Unit 1: Cell Structure and Function
Content Outline: Types of Cells and Cell Structures (1.1) – Part 1

I. Cells and The Cell Theory
- A. Cells are considered to be the basic unit of life. (Part 1 of the Cell Theory)
    - a. Proposed by Henri Dutrochet in 1837.
- B. All living organisms are composed of cells. (Part 2 of the Cell Theory)
    - a. Proposed by Theodor Schwann and Matthias Schleiden in 1839.
    - b. Theodor Schwann worked with animal tissues.
    - c. Matthias Schleidenworked with plant tissues.
- C. All cells come from pre-existing cells. (Part 3 of the Cell Theory)
    - a. Proposed by Rudolf Virchow in 1858
- D. 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" can emerge.
- E. 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. Microscope Development
- A. Robert Hooke developed a simple lens microscope in 1665. (It was basically like a magnifying glass)
- B. Anton von Leeuwenhoek developed a compound (meaning "more than one lens") microscope in 1674.
- C. Two principle types of microscopes used today for studying cells are:
    1. Light Microscopes
        - a. Light Microscopes use lenses to magnify and direct light in relation to a specimen.
        - b. **Resolution** of light microscopes
            - i. This term refers to the *distance* that two points appear as *separate* points. When they are so close together that they appear as one, we have lost resolution.
            - ii. 2 micrometers (μm) is about the best light microscopes can offer in resolution.
        - c. The magnification capabilities of most light microscopes is up to 1000X.
        - d. Benefits vs. Drawbacks. The benefits of the light microscope are that we can look at living things, they are "fairly" cheap, and they are "fairly small". The drawbacks are that they have limited resolution and limited magnification.
    2. Electron Microscopes
        - a. Electron Microscopes use an electron beam pathway to produce an image of a specimen on a computer screen.
        - b. Two main types are in use today:
            - i. **T**ransmission **E**lectron **M**icroscopes (TEM) – used to look inside of a specimen.
            - ii. **S**canning **E**lectron **M**icroscope (SEM) – used to view the surface of a specimen.
        - c. Benefits vs. Drawbacks The benefits of Electron Microscopes are that they provide much greater resolution and magnification. The drawbacks are that they are very expensive, very large, and they can only be used to look at things that are dead.

III. **Cytology** is the study of cells; **Cytologist** – a person who works with cells.

IV. Cell Types that exist
- A. **Prokaryotic cells** ("pro" means "before" , "kary" means "nucleus", "ote" means "organism")
  These organisms (bacteria) would have evolved before a nucleus had evolved into existence. Prokaryotic cells are the most abundant cell type.
- B. **Eukaryotic cells** ("Eu" means "true")
  These organisms would have evolved after a nucleus had evolved into existence because they possess a nucleus.

V. Surface-to-Volume Ratio Importance
- A. Cells can only be so small. (There has to be *enough* room [volume] to hold things and to perform work inside a cell)
- 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, Ribosomes, and some cytoplasm. 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 a cell is too large it becomes inefficient at moving food and waste so it divides to get back to a smaller state.

Cell Structures - Part 2

I. There are three main parts to Eukaryotic Cells
   A. Plasma "cell" membrane (This part holds the cell together)
   B. Nucleus (This part controls the activities of a cell by holding the DNA. The DNA contains the "instructions".)
   C. Cytoplasm or cytosol (This part creates room for work and space for holding organelles and ribosomes.)

II. Nucleus
   A. The Nucleus 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 *double* membrane layer of Phospholipids.
      2. It also contains pores (tunnels) composed from proteins for 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 of DNA, one set for each cell.)
   D. **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 of a *cheap, disposable copy* of DNA. We can make "messenger" RNA, mRNA, and send it to the cytoplasmic "construction site".
         a. Lots of these structures are present during *repair*.
         b. It is also responsible for helping to make Ribosomes, which are mostly RNA structures.
         c. It also makes mRNA and other types of RNA molecules.

III. **Ribosomes**
   A. Ribosