCs.
- C. Rh Factor on RBCs. (Pregnancy? – **second** pregnancy can be deadly if mother is Rh - and baby is Rh +.)
 1. Antibodies could have been made because of an Rh+ first birth. (Blood mixes during birth, antibodies made.)
- D. Tissue grafting and organ transplants. (Must have matching MHC's to work; Suppression of immune system is needed.)

II. Abnormal Immune System Function:

- A. **Allergy** (This is a *false* alarm. Mast cells are the problem by over producing **histamine**; so you take an *antihistamine*.)
- B. **Autoimmune Disorders** (Caused by faulty DNA genes.)
 1. **Lupus** (the wolf) – Characterized by a butterfly rash on the nose and kidney dysfunction. (Mostly women affected.)
 2. **Rheumatoid Arthritis** – WBCs attack and break down the connective tissues. (Mostly cartilage affected.)
 3. **Insulin – dependent Diabetes** (Type 1 – Juvenile Diabetes) – WBCs attack the pancreas cells that make Insulin.
 4. **Multiple Sclerosis (MS)** – WBCs attack the Schwann cells and myelin sheathes of neurons; leads to muscle burn.
- C. **Immunodeficiency Diseases (Having NO immune System.)**
 1. **SCID** - Infants born with no immune system. (A.K.A. Bubble people.)
 2. **Hodgkin's Lymphoma** - This is a cancer of the lymphocyte white blood cells. (Lymph nodes destroyed.)
 3. **Stress** – This weakens the Immune system.
 4. **HIV/AIDS** - This is caused by a **retrovirus**.
 - a. Host cell is the T-helper lymphocyte. (It keys in on the CD 4 membrane marker protein.)

II. Plant defenses against plant pathogen invasion: (“**virulent**” – means “deadly”; “**non-virulent**” – means “just harmful”.)

- A. **Gene-for-gene recognition** - This is a result of **coevolution**. (Resistance genes – like bacteria have.)
 1. If receptor protein matches the infecting ligand; no infection occurs.
- B. **Elicitors** (These are plant cell wall pieces traveling down the phloem indicating damage has occurred above.)
 1. **Oligosaccharines** released to cells causing them to produce **phytoalexins** and **PR proteins** (antibiotics).
- C. **Hypersensitive response** – *Massive release* of phytoalexins and PR proteins to injured infected cells.
 1. Causes a “sealing off” effect in leaves. (This tries to keep pathogen from advancing further.)
 2. This creates a “Dead Zone” that the pathogen may not be able to move past.
- D. **Systemic (whole plant) Acquired Resistance (SAR)** - Accomplished by releasing salicylic acid production.
(We call Salicylic acid ...Aspirin.)

AP Biology
Endocrine Systems

(Associated Learning Objectives: 1.15, 1.16, 2.12, 2.15, 2.16, 2.17, 2.18, 2.19, 2.20, 2.23, 2.36, 2.37, 3.32, 3.33, 3.34, 3.35, 3.36, 3.39)

Important concepts from previous units:

- 1) The **Signal Transduction Pathway** has three part – 1) Reception, 2) Transduction, 3) Response.
- 2) A **ligand** is a generic term for a *chemical messenger molecule* or a *form of stimulus energy*.
- 3) Cells can *amplify* a signal using the **kinase cascade system**.

I. **Hormone** – This is a chemical produced in one part of the body and *travels to another part* of the body to have an effect.

A. **Target tissue** – This is where the hormone travels to. (The target cells have the special proteins receptors “hands”.)

II. Three parts to the hormonal system of communication:

A. **Exocrine** – The hormone substance is put *into a duct or tube* to travel to another body part.

B. **Endocrine** – The hormone substance is put *into the blood* to travel to another body part.

C. **Neurosecretory** – Neurons that can *also* release hormones - such as the Pituitary gland and Hypothalamus.

III. **Local Hormones** – These hormones travel in *small, localized areas*.

A. **Growth Factors** – These are hormones that cause *cell replication*. They are used for “normal” growing or repair.

B. **Nitric oxide (NO)** – If from *neuron* – the gas acts as *neurotransmitter* to inhibit a process.

- If from *WBC* – the gas *kills* cell or pathogen.

- If from *endothelium of blood vessel* – the gas causes surrounding smooth muscle to *dilate* (relax).

C. **Prostaglandins** – These hormones helps with inflammatory response and muscle contraction.

D. **Cytokines** – Relay messages *between WBC's* about pathogens. For example, Interleukin 1(IL-1) or Interleukin 2 (IL-2).

IV. Hormone reception by cells:

A. **Ligand** (protein hormone) attaching to the *membrane receptor proteins* causes a **signal-transduction pathway** to begin.

1. If the pathway ends in the *cytoplasm* – turned on/off an enzyme.

2. If the pathway ends in the *nucleus* – turned on/off transcription.

B. Steroid (lipid ligand) hormones *go through the phospholipid bilayer* portion of the membrane to find its receptor protein in the cytoplasm. They do not need secondary messengers. Most are Transcription *activators*.

V. Hormonal control mechanisms:

A. **Negative feedback loops** – These *stop a process already occurring* and get it going in the *opposite* direction.

B. **Positive feedback loops** – These *enhance* a process that is already occurring.

VI. **Tropic hormones** – These are hormones that affect other endocrine glands causing the release of *secondary* hormone.

Major Endocrine Glands Of the Human Body

VII. **Hypothalamus gland** - This is the *master control* gland of homeostasis.

A. It controls the majority of the *homeostatic* mechanisms in our body.

B. Uses **releasing hormones** or **inhibiting hormones** as messengers. These affect the **pituitary gland** – second in command.

VIII. **Pituitary Gland** - This is the *second in charge* in control of homeostasis.

A. This gland is affected by Hypothalamus Hormones.

1. **Releasing hormones**—*Starts* a process.

2. **Inhibiting hormones** —*Stops* a process that is occurring.

B. Two Parts of the Pituitary Gland:

1. **Anterior** - Arises from the **Adenohypophysis**... muscle tissue of the mouth.

2. **Posterior** - Arises from the **Neurohypophysis**... neuron tissue of the brain.

AP Biology

Organismal Development – Part 1 - Prokaryotes and Protists

(Associated Learning Objectives: 1.14, 1.15, 1.16, 2.8, 2.9, 2.12, 2.31, 2.32, 2.33, 2.36, 2.37, 2.38, 3.1, 3.7, 3.8, 3.10, 3.27, 3.29, 3.30, 3.34, 4.15)

Important concepts from previous units:

- 1) Cells that divide by Mitosis produce *genetically identical* offspring.
- 2) Cells divide when they become *inefficient* at transport across the cell membrane.
- 3) Cells that reproduce sexually depend on cell-to-cell communication/contact.
- 4) All matter and energy for growth and development comes from the environment.

I. *Modes* (ways of doing) of reproduction:

- A. **Asexually** – Basically, the making of *genetically identical* clones. No *exchange* of DNA occurs.
- B. **Sexually** – The fusion of *two different gametes* (sperm and egg) to create a **Zygote** (fertilized egg) that has variation.
 1. Remember, variation is the key to survival in changing environments.
 2. To create sperm and eggs, certain **diploid** cells have to undergo **Meiosis**, which involves *two divisions* of chromosomes to become **haploid** cells.

II. *Types* of Asexual Reproduction:

- A. **Binary Fission** – term for *Bacterial* reproduction.
- B. **Budding** – organisms, such as polyps (*sessile form of jellyfish*), are generating *genetically identical* “buds” that break off to become a new organism.
- C. **Fragmentation and regeneration** - Seen in the Platyhelminthes (flatworms) and Echinoderms (starfish).

For example, a single arm of a starfish gets removed. The starfish will grow (regenerate) a new arm in that same place. The removed arm will (fragment) will become a new starfish.

BACTERIA

III. **Binary Fission**

- A. This is the process of Reproduction/Replication in prokaryotes (bacteria).
- B. DNA replication (S phase) starts at the “origin” and works around the entire *single, circular (theta) chromosome*, this results in two identical chromosomes in the **nucleoid** region.
- C. This is followed by producing a **cleavage furrow** (cytokinesis) to produce 2 new cells, that are referred to as **clones**. The cleavage furrow is produced using **actin** and **myosin** microfilaments.
- D. How is Binary Fission related to Mitosis in terms of evolution? Binary Fission would have evolved into Mitosis as the DNA content increased dramatically and also the endosymbiont hypothesis occurred to produce “organelles”. The two major steps are the same: synthesis and division.
- E. 100% genetically identical clones are produced by this process.

IV. Bacterial *Variation* Processes (Remember, variation *increases survival* chances within a *changing* environment.)

- A. **Transformation** - This is a simple change of DNA content.
 1. A bacteria *took in* DNA from an *external* source. Recombination of DNA occurred. Variation “created”.
 2. **Biotechnology**? This is what we do, in laboratories, to make bacteria “learn” new tricks.
- B. **Transduction** - This is when *new DNA* has been *carried in by a virus* thus creating the “change”.
 1. A phage (virus) *introduced* the *new DNA* into the bacterial. The two DNAs combined into one **genome**.
- C. **Conjugation** - This is “Bacterial sex”.
 1. Bacteria *exchange* plasmids (small circular pieces of DNA) through a **conjugation tube** from the “male” to the “female”. (Bacteria DO NOT have sexes like humans do.)
 2. **F factor** (If a bacteria possess this gene, they are considered “male”. Shown as F+.); (F- are “female”. They do NOT possess the F factor gene.)
 - a. **Pili** – This *structure* is a “sex whip” for pulling the “female” close so that a **conjugation tube** can be made between the two bacteria. The pili is created by *expressing* the F factor gene.

PROTISTS (These are mostly *single celled* organisms.)

V. Reproductive Means

- A. Some are *sexually* reproducing organisms. (Remember, this method favors *variety*.)
 - 1. The organism makes **haploid** gamete structures through the process of **Meiosis**.
 - 2. The gametes are *released* from the *parent* organism.
 - 3. The male and female gametes *combine* to form a genetically new **diploid zygote**.
 - 4. The **zygote** *develops* over time into the “adult” organism.
- B. Some are *asexual* reproducing organisms. (This is a *faster* process but produces *no variation*; they are all **clones**.)
 - 1. Essentially, it is a process just like **Binary Fission**, *except* that they have a nucleus with *linear* chromosomes and organelles in the cytoplasm; so therefore, there is a G2 phase and it is followed by **Mitosis** and Cytokinesis. (We call this *whole process* **Mitosis**, just like we discussed with the Cell cycle)

AP Biology

Organismal Development –Part 2 - Fungus and Plants

(Associated Learning Objectives: 1.15, 1.16, 2.8, 2.9, 2.22, 2.24, 2.31, 2.34, 2.37, 3.1, 3.9, 3.10, 3.11, 3.34, 3.35, 4.8, 4.9, 4.15)

Important concepts from previous units:

- 1) **Haploid** refers to having *one half* the DNA content of a normal Diploid cell. We represent it as “n”.
- 2) **Diploid** refers to having *two halves* (a whole) of the normal DNA content. We represent it as “2n”.
- 3) S phase *replicates* the DNA of a cell. Mitosis has *one division* of DNA. Meiosis has *2 divisions* of DNA.

FUNGUS

I. Fungal Life Cycles

- A. Majority of the life is spent as **haploid asexual** organisms.
 1. This allows the organism to reproduce *much faster* and colonize a dead organism for food and *reduce competition* with other organisms.
 2. **Haploid spores** can be produced by Mitosis and then released to reproduce, in favorable environments, very quickly.
2. Fungi use the **diploid** state to *create variation*. (Remember, variation helps with *survival in a changing environment*).
- B. All *sexual* reproduction, for all types of fungus, involves three phases:
 1. **Plasmogamy** - This is the *fusion* of cytoplasm. (+=male; -=female) The “female” is *signaled* by the release of **pheromones** from the “male”.
 - a. This fusion *together* of hyphae results in **heterokaryon** (Means “different nuclei”) or **Dikaryotic** (Means “two nuclei”).
 2. **Karyogamy** – This is the fusion of nuclei. This makes the hyphae now 2n (Diploid) in genetic content.
 3. **Meiosis** of the **diploid (2n) zygote** to return to a **haploid (n)** state.
 - a. Variation has been “created”.

PLANTS

II.

Sexual Reproduction in plants using **Alternation of Generations**.

- A. **Sporophyte (2n)** This generation produces **diploid spores** that undergo **Meiosis** to become **haploid (n) spores**.
 1. The **haploid spores are released** (in the case of the seedless plants) into the environment or *retained* in the case of gymnosperms and angiosperms (the seed producing plants).
 - a. **Released** spores hopefully *will find a suitable environment* to grow and produce **gametophyte**.
 - b. **Retained** spores will *develop into a single celled gametophyte, the sperm or egg*.
- B. The **haploid gametophyte (n)** produces **haploid gametes** that are **released if male and retained if female**.
 1. The male gamete, sperm, *travels to* the female gamete, egg, to *fertilize* and form a **diploid zygote**.
 - a. The **diploid zygote** will grow into the *new sporophyte* generation.

III.

Asexual reproduction methods in plants (A.K.A. **Vegetative Reproduction** or **Vegetative propagation**.)

- A. **Fragmentation** – A piece of the original plant breaks off and lands & implants the cut edge in the dirt.
 1. This *fragment* of cells begin to develop *missing parts*, so long as Xylem tissue runs in right direction... up.
- B. **Cuttings** – “Man” removes a piece and puts in water or soil to grow. (Like fragmentation; but caused by “man”).
- C. **Grafting** – This is the *combining of two different* plants.
 1. **Stock** – This is the part with established roots.
 2. **Scion** – This is the cutting to be attached to the stock plant.
- D. **Tissue Cultures** – This uses plant cells to make **clones**.
 1. These cells are said to be **totipotential** (means “they can make all types of cells”).

IV.

Apoptosis – this is the “programmed” cell death of cells to create important anatomical structures.

- A. It is controlled by *DNA genes* within the cells of developing organisms.
- B. An example would be the death and hollowing out of cells to create the water moving xylem tissue of plants.

AP Biology

Organismal Development – Part 3 - Male Animals

(Associated Learning Objectives: 1.14, 1.15, 1.16, 2.8, 2.9, 2.22, 2.23, 2.24, 2.31, 2.37, 2.38, 3.1, 3.9, 3.10, 3.11, 3.27, 3.34, 3.35, 4.5, 4.6)

Important concepts from previous units:

- 1) Mitochondria provide chemical energy (ATP) for cells by performing Cellular Respiration using sugars.
- 2) Pheromones are a form of long distance *communication* between organisms using chemical attractants.
- 3) Matter and energy for growth and development comes from the environment.

I. **Hermaphrodites** – Organisms possessing both sexual organs. (Most species *cannot* self-fertilize.)

A. **Sequential Hermaphrodites** - The organisms can *change sexes* based on *environmental pressures*.

1. **Protogynous** (“proto”; “alpha” means “first”; “gyn” refers to “females”) The Alpha female becomes male.
2. **Protoandrous** – (“andro” refers to “males”) The Alpha male becomes female.
3. This *guarantees* that the *most fit genes are passed on* to the next generation.

II. Mechanisms for sexual reproduction:

A. **Fertilization** - The *fusing* of haploid sperm and egg to create a diploid zygote.

1. **Externally** – Fertilization occurs *outside the body*. (This occurs in fish and amphibians.)
2. **Internally** – Fertilization occurs internally. (This occurs in most animals including reptiles, birds, and mammals.)
 - a. The *presence of water* is key to following the evolution of animals from fish to reptiles to mammals.

III. **Pheromones** – Chemicals that are *released* into the outside environment to *attract a mate or mark a territory*.

V. **Spermatogenesis** – This is the making of sperm.

A. **Spermatogonia** – These are the cells that make sperm (4 of them) by undergoing the *two divisions Meiosis*.

B. Sperm structure:

1. The **Head** contains the:
 - a. **Nucleus** - Site of the DNA. – It has 23 Chromosomes in humans. (It is n- haploid.)
 - b. **Acrosome** – The tip of the head that contains digestive enzymes used to eat through the protective jelly surrounding the female egg.
2. **Midpiece** – This part contains mitochondria for making energy (ATP) to power the swimming of the tail.
3. **Tail** – It is a flagella, composed of microtubules from the cytoskeleton.

VII. Male hormonal pattern

A. **Androgens** – These are the male hormones.

1. **Primary sex characteristics** – This refers to the **ABILITY** to make sperm. (This occurs at adolescence.)
2. **Secondary sexual characteristics** – These are the “traits” of men such as facial hair, muscle mass, deep voice.
3. Secondary characteristics start at puberty with the release of **GnRH**, from the Hypothalamus, to the Pituitary and continues until death usually. (This is why it is non-cyclic.)

B. These hormones are *not released* in a *cyclic pattern* like female hormones are.

AP Biology

Organismal Development – Part 4 - Female Animals

(Associated Learning Objectives: 1.15, 2.15, 2.16, 2.17, 2.18, 2.31, 2.32, 2.37, 2.38, 2.40, 3.1, 3.8, 3.9, 3.11, 3.34, 3.40, 3.42, 4.9)

Important concepts from previous units:

- 1) Ligands can be hormones.
- 2) The Signal Transduction Pathway has three parts – Reception, Transduction, and Response.

I. Female Reproductive Cycles

- A. Cycles favor *energy conservation*, especially during harsh environmental times, such as winter.
- B. Female reproductive cycles are controlled by *hormones* and *environmental cues*, such as temp., rainfall, day length.

II. Important Female Anatomy:

- A. **Uterus** – This is the muscular structure for *gestating* (growing) a fetus. (A.K.A. Womb)
 1. **Endometrium** – The inside lining of the uterus. It is responsible for menses. It can act as a *cushion* for a fetus.
- B. **Fallopian Tubes (Oviducts)** – These are the tubes leading from each ovary to the uterus.
 1. They are lined on the inside with ciliated cells. These help in collecting and *moving the egg* toward the uterus.
- C. **Ovaries** – These are the organs responsible for egg and hormone (**estrogen and progesterone**) production.
 1. **Follicle** – This structure is the protective case for a *maturing egg*, called an **ovum**.
 3. **Ovulation** – This term refers to the *releasing* of an adult egg ready to be fertilized. It is caused by **LH** hormone.

III. Oogenesis – This is the “creation” of a **haploid egg**.

- A. **Oogonium** – This is the **diploid** cell that undergoes **Meiosis**. It *stops* after the *first DNA division* to become a **primary oocyte**.
- B. It will be *reactivated* by **FSH** coming from the Anterior Pituitary at the *start* of a menstrual cycle.
- C. The **secondary oocyte** will be released at ovulation. (It will perform the second division *if and after fertilization* occurs.)
- D. Process results in *one haploid* cell and 2 polar bodies. (All organelles of the cell come from the mom’s egg cell.)

IV. Female Hormonal Pattern: (This is *cyclic*; unlike males.)

- A. **Menstrual cycles** - This cycle mainly occurs in humans. (A cycle is usually 28 days long.)
 1. It requires **menstruation** to release the sugar rich endometrium of the uterus, if no pregnancy occurs.
- B. **Estrous cycles** - Mainly occurs in other mammals. (No menstruation occurs because the endometrium is *reabsorbed*.)
 1. **Estrous** - This is a period of increased sexual activity. (A.K.A. heat.) It last only a couple of days per year.

IV. The Female Human Menstrual Cycle:

- A. **Days 1 – 5** - This is the **menstrual flow phase**. There is *shedding* of the *old* endometrium because pregnancy didn’t occur.
- B. **Days 5 – 13** - This is the **proliferative phase**. **Estrogen** causes a *new endometrium to be built back up*. (Fetal cushion)
- C. **Day 14** – This usually is the day **ovulation** (*release* of the egg) occurs.
- D. **Days 14 – 25** - This is the **secretory phase**. **Progesterone** causes the *new* endometrium to secrete a sugary substance.
 1. This sugar will serve to *feed* the developing fetus until an umbilical cord develops.
- E. **Days 25 – 28** – This is the **endometrial breakdown phase** – if *no pregnancy* has occurred. Breakdown tissues for menses.
 1. When menses begins, that marks day one of a new cycle beginning.

V. Ovarian Cycle: (This is **occurring at the same time as the menstrual cycle**.)

- A. **GnRH** released by the **Hypothalamus** travels to the **Anterior Pituitary gland**.
- B. The **Anterior Pituitary gland** releases **FSH** to travel to the ovaries to *stimulate* several follicles to begin to mature.
- C. **Follicular Phase** (Days 1 -13) – Follicle and egg mature and release **estrogen**. It travels to the uterus to *stimulate proliferation* of the endometrium in the uterus.
- D. **Ovulation** – The *release* of the egg to the fallopian tubes occurs. It travels toward the uterus and possible sperm.
- E. **Luteal Phase** (Days 15 -28) – **Corpus luteum** (empty follicle) produces progesterone and estrogen as it degrades.
 1. When the **corpus luteum** is “gone”, that causes the **Hypothalamus** to detect no **progesterone**; and releases **GnRH** to start the next cycle. A fetus *mimics* a corpus luteum until **HGH** can take over to prevent next cycle.

VI. Menopause – No more GnRH released. No more menstrual cycles – no more possible pregnancies. Occurs at 40 – 50 years old.

AP Biology
Organismal Development – Part 5 - Embryology

(Associated Learning Objectives: 1.15, 2.8, 2.9, 2.24, 2.28, 2.31, 2.34, 2.35, 2.37, 3.1, 3.11, 3.32, 3.34, 4.5, 4.8, 4.9, 4.10, 4.15)

Important concepts from previous unit:

- 1) Genes are composed of DNA nucleotides and “act” as the “blueprint” for making a protein or enzyme.
- 2) DNA is inherited from the parents using an egg (mother) and a sperm (father).
- 3) All the matter needed to “make” an organism is coming from the *cycles of matter* that occur in the *environment*.

I. DNA genes *control* the process of development through the *production* of proteins and enzymes.

- A. **Cytoplasmic determinants** (proteins in the cytoplasm) *act as signals* within the cells to control Mitosis.
- B. **Pattern genes** control the *pattern (shape)* of an organism while it is being developed.
 1. What is the basic pattern of a human? A dog? A frog? An insect?
- C. **Positional genes** control the *position (location)* of various structures, such as organs, bones, and muscles.
 1. Where is the heart located in humans? The Small Intestines? Brain and Spinal cord?
- D. **Apoptosis** – this is the “programmed” death of cells that is needed to create important anatomical structures.
 1. Examples of **apoptosis** include the death of cells *in-between* digits such as fingers and toes.

II. **Fertilization** (A.K.A. **Conception**) and Development Process (This is *just* Cell Signaling using *direct contact*.)

A. **Acrosomal Reaction**

1. **Acrosome** releases *digestive enzymes* that begin to eat away at the egg’s *protective* jelly coating.
2. **Acrosomal process** develops after getting through the jelly coating and *connecting* with the egg.
 - a. This allows the sperm to connect with the egg protein receptors “hands” for *verification*.
 - b. The connection with the first sperm causes all the other receptor protein “hands” to be *released from the egg* and thus *prevents* multiple sperm from fertilizing.
3. Sperm begins to enter the egg cell through a hole in the membrane. (The DNA in the sperm will *determine* the organism’s sex. If it has an X sex chromosome, it will be XX –female. If it has a Y sex chromosome, it will be XY – male.)

B. Sperm entering the egg causes the *rate of Cellular Respiration (making E) and Protein synthesis to increase*.

C. Egg undergoes the *second Meiotic division* to take the “mother’s DNA” to a **haploid** state.

1. This *only* happens if the egg is *fertilized*.

D. Egg DNA and sperm DNA *fuse together* to create a **diploid** state.

E. The tail of the sperm (microtubules) is broken down to help “create” the **spindle fibers** for Mitosis.

F. **Basal body** of sperm detaches to create the **centrioles** (anchors for Mitosis).

G. **Cleavage** (rapid cell division) occurs to create a **morula** (*solid* ball of stem cells).

1. Cells get smaller with each division – The *whole* structure *remains* the *same size* roughly.
 - a. Does *not* go through a *normal* G1 or G2 phase – *only* S phase and Mitosis really.

H. **Morula** continues to divide, but now *hollows out* to form a **Blastula** (*hollow* ball of cells) by **blastulation**.

1. The **blastula** only has *two* layers of tissues.
2. Stem cells are called **blastomeres** now. (They are beginning to *specialize or differentiate*.)
3. **Blastula** has two regions with different size cells in it.
 - a. Small cells on top. (**Animal pole** - makes the *head*.)
 - b. Large cells on bottom. (**Vegetal pole** - makes the *body*.)
 - c. Hollow space referred to as the **Blastocoel**. (“Coel” means “open space”)

I. **Blastula** continues to develop into a *three* tissue structure called a **gastrula** by **Gastrulation**.

1. Third layer is “created” by **involution** (cells moving *inward* from the *outer surface*) through the a *hole* in the structure called a **Blastopore**. (“pore” means “opening”)
2. Hollow space now called the **archenteron**. (This space becomes the digestive tract – “food tube”.)
 - a. **Dueterostomes** – make the *anus first* → work toward the mouth “making” the tube.
 - b. **Protostomes** – make the *mouth first* → work toward the anus “making” the tube.
3. **Ectoderm** – makes the skin and CNS.
4. **Mesoderm** – makes the muscles, bones, and kidneys.

5. **Endoderm** – makes the digestive tract organs, lungs, and bladder.
6. The **Blastopore** fills in after **gastrulation** with the **Yolk Plug**.
7. The **gastrula** will hopefully (25% chance) *implant in the uterus and continue to develop* into an **embryo**.
 - a. **Embryo** is a *developing* organism.

J. **Organogenesis** in the **embryo** follows **gastrulation**. (This is the first trimester of pregnancy/gestation.)

1. This is a very *important time*. If something goes wrong during this period, the organism will be *severely* affected.

K. **Placenta** (*connection* with the mother) will develop from cells on the bottom of **gastrula** called **trophoblasts**.

1. Mothers blood vessels and fetus's blood vessels **DO NOT MIX (ABO blood types and Rh factors remember.)**
2. Hormones such as **progesterone** and **HCG (Human Chorionic Gonadotropin)** are helping *control* the development and communicate with the mother's body. (**HCG** in the urine is what a pregnancy test detects.)
3. Development of the **Amniotic sac** occurs. (This contains salt water – same concentration as ocean water.)
 - a. An **amnion** can also be found in bird, reptile, and monotreme eggs.

L. Second Trimester – **fetus** (developing human) gets bigger in size by growth through cells undergoing Mitosis.

M. Third trimester – **fetus** packs on the weight, as it will soon lose its *constant* feeding source- Mom.

N. **Birth** – **Oxytocin** hormone helps expel the baby by causing the uterus muscles to *contract*.

O. **Lactation** (milk production) for breast feeding will be induced using the hormone **Prolactin**.

III. **Convergent extension** – this is the process of *going from a round structure to an elongated structure*. (Still cell's signaling.)

- A. Gastrula (round) going to an embryo (elongated) structure.
- B. The cells *move* (using the ECM) into single file line causing the structure to go from round to elongate.
- C. Protein receptor “hands” are *communicating* between the cells (called **CAM's – Cell Adhesion Molecules**).

IV. **Apical Ectodermal Ridges (AER)** – responsible for making the *limbs* (arms, legs, or wings) of an organism.

AP Biology
DNA History & Structure
(Associated Learning Objectives: 1.14, 1.15, 2.22, 3.1, 3.2, 3.29, 4.1, 4.23)

Important concepts from previous units:

- 1) The basic unit of DNA or RNA is a **nucleotide**; composed of a Nitrogen base, 5 Carbon sugar, and Phosphate.
 - 2) DNA is like a “million dollar blueprint” having the genetic information for *making* proteins and enzymes.
 - 3) **Base pairing** is always a pyrimidine (C, T, U) with a purine (A, G).
-
- I. Frederick Griffith (in 1928)
 - A. He was a British Army doctor who was studying Pneumonia in the hopes of finding a cure.
 - B. He is given credit for the **transformation** experiment, even though this was not his original intent.
 1. In the experiment, he took pathogenic (disease causing) bacteria and non-pathogenic bacteria and injected them into mice. The pathogenic bacteria killed the mice. The non-pathogenic did not kill the mice. He then took some pathogenic bacteria and killed them by exposing them to *heat*. He took the dead bacteria and injected them into more mice. The mice did not die. He then took some of the dead pathogenic bacteria and mixed them with the non-pathogenic bacteria. He then injected the mixture into some more mice. THEY DIED. His reasoning was some “instructional agent” was *exchanged* between the dead pathogenic bacteria and the living non-pathogenic bacteria allowing them to “learn” a new trick. How to make the toxin (poison). So, we say they were **transformed** from non-pathogenic into pathogenic bacteria.
 - II. Oswald Avery and associates (in 1944)
 - A. He retests Griffith’s experiment, but with the purpose to find out what the “instructional agent” was that led to the transformation of the non-pathogenic bacteria.
 - B. After the testing, he states that the transformation agent was DNA.
 - C. This statement sparks lots of controversy, as DNA is too simple a molecule, most scientists believe. It must be proteins, as they are very large complex molecules. So now the race is on to prove which was it, DNA or proteins.
 - III. Alfred Hershey and Martha Chase (in 1952)
 - A. They worked with the T2 Bacteriophage (a virus that infects bacteria) and E. Coli bacteria.
 - B. This becomes the **Hershey-Chase Experiment**.
 1. They used *radioactive Sulfur-35* to label the virus’s *protein outer capsid* in one container. (Remember, the amino acid Cysteine contains Sulfur. The radioactivity allows them to follow where the *proteins* go by using a Geiger counter. A Geiger counter is used to measure radioactivity.)
 2. They then used *radioactive Phosphorus-32* to label the *DNA* inside the virus in a *different* container. (Remember, Phosphorus is one piece of a **nucleotide**. They can also follow the DNA using the Geiger counter.)
 3. The radioactive viruses were then exposed to bacteria. The viruses infected the bacteria. In the radioactive Sulfur container, the radioactive Sulfur did NOT enter the bacteria. It remained outside the bacteria. When the viruses reproduced inside the bacteria, the reproduced viruses that came out of the dead bacteria were NOT radioactive. In the radioactive Phosphorus container, the radioactive Phosphorus did enter the bacteria. When they reproduced inside the bacteria, the reproduced viruses that came out of the dead bacteria *were* radioactive from the Phosphorus they possessed.
 4. This proved with 100% accuracy, that DNA was the “transformation agent” and that this carries the information “blueprint” from one generation to the next.
 - IV. Erwin Chargaff (in 1947)
 - A. He develops what becomes known as **Chargaff’s Rule**.
 - B. The rule states that, *FOR ALL ORGANISMS*, $[A] = [T]$ and $[C] = [G]$.
 1. This helps support the theme of *Unity* and *Diversity*. Unifying complementarity, as it *always* the *same* pairing of nucleotides. Diversity is in the percentages of each *grouped* nucleotide pairs *between* species.
(For example: If you know a species has 32% Thymine; then there must ALSO be 32% Adenine. $[32+32= 64\%]$ This means that there is 36% unaccounted for. $[100- 64 = 36.]$ Since this 36% is BOTH Cytosine and Guanine, divide by 2 to find the percentage of each. $[36 \div 2 = 18]$ There exists 18% Cytosine and 18% Guanine.)

- V. Rosalind Franklin (in the 1950's)
- A. She performed X-ray Crystallography on DNA. This picture was *extremely* important in helping Watson and Crick develop their model of DNA.
1. The picture indicates the Double Helix structure of DNA. (The picture would be from the view of *looking down* a strand of DNA. It would be similar to looking down a paper towel cardboard tube.)
 2. The picture also indicates that the Nitrogen bases (the X in the center) point inward and are *equal* lengths in binding, because it is *always* one Pyrimidine (C and T) and one Purine (A and G).
 3. The large areas *around* the "X" are the sugar phosphate backbone of DNA.
- VI. James Watson and Francis Crick (in 1953)
- A. They constructed the first *accurate* model of DNA.
- B. They used Chargaff's work and Franklin's work to fill in the gaps that they could not figure out.
- C. The Double Helix backbone is composed of Phosphorus and the 5 Carbon sugar Deoxyribose. (It would be like the side supports on a ladder.)
- D. The "rungs or steps of the ladder" would be the Purine base + Pyrimidine bases. (A=T and C=G)
1. A = T has 2 Hydrogen bonds existing between them.
 2. C = G has 3 Hydrogen bonds existing between them. (It takes *more energy* to separate these two.)
- E. **Hydrogen Bonds** hold the two sides together and it is twisted into the Double Helix shape (It looks like a twisted ladder.) Remember, **Hydrogen bonds** are *weak* bonds. We will want to "open up" the DNA during DNA replication AND Protein Synthesis.

AP Biology
DNA Structure and Replication

(Associated Learning Objectives: 1.14, 1.15, 1.16, 2.8, 2.9, 2.22, 2.31, 2.32, 2.34, 2.36, 3.1, 3.3, 3.7, 3.8, 4.1, 4.3)

Important concepts from previous units:

- 1) Monomers of Nucleic Acids are called Nucleotides; Polymers are DNA or RNA.
- 2) Nucleotides are *linked* together by a **covalent Phosphodiester bond**.
- 3) The *sequence* of nucleotides *determines* what protein or enzyme is made (expressed).

I. **DNA Replication**

- A. The process of making of a **complete copy of an entire length of DNA**. (Applies to all Chromosomes.)
 1. This occurs *during* the **S-Phase** of the Cell Cycle for Mitosis or Meiosis.
 2. In bacteria, it is referred to as *Circular* or Theta replication. (Symbol for Greek letter Theta is: Θ .)
 1. In other organisms that possess chromosomes, it is referred to as *Linear* Replication.
- B. It is easy to do for cells because the two sides are **complimentary**. (A with T and C with G always.)
- C. The **Semi-conservative Model** best explains the process of DNA replication.
 1. It shows one *original* DNA side serving as a *template (guide)* for making the *other DNA side*.
 2. Easy as A = T and C = G.
 3. The replication work is being done *in opposite directions*, but on *both sides at the same time*.
- D. In humans, it takes just a *few hours* to copy over 6 Billion nucleotides in our cells thanks to ENZYMES!

II. **Origins Of Replication (Starting points)**

- A. These are *specific nucleotide sequences* encoded in the DNA strands that act as “starting points”.
- B. The enzyme **helicase** *unwinds the DNA double helix* to create a **Replication Bubble** (This provides “space” to do the actual *building* work of making the *new complimentary side* of the *new DNA molecule* by other enzymes.)
 1. The *ends* of the bubbles are called **Replication Forks**. There is one on each end of the bubble.
 2. Work *is happening* on both sides of the forks *and* both sides of the bubbles.
 3. Many bubbles can be on the same DNA strand. (This speeds up the process of replication.)

III. **DNA Replication Elongation**

- A. Elongation of the *new* DNA complimentary side *will require* the enzyme **DNA Polymerase III**. (This enzyme performs the *addition of new nucleotides* to the new DNA complimentary side and also acts as a *proofreader* to help prevent *errors* in construction from occurring. (Look at the name and see the function. Remember, “polymers” means “many units” or “many monomers”. In this case, the monomers are called nucleotides. The ending “ase” tells you it is an enzyme.)
 1. The enzyme works at a rate of about 500 nucleotides being *added per second*.
- B. **DNA Nucleosides** are brought to the enzyme from the *cytoplasm* of a cell. (Nucleosides were “created” from broken down DNA strands found in the cells or particles of *food during the process of digestion*.
 1. A **nucleoside** has *three* phosphates to supply the bonding process with energy. (Remember, to create a bond requires “free” energy.)
 2. The **nucleoside** will *lose two phosphates* in the bonding (attachment) process to the new DNA.
 - a. Lose of phosphates makes it a nucleotide.
 3. This *saves* ATP for other cellular processes.
- C. The two sides of the Double Helix are said to be **Anti-parallel**. (“Anti” - This means that the DNA information runs in *different directions*. “Parallel” – The DNA strands are running side-by-side.)
 1. DNA is **ALWAYS READ AND MADE 5'→3'**. (**REMEMBER THIS IMPORTANT FACT!**)
 - a. The 5' Carbon of the sugar (Deoxyribose or Ribose) has a phosphate attached to it.
 - b. The 1' Carbon of the sugar has the Nitrogen Base attached to it.
 - c. The 3' Carbon of the sugar has an *open bond*. (This is the *connector site* for the *next* nucleoside.)
- D. **Helicase** enzyme causes the Double Helix to *unwind*.
- E. **Single-strand binding protein** keeps the two sides *apart and stable*. (Look at the name and see the function.)
- F. **Lead strand** of the replication fork (Remember, there are TWO forks going in OPPOSITE directions.)
 1. This strand runs in a *continuous 5'→3' direction* as it opens. (It is *leading* the way in the process.)
 2. To start *adding* nucleosides, we first need to attach an **RNA Primer** (Remember, RNA is a *disposable* form of DNA.) using **Primase** enzyme and go! (A “primer” is a *starting segment* of nucleotides. It will be *removed* later in the process and replaced with DNA or cut off if it is attached to a **telomere**, which are located at the chromosome ends.)

3. Lead strands on *both* sides of the replication bubble are LOCATED DIAGONALLY from each other. (If it is on top on one end of the bubble, it will be on the bottom on the other side of the bubble.)
 - a. This is because the two DNA strands are **anti-parallel**.

G. Lagging Strand

1. This side of the replication fork has DNA *not running in a 5'→3' direction*. (Therefore, it will always be *lagging* behind.)
2. This side of the fork has to wait for a *long segment* of DNA to become *exposed* first before we can start by adding a primer.
3. When a long segment has been “opened” by **Helicase**, a **RNA Primer** (disposable) will attach and then **DNA Polymerase III** will *work backwards* making an **Okazaki fragment**.
4. When the **DNA Polymerase III**, on the *newly created Okazaki fragment*, reaches the *previous* RNA primer of the *previous* Okazaki fragment, the DNA Polymerase III will *remove* the old RNA primer and replace it with new DNA nucleotides. This keeps the *DNA intact*.
5. The Okazaki fragments are “stitched” together using the enzyme **Ligase**.
6. The lagging strands of *each fork* on BOTH sides of the replication bubble are LOCATED DIAGONALLY ALSO.

IV. Correction of Errors (Proofreading)

- A. This function is performed by **DNA Polymerase III** as the *new* DNA strand is being made.
 1. **Mismatch Repair** is when the *wrong nucleotide* is added to the new sequence. DNA Polymerase will *reverse* a spot, *remove* the wrong nucleotide, and then *replace* with the *correct* nucleotide. (This would be equivalent to you hitting the following computer keyboard buttons Backspace/Delete and then continue when you make a typo while you are trying to write an English paper.)
- B. For errors that are “created” (what are called **Mutations**) *after* the DNA has been made – **Nucleotide Excision Repair** is used to correct these, if possible.
 1. Step 1: **Nuclease** –cuts *around* the faulty base pairing so they can be removed.
 2. Step 2: **DNA Polymerase III** – *replaces* the missing nucleotides.
 3. Step 3: **Ligase** - *stitches back together* the fragments.

V. Telomeres (TTAGGG is the nucleotide sequence.) (“Telo” means “last”; “mere” means “unit”)

- A. These are *repeated* nucleotide sequences found at the *ends of chromosomes* that are used for RNA primers to attach to so as to start replication, without having a bubble.
- B. The *number* of telomeres depends on the cell type. (It can range from 1 –10,000 telomeres. Heart cells and brain cells have VERY few. Skin cells have thousands.)
- C. Having these *protects* the important DNA information from replication erosion. Telomeres are *disposable*.
- D. **Apoptosis** - This is **programmed** cell death. (This is important in creating the spaces between your toes and fingers. Otherwise you would have fins for feet and hands. It is because the cells run out of Telomeres, so they *do not reproduce*. Thus when they die, they “create” the gaps.)

VI. Telomerase

- A. This is the enzyme that *replaces telomeres during fetal development*. After the fetus is *fully* developed, this enzyme *shuts off* and degrades over time. The DNA segment (called a gene) that is responsible for providing the “blueprint” on how to make this enzyme will become heavily methylated.
- B. Normally the active gene is found in gamete producing **germ** cells – Cancer? When this enzyme is turned back on *in children or adults* it leads to *abnormally fast growth of cells*. This abnormal growing group of cells is called a **tumor**. Some can be malignant and some can be benign.

AP Biology
Protein Synthesis – Part 1

(Associated Learning Objectives: 1.14, 1.15, 1.16, 2.22, 2.31, 2.33, 2.36, 2.37, 3.4, 3.6, 3.18, 3.24, 3.25, 4.1, 4.2, 4.3, 4.4)

Important concepts from previous units:

- 1) Proteins are constructed from the macromolecules called amino acids.
- 2) Amino Acids are linked by a covalent peptide bond by a hydrolysis reaction.
- 3) DNA is more stable than RNA; but RNA evolved before DNA did.

I. George Beadle and Edward Tatum (1934)

- A. They develop the one gene-one enzyme hypothesis. This proposes that a single gene has the genetic information for making one enzyme. This is later changed to become the **one gene - one polypeptide** (protein) hypothesis; as enzymes are a *type* of polypeptide (protein).

II. **Transcription** (means “ the process of making a *working copy* of an original”)

- A. This process is the making of a *disposable copy* of DNA but in the form of RNA. The *disposable* copy will become known as mRNA – messenger RNA. It is a *disposable copy* of the “Million Dollar DNA Blueprint”.
 1. The *message* (mRNA) will be sent to the *construction site* (ribosomes) *for building* the protein.
 2. RNA nucleotides use Ribose *instead* of Deoxyribose as the five-Carbon sugar. This makes the RNA *less stable* than DNA; that is good since the cell only needs it to send a *temporary* message on how to construct the protein.
 3. In RNA, Uracil replaces Thymine. Thymine can’t exit nuclear pores. (Remember, ribosomes are out in the cytoplasm, so Thymine needs to be substituted by Uracil.)
- B. DNA serves as a **template** (guide) for making the mRNA, A = U and C = G. (Still can use **Chargaff’s Rule**.)
- C. In Eukaryotic cells, the mRNA *must* first be “modified” before translation can occur. The modification occurs in the nucleus. (Prokaryotes **DO NOT** modify the mRNA. They sent it to the ribosome “as is”.)
 1. **Primary Transcript** (before modification) is modified to produce the **secondary transcript** (*after* modification has occurred). The **secondary transcript** is what will be sent out of the nucleus to the ribosome.
- D. This is considered the *first part* of **Protein Synthesis**.

III. **Translation** (“The process of taking from one language and *changing* to another language”.)

- A. In this process, the cell is *turning* nucleotide language (DNA/RNA) into amino acid language to make proteins. (Remember, amino acids are the building blocks of proteins.)
- B. This process occurs at the Ribosome. The ribosome has a nickname... “the Translator”. It is also considered a “construction site” since the cell is *building* a protein.
- C. This is considered the *second part* of **Protein Synthesis**.

IV. **Codon** “A.K.A Triplet Code” (This is the amino acid language.)

- A. Codons are *determined* by the template strand of DNA (Important Blueprint Information) but are READ ON THE RNA! (The mRNA is what is being translated; not the DNA.)
 1. **The codons MUST be read 5’ → 3’ on the mRNA!** (Because this is how the mRNA was made. You do not write a sentence and then read it backwards do you. It would make no sense.)
- B. **RNA Codon Chart** for Amino Acids (Contains the 20 known amino acids for living organisms.)
 1. The chart was started by Marshall Nirenberg. (early 1960’s) He won a Noble Prize for this.
 - a. UUU- Phenylalanine was the first one recorded.
 2. 61 of the 64 possible codons (4³) codes for an amino acid.
 - a. 4 refers to the four nucleotides possible (A, C, U, G); 3 refers to the number of pieces in a UNIT (codon).
 3. **AUG** is the **start codon** or Methionine. It depends on the *position* in the mRNA. If it is the first codon on the 5’ end, it will be the start codon. If it is not the first, it will be regular methionine.
 4. **UAA, UAG, and UGA** are the **stop codons**. These codons stop the process of transcription.
 5. Redundancy is *wasteful*, so enter Inosine. This nucleotide can act as a “Wild Card”. When put in the *third* position of an **anticodon**, it can represent *any* nucleotide. (This is useful for such amino acid sequences such as Serine or Arginine.) It is **ONLY** found in tRNA...transfer RNA.
 6. This chart is *universal* for *all* living organisms and viruses. (Viruses are *not* living.) This hits on the theme of *Unity* and *Diversity*. Unity in that it indicates Common Ancestry among all organisms and viruses. Diversity is in the differences of the *sequences* of amino acids strung together to make a protein.
 - a. Remember, RNA evolved first (but it is unstable) then mutated to DNA (which is more stable). This is why ALL living organisms and most viruses are DNA based.
- C. **Reading Frame** - This term refers to a set of 3 *consecutive nucleotides (codons)* read in 5’ → 3’ direction.

- V. **RNA Synthesis and Modification** -The *making* of mRNA. This process occurs at the **nucleolus**. (Remember, the nucleolus is “like” a copy machine because we are making a *cheap disposable copy* of the DNA sequence.)
- A. Three Phases of production to a **transcription unit** - piece of mRNA.
1. **Initiation** - This is building our *factory* to make mRNA basically.
 - a. A protein called a **Transcription Factor** attaches to the **TATA box** to *determine* the *direction* the “factory” will proceed. The **TATA box** is part of the **promoter** sequence. (Look at the TATA sequence, can you see it running in *different* directions. This orients the “factory” to the direction it will transcribe.)
 - b. Then additional transcription factors (proteins and enzymes) are added to the “factory”.
 - c. Finally, **RNA Polymerase II** joins to *complete* the factory. The whole “factory” is called a **Transcription Initiation Complex**. (Can you see the definition in the term? Transcription is the process being done. Initiation refers to the beginning process. Complex indicates we have many parts [enzymes] involved in making the structure.)
 - d. This is a *step-by-step controlled process*. (The cell “controls” each step to help make sure nothing goes wrong.)
 2. **Elongation** - This refers to the *actual making* of the mRNA molecule.
 - a. This *must* be made in the **5' → 3'** direction! (The 3' Carbon has the *open bond*.)
 - b. **RNA Polymerase II** *separates* the DNA Double Helix to *make room to work*.
 - c. **RNA Polymerase II** also *adds nucleosides* to the growing molecule.
 - i. Nucleosides come from the cytoplasm. **Lysosomes** recycle and provide them.
 - d. After **RNA Polymerase II** has past the DNA transcription point, the DNA reforms the helix.
 - e. Cells can make *multiple copies* of RNA because the DNA is *left intact and protected* in the nucleus.
 3. **Termination** (Just like it sounds... stop the transcription.)
 - a. A **stop codon** is made (for the ribosome) and the “factory” molecule slows down.
 - b. **RNA Polymerase II** slows down *until* it stops transcription by forming an AAUAAA sequence and is then released from the DNA.
- B. **Modification** of the Primary Transcript for EUKARYOTIC Cells (This also occurs in the nucleus.)
1. **Front end (5') modification** of the mRNA molecule.
 - a. A 5' *protective cap* is added. (This would be like you putting on a hard hat to protect your head when you go outside into a “construction site”.)
 - b. This cap acts as a *signal* to the ribosome particles, telling it where to attach.
 2. **Back end (3') modification** of the mRNA molecule.
 - a. A Poly A Tail is added. (“poly” means “many”; 50-250 Adenines will be added onto the tail.)
 - b. This acts as protection against *digestive enzymes* in the cytoplasm. (Remember, it is a construction site and things are being broken down as well as being built.)
 3. **Middle modification** of the mRNA molecule. (This modification is referred to as **RNA Alternative Splicing**.)
 - a. During this step, *remove* the non-coding **introns** (These act as spacers) using **Spliceosomes**. (A **spliceosome** is a *collection* of **snRNPs**.)
 - i. **snRNP's** (small **nuclear RiboNucleic Proteins** act as scissors.) Remember, Ribozymes are RNA molecules that *act as enzymes*.
 - b. Then *rearrange* the *separated* coding **exons** (*important blueprint pieces*) to the *needed* configuration. (This is why it is called *alternative*; pieces [exons] can be *rearranged* in *different orders*. This is REALLY important in the making of antibodies by our immune system. Remember, the *variable* portion of the antibody structure.)
 - c. “Stitch” the pieces together to make the *finalized* **secondary mRNA transcript** that is know *ready* for transport to the ribosomes for translation into proteins.

AP Biology
Protein Synthesis – Part 2

(Associated Learning Objectives: 1.14, 1.15, 1.16, 2.22, 2.31, 2.33, 2.36, 2.37, 3.4, 3.6, 3.18, 3.24, 3.25, 4.1, 4.2, 4.3, 4.4)

Important concepts from previous units:

- 1) Amino Acids are the building block macromolecules of proteins.
- 2) Amino acids are linked together by covalent peptide bonds in a dehydration reaction.
- 3) Proteins have to be *folded* in order to work; this involves *Hydrogen bonds* (2') and *disulfide bridges* (3').

I. **Translation** - This is the part of *actually making* the protein.

A. This process occurs at the **Ribosome**, “the Translator”.

B. The process *turns* the mRNA into a primary (1') sequence of amino acids for *making* of the protein.

C. This process needs the assistance of **tRNA (transfer RNA)** to transfer *free amino acids* from the cytoplasm to the construction site of the Ribosome.

1. Free amino acids are provided by the digestive system, by **catabolism** (breakdown) of proteins in food, and then delivered to the cells by the blood vessels. Inside the cells, they are used for **anabolism** (building) of proteins or undergo **deamination** (removal of the amine functional group) for ATP production in Cellular respiration.

D. There are 45 different tRNA molecules for 61 possible codon combinations.

1. **Inosine** (acts as a “wild card”) makes it possible for a cell to *conserve materials and energy*.
2. The use of **Inosine** creates the “**Wobble effect**” - It does not fit *perfectly*, but gets the job done.
3. **Inosine** is found in the *third slot* of the **anticodon only**. (Also only in tRNA...transfer RNAs.)
 - a. Remember, that the **ANTICODON** is found on the tRNA molecule, NOT the mRNA.
4. The **Anticodon** “matches” the **codon** on the mRNA molecule ensuring the *correct* amino acid is brought to the construction site of the Ribosome. If they DO NOT match ... it is the wrong Amino Acid!
5. The amino acid is connected to the *3' end* of the tRNA molecule.
 - a. Remember, the tRNA molecule is a nucleotide sequence; so there is a phosphate on the 5' end and an *open bond* on the 3' end... so this is where the amino acid gets attached so that it can be transported to the ribosome (construction site).
6. This *connection* between the tRNA molecule and the amino acid is constructed using the **Aminoacyl – tRNA synthetase** enzyme. (Can you see the definition in the name?)

E. **Ribosome** Structure: (This cellular *particle* has 2 parts.)

1. The **Small sub-unit** - This part acts as a *platform for work*; much like your desk.
2. The **Large sub-unit** - This part is the *factory for making* the protein.
 - a. The **A site** - This is where the *next* tRNA molecule is **ADDED** in the “factory”.
 - b. The **P site** - This is the part of the “factory” where the **PROTEIN** is attached.
 - c. The **E site** - This is where the “used tRNA molecule” **EXITS** the “factory” to be *reused*.
3. The ribosome “*walks*” down the mRNA *one codon at a time* until it gets to the stop codon at the end of the mRNA molecule. Thus having completed the “message” on how to make that particular protein. This “walking” is called **Translocation**. (Can you see function in the name?)
4. Remember, these are NOT organelles. *All cells possess these structures*.

F. The process of **translation** has three phases: (They are the *same 3* as **Transcription**.)

1. **Initiation** - This is *building the factory* needed to make the protein.
 - a. The **small sub-unit** attaches to the **5' cap**. This *interaction* signals the large sub unit.
 - b. **AUG** (the *start codon* on the mRNA molecule) brings in the tRNA (using the **anticodon**) molecule with Methionine attached. This *starts production* of our protein.
 - c. Then the **large sub-unit** is brought in using **initiation factors** (these are enzymes) and uses **GTP** for energy in the process. (Remember, GTP is “like” ATP...both are energy molecules.)
 - d. The **large sub-unit** is *aligned* so that Methionine is in the **P site**. The **A site** is *open* for the *addition* of the next tRNA molecule.
2. **Elongation** - This is the *actual making* of the 1' sequence of amino acids.
 - a. The ribosome **translocates** (“walks”) down the mRNA *one codon at a time* using **GTP**.
 - b. This adds a single amino acid, using tRNA, to the *open A site* using **GTP** each time.
 - c. Another GTP is used to make **peptide bond** between the amino acids of the P and A sites.
 - d. The rate of addition is *controlled* by **elongation factors** (enzymes).
3. **Termination**
 - a. This occurs when a termination codon reaches the A site.
 - b. A **Release factor** (enzyme) enters the A site causing a **hydrolysis reaction** to occur that *releases* the protein from the last tRNA molecule (which is sitting in the P site).

- c. After the hydrolysis reaction occurs, the ribosome detaches and the sub units separate to be *reused*.
- 4. The mRNA may be *reused* to make *more* of that particular protein or it may be broken down and the nucleotides *recycled*, as it is temporary RNA.
 - a. **Polyribosomes** (many ribosomes) can also occur on a strand of mRNA.
 - b. This allows for a cell to make many copies of the *same* protein very quickly. (Such as might be needed during repair or making antibodies.)

II. **POST (means “after”) Translation Modification** (This is the *protein folding* that *must* occur for the protein to be functional.)

- A. If the 1' sequence enters a **Chaperonin**, the protein *will stay inside* the cell.
 - 1. Entry is “guarded” by a **Signal Recognition Particle (SRP)** *inside* the bottom piece.
- B. If the 1' sequence enters the **RER**, the protein *will be exported out of the cell*.
 - 1. Signal Peptide on the 1' sequence. (This acts as a *siren*. It is “like” yelling “Take me to the RER!”)
 - 2. **Signal Recognition Particle (SRP)** - This particle acts as a *guide* leading the 1' sequence to the RER. It attaches to the Signal.

III. **Proteomics** (Study of Proteins)

- A. The study of genes and the corresponding polypeptide made by that gene segment of DNA. (Remember, the one gene-one polypeptide hypothesis.)

AP Biology
Protein Synthesis – Part 3

(Associated Learning Objectives: 1.14, 1.15, 1.16, 2.22, 2.24, 3.1, 3.4, 3.5, 3.6, 3.18, 3.25, 4.1, 4.2, 4.3, 4.7, 4.24)

Important concepts from previous units:

- 1) A *change* in the nucleotide sequence is called a **mutation**.
- 2) Some mutations can cause cancer (abnormal growth) in organisms.
- 3) Prokaryotes would have, over millions of years, given rise to Eukaryotes. (Endosymbiant Hypothesis)

I. Types of RNA

II. Prokaryotes vs. Eukaryotes

- A. Prokaryotes DO NOT have **introns** that need to be removed prior to Translation. The 1' transcript goes *straight to the ribosome* for Translation.
- B. **Genetic engineering?** We can take a 2' transcript out of a *Eukaryotic organism*. Use the enzyme **reverse transcriptase** to turn the mRNA molecule *back into* a DNA molecule. *Insert* the new DNA strand into bacteria. The bacteria will then be able to Transcribe and Translate off of this new inserted DNA and thus *make that protein*. This has been done for numerous human medicines such as Insulin or Human Growth Hormone.
- C. Eukaryotes DO have **introns**. This allows them to take out the introns and *rearrange the important exon pieces* to make an *almost unlimited number of different* proteins. This simple fact is the reason that humans are so vastly more complex than simple bacteria.
- D. The two types of cells basically do the *same process* of Transcription and Translation to make proteins. This *indicates* common ancestry among all organisms. (Unity *again*.)

III. **Mutations**

- A. *Change in the nucleotide sequence* of DNA or mRNA that code for a protein.
- B. Caused by **Mutagens** (Means to “**generate a mutation**”.)
 1. These are a *physical or chemical interactions* that changes the nucleotide sequence of DNA.
 2. Examples of mutagens:
 - a. Ultraviolet radiation (UV Radiation) from the sun
 - b. Cigarette Smoke
 - c. Alcohol in excess
 - d. Viruses
 - e. Car Exhaust
 - f. Chemicals (Laboratory, Pesticides, insecticides, poisons)
- C. Two major types of Mutations:
 1. **POINT mutations** - A *single nucleotide* mutates thus affecting a *single codon*.
 - a. **Silent Point Mutation**– The mutation causes ***no change*** in the *amino acid* coded for.
(We would never know because it has no effect. This can happen because the codon coding is *redundant*, remember?)
 - b. **Missense Point Mutation** – The mutation ***changes the amino acid*** coded for. (MISake)
(This is best seen in the mutation that causes Sickle cell.)
 - c. **Nonsense Point Mutation** – The mutation *changes from coding for an amino acid to coding for a **STOP codon*** . NO protein will be made. (NO sense)
 2. **READING FRAMESHIFT Mutation** (The whole DNA “sentence” is changed.)
 - a. These mutations alter the *codon sequence*.
 - b. **Insertion** – *adding nucleotides* to the sequence.
For Example: THE BIG TAN DOG RAN.
with *Inserted Letter*: THE BOI GTA NDO GRA N.
 - c. **Deletion** – *taking out nucleotides* from the sequence.
For Example: THE BIG TAN DOG RAN.
with *Deleted Letter*: THE BGT AND OGR AN.
- D. Gametes vs. Somatic – Who is affected? If a mutation occurs in *somatic cells*, the only one affected by the mutation is *the person that the mutation occurred to*. If the mutation occurs in *gametes (sex cells)*, the only one affected will be the organism “*created*” from that sex cell. This is how *future generations* may be affected and *this is a cause of evolution*. CHANGE in DNA over TIME.

AP Biology
Eukaryotic DNA Control Mechanisms for Gene Expression
(Associated Learning Objectives: 1.14, 1.15, 1.16, 2.22, 2.31, 2.37, 3.4, 3.20, 3.21, 3.23, 4.7, 4.17)

Important concepts from previous units:

- 1) During Interphase – The DNA is loose (Chromatin) for *easy access* for transcription. (It is “like” a bowl of spaghetti.)
- 2) During Mitosis or Meiosis – The DNA is tightly wound (Chromosome) for *easy separation*. (Looks like an “X”.)

I. Chromosome Structure in Eukaryotes

- A. **Histones** - These are *proteins* that are used for DNA to wrap around and thereby helping it to *condense*.
 1. These carry a *positive charge*. (Remember, DNA is negatively charged, so it is like a magnet.)
 2. Evolution? *All Eukaryotes* and a group of Bacteria (Archae bacteria) possess histones. This indicates *common ancestry* among these organisms.
- B. **Nucleosome** - A *unit* of DNA wrapped around a group of histones. (Nucleotides around histones.)
- C. **Supercoiling** – This is the process of DNA *condensing* from Chromatin to Chromosomes.
- D. **Heterochromatin** - This refers to DNA that *remains condensed* even during interphase. – It is NOT active.
 1. This CANNOT do transcription so it is *inactivated*. (“hetero” means “different”)
- E. **Euchromatin** - This refers to DNA that IS *loose* during interphase. – It IS active.
 1. It CAN do transcription and *be expressed*. (“Eu” means “true”)

II. **Cellular Differentiation (A.K.A. Specialization)** - The process of making cells “different” or “special in function”.

- A. This process is accomplished by turning certain genes “on” or “off”. This is known as **Differential Gene Expression**. This accounts for about 1.5% of our total DNA genome. These genes are the Exons.
 1. The genes turned “on” end up making that *protein/enzyme* to make that cell different or special.
- B. Control goes awry? Terrible things may occur such as death or cancer to the cell or organism.

III. Gene control during **transcription** (A through F are associated with *transcription*.)

- A. Is the DNA in a state of Heterochromatin vs. Euchromatin?
- B. **DNA Methylation** of the DNA
 1. This refers to putting a heavy “coat” of methyl (CH₃) groups of the DNA, thus *preventing* transcription from occurring. The Methyl groups attach to Cytosine or Adenine nucleotides.
 2. This is the source of **Genomic Imprinting** that occurs in gamete production. (It essentially “erases” information”).)
- C. **Histone Acetylation**
 1. This is the attaching of acetyl (COCH₃) groups to the histones Lysine amino acids.
 2. This attaching *breaks the bond* between the DNA and the histones by covering up the positive charges thus creating NO attraction for each other.
 3. This allows for RNA Polymerase and transcription factors to attach to the “freed” DNA so that transcription may occur.
- D. Building of the Transcription Initiation Complex (factory). (Remember, this is a *step-by-step process*. Each step can be controlled.)
 1. **Enhancers** and **Activators** - These help control *the rate* of transcription. (They are segments of DNA that basically “grab” the factory, using a bending protein, and move it down the DNA faster thus *enhancing* the process of transcription. They are “Pushers”).
 - a. They are always *in front* of gene to be transcribed.
 2. **Repressor** or **Silencer** - These *control* proteins sit on the TATA box – they *prevent* transcription from occurring. This *silences* or *represses* the gene from being expressed.
 3. Both are called **control elements**, because the control the *rate* of transcription.
- E. **Coordinated** Control of gene families
 1. The *same chemical signal* causes the *simultaneous* expression of multiple copies of the *same* gene. These multiple copies of the SAME gene are referred to as a **gene family**. (Hemoglobin, for red blood cells is an example. We need hundreds of copies of this gene to make the trillions of Red Blood cells our bodies need to deliver Oxygen through our body. Coordinated control is essential. It would also be like the bell at the end of the period *signaling* all classrooms to move to the next class at the *same* time)
- F. **Micro RNA (miRNA)** and small **interfering RNA (siRNA)**
 1. These are *little pieces of RNA* that attach to **mRNA** and thus *control transcription* of the mRNA.

- IV. *Post* Transcription Regulation
- A. **Alternative RNA Splicing** using **Spliceosomes (snRPS)**. (Primary becoming a Secondary transcript is controlled.)
 - B. Cytoplasmic Degradation - This occurs because of enzymes in the cytoplasm. (Can you “see” the term?)
 - 1. This refers to the removal of caps and tails on mRNA molecules, followed by nucleotide sequence catabolism, so they may be recycled. The more As in the Poly A tail, the *longer* the mRNA will last in the cytoplasm.
- V. **Translation** Control Mechanisms
- A. Building of the Translation Initiation Complex (Ribosome Factory) This is *also* a step-by-step process.
 - B. If a Faulty 5’ cap (signal) is attached, it will prevent Translation from occurring.
- VI. *Post* Translation Control Mechanisms:
- A. **Chaperonin** or **SRP** for RER. (Where does the 1’ sequence go for folding to occur?)
 - B. **Phosphorylation** of the protein/enzyme. (Remember, this is *activating* the molecule by using ATP to *add* a phosphate.) “On vs. Off” basically.
 - C. Transport through the inter-membrane system. (As the protein moves through the RER and Golgi, controlling the folding and modification of the protein.)
 - D. **Proteosomes** (special protein digesting Lysosomes) control HOW LONG the protein lasts.

AP Biology
Biotechnology Part 1 - Viruses and Gene Therapy
(Associated Learning Objectives: 3.14, 1.15, 1.16, 2.24, 3.1, 3.5, 3.22, 3.29, 3.30, 4.5, 4.6, 4.22)

- I. Viral Structure:
 - A. Viral Genome
 - 1. Viruses possess either a *double or single strand* of DNA or RNA. (This is how viruses are classified.)
 - 2. Viruses contain very small amounts of DNA or RNA—most are 4 to 500 genes total.
 - B. Viral Protein Coat (Referred to as the **Capsid**.)
 - 1. The Capsid serves two purposes:
 - a. *Protection* of the DNA or RNA strands inside.
 - b. *Attachment* of the virus to a host cell.
 - 2. It is built from protein units called **capsomeres**. (means “capsid unit”)
 - 3. Some viruses can also have a **viral envelope**.
 - a. This is a “cloak” derived from the *previous host cell* plasma membrane. (It is an example of mimicry. It looks like a normal cell, but it is actually like a Trojan horse. The danger is inside.)
 - b. The AIDS/HIV virus has a viral envelope derived from the T-helper white blood cells.
 - C. **Bacteriophages** (A.K.A. **Phages**) – These are viruses that attack bacteria.
 - 1. These are some of the largest and most complex viruses.
 - D. Viruses are NOT living organisms. They cannot be “killed”. They *can* be **denatured** using chemicals though. Some of these chemicals are in anti-viral products you may use, like hand soaps or Kleenex.
- II. Viral Reproduction
 - A. Viruses *must* have a host cell in order to reproduce. They are considered **Obligate Intracellular Parasites**. As the name indicates, viruses *must get inside the host cell* in order to reproduce.
 - B. Viruses *need* to use the host cells ribosomes and enzymes to make new DNA or RNA strands and new capsomeres to form new viruses.
 - C. **Host Range** – Refers to what organisms a virus can attack. It is determined by recognition of certain *glycoproteins or glycolipids on the host cell membrane*. (Sounds like cell signaling again.)
 - D. **Restriction enzymes** – These enzymes, found in bacteria, act as primitive *defense* against viruses. These enzymes *cut up the genome* and thus *inactivate* the genes from being transcribed. They are called *restriction enzymes* because they *only* cut at *certain nucleotide sequences*. In other words, they are *restricted* in where they can cut.
- III. Basic virus life cycles:
 - A. **Lytic** Life cycle- This cycle *destroys (lysis) the host cell* when the virus leaves. (A.K.A. **Virulent**. Sounds like violent.)
 - B. **Lysogenic** Life cycle – In this type of cycle, the virus *permanently incorporates* its DNA into the host genome, but does not immediately kill the host. (A.K.A. **Temperate**. Sounds like Temper.) The virus “lives” inside the host cell. As the host cell *reproduces by Mitosis*, so does the virus. When the virus becomes *aggravated*, it pulls out its genome, reproduces, and then leaves the cell by lysis and thereby killing the host in the process.
 - 1. **Prophage or Provirus** (These terms both refer to the inserted viral DNA in the bacterial DNA.)
 - 2. Herpes and HPV are both examples of viruses that have a lysogenic life cycle. When they get aggravated and cause destruction of host cells, blisters form the destroyed cells. We call them fever blisters or cold sores in the case of a Herpes Type I (around the mouth) infection.
 - a. The heat (usually direct sunlight) or cold caused the virus to become “aggravated”.
- IV. **Retroviruses**
 - A. Retroviruses are a unique type of viruses. (“retro” means “reverse or backward”)
 - 1. They use **REVERSE TRANSCRIPTASE**, an enzyme, to turn RNA into DNA (It. does transcription *backwards*. It turns “mRNA” into double stranded DNA, so that it can incorporate into the host DNA.
 - B. AIDS/HIV and the common cold virus are both retroviruses.
- V. **Gene Therapy**
 - A. Genes that are coding for proteins or enzymes are inserted into viral capsids. The viruses are then injected into individuals possessing genetic diseases associated with *missing or non-functional* proteins or enzymes in an effort to *treat* the person suffering from the condition. The DNA is hopefully taken up by the cells.

AP Biology

Biotechnology – Part 2 -Bacterial Genomes

(Associated Learning Objectives: 1.14, 1.15, 1.16, 2.22, 2.31, 2.33, 2.36, 2.37, 3.1, 3.18, 3.23, 3.24, 3.26, 3.27, 3.29, 3.30, 4.1, 4.17, 4.22,)

Important concepts from previous units:

- 1) Bacterial DNA has circular chromosomes.
- 2) Bacteria (Prokaryotes) do NOT possess **introns**.
- 3) Bacteria reproduce by Binary Fission. (It is like Mitosis, but No G₂ of Mitosis [division of nucleus] phases.)

I. Bacterial Genome

A. They possess *one circular (Theta)* strand of DNA that is located in the **nucleoid** region.

B. Plasmids

1. These are small, circular, *exchangeable pieces* of DNA.
2. These are *in addition* the main large circular DNA strand.
3. These help to *increase variation and survival*.

C. Bacterial Replication

1. *100% Identical clones* are produced through Binary Fission. Allows them to reproduce *very quickly*.

D. Ribosomes are needed to create proteins; but they do NOT possess any organelles.

II. Bacterial Variation Processes (Remember, variation *increases survival* chances in a *changing* environment.)

A. Transformation (This means simple change.)

1. A bacteria took in DNA from an external source. (Recombination of DNA occurred.)
2. Biotechnology? This is what we do to make bacteria “learn” new tricks, such as eat crude oil.

B. Transduction (This is new DNA has been *carried in* by a virus thus creating the “change”).

1. Phage introduced the new DNA into the bacterial DNA.

C. Conjugation (This is “Bacterial sex”).

1. Bacteria exchange plasmids through a conjugation tube from the “male” to the “female”. (Bacteria DO NOT have sexes like humans do.)
2. **F factor** (If a bacteria possess this gene, they are considered “male”; Shown as F+.); (F- are “female”. They do NOT possess the F factor gene.)
 - a. **Pili** – This structure is a protein “sex whip” for pulling the “female” close so that a conjugation tube can be made between the two bacteria. The pili is created by *expressing* the F factor gene.
3. **R Plasmids**
 - a. These plasmids exchange *antibiotic Resistance genetic information*. This *helped* in the evolution of MRSA. (Methicillin-Resistant Staphylococcus aureus)

III. Transcription *Control Mechanisms* (Remember, these are ways to *control* Gene Expression.)

A. Transposons “Jumping Genes” (These DNA *segments* act as “*Blockers*” to transcription.)

1. Barbara McClintock discovered this control mechanism in the 1940’s. She worked with Maize (Wild corn). She won a Nobel Prize for this work.
2. Two types of transposons that exist:
 - a. **Basic Insertion**
 - i. This is the *simplest* form.
 - ii. **Transposase** – enzyme that allows the DNA to “*jump*” from location to location.
 - b. **Composite (means “complex”)**
 - i. Transposase on *both sides of a resistance gene* are “jumping” as a unit.
3. These *also* occur in Eukaryotes. They also are control mechanisms in these cells too. Another example helping to show *common ancestry* among the life forms on Earth.

B. Operon System (“operator”)

1. Francois Jacob and Jacques Monod discovered this control mechanism.(1961)
2. **Operon** (“operator”) *controls* RNA Polymerase *access* to the DNA strand.
3. *Operon* is part of the **promoter** sequence. It is located between the TATA box and Start codon.
4. **Repressor** and **co-repressor** - These *molecules* act as an “off” “switch.”
5. **Inducer** - This *molecule* acts as an “on” switch.
6. These are *both* Negative Feedback loops. (They stop a process that is occurring, and get it going in the opposite direction.)
7. These are considered *regulatory genes* as well.

**AP Biology
Biotechnology Part 3**

(Associated Learning Objectives: 1.5, 1.14, 1.15, 1.16, 2.24, 3.1, 3.5, 3.6, 3.13, 3.18, 3.21, 3.26, 3.28, 4.1, 4.22)

Important concepts from previous units:

- 1) Nucleotides *always* base pair the same way – A with T and C with G.
- 2) *All* living organisms, and some viruses, have DNA as the inheritable form of information transfer.

I. **Genetic Engineering** - The field of science dealing with *manipulating* genomes.

A. **Recombinant DNA** is the major focus of genetic engineering.

1. In this process, DNA from *two different sources* is combined into *one* molecule of DNA.

B. **Biotechnology** - This term refers to the use of *computers and other devices* to help in performing science.

II. **Bacterial Cloning Process**

A. The first step in this process uses **restriction enzymes** to create “Sticky Ends” on a **plasmid** and DNA from another source.

1. These are enzymes that cut DNA at *specific nucleotide sequences*.

a. This specific DNA sequence is referred to as the **restriction site**.

2. These enzymes create **restriction fragments** as the DNA source is cut up into *fragments*.

3. The *same restriction enzyme* must be used on *both* the bacterial plasmid and the DNA source.

B. The second step is to *introduce the fragments* to the “open” plasmids for *recombination* to occur.

1. The “sticky ends” base pairs will match allowing for recombination to occur.

C. The third step uses the enzyme **Ligase** to *seal* the DNA fragments together.

D. The fourth step is to introduce the *recombined* plasmids *back into* the bacteria. The bacteria are also called a **Cloning Vector**. A **vector** is a *carrier* organism.

E. The fifth step is to allow the bacteria to *reproduce*, by Binary Fission, to achieve a *large working population*.

F. The sixth step is to *identify* the bacteria of interest (the bacteria containing the recombined plasmid of importance inside) using by **Nucleic Acid Hybridization**.

1. First, *create a radioactive nucleic acid probes* using radioactive Phosphorus. This will have the *complimentary* nucleotide sequence to the gene of interest.

a. Remember, the Hershey- Chase Experiment.

2. Then *denature* the DNA double helix using *heat*. (The DNA double strand *separates*.)

3. The radioactive probe *seeks out* the gene of interest and attaches to it, as the nucleotide sequences *match*.

4. The next step is to use film filter paper to identify radioactive colonies of bacteria.

a. The radioactivity will cause a *color change* on the film. This will tell where within the Petri dish the important bacteria are located.

5. Now *separate the colonies* of interest from “trash” colonies. These bacteria *will make* our protein of interest. (For example, making human Insulin or Human Growth Hormone.)

G. The last step is to culture (grow) the bacteria for experimentation and perform protein screening to *verify* the protein is being produced by the bacteria.

H. Reproduced recombinant plasmids will *be stored* in **Genomic Libraries** for future use.

III. Problems going from eukaryotes → prokaryotes in making proteins.

A. The **introns** *must be removed* from the eukaryotic DNA first. (Remember, Prokaryotes *do not* have introns.)

1. Scientists have to collect the *modified mRNA* that *exits* the nucleus first.

2. Then they need the enzyme **reverse transcriptase** to turn the single stranded m RNA molecule *back into* a double stranded DNA molecule.

a. The “new” DNA molecule is known as **cDNA (Complimentary DNA)**. A copy of this cDNA molecule will be stored in a **cDNA library**.

B. Need to then attach a **promoter** sequence (**expression vector**) at the *beginning* of the cDNA molecule so that a transcription complex (“factory”) can be build.

C. Then attach “sticky end” sequences and insert into the bacteria to start production.

IV. **Yeast Artificial Chromosomes (YAC's)** - Process for “building” a chromosome with *multiple genes* for cloning.

A. Yeast are single celled *fungus*. (These are Eukaryotic organisms.)

B. They *will* recognize introns; therefore, scientists can use *straight DNA from the source*. They *do not* have to acquire mRNA and perform the above procedure.

C. Then they *recombine* all the DNA segments using **Ligase**.

D. Attach a **Centromere** for Mitosis. (Remember, this is the *spindle fiber attachment point* on chromosomes.)

E. Attach *numerous telomeres* using the enzyme **telomerase**. These are for *replication* during the S phase.

F. Introduce the *artificial chromosome* to the yeast cell by **Electroporation** (Electrical Shock).

**AP Biology
Biotechnology Part 4**

(Associated Learning Objectives: 1.5, 1.14, 1.15, 1.16, 2.8, 3.1, 3.5, 3.13, 3.24, 3.26, 3.28, 4.1, 4.6, 4.22, 4.25)

Important concepts from previous units:

- 1) DNA has a *negative charge* because of the negatively charged phosphates in the sugar-phosphate “backbone”.
- 2) Like charges *repel* and opposite charges *attract*.

I. Polymerase Chain Reaction (PCR) (Requires *no organism* in the production of *new* DNA molecules.)

- A. The process was developed in 1983 by Kary Mullis. He won a Nobel Prize in 1993 for this.
- B. The process is used to turn a *single* molecule of DNA into a *large, workable sample* of 100% identical DNA molecules.
 1. This is widely used in criminal forensics (Murder cases).
- C. The process:
 1. Put the DNA sample in a **PCR Thermal Cycler** machine.
 - a. The machine uses *heat*, DNA Primers, enzymes and a constant supply of nucleosides to build DNA molecules that are *identical* to the original molecule in nucleotide sequence.
 - b. First step: *Heat* is used to *separate* the DNA double helix so that replication can occur.
 - c. Second step: The attachment of a DNA Primer to the template DNA strand will occur to start replication.
 - d. Third step: The **DNA polymerase** enzyme *works 5'→3'* attaching nucleosides to the growing “new” side of the replicated DNA molecule.
 - e. Fourth step: *Cool* the mixture to recombine DNA back into a double strand.
 - f. *Repeat the cycle many times* to get large, workable sample of the DNA.

II. Genomics - The study of *large* amounts of genetic information (genomes).

III. Gel Electrophoresis

- A. This process is used to create a “DNA fingerprint”.
- B. Take *different* DNA samples and expose them to the *same* restriction enzyme to cut the DNA into *fragments*.
 1. This creates **Restriction Fragment Length Polymorphisms (RFLP's)**
 - a. These are *fragments* of DNA having *different lengths*. (Can you see that in the term?)
- C. Then take the DNA RFLP's and load them into the agar gel.
- D. Turn on the *electricity*. (Remember, DNA is *negatively* charged because of the phosphate backbone, so it will be repelled on the negative end [Black] and pulled by the positive end [Red].) Electricity *will flow* from the Black → Red strips.
- E. The RFLP's will *separate* according to *length/size of the fragments*.
 - a. Big pieces move *slowly* through the gel.
 - b. Small pieces move *quickly* through the gel.
- F. Stain the gel with Carolina Blue to see the DNA fragments *within* the gel.
- G. The DNA Bands *create a unique “fingerprint”* of the individuals DNA.
 1. 1 in 70 *Trillion* genetic possibility of *identical* copy. (There are only 7.5 *billion* people on Earth.)

IV. Human Genome Project (HGP)

- A. The project was begun in 1990 and ended in 2003.
- B. The project mapped out the *entire DNA genome* nucleotide sequence for *all humans as a species*.
- C. It found we have around 40,000 *different* genes in our genome.
- D. These make up *only* about 3% of the total genome.
- E. **Alternative RNA Splicing** is the *key* to making the hundreds of thousands of *different* proteins and enzymes our bodies need or use.
- F. A “project” is now being done for thousands of different species and comparing using **Bioinformatics**.
- G. Genome nucleotide *sequences* can then be *compared* to establish *relatedness* among species.

V. DNA Nucleotide Sequencing processes were involved in the above project.

- A. **DNA Microarray Assay** (This process looks *like* a Light-Brite toy.)
 1. Uses *radioactively labeled and colored* nucleotides to create a *visible* sequence on a monitor.
 2. Follow the colored *sequence* to determine the DNA sequence. (For example, red = adenine)
- B. **Dideoxy Chain Termination Method**
 1. Run like a PCR, but has special Dideoxyribonucleotides *added to the mix*. (This *stops* replication.)
 2. The procedure produces *chains of different length* due to termination by dideoxy nucleotide.
 3. Then the fragments are run through a gel and scanned using a laser to identify the dideoxy.
 4. Pieces are then combined together using the Dideoxy hits to “create” the nucleotide sequence.

- VI. Using a Gel Electrophoresis to create a plasmid map
 - A. This allows scientists to *know the genes and their sizes* found on bacterial plasmids.
- VII. Uses for DNA Technology
 - A. Gene Therapy
 - 1. This uses a virus to introduce a new gene to the cell's genome in our body's cells.
 - 2. Somatic cells vs. Germ cells (Somatic cells only affect you; germ cells affect future generations.)
 - B. Pharmaceuticals
 - 1. Helps with creating new medicines.
 - 2. Vaccines against diseases and maybe even cancers in the future.
 - C. Criminal Forensics
 - 1. DNA fingerprints of suspects.
 - 2. Paternity/Maternity testing.
 - D. Environmental Clean-up
 - 1. Bacteria are used to process human sewage in water treatment plants.
 - 2. Bacteria that can clean up Oil Spills or breakdown Plastic by eating the oil compounds.
 - 3. Organisms helping clean up heavy metals (such as Mercury) from mining or waste collection.
 - E. Agriculture
 - 1. Having organisms produce more food.
 - 2. Having organisms produce "larger" food.
 - 3. Having organisms produce hardier food for easy transport across the world.
 - 4. Having organisms produce healthier foods.
 - 5. Having organisms that can produce food during winter. (Winterized)
 - F. Livestock
 - 1. Organisms that are "meatier".
 - 2. Organisms that are "leaner". (Having less fat.)
 - 3. Organisms that are disease resistant.
- VIII. **Transgenic** Organisms
 - A. DNA from two *different* organisms are *combined* to make one organism that *possess traits* from both "parent" organisms. These traits will be passed on through reproduction, using gametes.
- IX. **Genetically Modified (GM)** Foods
 - A. These are foods that have been produced/altered in the DNA.

AP Biology
Genes and Organism Development

(Associated Learning Objectives: 1.14, 1.15, 1.16, 2.22, 2.31, 2.32, 2.33, 2.34, 2.36, 2.37, 3.1, 3.5, 3.9, 3.11, 3.20, 3.21, 3.22, 3.23, 4.1, 4.7, 4.17)

Important concepts from previous units:

- I) Genes are segments of DNA that are the “blueprints” for making proteins and enzymes within cells.
- I. **Zygote** (One 2n [diploid] cell that is the result of a n [haploid] sperm fertilizing a n [haploid] egg.)
 - A. This cell will give rise to over two hundred different human cells, all with the 100% identical genome within them during development.
- II. **Cell Differentiation** (A.K.A. **Specialization**.)
 - A. Expressing *different* genes makes cells *different or specialized* in function and shape.
 - B. Specialized functions are the products of “adult” cells.
- III. **Morphogenesis** (“morph” means “body shape”; “genesis” means “creation of”)
 - A. The process of morphogenesis is the *product of cell differentiation* occurring during *development*.
 - B. **Apoptosis** (Programmed cell death) is a *crucial* part of development too. (For example, apoptosis helps to “create” the spaces between your fingers and toes by “killing off” those cells in the webbing.)
 - C. Morphogenesis in *plants*:
 1. The cells of plants *do not move* as they are restricted by the cell wall. They mature *in place* and *respond* to environmental cues.
 2. Plants display *continual growth* until they die. (The growth occurs at the **Apical Meristem**. These tissues are found at the *tips* of roots and stems.)
 - D. Morphogenesis in *animals*:
 1. The cells of animals *move* into their final position during development.
 2. Animals display *limited growth*. (They die after a certain number of years.)
- IV. **Cloning and Clones**
 - A. **Cloning** is the process of making *100% genetically identical* organisms called **Clones**.
 - B. Animal Cloning process:
 1. First step: Remove an *egg cell* from a *female* organism.
 - a. This cell has all the enzymes and machinery to make development possible.
 2. Second Step: Remove the *Haploid* nucleus from the egg cell.
 3. Third Step: Take a *somatic cell nucleus (Diploid)* out of a somatic cell and put it in the egg cell.
 4. Fourth Step: Put the “egg” cell in a *surrogate organism (female)* to develop until birth.
 - C. Ian Wilmut and Dolly (1997) He was the first to develop this process of cloning. Dolly was the name of the first cloned sheep.
- V. **Stem cells**
 - A. These animal cells are said to be **Pluripotent**. (They can become any type of cell. “pluri” means “many”)
 1. These cells have *many possibilities* as to what they will develop into as they develop.
 - B. They are said to be “embryonic” in development. They also have no genes “locked up”; therefore, they can make *any* protein or enzyme.
 - C. Origins of stem cells. (Embryonic vs. Adult) Embryonic are found in *developing embryos* and adult stem cells are found within *developed* tissues. The difference is that adult stem cells have undergone a small amount of differentiation and therefore CANNOT make *every* protein/enzyme and therefore are *limited* in what type of cell they can become. Embryonic stem (Morula stage) cells have NOT undergone ANY differentiation. They CAN make *every* protein/enzymes.
 - D. **Research?** Embryonic stem cells are more valuable in research because of the *unlimited* possibilities. They could cure diseases such as Diabetes or SCIDS, repair spinal cord injuries, or be used to grow new organs for transplants.
- VI. **Pattern Formation**
 - A. DNA information (genes) that *controls* the development of the species’ “pattern”.
 - B. Each species is *unique* to an extent in the “pattern” and DNA sequences that creates it.
- VII. **Positional Information**
 - A. The cell “position” is accomplished through *cell-to-cell communication*.
 1. **Where** in relation to the whole organism?
 2. **What** is next to it?

VIII. **Maternal Effect Genes (A.K.A. Egg Polarity Genes)**

- A. Controlling the *polarity of the Zygote* helps to determine the Head and Tail or Root and Shoot.
- B. This “control” is accomplished by production of **cytoplasmic determinant proteins** and **morphogens**. (Proteins that affect morphogenesis.)
- C. They will accumulate on *one* side of the zygote cell. This accumulation *determines* the poles of the cell and what each end will start development of in the organism.
- D. They are referred to as “maternal” because they are produced in the *female egg cell*.

IX. **Segmentation Genes**

- A. These genes produce proteins that influence what will happen in a particular segment of an organism. (Best examples are insects and crustaceans.)

X. **Homeotic Genes (A.K.A. Hox genes)**

- A. These genes are the *master control* genes for an organism’s development. These are the *most important genes* in any organism... as the control *total development* from start to finish.)
- B. They contain the **Homeobox** (A *unique* DNA nucleotide sequence.)
 - 1. It is a 180 Nucleotide sequence found in **Hox genes**.
 - 2. Evolution? The *more similar the sequence* between organisms; the *more closely related* in terms of evolution they are. The *more different the sequence*; they *less related* they are.

AP Biology
The Process of Meiosis - Part 1

(Associated Learning Objectives: 1.5, 1.14, 1.15, 1.16, 2.24, 3.1, 3.4, 3.7, 3.8, 3.9, 3.10, 3.11, 3.12, 3.13, 3.27, 3.28, 4.1, 4.17, 4.23, 4.24, 4.25)

Important concepts from previous units:

- 1) DNA is *replicated* in the **S phase** of the cell cycle.
- 2) **Mitosis** is normal cell division. It involves *one* division. Mitosis means “division of the nucleus”.
- 3) **Meiosis** makes gametes, sperm and egg. This involves *two* divisions.

I. Heredity

- A. This refers to the *transmission of traits* from one generation to the next by *inheriting* DNA from the parent (for asexual reproduction) or parents (for sexual reproduction).
1. Most DNA is for *common* information. (*Unity* among species and within a species, like blood.)
 2. Some DNA is for *varied* information. (*Diversity* among species and within a species, such as the fur coloration between a zebra and a horse or freckles on one person and no freckles on another.)

II. Genetics

- A. This is the science that deals with the *transmission of information* in the form of DNA. It can range from studying how traits are passed from one generation to the next using Punnet squares or identifying DNA segments (what we call genes) and the proteins or enzymes that they make. It is a huge field of science.
- B. This field has had a tremendous impact on society as a whole. Such things as cloning, to new medicines, to making bacteria and yeast making human hormones, to making biological weapons such as Super Anthrax.
- C. Ethics can be involved. (Ethics is looking at the Good vs. Bad in terms of morality.) It is *always* an issue in science, particularly in this field.

III. Gene

- A. A *unit of hereditary information* in the form of a DNA *sequence of nucleotides* found on chromosomes.
1. Most genes code for some type of protein or enzyme. It is the “million dollar blueprint” for making *one* thing. (It would be like the blueprint for making a steering wheel.)

IV. Genome

- A. This refers to an organism’s *entire* genetic make-up. *All* the DNA within a cell. It would be like the “blueprint” for making the *whole* functioning car.
1. Only one half (n) is considered the Genome, they essentially carry the same information (genes).

V. Locus

- A. The *location* of a gene on a chromosome. This is important when you are talking about autosome vs. sex chromosomes.

VI. The two types of reproduction that can occur by living organisms:

A. Asexual Reproduction

1. This involves only *one* parent. The parent is producing *genetic clones* of it’s self. The parent and offspring are 100% identical in terms of DNA content and DNA nucleotide sequence.
2. Benefits – Reproduction can occur very *quickly*. (Good for taking over a new area.)
3. Risks – Every organism is *the same*. So if a disease affects one, it can affect *all*. (There is NO variation!) This caused the Irish Potato Famine. Potatoes are originally from South America. One species of potato plant was taken to Ireland. This became the only species that the farmers could plant, as no new species were brought over afterwards. A pathogenic fungus, called Potato Blight, began attacking the plants. Since they were all alike in terms of DNA because they were clones, they fungus wiped them out quickly causing the famine to occur.

B. Sexual Reproduction

1. This involves *two* parents to contribute DNA. This process “*creates*” *variation*, which is important in terms of *survival*.
2. Benefits – It produces *variation*. This is why some organisms have *advantages* over others within the same species in terms of survival and *the ability to reproduce*. Variety means there exists the *possibility* to evolve over time while living in an ever changing environment. For example, Woolly Mammoth. Those with *less* hair survived and passed on those genes for *less* hair to their offspring as the environment became *warmer* over time. This lead to the evolution of our modern elephant, which has very little hair. The mammoths with *more* hair died before they could reproduce; thereby, “wiping” out those genes and eventually causing the extinction of the *old* species.

3. Risks – It takes *two* to be *able* to reproduce and they *must* be of the opposite sex for the physical reproduction to occur. This is not good for an *endangered species*. It also takes more *time*. It also involves a *more complicated process to create the gametes* that have half the DNA content.

VII. Three possible types of life cycles, *based on DNA content* within cells:

A. **Haploid Majority**

1. This type occurs mostly in Fungi and some Protists. (These are single celled organisms mainly.)
2. The *majority* of these organisms life-time is spent with cells that are *haploid* in terms of DNA content.
3. They come together to make *diploid* cells to “create” variation to increase survivability in a *changing environment*. After recombining DNA, they undergo **Meiosis** to *return* to a haploid state, but with a *different* DNA composition within the cells.

B. **Diploid Majority**

1. This type of life cycle is seen in Animals.
2. The *majority* of these organisms life-time is spent with cells that are *diploid* in terms of DNA content.
3. The diploid parent organisms make *haploid gametes (sperm or egg)* by undergoing **Meiosis**. These cells are made and *stored* in the reproductive organs. They (sperm and egg) come together during sex to bring the DNA content *back to* diploid, so as to be able to make a *new organism*. The diploid cells undergo **Mitosis** to keep making new diploid *cells* and thereby the organism.

C. **Alternation of Generations** (half-n-half basically)

1. This type of life cycle is seen in Plants and most Algae. (These Algae are multi-cellular protists.)

VIII. Human Life Cycle is Diploid Majority

A. **Somatic** (“soma” means “body”) cells make up most of our body.

1. These cells possess 46 chromosomes inside them. They are 2n (diploid).
2. **Karyotypes** will *display* all 46. A **karyotype** is basically *pictures* of the chromosomes.
3. **Homologous** (“same”) **Chromosomes** can be seen. These are called **Autosomes**. 44 = 22 *pairs* exist in all human cells. (If *female*, the two *sex* are the same too... two X chromosomes.)
4. **Heterologous** (“different”) **Chromosomes** *may* be seen in males. These may be the 2 sex chromosomes. (In *males*, there is one X and one Y chromosome.)
 - a. Female (XX); Male (XY)

B. **Germ** (“germ” means “beginning”) cells (A.K.A. **gametes**)

1. These are the *sex cells*. They are n – haploid. (egg - female; sperm - male)
2. **Fertilization**, which is the *fusion of egg and sperm together*, must occur to be able to reproduce.
 - a. This fusion between egg and sperm produces a *single diploid* cell called a **zygote**.
 - b. The **zygote** goes on, through repeated *Mitosis*, to produce the new organism.

AP Biology
The Process of Meiosis - Part 2

(Associated Learning Objectives: 1.5, 1.14,1.15, 1.16, 2.22, 2.31, 2.32, 3.1, 3.3, 3.8, 3.9, 3.10, 3.11, 3.12, 4.1)

Important concepts from previous units:

- 1) Evolution is “change over time”.
- 2) Sexual reproduction involves *haploid* sperm and egg gametes.
- 3) The DNA within the egg and sperm *will create* the *next* generation organism.

I. **Meiosis** - means “The process of *gamete* formation”.

A. This process occurs in the cells of the *sex* organs of the organism. These organs are called **Gonads**.

B. This process has 2 *divisions* in the process *after* the S and G₂ phases.

1. Remember, that the S phase *doubles the number of chromosomes*. In humans $46 \rightarrow 46 + 46r$.

a. Each “chromosome” is now called a “chromatid” in let it be known it was *replicated*.

2. **Meiosis I** - This division is the separation of chromosome *pairs*. In humans, $46 + 46r \rightarrow 46$

3. **Meiosis II** - This division is the separation of *sister chromatids*. In humans, $46 \rightarrow 23$

C. In this process, males produce **4** haploid sperm; each having 23 chromatids.

D. In this process, females produce **1** haploid egg with 23 chromatids. The other three cells *degrade* into structures called **polar bodies** during the process. These can be seen on the *nucleus membrane* in female cells, not males.

E. Stages to the process of Meiosis

1. These stages are *very similar* to the stages of Mitosis.

2. *Three major differences*, from Mitosis, are present to *increase variation*.

(Remember, Mitosis is *normal* cell division. It basically makes *clones* of the adult. *No variation*.)

a. **Crossover** (“genetic swapping”) occurs in **Prophase I**. (Creates variation.)

b. Chromosome *pairs* separate in **Anaphase I**. (Creates Variation.)

c. *Sister Chromatids* separate in **Anaphase II**. (Creates Variation.)

II. **Crossover** (“genetic swapping”) between *homologous* chromatids.

A. This creates *variation from the parent’s genome*. They are then called **Recombinant Chromatids**.

B. **Synapsis** – Chromatids that are in a state of being *intertwined together*. (“syn” means “together”; “sis” means “process of”)

C. **Tetrad** - *Four* chromatids *twisted together*. (“tetra” means “four”... Like the game Tetris has four different shapes.)

D. **Chiasmata** – Where the chromatids physically *overlap* making an “X”. (Chi is the Greek letter for X.)

III. Major *differences* between Mitosis and Meiosis:

A. The *number of divisions*. (Mitosis has 1; Meiosis has 2.)

B. The *final products* of each process. (Mitosis – “cloned” daughter cells; Meiosis – haploid gametes.)

C. **Crossover**, in Prophase I, creates variation. (No crossover in Mitosis.)

D. Chromatid pairs vs. sister chromatids separating in the *second division* to *reduce* DNA to haploid state.

IV. *Sources* of variation creation:

A. *Independent* assortment of chromosomes. (This happens in Anaphase I and and to some degree Anaphase II.)

1. 2^n = Total number of possibilities (One goes one way; the other the other way in separation.)

a. n = number of variables; 23 = number needed to make a haploid set in humans.

b. $2^n = 2^{23}$

2. For humans the total is about 8 *Million possibilities* for *each parent with each* division.

3. 8 Million possible outcomes X 2 divisions X 2 parents = 4,096,000,000 *possible combinations* for just 46 chromosomes!

B. Now add in **Crossover** (“genetic swapping”)

1. Amount of crossing over varies from tetrad to tetrad. If *little* crossover occurs, the offspring looks *very much like* the adult parent. If *lots* of crossover occurs, the offspring looks *very different* from the adult parent.

C. *Random* fertilization by a sperm. (There are millions released by the male. Which one will make it to the finish line?)

D. That makes *you* a 1 in 70 *trillion possibility* – YOU ARE PRETTY DARN SPECIAL!

V. Evolution? As organisms became *more complex*, a more complex and more *survival oriented* way of reproducing came into existence over *millions of years*. The addition of a *second division* with a couple of slight changes in the *same* four steps (Prophase, Metaphase, Anaphase, and Telophase) creates the variation. The variation helps with survival and this would be beneficial in *changing environments*. Those that survive long enough get to

reproduce and keep the species going. Those that don't do not pass on those *defective* traits for surviving in that environment.

AP Biology
Mendelian Genetics – Part 1

(Associated Learning Objectives: 1.16, 2.31, 3.1, 3.2, 3.9, 3.10, 3.11, 3.12, 3.14, 3.18, 3.19, 3.24, 3.26, 4.1, 4.25)

Important concepts from previous units:

- 1) Genes are DNA segments that are *inherited from parents* during reproduction.
 - 2) A gene is the “blueprint” for making a **polypeptide** (protein).
 - 3) Proteins are made (expressed) by the processes of **transcription** and **translation (Protein Synthesis)**.
-
- I. Gregor Mendel (1850) - He is considered to be the “Father of Genetics”.
 - A. He was a monk who worked with pea plants, this is because he was the cook too.
 - II. **Character** - An *inheritable physical feature*. (This is a *characteristic* such as *eye color* or *hair color*.)
 - III. **Trait** - This is a *variation* of a character. (Such as *blue* colored eyes or *black* colored hair.)
 - A. This *requires* inheriting *two* alleles; one from each parent.
 - IV. **Alleles**
 - A. This term refers to *different versions of a gene*. (Remember, a gene is a distinct *DNA nucleotide sequence* that can make one protein or enzyme. (Brown, blue, green eye color. These are three different *versions* or *DNA sequences of a single gene*, but they *all* are making the *eye color*.)
 - B. Each trait needs *two* alleles. One from each parent to be made or “expressed”.
 - C. **Dominant** alleles are given *capital letters*. (These are like books or recipe cards *with information* in them.)
 - D. **Recessive** alleles are given *lower case letters*. (These are like books or recipe cards *with blank pages* – “no” functional information is on them on *how* to make a functional protein or enzyme.)
 - V. **True “pure” breed** - These organisms *only* have one *type* of **alleles** for that trait.
 - A. A.K.A. Homozygous alleles. (“Homo” means “same”) Such as BB or bb.
 - VI. **Hybridization** - This is the process of “creating” an organism with two *different* types of **alleles** for that trait.
 - A. Referred to as **Hybrid** or **Heterozygous** alleles. (“hybrid” and “hetero” mean “different”) Such as Bb.
 - VII. **Phenotype** (“pheno” means “physical”)
 - A. This term refers to a *physical trait* that can be “seen”. (Blue eyes or Type A blood, would be examples.)
 - VIII. **Genotype** (“geno” means “genetic”)
 - A. This term refers to an organism’s *genetic (DNA) make-up for a trait*. (Such as BB, Bb, and bb.)
 - B. If the **genotype** of an organism is *unknown*, we can perform a **test cross** to *find* it.
 1. To perform this test, we *must* use a **homozygous recessive** to *mate* with our unknown.
 - a. This allows for no information to be “covered up” by a *known* dominate allele.
 - IX. **Punnett Square** - a chart showing the *possible genotypic outcomes* for a mating based on parent’s **genotypes**.
 - A. **Monohybrid** – This chart displays *one trait*. (It has 4 squares. $4^1 = 4$ squares)
 - B. **Dihybrid** – This chart displays *two traits*. (It has 16 squares. $4^2 = 16$ squares)
 - C. **Trihybrid** – This chart displays *three traits*. (It has 64 squares. $4^3 = 64$ squares)
 - X. Mendel’s **Law of Segregation** (“Segregate” means “to separate”)
 - A. The *homologous* chromosomes or **sister chromatids** can move *independently* of one another.
 - B. This is *supported* by what happens during Anaphase I and to some extent Anaphase II of Meiosis.
 - XI. Mendel’s **Law of Independent Assortment** - This basically states that *variations* are possible on *sets of chromosomes*. (Assortment means “variety exists”.)
 - A. This states that chromosomes line up *independently* of one another on the *midplane* of a cell.
 - B. This occurs at Metaphase I and II in Meiosis.
 - XII. **Probability** “Chance”
 - A. This refers to the *likelihood* of a *certain* outcome actually happening. (What are the chances of...occurring?)
 - B. **Probability** ranges on a scale between 0 and 1.00. (From 0% to 100% essentially.) 0.5 is 50% and so on.
 - XIII. Quick way to assess **probability** in a mating cross (Use the worksheet provided by your teacher)
 - A. Uses the **Rule of Multiplication**. This applies to the *parent’s* genetics coming together to make an *offspring*.
 - B. A calculation to *determine* the outcome for a *specific* genotype combination in the offspring.

AP Biology

Mendelian Genetics – Part 2

(Associated Learning Objectives: 1.5, 1.16, 2.22, 2.23, 3.1, 3.13, 3.14, 3.15, 3.16, 3.17, 3.18, 3.19, 3.22, 3.24, 3.26, 4.17, 4.23, 4.24, 4.25)

Important concepts from previous units:

- 1) Phenotypes occur from proteins or enzymes and they are the result of genes being “expressed” within cells.
- 2) A gene's nucleotide sequence *determines* the **codons** that are used to construct proteins by the ribosomes.

I. **Incomplete Dominance**

- A. This is where the genetic information is “*blended*” together. (For example, Red + white = Pink.) Neither phenotype is *completely* dominating the other. They are *both seen* in a “blended” version.

II. **Complete Dominance**

- A. This is where the *dominant allele* has DNA nucleotide information for a *fully functioning* protein or enzyme and it is “suppressing” the *recessive allele* DNA nucleotide sequence.

III. **Codominance**

- A. This is where *both* alleles are seen but they are “*not blended*” together. They are both *equally* present in terms of phenotype. (Such as AB blood type...these cells have A and B protein “hands”.)

IV. **Multiple Alleles** - This is where there are *multiple* different versions of the *same basic allele*.

- A. The glycoprotein “hands” of red blood cells would be a great example of this. These “hands” identify the blood types. One type of hand is “A”. Another is “B”. Another is **codominance** “AB”. Then there is the homozygous **recessive** “O”. Since it is recessive, “no blueprint information” was *in* the DNA on how to make the glycoprotein hands “A” or “B”.
- B. **Hemophylactic Shock** – This occurs when someone is given the wrong blood type. (The “hands” don’t match. So the white blood cells begin killing the new red blood cells.)
- C. **Universal Donor** – Can *give* blood to anyone. (Blood Type O –. These cells have NO hands. So they match everyone.)
- D. **Universal Recipient** – Can *receive* blood from anyone. (Blood Type AB. They have BOTH types of hands. So they can match everyone.)

V. **Pleiotropy** - This is where one gene *affects multiple phenotypes*. (“Pleio” means “multiple”)

- A. Sickle Cell Disease is a great example. This gene *affects* the red blood cells shape, Oxygen carrying ability, Malaria resistance, etc..

VI. **Epistasis** - A gene at *one locus* affects a gene at a *second locus*.

- A. Hair is a great example. Several genes are interacting to “create” hair’s phenotypes – These are: color, shape, thickness, texture. (“epi” means “source”; “stasis” means location) The source is affecting another location.
- B. This usually has a 9:3:4 ratio; not the *normal* 9:3:3:1 ratio as seen with most dihybrids.

VII. **Polygenic Inheritance** - This is where there exist *many different degrees* of phenotypic outcomes.

- A. This is due to **Quantitative Characters**. (Quantity -*how many* alleles did you *inherit* from your parents.) (“poly” means “many”; “genie” refers to “genes”; “inheritance” from your parents)
- B. Skin Color is a great example. We have many *different degrees of skin pigmentation* ranging from Albino → Black, Black. It *depends on how many copies of the same gene* for making the skin pigment melanin you inherited from your parents in the sperm and egg.
- C. **Norm of the Reaction** – This refers to where the *majority* of organisms fall on the bell curve for that trait.
 1. Evolution? The norm can tell you about the *type of environment* organisms live in. The norm is because some trait is *beneficial* in that environment.

VIII. **Multifactorial**

- A. Many *environmental factors* are affecting the phenotypic display of genes in that organism.
- B. This gives fuel to the argument over Nature vs. Nurture in organisms. (The genetics vs. the environment.)
 1. While there are equally legitimate arguments for both sides. The overwhelming evidence supports a 50/50 reality. 50% of our behavior is innate (in our genetics); after all who teaches a dog to bark. The other 50% comes from our experiences or living environment (called **epigenetic**); such as eating good foods affects the body you “create” over time.
 2. Height, intelligence, and weight can all be considered multifactorial.

AP Biology
Mendelian Genetics – Part 3
(Associated Learning Objectives: 3.1, 3.2, 3.9, 3.11, 3.12, 3.13, 3.14, 3.19, 4.23, 4.24)

- I. **Pedigree**
 - A. This is a *family history* of trait occurrence in chart form. *Affected* individuals are *shaded in* on the chart.
 - B. These help tell the past occurrence and can be useful in *predicting the future occurrence by mating*.
- II. **Recessive Disorders** (“No functional information inherited on *both* chromosomes”.)
 - A. These disorders tend to be very harmful to the organism.
 - B. They *only* occur in the *homozygous recessive genotype*.
 1. There is nothing to be dominated by, so the disorder is present.
 - C. **Carriers** – These are organisms that are *heterozygous in genotype*. They are 50/50 in terms of *passing on* the trait. It depends on which allele was present in the *gamete* that was involved in making the offspring. These organisms usually appear *normal* for the trait, as they possess one dominant allele.
 - D. Human recessive disorders:
 1. **Cystic Fibrosis** (Also referred to as “CF”.)
 - a. This is the most common lethal genetic disease.
 - b. This disorder affects 1 in 2,500 births.
 - c. In Caucasians, 1 in 25 people is a carrier for the disorder.
 - d. The disorder creates a faulty Chloride ion (Cl⁻) protein carrier on cell membranes in the lungs. This causes fluid (water) to build up in the lung tissues.
 - i. People drown in their own fluid.
 - ii. They are also prone to get multiple infections in the lungs.
 - e. Treatment? Since it is *genetic* there is NO cure. Patients have to get the fluid drained from the lungs periodically for their *entire* life. There are medicines to help reduce the number of times this has to occur.
 2. **Tay-Sachs Disease**
 - a. This disorder creates a *non-functional lysosome in brain cells*. Brain cells need massive amounts of energy to function properly; therefore, they feed upon *lipids* primarily. The lysosomes break them down using beta oxidation for use in cellular respiration. The lysosomes associated with this disorder are missing an enzyme to be able to do this; so they just fill up with lipids. The cells fill with lipids and then die.
 - b. This disorder mainly affects the Jewish Culture because of marrying within the culture. The Jewish culture has a high percentage of carriers.
 - c. The children affected, usually die a painful, blind death by age 5.
 3. **Sickle-cell Disease**
 - a. This disorder is the most common genetic disorder within the black population. Other populations *can get it* too. **It is not exclusive.**
 - b. It affects 1 in 400 births.
 - c. The *6th Amino Acid* is changed (Glutamine → Valine) in the *primary sequence* of one of the proteins needed to make red blood cells.
 - d. **Sickle-cell trait** (“trait” is used to refer to individuals that are *carriers*.)
 - i. These individuals have *resistance to Malaria* because of the one recessive allele they possess but mainly have normal red blood cells for carrying Oxygen.
 - ii. This is referred to as the **Heterozygous Advantage**. They have an *advantage* over individuals that are homozygous dominant or homozygous recessive. Homozygous dominant are NOT resistant to Malaria. Homozygous recessive are also resistant to Malaria; BUT they have the disease to contend with.
 - iii. Sickle-cell identification of carriers in individuals is *important to avoid* this disorder from occurring.
 - e. These sickle shaped cells have *reduced Oxygen carrying ability*. They also are painful when the points of the cell jab into the walls of the blood vessels.
 - f. Treatment? There is no cure as it is genetic. Some medicines help with the pain or low oxygen levels.
- III. **Dominant Disorders**
 - A. *Only* need *one dominant* allele for these disorders to be present or “expressed”.
 - B. If an individual is homozygous dominant, then the disease is much worse and usually fatal.
 - C. Human Dominant Disorders:
 1. **Achondroplasia** - This is referred to as *Genetic Dwarfism*.

- a. This disorder affects 1 in 10,000 births.
- b. Most people are homozygous recessive and therefore much taller than these individuals.
- 2. **Huntingdon's Disease**
 - a. This disorder affects 1 in 10,000 births.
 - b. It has a late life onset – usually in the 40 - 50 age range. Usually *after* children are born.
 - c. The dominant gene has a locus on tip of Autosome 4.
 - d. Family history is important in diagnosis of this disorder. Pedigree can help diagnose.
 - e. It is a *slow degenerative* disorder affecting the brain that is almost always fatal.

IV. **Multifactorial** Diseases (“Factorial” refers to “the environment”.)

- A. Heart Disease - Genetics, diet, alcohol, and smoking are all factors that *contribute* to the development.
- B. Diabetes - Genetic, diet, and race are all factors that *contribute* to the development of the disease.
- C. Cancer - Genetics, life style habits in general are all factors that *contribute* to development of the disease.
- D. Alcoholism - Genetics, lifestyle, and mental state are all factors that *contribute* to development.
- E. These factors are considered part of **epigenetics**.

- 1. **Epigenetics** refers to the influence of an environmental factor (“source”...”epi”) that affects the expression of a trait by affecting transcription/translation.

V. **Penetrance** – The proportion (percentage) of individuals in a group with a given genotype that *actually* show the expected phenotype.

- A. For example, Huntington's Disease – 95% of the people who get the dominant allele *actually* express the disease. 5% do not express. So we say there is 95% penetrance for that *allele*.

VI. **Expressivity** – the *degree* to which a genotype is expressed in an *individual*. Tends to be more severe in homozygous states, where there are TWO copies of a gene.

AP Biology
Mendelian Genetics – Part 4
(Associated Learning Objectives: 3.1, 3.2, 3.9, 3.11, 3.12, 3.13, 3.15, 3.16, 3.17, 3.19, 3.24)

Important concepts from previous units:

- 1) Genes are located on chromosomes.
- 2) There are two types chromosomes associated humans – **autosomes** and **sex chromosomes**.
- 3) Chromosomes are *inherited* from the parents.

I. **Linked Genes**

- A. These are usually inherited as a *linked* unit because they are found on the *same chromosome*.
- B. This term usually is associated with genes on *Autosomes* (1-22).

II. Alfred Sturtevant

- A. He was the pioneer of **genetic mapping** – locating the *loci of genes*.
- B. He used *crossover rates* to determine the loci on chromosomes.
 1. The finished product is called a **Linkage Map**.
 2. The *smaller the rate*; the *closer* they are to each other on the *same chromosome*.
 3. The *higher the rate*; the *farther apart* they are from each other on the *same chromosome*.
 4. The loci are measured in **Centimorgans** or **map units**.

III. **Sex-Linked Genes**

- A. This term refers to genes found on the *sex chromosomes*; 95% of the time it mainly refers to the X chromosome. (Think X when it is seX linked.)
 1. This is because *both sexes* have at least one X chromosome in their genome.
 2. XX (Female and homologous) ; XY (Male and heterologous)
- B. Sex chromosomes undergo *very little crossover* during Prophase I of Meiosis.
- C. Sex of the organism will be *determined* at conception. This is when egg is fertilized by the sperm. You *will* either get a sperm containing an X chromosome or a sperm containing a Y chromosome.
- D. Everyone starts out female. (This is why we all have nipples.)
 1. At about two months of age in the womb, the Y chromosome's **SRY gene** goes *active* to make testosterone, from estrogen, to finish development of the male. (Remember, **functional groups**.)
 2. *After* development is complete, testosterone production is turned off until puberty. At puberty it is turned back on so as to make the *secondary* sexual characteristics, such as facial hair.
- E. *Patterns* of Inheritance and some Human **Sex-Linked** Genetic Disorders: (NO cure exists, because the problem is in the DNA.)
 1. **Color Blindness**
 - a. This is the result of a faulty gene (*recessive*) on the X chromosome for making a particular type of *light wavelength (color) absorbing protein* in cones of the retina of the eye.
 - b. The most common type is Red/Green Colorblindness. (Red and Green appear gray.)
 2. **Hemophilia** (Means “love of bleeding”)
 - a. These individuals CANNOT make (*recessive*) **Anti-hemolytic Factor**. (AHF for short.)
 - b. They may experience problems with possible bleeding to death.
 - c. This was a disorder associated with the “Royal Blue-Bloods of Europe” – They were *inbreeding* to keep the crown “In the Family”.
 - d. Treatment? These individuals have to keep AHF with them at all times in case they get hurt. If they do get hurt and start to bleed, they will *require* a shot of AHF to stop the bleeding. Even a bruise (bleeding under the skin) can possibly lead to death.
 3. **THE PATTERN ON A PEDIGREE**: It will *appear to mainly affect males* (as they only have *one* X chromosome). This is because if the inherited X chromosome has a recessive gene on it; it will NOT be covered up by a dominant one on another X chromosome (as is the case in most females). Females *can still get these disorders*, but they must inherit *two* recessive X chromosomes. The females tend to be **carriers**, so they appear unaffected. So they tend to pass the recessive X on to their sons. The son will be a *sufferer*, if he gets the recessive X, of the disorder. It *appears to skip* a generation, because the mother is a carrier and the sons are showing the disorder.

IV. Genes associated with these two terms *do not* follow Mendel's Laws of Inheritance and normal ratios.

- A. This is because these terms are mostly referencing *one* chromosome and not inherited *pairs* of chromosomes.
- B. Variation on linked chromosomes is associated with crossover frequency with its homologous mate.
- C. Sex –linked is referencing the X chromosome only. Males have 1 and females two *copies*.

AP Biology
Mendelian Genetics – Part 5

(Associated Learning Objectives: 1.14, 1.15, 1.16, 2.31, 2.32, 2.33, 3.1, 3.9, 3.11, 3.12, 3.13, 3.17, 4.1)

Important concepts from previous units:

- 1) There are also *gene* errors – **point mutations** and **reading frame mutations**.

I. **Chromosomal Errors** than can occur:

A. These could occur during Mitosis *or* Meiosis.

1. They would occur during the *Anaphase* Stages where *chromosomes are moving*.
2. They could also occur during *Crossover* where *gene DNA segments are moving*.

B. Two *types* of errors can occur:

1. **Chromosomal Number** (**Aneuploidy** means “Abnormal *number* of chromosomes”.)
 - a. This is the result of **non-disjunction**. (“Failure to separate” during Anaphase.)
 - b. **Trisomic** - *Three* of 1 kind of chromosome.
 - c. **Monosomic** - *Missing one*, the other half of the pair. (It is located in the Trisomic gamete.)
 - d. **Polyploidy** - Many *extra sets of chromosomes*.
 - i. **3n (triploid)** - Three “halves” are in this cell.
 - ii. **4n (tetraploid)** - Four “halves” are in this cell.
 - iii. Deadly in most animals; Plants not really affected because they are simple organisms.
2. **Individual Chromosome Structure** (Try to “see” the terms.)
 - a. These occur because of *faulty crossover*.
 - b. **Deletion** – Chromosome segment is “missing”. (It got stuck *on the other* homologous chromosome during crossover.)
 - c. **Duplication** – A chromosome segment was “copied” twice. Two genes on one chromosome. (It is “missing” from the other homologous chromosome.)
 - d. **Inversion** – A chromosomal segment is “backwards”. It was *inverted* (“backwards”) during crossover.
 - e. **Translocation** – A chromosomal segment is attached to *a different autosome*. (It accidentally broke loose and ended up on another chromosome.)

II. **Syndrome**

A. This term refers to an organism “possessing” the *identifying traits* of a particular genetic disorder.

B. Human Genetic Disorders due to two *abnormal chromosomal number*:

1. **Down’s Syndrome**

- a. This affects about 1 in 700 births.
- b. This individuals possess an *extra 21 Autosome*. (A.K.A. **Trisomy 21**)
- c. General syndrome features – mental retardation, flat face, squinted eyes, small.
- d. Mainly the result of women of *advanced age* having babies. (Weak spindle fibers during the Anaphase II separation after fertilization.)

III. **Extranuclear DNA** (“extra” means “outside of”)

A. DNA that is located *outside the nucleus* in organelles. (These are Mitochondria, Chloroplasts, and Plastids.)

B. Mitochondria inherited from the *mother inside the egg*. They are exactly alike. (Helps in Criminal Forensics cases trying to establish relationship between individuals.)

C. **Mitochondrial Myopathy** - These mitochondria *lack the ability* to make large quantities of ATP because they possess faulty DNA for making some of the enzymes or proton pump proteins in the cellular respiration process.)

1. General Characteristics: These individuals are very tired *all* the time.

AP Biology
Ecology Basics

(Associated Learning objectives: 2.1, 2.2, 2.3, 4.11, 4.13, 4.14, 4.15, 4.16,)

Important concepts from previous units:

- 1) Regulation means control.
- 2) Transpiration is water loss through the stomata associated with plant leaves.
- 3) Water, because of its 4 possible Hydrogen bonds, can absorb huge amounts of sunlight energy.

- I. **Ecology** – Is the study of the *interactions* occurring between organisms and their environment.
 - A. Ecology also studies *location* and *abundance* of species, either individually or collectively
 - B. **Abiotic** – environmental factors that are *without life*. (temperature, light, water, nutrients, soil, and wind)
 - C. **Biotic** – environmental factors that *possess life*. (bacteria, protists, fungi, plants, animals, competition, and symbiosis)
 - D. Another aspect of ecology is Evolutionary time (very long periods) vs. Ecological time (short periods of time).

- II. **Biogeography** – the *distribution* of species and distribution *patterns* seen within an area as well as the **species richness** (number of *different* species within that area).

A. **Normal species** (Also referred to as indigenous or native species)

B. **Transplant species** (Species from *another* area living in a foreign environment.)

1. Accidental transplant species – Examples are Zebra Mussels and Fire Ants.
2. Human purposeful transplant species – Examples are African “killer” honeybees and Kudzu.
3. Transplant experiments should first be done *but* they cost lots of money and time to perform.
 - a. **Tens Rule** -1 in 10 transplants will be successful and live; 1 of 10 successful becomes a pest.
 - i. Most are harmful to the environment or other species. (They will have no *natural* enemies... so they take over and destroy that environment.)

C. Abiotic (non-living) Factors:

1. Temperature
2. Water availability (**Osmoregulation** and **transpiration** rates are important environmental factors.)
3. Sunlight amount (Photosynthesis rates or photoperiods indicates the amount of energy for a system.)
4. Wind (It can affect *heat* and *water loss* for an environment.)
5. Rocks and soil types (pH and composition of the soil mainly affects plants *directly*; animals *indirectly*.)

- III. **Climate** – the *average* weather conditions for an environment. Usually measured on a yearly or monthly basis.

A. **Weather** – the *daily* conditions. (Look outside and you’ll get the weather report.)

- IV. **Biomes** – Refers to *large* ecosystems in general with *similar climate conditions*.

A. These are *affected* by climate patterns. (Sun, wind, and rain patterns as seen by **Hadley cells**.)

1. The **Hadley model** basically shows that at the equator we have mostly water on a global perspective. Due to the *intense* heat, the water evaporates and rises. It then begins to move toward the poles. As it moves higher in the air and toward the poles, the water vapor cools and condenses into rain. The rain mainly falls out of the air before reaching the Tropics, that is why we mainly find the Rainforests between the Tropics. Since all the moisture is *gone* from the air by the time the wind reaches the Tropics, we see deserts along the Tropic lines. Here again, *any* water is evaporated because of the *high* heat and mixed with water vapor from the oceans to rise into the atmosphere. As it rises and continues to move toward the poles, it condenses and rains or snows below the polar circles. So we see lots of vegetation in this area. Because all the moisture is *gone* by the time the wind reaches the poles, the poles are also considered desert based on the lack of precipitation received.

- a. Tropics (23.5° latitude= tilt of Earth North –Tropic of Cancer; South- Tropic of Capricorn)
- b. Equator - 0° ; Poles 90° ; Arctic or Antarctic circle – 66.6°

2. *Local effects* because of geography

- a. Oceans – These act as *heat banks*. (Coastal/island areas generally warmer than interior areas.)
 - This is related to the **Specific Heat** of water. (**Water's ability to resist temp. changes.**) It *absorbs* the sunlight's energy (so we don't fry) during the day and *releases* the energy at night to keep the dark side of the planet warm.
- b. Mountains –These create the *rain shadow effect*. This creates deserts on the *backside*.
 - As the winds come off the water, they are *heavy* with moisture. When those winds run into mountains, the air is *forced* upward resulting in the moisture getting cooler and condensing resulting in lots of rain on the *front* side of the mountain. With no moisture left as the winds reach the backside or “shadow side” of the mountain, you get deserts typically.
(Look at California and Nevada.)
 - Winds increase with *altitude*. So plants *tend to be* smaller and animals *fewer*.
 - Temperatures on average *drop 6°C for each 1000 meters up* in altitude.
- c. Ponds and lakes – *stratification* of temperature creates *layers* of differing temperature within the body of water and this leads to **thermoclines** and **turnover** of nutrients and O_2 . This is ultimately due to seasonal changes in temperature. Warmer water rises and colder water sinks. Ice on the surfaces helps prevent this in winter so that the whole body of water does not freeze and thereby kill all life forms in the body of water.

VII. **Microclimates** – These are *small* ecosystems /environments. (For example, under a log/ shady side of a house.)

AP Biology
Water and Aquatic Biomes

(Associated Learning objectives: 2.1, 2.2, 2.3, 2.4, 2.8, 2.22, 2.23, 2.24, 4.11, 4.14, 4.15, 4.16)

Important concepts from previous units:

- 1) Regulation requires *energy*. Organisms *must* regulate water levels within them in order to survive.
- 2) Water and sunlight energy are *needed* for photosynthesis to occur by producers.
- 3) Producers are the starting point of food chains and food webs. They determine all the *other* organisms present.
- 4) Sunlight = Photosynthesis = Energy for life = Producers = Consumers, so more light = more life *may exist*.

I. Aquatic Biomes

- A. These cover roughly 75% of the Earth's surface.
- B. These are *initially* responsible for rainfall and global temperature *regulation* by absorbing some solar energy.
- C. They help with O₂ production and CO₂ consumption. (Phytoplankton performing photosynthesis.)

II. Regions to an *Ocean body* of water, commonly referred to as marine systems:

- A. **Photic Zone** – This is the *upper* region *with* light penetration. (“photo” means “having light”)
 1. Red light penetrates *deeper* than other wavelengths of white light. (Because it has the *longest* waves.)
- B. **Aphotic Zone** – This is the *lower* region *without* light penetration. (“Aphoto” means “having no light”)
- C. **Benthic Zone** - *Bottom* of the ocean. (**Benthos** – *communities* of bottom dwelling, detritus feeding organisms.)
 1. Organisms here get no sunlight, so *no* photosynthesis can occur. Here producers use Chemosynthesis to convert Hydrogen sulfide into sugars.
- D. **Abyss** – These are the *deepest* parts of the Benthic Zone. (These are deep-sea trenches mostly.)
- E. **Pelagic Zone** – Area ranging from the surface to bottom in the “*mid-region*” for the body of water.
- F. **Thermocline** - These are temperature *gradients*, like incline or decline, that occur within a body of water as water heats or cools.

III. Regions to a *Fresh water* body: (lakes, ponds, and streams)

- A. **Littoral Zone** – The *shallows*. (“*Littorally* where you find *most* of the organisms”). Light is present for plants.
- B. **Limnetic Zone** – This is the “*middle*” *surface* region. Mostly phytoplankton and zooplankton live here *floating* on top. (“Plankton” refers to “organisms on the surface of water”).
- C. **Profundal Zone** – This is the *deep* “*middle*” region. (This is usually where fish group.)
- D. **Benthic Zone** – The *bottom* area. (It may or may not have plants; it depends on *depth of light penetration*.)
- E. **Pelagic Zone** – This area ranges from surface to bottom in the “*mid-region*”.

IV. Types of lakes based upon *Nutrient Availability*:

- A. **Oligiotrophic** – These are *nutrient poor* (“oligio” means “little”) due to tending to be very deep and very cold.
 1. Appear clear due to lack of phytoplankton and nutrients at surface.
 2. Very little plant and animals because nutrients are at the *bottom* and thermocline is hard to occur.
- B. **Eutrophic** – These are *nutrient rich* (“eu” means “broad” or “much”), and are fairly shallow and warm.
 1. They appear murky due to abundance of phytoplankton and dissolved nutrients in the water.
 2. Tend to have lots of plants and animals because nutrients *within reach*.
- C. **Mesotrophic** – These lakes are in between conditions. (“meso” means “middle”)
 1. Moderate plant and animals present; mostly around the edge areas.

V. Streams and Rivers

A. **Headwaters** – These located in the *mountains*.

1. Waters are cold, clear, fast, narrow, nutrient poor, high dissolved O₂ so this affects the animals and plants found here – high Oxygen demand organisms, such as trout.

B. **Midstream** – These are located in between mountains and coast.

1. Waters are warm, slow, wide, nutrient rich and murky due to erosion, lower dissolved O₂ . Plants and animals are moderate Oxygen demanding, such as bass or catfish.

C. **Estuary** – This is where fresh water *meets* salt water. (Such as the Bay of Mobile.)

1. *Very* nutrient rich because of all the dissolved materials from upstream; water appears almost black.
2. *Very* rich in **biodiversity** -amount and types of life forms. (Almost as rich as a rainforest or coral reef.)

D. **Wetlands** – These are lands possessing water and above water plants.

1. Two types exist: **swamp** (defined by having trees) and **marsh** (defined by having reed grasses only).
2. They are *very* rich in biodiversity.
3. These areas are *protected by law* and are Gamelands and wildlife refuges.
3. These help to reduce flooding by holding rainwaters or hurricane waters. (VERY IMPORTANT!)

VI. Marine Biomes

A. **Intertidal Zone** – This is a *very harsh* environment due to tides crashing and receding. It is rich in biodiversity due to the *presence* of light for photosynthesis.

B. **Neritic Zone** – This runs from shore to the continental shelf drop off. It is *very* rich in biodiversity due to light.

C. **Oceanic Pelagic** – Contains the *photic and aphotic* and *lacks* biodiversity; it is mostly big fish and mammals and plankton on the surface.

D. **Coral Reef** – These are *very* rich in biodiversity.

- Called the rainforests of the oceans.
- They are *endangered* and therefore *protected* by laws.
- They are found in *warm* water climates.

E. **Benthic** – Moderate in biodiversity. (Mostly around deep-sea thermal vents and mid ocean rift valleys.)

AP Biology

Transition of Life from Aquatic to Terrestrial Biomes

(Associated Learning Objectives: 1.15, 1.16, 2.2, 2.15, 2.16, 2.21, 2.22, 2.23, 2.27, 2.28, 2.35, 2.36, 2.39)

Important concepts from previous units:

- 1) All life forms are mostly water; therefore, they are affected by sunlight intensity.
- 2) Water helps regulate the temperature of the Earth; as well as, for most life forms.
- 3) Gene expression is involved in all organisms' developmental processes and is controlled by enzymes.

I. Sunlight and Ecosystems

A. Sunlight is the ultimate source of energy and warmth for earth.

1. Sunlight is used to power photosynthesis by producers; as well as, keep the Earth warm enough to support life.
2. Sunlight intensity is a major force behind the types of Biomes/ Ecosystems found on Earth.
 - a. The intensity of sunlight, mixed with the wind patterns of Earth, can be seen in the Hadley cell models.
 - i. Light intensity is greatest at the equator – causing massive evaporation of water from the oceans and life forms.
 - ii. Light intensity lessens as you approach the poles- very little evaporation.
 - iii. Tropics (23.5°) are deserts due to high light intensity and little water availability and high evaporation.

II. Sunlight, temperature, and water regulation in plants

A. Plants require sunlight and water to power energy production in the process of Photosynthesis.

1. The process of photosynthesis yields the energy storage macromolecules of carbohydrates.

B. Sunlight is also responsible for “directing” plant growth.

1. Plants release the hormone Auxin in the Apical (tip) meristems of shoots.
 - a. The Auxin travels down the “dark” side of the plant and thus stimulates those cells to elongate at a greater rate than the “light” side. This *unequal* growth causes the plant to bend, by growth, toward the light for maximum light exposure in the leaves. This growth is referred to as **phototropism**. (“photo” means light; “tropism” refers to a turning movement of growth in response to a *stimulus*.)
 - b. This was first determined in an experiment by the naturalist Charles Darwin.
2. The *absence* of sunlight (darkness or nighttime) is responsible for flowering in plants.
 - a. Flowering is determined primarily by genetics and protein/enzyme activation.
 - b. These proteins, called **phytochromes**, essentially act as biological “clocks” for telling time.
 - i. Sunlight causes a shape change in the protein. (Cell Signaling again!) This shape change allows for the activation of Transcription and Translation of genes associated with making leaves into flowers by adding different light wavelength (color) *reflecting* pigments to the cells.
 - ii. **Long night flowers** – require *long, uninterrupted* periods of night to flower, such as seen in the fall and winter.
 - iii. **Short night flowers** – require *short* periods of night to flower.
 - iv. The duration of night needed to flower is referred to as the **critical limit**.

C. **Transpiration** (water loss through the **stomata**) is regulated by the **guard cells**.

1. The **guard cells** are controlled by phytochromes and Potassium ions (K⁺) movement.
 - a. Potassium is moved by *active transport* and water *follows*.
 - i. Potassium is *pumped in* to the guard cells; they swell because of water and open the stomata.
 - ii. Potassium is *pumped out* of the guard cells; they go flaccid and the stomata closes.
2. The stomata *must be open* to allow CO₂ in to the leaf for photosynthesis to occur.
3. So it becomes a *battle* to control water loss versus CO₂ intake for photosynthesis for land plants.
 - a. Remember the C₃, C₄, and CAM plants. These are related to the types of environments and water availability for photosynthesis. Then think about food chains and life forms found in each environment. It is *all* related... light, water, and life.

4. Transpiration rates are influenced by light intensity, wind, and humidity (moisture in the air).

III. Sunlight, temperature, and water in animals

- A. Water loss by animals is also in need of regulation. This is referred to as **osmoregulation**. This is part of **homeostasis** (maintaining a *stable* internal environment). Homeostasis *requires* tremendous amounts of energy.
 1. This water loss could be from sweating, panting, breathing, and also waste removal (solid or liquid).
 2. Removal of Ammonia (NH₃) is essential to ward off death, but *requires* use of water. Ammonia is a byproduct of using amino acids in Cellular Respiration by **deamination**. It is removed from the body by the excretory system.
 - a. Fish release the Ammonia directly into the water.
 - b. Other animals *must use* water to convert the Ammonia to either Urea or Uric acid. This allows it to be stored and removed easily without causing death.
 - i. Mammals and Amphibians use Urine, a *diluted* form of Urea, for waste removal. It also contains excess salt and other waste.
 - ii. Uric Acid is a paste-like substance (saves water) released by reptiles and birds.
 3. Sweating or panting may be used to *cool* the body off during periods of *extreme heat*.
 - a. Water from the body is used to remove heat. Remember, water acts as a heat “trapper”, therefore it can be used to remove *excess* heat *quicker*.
 - b. This “warm” water is moved to the surface and released. The wind (air movement) removes the water as it evaporates. This is referred to as **evaporative cooling**.
 - c. Animals that generate heat from their *internal metabolism* are referred to as **endotherms**.
 - d. Animals, such as reptiles, *conform* their body temperature to the *surrounding environments*. They are called **ectotherms**. (“ecto” means outer). They would not need to sweat. This *saves water*. Most of these are found in very warm environments, such as deserts
 4. During periods of cold, temperature is control by **counter-current heat exchange**. This uses the water in the circulatory system to help *transfer* heat from the internal body coming out in arteries to *inward flowing* blood in veins. The heat is transferred; not the water. Remember, water can *absorb* heat. Metabolism and shivering can *also* help increase body temperature.
 5. Controlling heat within an organism is referred to as **thermoregulation**. The structure in the brain that controls temperature is the **Hypothalamus**.
 6. *Moist* surfaces such as fish gills, amphibian skin, or internal lungs are *required* for gas exchange (CO₂ and O₂) to be possible. This causes land-based animals to *lose* water as they respire (breath).

AP Biology
Behavioral Ecology – Part 1

(Associated Learning Objectives: 1.1,1.2,1.15,1.16, 2.1,2.2, 2.4, 2.19, 2.21, 2.23,2.24,3.40, 3.41, 4.15)

Important concepts from previous units:

- 1) DNA is responsible for being the “blueprint information” for making proteins and enzymes.
- 2) Enzymes and proteins are the *workhorses* within cells.
- 3) Energy is *necessary* to carry out all cellular processes except osmosis or diffusion (passive transport).

I. Organismal Behavior (What an organism does and how it does it basically.)

- A. Behaviors *evolve over time* based on awareness and survival benefit.
- B. Organisms are 50% genetics and 50% experiences. (This is the nature vs. nurture argument.)
- C. Behavior can be *influenced* by an organism’s interactions with other organisms.
- D. Outward behaviors (are observable) vs. inward behaviors (are the results of learning mainly).

II. **Innate Behavior** – These are behaviors that an organism is *born with*. (Behavior is coded *in the genes* - DNA.)

- A. It is said to be *developmentally fixed*. This is because development is *governed* by the genes *inherited*.
- B. The behavior is *the same* among all members of the same species. (Babies crying when hungry or Dogs barking.)

III. **Ethology** (A.K.A. Behavioral Science)

- A. The science concerned with *how an organism behaves* in its natural environment.
- B. **Fixed Action Potential** (FAP’s for short.)
 1. This is a behavior, that once it is initiated, it *must* be carried through to some *fixed conclusion*.
 2. It is initiated by a *trigger “sign” stimulus*.

For example: Cardinal attacking red crate paper near it’s nest. (trickery)
Moth hit by bat radar plays dead to avoid capture.
Baby hand grasping an object put in it’s palm.
 3. Survival? (Organisms that *survive* get to *reproduce* and *pass on those DNA traits* to the gene pool.)

IV. **Behavioral Ecology**

- A. The study of behavior as it relates to *evolving* within an environment.
 1. *Natural selection* plays a huge role in these behaviors evolving.
 - a. Different *rates of reproductive success* due to behavior. (Good behavior vs. harmful behavior?)
 - b. Strong traits *survive and reproduce* more to make more offspring with those good traits.
 - c. Weak individuals *die off* weeding out the genes that were “weak” or not beneficial.
- B. **Foraging** (Organisms Finding food)
 1. **Optimal foraging theory** (This is basically a *cost analysis* of energy input vs. energy yield.)
 2. Crow and Welk experiment

Basically Crows that *learn* to drop the welk from 5 m get the most energy out of their food vs. energy input (Flight). Those that go below 5m will have to expend more energy by more flights to crack the welk. Those that fly higher are also *wasting* more energy than need be.
 3. Reproductive fitness and Energy? (Those organisms that save energy on foraging will mostly use that *saved* energy in reproducing. So most fit genes get passed on the most.)
 - a. “Positive” learning is rewarded and promoted by natural selection.

AP Biology
Behavioral Ecology – Part 2

(Associated Learning Objectives: 1.15, 1.16, 2.1, 2.2, 2.19, 2.21, 2.22, 2.24, 2.37, 3.40, 3.41, 3.42, 4.15)

I. **Learning** – A *modification* of behavior resulting from *past* experiences.

A. Usually the behavior gets better with practice or bad behavior is avoided.

Examples; Public speaking or putting your hand on a red stove eye.

B. It is a higher, more complex brain function.

C. Social *confirmation* influences the behavior sometimes. (Good vs. bad and social outcomes?)

II. **Maturation** – This term refers to *developmental changes* (physical or mental) that occur with age.

III. **Habituation** – Behaviors that occur even though the organism *doesn't realize* it is occurring because it is so *routine*.

A. Bad vs. Good → survival (Good behavior usually *promotes* survival and reproduction.)

IV. **Imprinting** – This refers to learning that occurs during a *critical/sensitive time period* of development.

- It is *permanent*, in that once it is learned it is not forgotten because it is associated with survival.

A. Ducks recognizing their mother or bird's learning their species specific song.

V. **Associative Learning** – This refers to learning that is *associated with some kind of stimulus*(good or bad).

A. Two types occur:

1. **Classical Conditioning** (Repeating of the stimulus...Pavlov's dog experiment.)

In Pavlov's experiment, he would first ring a bell and then the dog's food would appear. He did this several times. Each time the dog would salivate because of the thought of food coming. Eventually, he would ring the bell and the dog would begin salivating even if no food was given. The dog *associated* the ringing with the food.

2. **Operant Conditioning** (Trial and error...Skinner's Box and mice.)

In a Skinner's box experiment, a mouse is put in a wooden box maze. There is a push down lever somewhere in the maze. The lever, when pushed down, opens a door revealing cheese. The mouse wanders through the maze and when it encounters the lever, eventually it may push it down and open the door. Next time it takes smaller amounts of time to decide to pull the lever down to get the food. Eventually it becomes an automatic response.

VI. **Play** (A.K.A. Game Theory)

A. This behavior is to *coordinate and practice* movements needed for survival. (Humans vs. animals?)

B. This can be a tool for teaching proper social behavior. (Winning vs. losing?)

C. Can be potentially harmful too. (A learning experience too. Sometimes play is too rough and injuries occur.)

VII. **Cognition** (A.K.A. Thinking/Problem solving)

A. This is the *second highest* level brain function.

B. **Cognitive Ethology** – A branch of ethology dealing with *problem solving behaviors*.

C. **Cognitive Movement** – Refers to moving through an environment *using* stimulus or signals and "reacting".

1. Various levels of cognitive movement exist:

a. **Kinesis** (simplest) – A change in behavior due to stimulus. (Yelling stop to a child to stop.)

b. **Taxis** – A moving toward (+) or away from (-) a stimulus.(Fish orienting to river flow direction.)

c. **Landmarking** -This involves *spatial* learning. (Like using road signs while driving.)

- d. **Cognitive Mapping** – This is movement involving *thinking*. (Treasure Map Game)
- e. **Migration** – This is movement based on *environmental cues*. (Regular vs. seasonal?)
 - (Regular migration would be like humans moving into areas for work, etc.)
 - i. Three types of migration can be exhibited by animals:
 - α. **Piloting**- These are *short trips* to a specific point such as a specific landmark.
(Squirrels looking for their buried food reserve.)
 - β. **Orientation** – These are *long trips* using points of reference to position.
(Magnetic fields, stars or sun & Old time sailors, birds, and salmon)
 - γ. **Navigation** – These are *long trips* using landmarks and orientation.
(Migratory birds, humans going cross-country on vacation.)

VIII. **Consciousness** – This is the interpretation of many stimuli *and integration* with past experiences and outcomes.

- A. Basically it is knowing right from wrong. (Involves morality and ethics. Example: performing a cost benefit analysis in your head about cheating on a test.)
- B. This is the *highest* level of brain function.

AP Biology
Behavior Ecology – Part 3

(Associated Learning Objectives: 1.15, 1.16, 2.1, 2.2, 2.24, 3.40, 3.41, 3.42, 4.11, 4.13, 4.15, 4.18, 4.19, 4.20, 4.26)

Important concepts from previous units:

- 1) Signals (ligands) can be chemical or visual.
- 2) Signals initiate a process that eventually leads to a response.

I. Social Behavior – This behavior involves the *interactions* that occur between individuals within a given area.

A. Examples: Aggression, Competition, Courtship, or Cooperation.

II. Sociobiology – The study of *social behavior* as it relates to evolution.

A. **Cooperative Behavior** – Groups get advantages over other organisms by working as a team.

B. **Agonistic Behaviors** – These are tests of strength and aggression. (Rams butting heads or Lion King movie.)

1. Fighting is followed by *submission/reconciliation* behavior or even death.
2. Rituals performed by native tribes.

C. **Dominance Hierarchy** (A.K.A. “Pecking Orders”)

1. Alpha, Beta, Gamma, → Omega (Alpha gets first rights at resources, then Beta, etc.)

D. **Territoriality** – This is defending a given area. (Example: Male Lions defending their area and “family”.)

1. Reasons for this behavior include food, mating, or water. (Usually something that is *limited*.)
2. Small number of niches leads to number control.

F. **Courtship** (“dating” or “mating rituals”)

1. Performed to I.D. a potential mate vs. competition or threat. (Snakes looking for food or to mate.)
2. To assess *parental investment* of mate in *helping* to raise offspring.
 - a. Involves competition *between* possible mates. (*Intersexual* competition – usually females chose.)

(Example: Male birds displaying their colors: female chooses the winner.)

3. **Promiscuous** – This is many mating with many. (Advantages/disadvantages?)

ADV: increases relative fitness. DIS: Not much investment in parenting. (Survival is low.)

a. **Fitness** – the number of offspring an individual produces in their lifetime.

4. **Monogamous** – This is one mating with one. (Advantages/disadvantages?)

ADV: Increases parenting and survival. DIS: Lower fitness.

5. **Polygamous** – This is one mating with many. (Advantages/disadvantages?)

ADV: Strongest genes passed on. DIS: Not much variation in terms of genetics.

a. **Polygyny** (means “many females”) – This is one male with many females. (A harem.)

b. **Polyandry** (means “Many males”) – This is one female with many males. (Queen bees)

III. Signals – These are behaviors that cause a *change* in another organism’s behavior.

A. The signal conveys communication. (Visual, auditory, pheromones, tactile [touch] are examples of signals.)

1. Round dance of bees – This indicates location of food that is *less than* 50m away.
2. Waggle dance of bees – This indicates location of food that is *greater than* 50m away.

IV. Altruism – This is the *unselfish* behavior that is for the benefit of all. (Worker bees supporting the whole colony.)

A. This can be influenced by *kin relationship*. (“Blood is thicker than water.” Which means we are more apt to help a blood relative before helping a stranger.)

AP Biology
Population Ecology – Part 1

(Associated Learning Objectives: 1.2, 2.2, 2.22, 2.24, 4.11, 4.12, 4.13, 4.14, 4.15, 4.19, 4.20, 4.21, 4.27)

- I. **Population Ecology**
 - A. This field of Biology deals with *species* populations and the population's *environment*.
 - B. A **population** is the same species, same time, same place, and showing signs of reproduction.
 - C. The human population will soon be over 7 *billion* people on Earth.
 - D. It mainly focuses on **Density** (number of organisms in a *given area*) and boundaries.
 - 1. Man made boundaries or natural boundaries exist.
 - E. **Dispersion** – This term refers to *where* within the boundaries are the organisms located.
- II. Measuring Density
 - A. **Mark-Recapture Method**
$$N = \frac{\text{\#Captured and marked in first group} \times \text{total of second group that is caught}}{\text{\# Recaptured from first time}}$$

N is the estimated population size for that defined area.
- III. Patterns of Dispersion:
 - A. **Clumped** – This usually results from a need for nutrients, mating, or employment. (Humans?)
 - B. **Uniform** (evenly) – This usually results from territoriality or favorable environment.
 - C. **Random** – There is no apparent reason seen in the dispersion pattern.
- IV. **Demography** – The study of population sizes and distribution.
 - A. **Growth** – This occurs by birth or immigration (to enter into a new area).
 - B. **Decline** – This occurs by death or emigration (to exit an area).
 - C. **Life Tables**
 - 1. Provides Age Specific Traits for cohorts (individuals of the same age or demographic).
 - 2. These are expensive and time consuming to produce. (Like the U.S. census.)
 - D. **Survivorship Curves**
 - 1. Three basic types of curves can exist in nature:
 - a. **Type I** (Many young → numerous middle → few old) (Type of environment?)
This environment favors the young and usually indicates that the environment is favorable. These organisms are usually at the top of food chain and there seems to be *extensive parental care and energy investment*.
 - b. **Type II** (*Constant* decline) (Type of environment?)
This indicates that the environment is relatively favorable but the organism may be a food source for another organism. The parental cares is modest.
 - c. **Type III** (Many young → few middle → very few old) (Type of environment?)
This indicates a *harsh* environment because most of the young die at an early age. This indicates that they are a food source that is low on the food chain as well as have *practically no parental investment*. Young are left to fend for themselves.
 - E. **Reproductive tables**
 - 1. These tables are only concerned with *females of reproductive age or possibility*.
These are the only *real* individuals who will be able to impact a population size since it is the female who provides the birth. (Low # of females indicates a threatened or dying population; High # indicates a thriving population.)

AP Biology
Population Ecology – Part 2

(Associated Learning Objectives: 1.2, 2.2, 2.22, 2.24, 4.11, 4.12, 4.13, 4.14, 4.15, 4.19, 4.20, 4.21, 4.27)

Important concepts from previous units:

- 1) Traits within cells or organisms are directly associated with inherited DNA (genes).
- 2) DNA is inherited from the parents by fertilization occurring between a sperm and egg. (Sexual reproduction)
- 3) Positive feedback loops *enhance* a process that is *already* in action.

I. Life Histories

- A. A life history can tell a lot about a species' *fitness*.
- B. Traits needed for survival in a particular environment can be determined.
- C. Two types of life histories can typically be seen:
 1. **Semelparity** (Big Bang) – Reproduce *one time with huge numbers* of offspring. Organism usually dies after reproducing, so it went out with a *Big Bang*. Tremendous amounts of time, energy, and resources *invested* in making numerous offspring. This type of history usually indicates a harsh environment and low survival rates. (Examples: Salmon or Century Plant)
 2. **Iteroparity** - *Repeated* Reproduction year after year. (Applies to most organisms usually.) This history indicates a *favorable environment* and good survival rates. Modest time, energy, resource investment are required.
 3. Environmental Conditions and survival rates?
 - a. Environment is *directly* related to time, energy involved, and resources available.
 - b. *Compromises* (When, how often, how many?)(Natural selection?)
Natural selection is very obvious with Semelparity...strongest survive.
Natural selection with Iteroparity is directly related to competition.

II. Population Growth Models:

A. **Exponential Growth Models** (“*Ideal*” Growth)

1. Involves **r-selection species**. (r - think rapid growth.)(A.K. A. **Density – independent**)
There population size is related to resources, *not number* of organisms.
2. Produces a **J curve graph**.
3. Environment has *unlimited resources*. (Good for ideal growth.)
4. Occurs mainly in a *new* environments and involves **pioneer species** such as bacteria, lichens, and mosses as they are the *first organisms* to colonize the new environment. (This is in areas that are just formed like Hawaii was millions of year ago. Hawaii started as barren rock, until the pioneers arrived and began to make soil. The soil enabled plants to grow. The seeds of the plants arrived in the bird dropping of birds that stopped while migrating to feed on the mosses and lichens. Larger plant roots sped up soil formation to allow for larger plants.)
5. $\Delta N/\Delta t = B - D$ (Means *change* in population is equal to births – deaths in that time.)
= (bN) – (dN) (birth *rate* – death *rate*) (This is equal to rN.)
= rN ; r = b – d (If r is positive = growth greater; if r is negative = death greater.)
6. **ZPG** (Zero Population Growth ; r = 0)
7. **Intrinsic growth** = $r_{\max}$ (Population is growing as fast as possible/doubling. This is seen as the curve begins to make a straight up curve.)

B. **Logistic Growth Model** (“*Realistic*” growth)

1. Involves **K-selection species usually**. (K refers to a population that is *hovering* around the **carrying capacity**, “which is represented by “K”.) (**Density – dependent**)
These species numbers are *about number* because there *are limited resources* because the species is near the *carrying capacity* for that environment.
2. Produces an **S curve graph**. (“Snakes” around the carrying capacity line.)
3. Environment has *limited resources*; that is why organisms stay around the K.
 - a. More organisms than K, means damage *will* be done to the environment.
 - b. More damage done to environment can cause K to drop *even farther*.
This can be an example of a *positive feedback loop*.

c. Wars, disease, and famine breakout in a population to bring numbers down below K.
(*Extinction* is possible? → depends on damage to environment and K.)

4. $dN/dt = r_{\max} N (K-N/K)$ (As a population “N” approaches K... K-N approaches zero.)
Meaning when K- N is equal to 0 you are at the carrying capacity for that environment.
When K- N becomes 0, the whole equation becomes 0.
Before this time, a population is experiencing exponential growth so you have r maxed.
5. **Lag time** - This accounts for the *overshoot*. It takes *time* to begin to see the effects.
(So the line goes above K and this is when death, war, disease, and famine accelerate.)
6. **Allee effect** –This situation occurs when you have a small number of organisms.
This low number causes inbreeding to occur and then this results in *no variation*
for a gene pool. This then leads to increased genetic diseases that can be lethal
to accumulate in the already small population and then the population enters
what is referred to as the “Extinction Vortex”. It is *extremely* difficult to break
out of the vortex. (Like a black whole of extinction.)

AP Biology
Population Ecology – Part 3

(Associated Learning Objectives: 1.2, 1.3, 1.5, 2.2, 2.3, 2.22, 2.23, 2.24, 2.28, 4.11, 4.12, 4.13, 4.15, 4.16, 4.19, 4.21, 4.27)

- I. Population **Limiting Factors:** (All *can* limit a populations size... could even be more than one at a time.)
 - A. Resources (This can be food, water, or space...if it is a territorial species.)
 - 1. Competition rises as resources become scarce, *draining energy* away from reproduction.
 - B. Health conditions (Such as crowding and disease.)
 - C. Predation by another species.
 - D. Intrinsic Factors (Such as aggression, stress, or personality issues with humans.)
 - E. Carrying capacity for the given environment.

- II. **Boom-Bust cycles** of Growth (This describes a Predator/Prey relationship mainly.)
 - A. Shows the *lag-time* for other species to *adjust* to a change in a species population number.
 - B. The two population “lines” are chasing each other because of their direct relationship.
 - C. This relationship also promotes natural selection as it will be the strongest that survive and reproduce... so each species is causing the other to evolve... which is referred to as **co-evolution**.

- III. Human Population growth pattern:
 - A. The population explosion that *is* occurring has changed the dynamics of Earth tremendously.
 - 1. Environmental degradation and over-consumption of resources *is* occurring.
 - 2. Species loss (extinction) *is* occurring at a fast rate.
 - 3. Overpopulation is being seen in India, China, and some other Island nation.
 - B. Ethics/Freedom/Control
 - 1. China and India and United States, for examples.
China has imposed laws to get control of birth rates. (These can be found on the internet.)
India has not *yet* imposed laws, but is seeing resource issues currently.
The U.S. is not near the size in population as China or India ; but the United States uses *most* of the world’s resources; which is an issue for China and India and the rest of the world.
 - C. Human Growth History
 - 1. The human species started as a Hunter gathers society. (They were Nomads.)(Energy?)
Their energy mainly went toward *following* the food so little was left for reproduction. (They were basically too tired and health issues also drained energy.)
 - 2. Agricultural Revolution and the plow
With the invention of the plow, more food and not having to travel *increased* health and energy reserves. These could be put toward reproducing... so the population begins to climb. This also leads to the formation of towns and villages.
 - 3. Industrial Revolution
This help lead to cities because now everyone didn’t have to produce their own food, it could be grown in the countryside and trucked into the city for sale. Also this allowed for an increase in reserve energy to put toward reproduction. Also health care improved for most people.
 - 4. Technology Revolution and Medicine
Better health causing people to live longer now and survival of babies increases. Women, in general, are having more children because families are becoming more affluent. Technology, while mostly good for society, makes most people less active and puts even more energy toward reproduction and obesity.
 - D. **Age Structure pyramids**
 - 1. These can show the number of individuals at each *age group* (**cohorts**).
 - 2. These can be used to identify current trends/problems. (Life expectancy or Infant mortality.)
 - 3. Can be used to identify future trends/problems.
More elderly and less young to support them or future unemployment for example.

AP Biology
Community Ecology – Part 1

(Associated Learning Objectives: 1.2, 1.3, 1.5, 2.1, 2.2, 2.3, 2.4, 2.9, 2.21, 2.22, 2.23, 2.24, 2.28, 4.11, 4.12, 4.13, 4.14, 4.15, 4.16, 4.18, 4.19, 4.21, 4.25, 4.26, 4.27)

Important concepts from previous units:

- 1) Producers are responsible for providing available energy, in the form of sugars, for the food chain.
- 2) Consumers eat the producers to obtain the energy found in their biomass.

- I. **Community** – The term refers to a collection of *interacting* populations within the same given area.
 - A. **Species Richness** – Refers to the number of *different* species within a given area.
 - B. **Relative Abundance** – Refers to the population *size* for each species within that given area.
 1. Rare – few exist; common – many exist
 - C. **Rivet model** is the best way to explain the interaction among species (A.K.A. Food web model.) It basically is stating that every species is important in the proper functioning of that ecosystem. If you start removing species (extinction) from the system (what we commonly call a food web), it is like removing a rivet from an airplane. It damages the *whole* system. The more you remove, the more damage done. At some point, you have removed so many that the whole system collapses...the plane crashes killing all or most.
- II. **Interspecific Interactions** (These are *between* two different species.)
 - A. **Competition** (-); (-) It is considered a negative- negative relationship.
 1. Competition exists because a resource is in small supply.
 2. Active competition *drains energy* away from reproduction. So populations are small.
 3. **Competitive exclusion model** - States each species has it's own niche in an environment.
 - a. Two species *cannot* occupy the *same* niche... So one is *excluded* from getting the resource.
 - b. **Resource partitioning** (dividing) occurs due to displacement. This can cause evolution to proceed faster – such as occurred with Darwin's finches of the Galapagos. The “excluded” species has three basic options: 1) Leave the area to look elsewhere for the resource. 2) Die off. or 3) Find a replacement resource. (This promotes evolution.)
 - B. **Predation** (+); (-) Considered a positive – negative relationship.
 1. Normal predation (Carnivore or Omnivore eats an herbivore.)
 2. **Herbivory** - Eating plants. (Also considered predation...since they are a different species.)
 3. **Parasitism** – Death does not occur; but *harm* is done to another species.
 - a. Three types occur 1) **Ectoparasites** – These attack from the *outside*. (mosquito)
 - 2) **Endoparasite** – These attack from the *inside*. (tapeworm)
 - 3) **Parasitoidism** – Insects *laying eggs* on a host that will eventually become food for the larva. “oid” means “like” It is like parasitism in that there is still harm, but it is the larva (secondary) causing the harm and not the insect (primary) that laid the eggs.
 4. Adaptations for being a predator – claws, teeth, poisons, fast locomotion, muscular (All help kill.)
 - a. Self defense adaptations against predators – long legs, faster, flight, horns, coloration, very good smell
 - i. **Cryptic coloration** – camouflage (like encryption)
 - ii. **Aposematic** (warning) **coloration** – bright colors, like reds or oranges
 - iii. **Mimicry** – **Batesian type** – A harmless *looks like* a harmful organism. This becomes an **associative learning** exercise for the attacking species. They become very scared to attack organisms that look similar to that bad experience. This increases survival rates for the mimickers.
 - **Müllerian type** – A harmful looks like *another harmful*.
 - C. **Mutualism** (+); (+) Considered a positive-positive relationship.
 1. This relationship *promotes co-evolution*, but remember that co-evolution can either be good or bad, such as the predator/ prey relationship... it is co-evolution too.

D. **Commensalism** (+); (0) Considered a positive- no effect relationship.

1. Few exist in nature and it is hard to see if there is no reciprocal effect.

III. Community Control Models – Essentially what factor is *controlling* the species composition in an area.

A. **Bottom Up Model** (Nutrients in the soil determine community composition...most cases in nature.)

1. Nutrients → Plants → Herbivores → Predators

B. **Top Down Model** (Predators determine the community composition.)

1. Predators → Herbivores → plants → Nutrients

AP Biology
Community Ecology – Part 2
(Associated Learning Objectives: 1.2, 1.3, 1.5, 2.3, 2.22, 2.23, 2.24, 2.28, 4.21, 4.27)

- I. **Stability** – A community at *equilibrium*. Very little disturbance/change occurs over time.
- II. **Non-equilibrium Model**
 - A. *Periodic* disturbances occur *altering* the environments species composition over time.
 - B. Examples of disturbances: Fire, flood, drought, human actions, storms, or hurricanes/typhoons.
 - C. These help create *new possibilities* in an environment by opening up new niches.
- III. **Ecological Succession** – Change in community composition due to time and disturbance.
 - A. Two types can occur within environments:
 - 1. **Primary Succession** – This is “starting from scratch” using pioneer species – lichens and mosses.
 - a. Hawaii going from barren volcanic rock to lush, tropical island.
 - b. Pioneers make the dirt needed for the plants & birds bring seeds in their feces as they feed upon lichens.
 - c. Lichens → grasses → bushes → gymnosperms → hardwood trees → Climax
 - d. **Climax Community** – Hardwood forest exists all over.
 - 2. **Secondary Succession** – This is “starting over at the grasses level” not from scratch.
(Such as the farming of fields to grow crops.)
 - a. Dirt already exists
 - b. Grasses → bushes → Gymnosperms → hardwood trees → Climax
- IV. **Biodiversity**
 - A. This measurement includes **Species Richness** and **Relative abundance** in the calculation.
 - 1. Primarily looking at the degree of Heterogeneity (difference).
 - B. Size and Location of an environment
 - 1. Large Area – Usually means more species.
 - a. More habitats and niches present → therefore more species can exist.
 - 2. Equatorial → Polar gradient (Going from equator to north or south pole.)
 - a. *Less biodiversity* the farther north or south you get from equator.
 - b. Temperature and seasons, sunlight for photosynthesis, water availability all change toward a more harsh environment the closer you get to the poles.
 - c. Equator → It is summer ALL year... so more plants and animals.
 - d. Poles → Winter ALL year... so less plants and animals.
 - e. Above the tropics → Seasonal changes occur over the year.
 - f. Tropics → desert (More plants and animals in the tropics versus the desert.)
 - 3. Islands Biodiversity (Defined by E. O. Wilson – 1960’s – He is a native of Alabama.)
 - a. Size of Island (Big – usually has much biodiversity; Small usually has less.)
 - i. **Pygmism** – Smaller sizes exist on some islands due to smaller environment.
(Smaller amounts of resources tends to lead toward the evolution of smaller organisms and populations.)
 - b. Location of island in relation to mainland: Close – less variation; far – more variation exists.
 - i. Similarity of the environments is greater if the island is closer to the mainland.
 - c. Amount of disturbance can also affects the biodiversity. If there is recurring, frequent disturbances there will be less biodiversity. A calmer environment promotes progression and evolution.

AP Biology
Ecosystems Ecology – Part 1

(Associated Learning Objectives: 2.1, 2.2, 2.3, 2.9, 2.22, 2.23, 2.24, 2.28, 4.11, 4.12, 4.13, 4.14, 4.15, 4.16, 4.19, 4.21)

Most of this information is important review material.

I. **Ecosystems** – Refers to all the *interacting* communities within a given area *plus* the abiotic factors affecting it.

A. Abiotic factors mainly deal with *energy flow, nutrient cycling, temperature, and water*.

II. **Trophic levels** (A.K.A. feeding relationships) within an ecosystem and energy flow:

A. **Primary Producers** - Organisms that can perform photosynthesis or chemosynthesis.

(A.K.A. **Autotrophes** – “Auto” means “self”; “Trophe” means “feeding”)

1. These organisms take the inorganic and *convert* it into organic energy molecules. These molecules will then be *available* to other organisms through the food chains.

B. **Consumers** (A.K.A. **Heterotrophes** – “hetero” means “different”)

1. Different levels can exist, such as: 1’ (primary), 2’ (secondary), 3’ (tertiary), 4’ (quaternary), etc.

2. Primary consumers (1’) feed upon producers. Secondary consumers feed upon primary consumers. Tertiary feed upon secondary and so forth upon the chain.

C. **Decomposers** (A.K.A. **Detritivores**) – These organisms feed on *dead* organic material called **detritus**.

1. They take dead decaying organic material (detritus) and convert it back to the inorganic state for *recycling* and use by the primary consumers.

D. **Law of Conservation of Energy (E) and Second Law of Thermodynamics**

1. Energy is neither created, nor destroyed... just transformed or transferred. (Law of Conservation)

2. All E proceeds *toward* a state of **entropy** (disorder) with *each* transfer. (Law of Thermodynamics)

a. All E enters Earth as Sunlight. (This is *high* quality E with a low degree of entropy. It is *highly organized* and *can* perform work such as powering photosynthesis or splitting water.)

b. All E leaves as heat. (This is *low* quality E with a high degree of entropy and *cannot* perform work.)

3. The **10% rule** applies from trophic level to trophic level. The 10% rule states that roughly 10% of the energy from one trophic level will be *available* to fuel the next trophic level in the food chain. 90% is *lost* in the actual keeping alive of the organism (80%) and also waste (10%). The energy that was used to keep the organism alive was ultimately converted to heat energy and released to the environment.

E. Nutrients are *recycled* in ecosystems. (This is the **Law of Conservation of Matter**.)

1. Matter is neither created, nor destroyed...just transformed or transferred.

III. **Primary Production** – Refers to the *total* amount of solar E *converted* to chemical E by photosynthesis by producers.

A. **Global E budget** - This refers to the amount of E that the earth uses for the process of photosynthesis.

1. *Only* 1 % of solar E is *used* to power photosynthesis, but it *makes 170 BILLION tons of sugar/year*.

2. 99% of solar E is absorbed by water or reflected back into space/atmosphere by water/ice.

3. This reflected E contributes to the Greenhouse effect and helping the temperature of Earth rise.

4. The absorbed E by water will be released at night to help keep the unlighted side of Earth warm.

B. **Gross Primary Production (GPP)** – This is the amount of chemical E *produced before any use* by those autotrophic organisms that made it over a certain period of time.

C. **Net Primary Production (NPP)**

1. This is the amount of **E left** after self-preservation (R) of those autotrophs occurs.

- a. Self- preservation includes items such as Cellular Respiration, Homeostasis, growth, repair.
- b. NPP is the E that will be available to the next trophic level; usually 10 %. (The 10% rule.)

2. $NPP = GPP - R$

D. Biomass – This is the *dry* weight of the material of life. (It is mostly in the form of proteins.)

IV. Eutrophication – The “choking off” of Oxygen from a body of water due to a thick algal bloom covering the surface of the body of water. This in turn can kill the plants, animals, and fungi living in the water below the surface.

A. Cultural Eutrophication- This is the result of *sewage and fertilizers* (P mainly, N, or K) being put into the body of water by runoff or dumping.

1. The book *Silent Spring* by R. Carson talked extensively about this problem and the effects of it on the environment. The book was written in the 1960's but it's principles are still important today.

V. Production Efficiency

A. This is a *comparison* between the amounts of E *used for respiration* verses the amount of E *assimilated* (turned into) into biomass by the organism. (It is maintenance vs. growth essentially.)

B. Production Efficiency = Net secondary production (biomass)/ Net Assimilation of all E used and stored.

C. Birds are about 1-3 % efficient; Humans are about 10% efficient; Insects are about 40% efficient – This is why they are the most numerous animals on earth. They have lots of E to put towards reproduction.

VI. Pyramids of Production (A.K.A. as E Pyramids) These demonstrate the 10% rule of energy between trophic levels. The producers are at the bottom producing the sugars of photosynthesis. All above the producers, on the pyramid, are the consumers. These usually measured in some unit of energy, usually joules.

VII. Pyramids of Biomass - These, remember, are based on the total *dry* weight of the trophic level. In terrestrial (land systems), the producers usually outnumber, in biomass, the consumers trophic levels. This creates the traditional shaped pyramid. In aquatic (water systems) such as the open ocean, the producers (phytoplankton) maybe outnumbered by the consumers such as whales and large fish. This creates an *inverted (upside down)* pyramid.

VIII. Pyramids of Numbers - These are created using population numbers. The producers outnumber the consumers. There will be less secondary consumers when compared to primary consumers. Each higher level in the pyramid will have fewer numbers because of the ten percent rule limiting the energy available to support life.

AP Biology
Ecosystems Ecology – Part 2

(Associated Learning Objectives: 2.8, 2.9, 2.22, 2.23, 2.24, 2.28, 4.16)

Most of this information is important review material.

I. **Biogeochemical Cycles** (“Bio” means “life”; “geo” means “earth”) These refer to the *cycling* of matter.

- A. **Water cycle** – Water vapor is created by the sun causing evaporation of the bodies of water such as oceans and lakes. This water vapor is carried by the winds to almost the whole world. It condenses in the air to make rain or snow (referred to as precipitation) and is returned to the land or ocean. Eventually the water that lands on land, makes its way to plants or rivers and streams that lead back to the oceans. Plants take in the water and use it for photosynthesis but also can lose it in the form of transpiration to the air.
- A. **Carbon Cycle** - Carbon dioxide (CO_2) is *removed* from the air by photosynthesizing organisms such as plants, phytoplankton and bacteria. They use the Carbon dioxide to aid in the development of sugars during photosynthesis. These sugars, which contain the Carbon ($\text{C}_6\text{H}_{12}\text{O}_6$) are then passed from organism to organism through the food chain. All organisms then release the Carbon, in the form of Carbon dioxide, by performing the process of Cellular Respiration in their cells. The burning of plant materials, natural gas and fossil fuels, which are the remains of dead life forms such as dinosaurs and pre-historic forests, puts Carbon dioxide back into the air as well.
- B. **Nitrogen Cycle** - The majority of Nitrogen is *removed* from the air by water. Remember, water is the universal solvent, so the gas is dissolved in the rain or snow. The Nitrogen in the water mainly is consumed by **Nitrogen Fixing bacteria**, in the soil, that convert it into Ammonium (NH_4). This process is referred to as **Nitrogen Fixation**. The Ammonium can then be *absorbed* by plants to help make proteins and DNA or RNA. Some Ammonium (NH_4) in the soil is also consumed by **Nitrifying Bacteria**, and converted to Nitrite (NO_2) first and then ultimately into Nitrate (NO_3). This process is called **Nitrification**. The Nitrates are also *absorbed* by the plants, just as was the Ammonium. (The plants *ate* the Nitrates and Ammonium, but not the Nitrites.) Some other bacteria in the soil can also eat the Nitrates. These are called **Denitrifying Bacteria**. They consume the Nitrates and break it down into Oxygen gas (O_2) and Nitrogen gas (N_2) and both are returned to the air to be used again. This process is called **Denitrification**. As plants are eaten by animals, the Nitrogen travels through the food chain. When all life forms die, the bodies decompose and create Ammonia (NH_3), which is why they stink. The Ammonia is converted by bacteria into Ammonium to be used again by plants and bacteria. This conversion is called **Ammonification**. Some Nitrogen is also released by animals in their Urine. It too undergoes Ammonification.
- C. **Phosphorus Cycle**- The Phosphorus is initially a component of rock. As the rock breaks down over time, called **weathering**, the Phosphorus is released into the soil. Some dissolves into the water as the rains pass through the soil. This Phosphorus makes its way into bodies of water, such as lakes and oceans, and is available for producers (phytoplankton) to use to help make organic compounds such as phospholipids and DNA or RNA. Plants (also producers) can also retrieve the Phosphorus from the soil and use it to make organic compounds too. When organisms die, decomposers break down the bodies and return the Phosphorus back to the soil to be reused.

E. Temperature affects the cycling rates

1. High Temperature cause *faster* recycling of the chemicals. (Such as in the Tropical Rain Forest.)

2. Low Temperature causes *slower* recycling of the chemicals. (Such as in the Tundra.)

F. Harvesting and deforestation on Nutrient retention? These processes *remove* the nutrients from that area and cause disruption of the cycles to occur. So areas become nutrient poor, thus creating the need for fertilizers to *be added* to replenish the nutrients. (Remember, cultural eutrophication.)

AP Biology
Ecosystems Ecology – Part 3

(Associated Learning Objectives: 2.2, 2.4, 2.22, 2.23, 2.24, 2.25, 2.27, .28, 4.11, 4.12, 4.13, 4.14, 4.15, 4.21)

Important concepts from previous units:

- 1) C3 plants perform the light reaction and Calvin cycle in the same cell.
- 2) C4 plants perform the light reaction in one cell and the Calvin Cycle in the bundle sheath cell.
- 3) Transpiration, through the stomata, is important to control (regulate) by plants at the stomata.

I. Human Impact on Ecosystems

A. Agriculture

1. Harvesting Food - Promotes a *loss* of nutrients from that area.
 - a. Fertilizers (Good in that it replaces or Bad in that it could lead to cultural eutrophication.)
 - b. **Critical Load** - Refers to the *maximum amount* of nutrients that plants can *absorb*.
(The *excess* fertilizer *damages* the ecosystem by promoting **cultural eutrophication**.)

B. Fossil Fuels

1. Burning these can cause **Acid Precipitation** (Remember, It is Rain/snow/sleet/ice with a pH of < 5.6.)
 - a. Sulfur and Nitrogen oxides are the main causes; these are released by burning fossil fuels.
 - b. Effects? It kills plants and **leaches** the soil (nutrients moved away from the roots).

C. Biological Magnification (The buildup of poisons and heavy metals in organisms.) The higher up the food chain you get, the poisons get *more and more concentrated*, which causes health and reproductive problems.

1. DDT and PCB, to name a couple, use has lead to organism extinct, health issues, and polluted water.
2. The book *Silent Spring* by Rachel Carson discusses these in depth.
 - a. This book led to the eventual banning of DDT in the U.S. in 1971.
 - b. The DDT was used to kill mosquitoes, but it was going up the food chain and killing the Bald Eagle populations. The DDT caused the bird's eggs shells to be paper-thin. So when the mother went to sit on the eggs to keep them warm; she ended up crushing them instead.

D. Rising Atmospheric CO₂ levels

1. Deforestation and Fossil Fuels are major sources helping to increase the concentration in the atmosphere. There are no trees to pull CO₂ out of the air and fossil fuels are releasing it.

E. Average daily temperature of the Planet

1. C3 plants (Most are food producing plants.) vs. C4 plants (Few produce food, except corn.)
 - a. C3 plants don't thrive in very warm climates; but C4 will. The warmer it gets, the less food we will be able to grow, which will lead to famine on a larger scale.
2. The Greenhouse Effect and Greenhouse Gases increasing will help raise the Earth's temperature.

F. Ozone Depletion and CFC's (Chloro-fluro-carbons are propellants found in aerosol cans and refrigerants.)

1. *Each* CFC can destroy up to *100,000 Ozone molecules*. (It is a chain reaction or *positive feedback loop*.)
2. Ozone helps block out harmful radiation from the sun, so we don't burn up.
3. Ozone holes in Antarctica and Northeastern Canada exist. These holes are causing ice to melt faster and also causing more health related issues.

F. Species extinction on Earth

1. There is an extinction crisis currently occurring on earth due to over hunting, over consumption, and habitat destruction. As biodiversity disappears, so does the stability of food webs.

AP Biology
Evolution and Darwin's Theory of Natural Selection – Part 1
(Associated Learning Objectives: 1.9, 1.10, 1.11, 1.12, 1.20, 1.21, 1.26, 1.32, 4.20, 4.23)

Important concepts from previous units:

- 1) Traits are the *expression* of nucleotide sequences referred to as genes.
 - 2) Genes are inherited from the *previous generation*; which we refer to as parents.
 - 3) All cells come pre-existing cells is a *central* component of the Cell Theory.
 - 4) Ecosystems are influenced by abiotic and biotic *interactions*.
- I. November 24, 1859 Darwin publishes *On the Origin of Species by Means of Natural Selection*.
- A. This book deals with the biodiversity seen on Earth. It has three main themes:
 1. The *similarities* and *differences* that exists among species.
 2. The adaptations that evolved in species in order to *survive* in an environment.
 3. The geographic *distribution* of species around the world.
 - B. Evolution is a *central theme* to the science of Biology.
 - C. Ancestry and common ancestors among species are discussed throughout the book; thus helping support Darwin's **Theory of Natural Selection**.
 1. Natural Selection and competition are major driving forces to the evolution of species over time. "Nature" decides what species are able to survive the environmental pressures and reproduce within an environment. Those with favorable traits for that environment *survive and reproduce*; those with unfavorable traits *struggle* to survive and rarely reproduce. Over time, because of the struggle, the weaker species eventually goes extinct, adapts to the pressures, *or* moves "migrates" to a different more favorable environment, if possible.
- II. Carolus Linnaeus (1707 – 1778)
- A. He is considered the Father of **Taxonomy**. Taxonomy is the Science of species classification. There were originally only two Kingdoms in his system: Plantae & Animalia.
 - B. His system uses **Binomial Nomenclature**. (This term means "Two name naming system".)
 1. Rules of Binomial Nomenclature:
 - a. The **Genus** name is written *first and has a capitalized first letter*.
 - b. The **Species** name is written *second and is not capitalized*.
 - c. *The whole name is written in Latin and italicized*. (Latin is used because Latin is considered a "dead" language. Therefore, the meaning of words will *not* change over time.)
 - C. The current levels (called "taxons") of classification.
 1. Domain (This is the *most* inclusive; yet *least* specific taxon.)
 - a. Domains are composed from *similar* Kingdoms.
 2. Kingdoms
 - a. Kingdoms are composed from *similar* Phylums or Divisions (if it is plants).
 3. Phylums or Divisions (plants)
 - a. Phylums or Divisions are composed of *similar* Classes.
 4. Classes
 - a. Classes are composed of *similar* Orders.
 5. Order
 - a. Orders are composed of *similar* Families.
 6. Family
 - a. Families are composed of *similar* Genus.
 7. Genus
 - a. Genus is composed of *similar* Species.
 8. Species (This is the *least* inclusive; yet *most* specific taxon)
 - Breeds is a sub category of species. (Like for dogs, cats, horses, etc.)
 9. Easy way to remember the order of system: **D**ominating **K**ing **P**hillip **C**ame **O**ver **F**or **G**reen **S**alad.
- III. Georges Cuvier (1769 – 1832)
- A. Famous Paleontologist. This is someone who studies *fossils*. ("paleo" means "old"; "onto" means "bones")
 - B. Fossils are mostly found in *sedimentary* rock, but some are found in plant sap (called Amber... like in the movie *Jurassic Park*.) or ice. Sedimentary rock is mostly formed by being at the bottom of a body of water (Such as a lake, swamp, river, or ocean.). When organisms die, then settle to the bottom of that body of water, they get covered up by **LAYERS** of sediment (eroded earth). The *weight* of the sediment and water *preserves* the organism in a fossilized state. Without the body of water and sediment in the water, it is very hard to have the process of fossilization occur and this is why we do not have fossils for every species that has ever occurred on earth. Also some are *still* hidden in the dirt.

1. The term “Strata” means “layer”.
 2. We can tell the *age* of rocks and fossil based on location of the strata. The oldest layers are on the bottom and the youngest layers are on top.
- C. He proposed the **Theory of Catastrophism**. This theory tries to explain why organisms seem to suddenly disappear from existence on Earth, such as the extinction of the dinosaurs. Some catastrophic event must have occurred to cause their sudden, in geologic terms, extinction to occur.
- IV. James Hutton (1726 – 1797)
- A. He was a Geologist. This is someone who studies rocks and Earth’s processes.
- B. He proposed the **Theory of Gradualism**. This theory tries to explain that that the Earth must be very, very old because in order for some processes to occur, such as mountain formation or canyon formation, it would require enormous amounts of time.
1. According to the theory, Earth must be very old. This is *very* important to Darwin’s theory of Natural Selection because the Theory of Gradualism *supports the time frame* needed for Natural Selection to transform species *over generations*.
- V. Charles Lyell (1797 – 1875)
- A. He was also a Geologist.
1. He wrote a book titled *Principles of Geology*. (Darwin took this book on the Beagle voyage.)
 2. In the book, Lyell proposed the **Theory of Uniformitarianism**. (“The key to the past is the present”.) The theory tries to explain that the same geologic processes that are occurring today, also occurred in the past. These processes helped to create, over millions of years, the geologic formations we see today. For example, erosion, over millions of years and *still* today, led to the formation of the Grand Canyon.
 3. For this theory, Earth must be hundreds of millions of years old. (This also supports Darwin’s theory... it provides enough *time to pass* so that we get the millions of different species to evolve.)
- VI. Jean Baptiste Lamarck (1744 – 1829)
- A. He proposes a theory of evolution in 1809 (the year that Darwin is born) that turns out to be only *partially* correct. (He got the part about evolution needing long periods of time to occur.)
- B. His theory is called **Inheritance of Acquired Characteristics by means of use versus disuse** (This will become referred to as Lamarckian Evolution.) This basically states that if an organism uses a body part routinely it must be of importance and therefore, that body part will be passed on to the next generation. If an organism does not use a body part, it will disappear over time because it must not be important. (This is the part he got wrong... if it were true, think about body builders with their massive muscles. If it were true, their children would be born with massive muscles, but that is not the case. Also if someone lost a leg, their children should be missing that leg when born, as it was not being “used”. The change *must* occur in the DNA of a sperm or egg [gametes] to be passed on to the next generation.)
- C. Lamarck also makes *no* mention of the *environment’s* role in evolution. (Which he had wrong too.)
- VII. Thomas Malthus (1766 -1834)
- A. He was an Economist. Someone who studies *business and money*.
- B. He wrote an essay titled *Principles of Population*. (Darwin took this book on the Beagle to read too.)
1. The book basically states that more organisms are produced than nature can *allow* to survive.
 2. Life for *all* organisms is a “Struggle for Existence”.
 3. Life becomes “Survival of the Fittest” – this term was coined by a psychologist; not Darwin.
 - a. This becomes taken out of context to promote Social Darwinism in the early 20th century and Eugenics (the “killing” off of genetically inferior individuals...race, color, religious belief, nationality, or genetic diseases such as Down syndrome.)

AP Biology
Evolution and Darwin's Theory of Natural Selection – Part 2
(Associated Learning Objectives: 1.2, 1.4, 1.8, 1.9, 1.10, 1.11, 1.12, 1.26, 2.24, 2.32, 3.5, 3.26, 4.23)

Important concepts from previous units:

- 1) Reproduction is *necessary* to make the *next generation*.
 - 2) Genes are *segments* of DNA nucleotides that *code* for traits by polypeptide expression.
 - 3) Mendelian Genetics deals with the *inheritance* patterns of genes in gametes.
 - 4) Populations are defined as the same species, in the same place, at the same time, and showing reproduction.
-
- I. Feb. 12, 1809 in Shrewsbury, England Charles Darwin is born. (Same day that Abraham Lincoln was born too.)
 - A. Darwin attends University of Edinburgh at age of 16 to become a doctor, like his father and grandfather did.
 - B. Darwin wishing to not pursue medicine, leaves Edinburgh to attend Christ College of Cambridge to pursue being a Naturalist, someone who studies nature.
 - C. He is also studying to become a priest, as this is a religious university. Also most naturalists, at the time, were priests.
 - II. December 1831
 - A. Darwin has graduated college and instead of entering the seminary, he decides to join Captain Robert Fitzroy on the H.M.S. Beagle as doctor and naturalist of the ship. All ships at this time were *required* to have a naturalist onboard in case a new species was found.
 - B. This journey takes him *around* the world in five years. Darwin returns in 1836.
 - C. Darwin *collects* plants, animals, and fossils at *every stop* on this journey and sends them back to England.
 - D. He took two important books/essays to read while on the journey:
 1. *Principles of Geology* by John Lyell
 2. *Principles of Populations* by Thomas Malthus
 - III. November 24, 1859
 - A. *On the Origin of Species by Means of Natural Selection* is published.
 - B. “Descent with Modification” is used *instead* of the word “evolution”. The word “evolution” is only used once in the whole book and it is the last word in the whole book. Descent *indicates* that long periods of time are required to bring about the *modifications* within a *species* that occur to be better able to survive and reproduce within that environment. “Evolve” just means “to change over time”.
 - IV. **Natural Selection**
 - A. This theory of Darwin’s basically states that in nature there are *different levels of success in reproduction* based on *the ability to survive* in that environment. The differing rates of success act as a “filtering out” effect on “weak” traits.
 1. “weak” vs. “strong”- *Strong traits* would be *beneficial* in surviving and reproducing; whereas, *weak traits* would *not be beneficial* to reproducing or surviving the harsh characteristics of that environment.
 - B. Environmental *stresses* affect the success rate of individuals in a population in different ways. (For example, some people work well under pressure and others fail when there is pressure.)
 - C. *Populations evolve not individuals.*
 1. Somatic cells (cells that make up the body) vs. germ cells (the cells of sperm and eggs).
 2. Germ cells are *passed on* to “create” the next generation of organisms... so the change must occur *in these cells* if it is going to affect the *future* of the species.
 - D. Life is a struggle for existence (Malthus) and “nature” ultimately decides who gets to survive and reproduce and who doesn’t by excessive environmental “forces” killing them off.
 - V. **Artificial Selection**
 - A. This is where *man* selects what traits are desirable (beneficial) in a species.
 1. Plants (Which ones make the best or most fruit or are the most appealing in the yard or garden.)
 2. Domestic animals (Which ones are the most valuable in terms of food or other characteristics.)
 - B. Man can potentially “erase” what nature took thousands of years to “create” (gradualism) by *controlling* which organisms get to reproduce and which don’t.
 - C. This is *not* always the best outcome for that environment.
 - VI. Examples of Artificial Selection “backfiring”:
 - A. Insecticides creating insecticide resistant bugs. (Called “super bugs”.)
 - B. HIV/AIDS virus becoming resistant to our medicinal treatments.
 - C. MRSA, the antibiotic resistant strain of staphylococcus bacteria that causes staph infections.

D. Potential Harm worldwide? How will these affect our ability to survive in this environment we call earth?

VII. Supporting evidence for Common Ancestry among organisms includes:

A. **Homologous** (means “same”) **Structures** (Examples include skeletal structure, limb structure, or cephalization.) Remember, Darwin wrote about these in his book.

1. **Vestigial organs** are organs that appear to have been *needed in the past*, but are slowly disappearing.

B. **Embryological Homologies** are seen as common *stages of development* that embryos go through. (Darwin wrote about these in his book to help show support for Common Ancestry.)

C. **Molecular Homologies** refers to *DNA nucleotide sequences* being exact in order and function. (Darwin could not write about these, as they had not been discovered yet.)

D. *All* these homologies *parallel* the classification taxon levels.

VIII. **Biogeography**

A. This is the *geographic distribution* of species. (Where a species is found, basically.)

B. **Endemic** – refers to a species that is only found in *one* place on Earth. (Usually refers to organisms on islands.)

C. **Convergent Evolution**

1. This term is used for organisms that *only visually appear* to be to be closely related simply because they evolved in *similar environments* under *similar environmental pressures*. The reality is they maybe distantly related to each other.

2. **Analogous Structures** have the *same function*. Such as a bat wing (which has bones and muscles) and an insect wing (which doesn’t have muscles and bones in it); but they both produce flight.

a. Do not confuse with homologous structures.

b. Homologous *indicates* common ancestry and analogous does not.

IX. Fossil Evidence supports the theory of natural selection by displaying common structures between species. The fossil record is incomplete because of the nature of how a fossil is made (only under certain conditions) and the fact that some are still undiscovered in the dirt or at the bottom of some body of water.

AP Biology
Microevolution– Part 1

(Associated Learning Objectives: 1.1, 1.2, 1.3, 1.4, 1.5, 1.6, 1.7, 1.8, 1.13, 1.22, 1.25, 1.26, 2.23, 2.24, 3.1, 3.24, 4.11, 4.12, 4.23, 4.26)

Important concepts from previous units:

- 1) Alleles are *differing versions* of a gene.
- 2) Most organisms are *diploid* in terms of genetic content within the genome.
- 3) Fertilization is the *combining* of parental genes in the hopes of reproducing the *next generation* of the species.

I. **Natural Selection & Evolution**

A. Populations evolve, not individuals.

This is because we “are” what we “are” because of the genetics we *inherited*. You can’t change your somatic cells’ DNA by choice, only by random mutation. If a mutation occurs in the DNA that located in the gametes (sperm and eggs), then those changes *may* affect the *next* generation of offspring and therefore, a change in traits has occurred. In other words, the “population” is evolving from generation to generation. “Evolve” just means “change over time” and that is what has occurred.

B. Individuals “suffer” or “benefit” as a result of the traits they inherited or mutations they acquired during their life.

1. “Weak” vs. “strong” genes is the way it is usually communicated. “Weak” are considered *detrimental* traits and “strong” are considered *favorable* traits in terms of survival and reproduction.

II. **Population Genetics**

A. This is the field of science that studies the *trait variation rates over time* within a population.

B. It basically is following **allele frequency rates** in a gene pool. (A.K.A. a population.)

III. **Species**

A. Mostly defined as organisms that are so *genetically similar* in genome that there exists the *potential to breed* and produce viable (living) fertile (able to reproduce eventually themselves) offspring.

B. Genetics are *very similar* is important to defining a species since it is the “blueprint” for “constructing” an organism. The “plans” must be very similar or there will be confusion in “construction” and problems will arise during development. Problems are a terrible thing to encounter since we are discussing the making of a *living* organism.

C. **Geographic range** vs. population

1. A population is in one *specific* given area; but, in the case of organisms that are quite common (For example, grey squirrels or humans.), we may have several populations that cover a wider expanse of territory. In the case of humans, as a species we are global in our range; but we have millions of different populations, such as the population of Montgomery or the population of Birmingham. “Range” refers to *everywhere* where that species *may* be found.
2. Gene pools may or may not interact; it depends on the species and if any *geographic barriers* (such as large mountains or large bodies of water) interfere with the ability to interact.
3. **Allele frequency** (Remember, an allele is a version of a gene.)
 - a. “Frequency” refers to “how many” are *present at that time* within the population (gene pool).
 - b. It is considered fixed, if there is *no* change in frequency—*no* evolution is evident. (Basically, a state of *equilibrium* is occurring.)
 - c. It is considered evolving, if frequency is *changing*— evolution is occurring. (Basically, a state of change is occurring over time from generation to generation.)

IV. **Hardy-Weinberg Theorem**

A. This set of equations is used to *follow allele frequency* within a population (also considered a gene pool).

1. If the numbers (rates) *change* from generation to generation, the population is evolving over time.
2. If the numbers (rates) *do not change* from generation to generation, the population is not evolving over time and is then said to be in a state of equilibrium.

B. Equation #1: $p + q = 1$. This equation is for **alleles**. “p” refers to the “dominant” allele percentage and “q” refers to the recessive allele percentage. Together $p + q$ percentages *must equal* 100% of the gene pool or 1.

C. Equation #2: $p^2 + 2pq + q^2 = 1$. This equation refers to the *percent composition/number of organisms* within the population (gene pool) at that time. It is essentially a Punnett square, but in math format.

1. p^2 = the homozygous dominant percentage of organisms within the population at that time.
2. $2pq$ = the heterozygous percentage of organisms within the population at that time.
3. q^2 = the homozygous recessive percentage of organisms within the population at that time.

4. *All three must add up to 100% (1) of the population.*
- D. These equations are mainly used in health sciences to explain the frequency of genetic conditions.
- E. These equations can be used to show how or if variation is preserved over time.
- F. *Five conditions must be met* for a population to be in *Equilibrium* (Allele Frequency is not changing):
1. *Large population* must exist. (This dilutes any non-random processes that are occurring.)
 2. *No migration in or out* of the population is occurring at that time. (The population is not being influenced by outside environmental factors.)
 3. *No mutations* are occurring within the genome. (No random, unforeseen change due to an environmental stress.)
 4. *Random mating* is occurring (No preferences are being displayed for one trait over another trait...everyone is *equal* in fitness.)
 5. *No natural selection* is occurring on the population at this time. (Nature favors all equally in terms of fitness.)

AP Biology
Microevolution– Part 2

(Associated Learning Objectives: 1.5, 1.6, 1.7, 1.8, 1.13, 1.15, 1.16, 2.24, 2.28, 3.1, 3.9, 3.10, 3.12, 3.24, 3.26, 3.28, 4.11, 4.20, 4.23, 4.24, 4.26)

Important concepts from previous units:

- 1) Alleles are *differing versions* of a gene.
- 2) Most organisms are *diploid* in terms of genetic content.
- 3) Fertilization is the *combining* of parental genes in the hopes of reproducing the *next generation* of the species.

I. **Variation** (*Different* traits exist within a given species or population.)

A. Variation is *key to surviving in a changing environment*. (This is because you have “*options*”).

Perhaps some of the members of that species or population will survive and reproduce.

B. These “*options*” are the raw building materials of evolution to utilize. If there is no variation or “option” from which to utilize, a species is *confined* to what is available; even if it is weak or unfavorable. Variation, on the most basic level, will only come into existence with a *change in the DNA nucleotide sequence*, what we refer to as a **mutation**. Some mutations are favorable, but *most* are harmful.

C. Variation exists between individuals and populations unless the population is composed of clones.

II. “Creating” Variation for evolution to build upon:

A. Through mutations

1. These changes are *rare and random in gametes*. (Because gamete cells are normally not exposed to the environmental stresses an organism may encounter in their existence.)
2. Mutations mostly occur in *somatic* cells because these cells are exposed to the environmental stresses.
3. Most mutations, unfortunately, are harmful to the cell or organism, so it usually dies.

B. Through sexual reproduction

1. The **process of crossover**, during Prophase I of Meiosis, “swaps genes from one chromosome to another, its equal “mate” usually, during gamete formation. This is so that each sperm or egg is unique in its genetic composition.
2. The **Segregation (means “separation”) of Chromosomes** during Anaphase I and II and **Independent Assortment** (lining up of chromosomes on the mid-plane) during Meiosis so as to *reduce the genetic content* (number of chromosomes) found within a sperm or egg to one-half (referred to as “haploid”) the normal content (referred to as “diploid”) and have a variety of alleles in each.
3. The **random fertilization** of a sperm by an egg increases variety. Each sperm and egg are different remember... so each coming together between egg and sperm (what is referred to as fertilization) will be different too.

III. **Microevolution** (Evolution/change on a *small* scale.)

- A. This term usually refers to changes in *allele frequency* within a population of a species.
- B. Microevolution *can eventually* lead to **macroevolution**. (The evolution of a *new species* or *higher taxon* in the classification system from a *pre-existing* species.)
- C. Remember: Change over time is referred to as **evolution**. Evolution is a scientific *law*... the environment changes from minute to minute, hour to hour, day to day; just as a genome may. Please do not confuse this “change over time” with the belief of creationism. These are two different concepts that are confused with each other because of misconceptions of the definition. Darwin’s *theory* is Natural Selection.

IV. **Genetic Drift** causing *random change* in allele frequency of a population. (“drift” indicates “random”)

- A. Random (unpredictable) change in allele frequency that occurs within a population’s gene pool.
- B. This process is more *severe on small parent populations* rather than large populations usually.
- C. Two ways that random drift can occur:

1. **Bottleneck effect** -This has a *negative* effect by *reducing variation*. This is usually caused by a *random act of nature*, such as a hurricane. Imagine an island with a parent population consisting of variation within the gene pool. A hurricane ravishes the island and most of the individuals of that species die. The survivors (the individuals who made it *out of the bottle’s neck*) are now the sole survivors. They comprise the *new* gene pool for that population and the allele frequency *has* dramatically changed because of this unpredictable event.

2. **Founder effect** -This also has a *negative* effect by *reducing variation*. This is also caused by a *random event*. In this situation, a small part of a parent population leaves or becomes isolated from the larger parent population. This leaving or isolation “creates” a new *founding* gene pool for the area they will occupy. Think of the “founding fathers” leaving Europe or Africa for America. They will “create” a *new* gene pool (with a *new* allele frequency) for their *new* environment. The larger older parent population *may* have its allele frequency changed as well.

V. **Natural Selection**

- A. *Always* has a *positive* effect on variation because “nature” favors those traits that make a population or species *more able to survive* within an environment and *increases* their ability to reproduce and keep the species viable. The weak traits perish over time.

VI. **Gene Flow** (Flow indicates *purposeful* movement between populations.)

- A. This may have a negative effect, a positive effect, or no effect on allele frequency within a population.
- B. Migration in and out of an area *may* affect the gene pool.
- C. *Reduced variation* can occur if the *interaction (reproduction)* between populations is permitted to occur. They may begin to merge into one unified population instead of two distinct populations.
- D. Variation may also increase if new “traits” are introduced to a stagnate gene pool. Usually seen in captive breeding of endangered species.

AP Biology
Microevolution – Part 3

(Associated Learning Objectives: 1.2, 1.3, 1.4, 1.5, 1.6, 1.7, 1.12, 1.13, 1.22, 1.24, 1.25, 1.26, 2.24, 3.1, 3.18, 3.19, 3.24, 3.28)

Important concepts from previous units:

- 1) Alleles are *differing versions* of a gene. It takes two alleles to make a trait.
- 2) Most organisms are *diploid* in terms of genetic content.
- 3) Most things that appear stark *white* are homozygous recessive in genotype.

I. Phenotypic Polymorphism (A.K.A. Discrete Characters.)

- A. These are referred to as *single gene* traits for the “discrete” phenotypic outcome.
- B. They are also called *either – or – traits* (You either have the gene or you don’t, which in turn means you either produce the trait or you don’t.)
- C. Phenotypic (means “the physical outcome of a gene); polymorphisms (means “many versions or types”)
 1. This basically means that there may exist *multiple versions of the same basic gene trait* simply because of a different sequence of nucleotides that make that gene.
 1. A, B, AB, and O Blood types for example. (These are all blood; but different versions or types of the same main gene being expressed.)

II. Genotypic Polymorphisms (A.K.A. Quantitative Characters.)

- A. These are traits for which there may exist *several phenotypic outcomes* based on the fact that these traits are the cumulative interaction of *several genes interacting* with one another.
- B. The fact that there are several genes involved is why they are also referred to as Quantitative (how many alleles) characters.
 1. Skin color is basically based upon how many dominant alleles you inherit from your parents. The dominant allele makes the protein pigment found in skin called melanin. *Every* human makes this protein pigment, except people suffering from Albinism (a genetic condition where the individual inherited ZERO dominant alleles and therefore does not have a single DNA blueprint for making the protein pigment; so they “appear” white because they have zero pigment in their cells. In those individuals who did inherit at least one dominant allele they will have skin pigmentation. So basically, the more dominant alleles that are inherited; the darker the skin will be. Race is a man made construct that tries to group individuals based on geographic origin or degree of skin pigmentation, but we are *all human*. We now recognize the direct relationship between the environment and the degree of pigmentation. Populations around the Equator are darker (in an attempt to counteract the harmful effects of the sunlight) and as we move away from the equator the amount of pigmentation decreases generally. Race is an antiquated term as we now scientifically understand we are all *Homo sapiens*. Racism is showing your scientific illiteracy.

III. How we can measure variation on the *cellular level*:

- A. **Gene Diversity** – looking at the genotypes that are present. (It has been documented in humans that most traits are homozygous in nature...14% Heterozygous; 86% Homozygous.)
- B. **Nucleotide Diversity** – looks at the nucleotide *sequence* of DNA nucleotides. (It has been scientifically proven, the Human Genome Project, that ALL humans are very similar in their DNA sequence - .01% Difference; 99.99% Identical. That is amazing!)
 1. **Single Nucleotide Polymorphisms** – this term refers to genes where a *single nucleotide* difference in sequence can affect the *phenotypic outcome* (For example the color of the actual protein pigment associated with normal red blood cell vs. sickle red blood cell. A **point mutation**.)

IV. Geographic Variation can exist within a *species*.

- A. Differences between populations (gene pools) because each population exists in a *different environment*.
- B. **Cline** (Think incline or decline.)
 1. This term refers to variation within a species that is directly due to an increase or decrease in *elevation* (up/down) or *latitude* (north/south).

V. Evolutionary *flow* (ways of selection “affecting” *phenotypic* outcomes.)

- A. **Directional** – the “bell curve” for a trait flows in *one direction only*.
- B. **Diversifying** (Disruptive) - the “bell curve” for a trait *separates in opposite directions at the same time*.
- C. **Stabilizing** – the “bell curve” moves to the “*stable*” center.
- D. These are *all* related to some trait that is beneficial for survival within that changing environment.

VI. **Preservation** (keeping) of genetic variation within existing gene pools (populations).

A. Being *Diploid* organisms vs. *Haploid* organisms.

1. The recessive allele can be preserved as well as *hidden* because of the fact we require two alleles to produce a trait. This allows for multiple genotypic combinations. (Look at a Punnett square results.)

B. **Balanced Polymorphism** (*Equal* amounts of each allele are present in the gene pool.)

1. **Heterozygous Advantage** - This prevents too much of one allele from building up by providing some benefit to each allele when mixed. (For example, Malaria resistance in Africa. Humans that would have evolved in Africa were prone to Malaria, a deadly disease carried by mosquitoes. The pathogenic organism lives and reproduces within red blood cells. So nature's way of trying to defend against this was to "change by mutation" a single nucleotide within the DNA sequence for the gene that is responsible for making red blood cells. This change collapses the red blood cell inward, so there is no room for the pathogen. The side effect is its sickle-shaped and doesn't carry as much oxygen as the round version. The sickle- shape makes it painful when it punctures the blood vessel wall too. So it was not a perfect fix. The genotypic outcomes are this: Homozygous Dominant – these individuals are resistant to malaria, but suffer from Sickle Cell Disease. Homozygous Recessive- these individuals have normal red blood cells but are susceptible to Malaria. Heterozygous – the individuals have some side effect associated with Sickle cell (referred to as Sickle-Cell trait) *and* also have a higher amount of normal cells, but they are resistant to Malaria invasion. So it is the "Best" of both worlds hence the Heterozygous Advantage. So in these individuals we mainly have heterozygous genotypes and few homozygous.)

VII. **Sexual Dimorphism** ("di" means "two"; "morph" means "structures/versions")

A. The two "versions" (male or female) are the direct result of the secondary sexual characteristics associated with estrogen versus testosterone production.

B. This difference leads to *sexual selection* among the populations organisms.

1. **Intrasexual** ("intra" means "*within* one same sex")

a. Males mainly "fight" for reproductive rights. (It becomes "Survival of the fittest", basically.)

2. **Intersexual** selection ("inter" means "*between* the two sexes")

a. Males strut to attract the females attention. (Mostly seen in birds with bright coloration.)

b. Females choose based on "fittest" looks. (This indicates good health.)

C. The competition between individuals makes sure that the "best or most fit" genes get passed to the next generation.

AP Biology
Macroevolution – Part 1

(Associated Learning Objectives: 1.4, 1.9, 1.10, 1.12, 1.13, 1.20, 1.23, 1.24, 2.25, 2.26, 2.27, 2.37, 3.27, 4.11, 4.23)

Important concepts from previous units:

- 1) All traits are determined by gene expression using protein synthesis.
- 2) Apoptosis is “programmed” cell death during development. The “programming” is associated with the DNA telomeres.
- 3) Positional genes determining position of structures and pattern genes determine a species’ unique pattern.
- 4) Positional and pattern genes are in the group referred to the Hox genes.
- 5) A zygote is the result of a sperm and egg fusing together in fertilization.

- I. **Macroevolution** (Evolution/Change on a *large* scale.)
 - A. This term refers to the evolution of a *new taxon* from a *pre-existing taxon*. (Basically, the evolution of a new species or higher on the classification scale.)
- II. **Speciation** (Means “the evolution of a new species”.)
 - A. Two *types* (pathways) of speciation that have occurred in nature in the past.
 1. **Anagenesis** - Basically, there is *no break* within the pathway of evolution. (“ana” = without)
 - a. The accumulation of new changes over time within a species leads to a new species.
 2. **Cladogenesis** - There exists a *break into different groups*.
 - a. Branching off of an existing species occurs because of moving into new environments, reproductive isolation, or other environmental stresses.
 - B. Both pathways are supported by fossil evidence, bacterial research and/or research at Galapagos Islands.
- III. The various ways of *defining* a “species”:
 - A. **Biological Species Concept** (This is the main way used in science today.)
 1. This method is based on *genetic similarity* among individuals.
 2. The genetics are so similar that the ability to produce viable, fertile offspring exists.
 3. Reproductive *Isolation Mechanisms* to preserve a species: (Ways to keep them pure.)
 - a. **Pre-zygotic Barriers** - These prevent *before* a zygote, fertilized egg, can form.
 - i. **Habitat** Isolation - The organisms live in two different *environments*.
 - ii. **Behavioral** Isolation – The “*Mating Dances*” are not recognized by the other.
 - iii. **Temporal** (time) Isolation – They have different *times* of year they can reproduce.
 - iv. **Mechanical** Isolation – The *reproductive parts* just don’t fit together correctly.
 - v. **Gametic** Isolation – The *sperm and egg* do not recognize the other.
 - b. **Post –zygotic Barriers** - These prevent *after* a zygote has formed from the fertilization.
 - i. **Reduced Hybrid Viability** – The hybrid organism *can’t survive for long* during development.
 - ii. **Reduced Hybrid Fertility** – The hybrid organism survives, it just *can’t reproduce*.
 - iii. **Hybrid Breakdown** – The hybrid organism lives, *it just loses the ability to reproduce over successive generations*.
 4. This concept model poses problems with bacteria, which are asexual organisms.
 - B. **Ecological Species Concept** (This method is used for discussing an organisms ecological niche in an area.)
 1. Organisms defined by *niche (role) within an ecosystem*.
 2. This method uses terms like: producer, consumer, decomposer, keystone species.
 - C. **Phylogenetic Species Concept** (Remember Molecular Homologies)
 1. The method compares *DNA Nucleotide or Amino Acid Sequencing*.
 2. If sequences have *a lot* in common, then the organisms are *very closely related*.
 - a. The two species share a common ancestor *not too long ago in time*.
 3. If sequences have *very little* in common, then the organisms are *not as closely related*.
 - a. The two species share a common ancestor a *very long time ago*.
 - D. There is no right or wrong way to define a species. It all depends on what your are trying to communicate. Each method fits a different situation or discussion.

AP Biology
Macroevolution – Part 2

(Associated Learning Objectives: 1.5, 1.9, 1.10, 1.11, 1.13, 1.17, 1.20, 1.23, 1.24, 1.25, 2.26, 2.28, 3.1, 3.9, 4.23)

Important concepts from previous units:

- 1) In order to keep a species extant (living) reproduction *must* be possible.
- 2) Genomes of organisms must be *similar* enough to allow for reproduction to go to completion with viable offspring.
- 3) Environments change over time and distances.

I. Modes (Ways to) of Speciation:

A. **Allopatric** (“Allo” means “different”; “Patric” means “place”)

1. In this way, a geographic barrier becomes present within the environment separating the parent population. This barrier can create two different environments, which could cause each species to begin to change/evolve over time and potentially lead to two different species.
 - a. **Ring Species** – In this type of allopatric speciation a migrating species moves *around a geographic barrier*. If the barrier is large enough, it can force each species into different environments. Each could potentially change to adapt to the new environment over time and successive generations until new species exist.
 - b. **Adaptive Radiation** - In this type of allopatric speciation, a species also *migrates* into new environments. As time and successive generations go by, those organisms may begin to change/evolve to meet the requirements of that new environment. Then some of the new species population moves *farther out* to the next island causing the process of change/evolution to occur over time again. So ultimately, what happens is that each island has its own species that evolved in response to that island's environment. They all came from the mainland parent population initially and changed/evolved as time went by on each island. So when you look at all the species in respect to the parent species, we see a couple of things. On the island that is *closest* to the mainland, we see the *fewest changes* from the parent species, because that island environment is probably very similar to the mainland environment. On the island that is *farthest* from the mainland, we see the *most changes* from the parent species, because that environment is most likely very different than the mainland environment.
 - i. Galapagos Islands & Darwin's finches are great examples of this process.
 - ii. If the island is close to the mainland, we see little change occur.
 - iii. If the island is farthest from mainland, we see more changes occur.

B. **Sympatric** (“Sym” means “same”) In this process, a new species evolves out of the parent species while both remain in *the same environment*.

1. For animals – This may occur because of competition for resources, such as food. The dominant individuals, having the more favorable traits, will get the resource that is being competed for. The weaker group, having the lesser favorable traits, will have to find a different resource to use. This change in resource utilization may lead to change/evolution of the weaker group over time and successive generations until we get two different species within the same environment.
2. For plants – This mainly occurs because of **polyploidy** (a condition of having abnormal chromosomal numbers) because of cross-fertilization between plants that have had meiosis go awry in the formation of gametes.
 - a. **Autopolyploidy** - Is the result of *self-fertilization*. (“auto” = “self”; “poly” = “many”; “ploidy” = “genetic content”)
 - b. **Allopolyploidy** - Is the result of *different* plants cross-fertilizing.

C. **Punctuated Equilibrium**

1. This way of speciation was proposed in 1976 by Stephen Jay Gould, a famous Harvard professor.
2. In this method, *long periods of stability (this is the equilibrium)* are interrupted *suddenly (this is the punctuated)* by a major disruption (such as an asteroid hitting the earth) that causes a mass extinction of existing species to occur. Once all disruption has calmed down (usually after several years), a mass evolution of new species will occur to occupy all the new open niches that were created due to the mass extinction. (These punctuations usually mark/cause the end of an era.)
3. Snowball Earth caused the end of the Pre-Cambrian era. 7/8 of the Earth was covered by ice. It took millions of years to thaw out. Most organisms died. Those that survived were around deep-sea thermal vents, where it was warm enough to support life. Once the ice melted, the Cambrian explosion of species occurred to start the beginning of the Paleozoic Era (called the Age of Fish).

4. Pangaea, the super continent, caused the end of the Paleozoic era. This coming together of all the continents caused the earth's water to be dramatically displaced. The interior swamps and oceans disappeared and over time became vast deserts. Most aquatic and terrestrial animal and plant species went extinct due to loss of water. Those that survived were around the edge of the supercontinent or in the one big ocean. This mass extinction allowed for the mass explosion of new reptile species and desert plants. This began the Mesozoic Era (called the Age of Reptiles).
5. The Asteroid that hit the Earth 65 million years ago caused the end of the Mesozoic Era and the extinction of the dinosaurs and many plant species. It caused the sun to be blocked out by soot and ash for years. The planet became very cold. The organisms that survived were mainly Mammals, because of their warm fur. Some reptiles, amphibians, and fish survived too. Also some plants. Once the sun returned to the entire Earth, we see the mass explosion of mammals and the beginning of the Cenozoic Era (called the Age of Mammals).

II. Microevolution *can cause* Macroevolution to occur *with enough time and enough changes in the DNA*.

III. Descent with modification is what occurs to structures or traits in organisms over time. This is the phrase that Darwin used in his book, not evolution. This modification is best exhibited by the evolution of the eye.

- A. The eye starts out as a collection of light sensing pigments (called an Oscilli) located on the external surface of the bell of jellyfish. This allows them to tell basic direction (up toward the sun and down into the dark bottom). They can also see shadows (either predators or food moving). You can do the same with your eyes closed. The problem is the cells are on the surface where they can be damaged with a brush against a rock or other rough surface. Nature tried to solve this problem over time by recessing the cells into a sunken recess (such as we see in the Eye Spots of Platyhelminthes- flatworms). This protected the light sensing cells, but created a new problem...sediment collection in the recess. Nature tried to solve this problem over time by sinking the cells down further and reducing the opening to the recess, such as we see in some annelids and mollusks. Problem solved regarding the sediment in the recess... but new problem created ... lack of light entering the recess causing decreased vision and light detection. Nature tried to solve this problem over time by putting a layer of transparent cells over the opening. This would act as a simple magnifying glass to increase the amount of light entering the "eye". Problem solved ... but new problem created. The "vision" is not clear because of the layer of cells the light passes through. Nature tried to solve this problem over time by forming a lens using a clear protein called crystalline. This would enhance and clarify any image. This is seen in Arthropods. By this time these animals were able to move quickly within their environments. So a new problem... No depth perception, all vision is basically 2D. Nature tried to solve this problem over time by attaching muscles to the lens to stretch it when needed. This manipulation of the lens allowed for the ability to detect differences in depth and thus more 3D to a degree. This is seen in all higher organisms such as cephalopods, fish, amphibians, reptiles, birds, and mammals. Problem solved. It works well and that is why we see it unchanged essentially in the higher organisms.

AP Biology
Phylogeny and Geologic Time

(Associated Learning Objectives: 1.9, 1.10, 1.11, 1.12, 1.13, 1.17, 1.18, 1.19, 1.20, 1.21, 1.27, 1.28, 1.29, 1.30, 1.31, 1.32, 4.20)

- I. **Phylogeny**
 - A. This term refers to the *evolutionary history* of a species.
- II. **Molecular Phylogeny**
 - A. This is looking at *DNA/RNA nucleotide sequences* over the history of a species.
 - B. Uses computers and DNA microarray assays to “speed up” the gathering of information. (**Bioinformatics**)
 - C. Lots of similarities? Species are *very related*.
 - D. Few similarities? Not as related, but *still* related by common ancestry.
- III. Dating Fossils to create a geologic “time line”:
 - A. Two ways this can be achieved:
 1. **Absolute “Radiometric” dating**
 - a. Uses the *half-life* of radioactive elements that accumulate in an organism over time.
 - b. C-14 (Used for thousands.); U-238 (Used for millions → billions.)
 2. **Relative Dating**
 - a. Uses the *different strata of rock* and **index fossils** to establish a time line. **Index Fossils** are fossils that we know a specific time period they existed. They are compared to the location or strata where we found an “unknown” dated fossil. If the “unknown” is found above the index, the “unknown” is younger. If the “unknown” is found below the index, the “unknown” is older. *Positions are relative to time.*
- IV. Geologic Time Scale, Plate Tectonics, and Major Geologic events:
 - A. **Eras** – These are the *largest* periods of time.
 1. Separated by *catastrophic global* event. (See below.)
 2. Eras are broken into smaller time frames called **Periods**.
 - a. Periods are broken into smaller time frames called **Epochs**.
 3. These time frames are based on strata fossil evidence of primary plants and animals found.
 - B. **Plate tectonics**
 1. Refers to the *moving* of the continental plates.
 2. The continents moving are a direct cause of the biogeography of species.
 3. Collisions? (Mountains form.)
 4. Separation? (Sea floor spreading... see the “world’s Zipper” in the Atlantic Ocean floor.)
 5. Subduction and slipping? (Plates being pushed under the other, such as by Japan; Plates sliding past one another, as in California.)
 6. “Ring of Fire” (Refers to all the volcanoes around the Pacific Plate.)
 - C. **Pangaea (Punctuated Equilibrium occurred.)**
 1. The *super-continent* formed 250 mya and then separated 180 mya.
 2. Separates the Paleozoic Era from the Mesozoic Era.
 3. Global effects? Most land is desert, except for along the coast of the one ocean.
 4. Life affected? All life forms.
 5. This is supported through fossil and geologic evidence.
 - D. **Impact Theory** (around 65 mya) (**Punctuated Equilibrium** occurred here too.)
 1. Separates the Mesozoic Era from the Cenozoic Era.
 2. Walter & Luis Alvarez came up with the theory.
 3. Global Effects? Sunlight was absent from most of the earth. Dinosaurs go extinct.
 4. Iridium, element found in asteroids, is found at the K/T boundary only in soil samples.
 5. The impact point was around the modern day town of Chicalub, Mexico. (On the Yucatan Peninsula.)
 - E. **Snowball Earth (Punctuated Equilibrium occurred here too.)**
 1. Formed 750 mya lasted til 570 mya.
 2. Separates the Pre-Cambrian Era from the Paleozoic Era.
 3. Global Effects? Most life dies, except around deep-sea vents.
 - F. Eukaryotic Life forms evolve about 2.7 billion years ago. (Remember, the Endosymbiont Hypothesis?)
 - G. Oxygen Catastrophe or Oxygen Revolution
 1. The rapid rise in atmospheric free Oxygen (O₂) occurred about 2.7 Billion years ago by the evolution of Cyanobacteria in the Earth’s water bodies. (“cyano” means “blue-green”)
 2. This caused a mass extinction of anaerobic organisms. Oxygen was deadly to them.

H. Prokaryotic Life forms evolve about 3.5 Billion years ago. (Remember, the Stanley Miller experiment?)

V. **Homologous** structure vs. **Analogous** structures

A. Homologous structures indicate common ancestry.

B. Analogous do not indicate common ancestry. (JUST similar function.)

1. Fly wing vs. Bird wing

C. **Convergent Evolution** –Remember, only *appear* to be related due to *similar* environments and pressures.

VI. **Cladogram** or **Phylogenetic Tree**

A. It is an “Either – or” evolutionary tree based on *shared characteristics*.

B. *Common ancestors* are indicated at the “Y”.

C. Each branch called a **clade**.

1. *Must* be common ancestor and *all* of its descendants.

D. Construction of one:

1. **Ingroup** (common structure) vs. **outgroup** (outcast)

a. Ingroup organisms get a 1; outgroup organism gets a 0.

2. **Shared Primitive Character**

a. Trait that is *common to many taxons* or clades. (For example, a Backbone.)

3. **Shared Derived Character**

a. Trait that is *common to one clade* only. (For example. Hair on mammals.)

VII. **Molecular clocks**

A. Measuring time based on the constant rate that nucleotides *change (mutate) in particular gene sequences*.

B. Some changes in nucleotides are neutral in effect. (Known as the **Neutral Theory**.)

C. Most changes are by natural selection via environmental pressures.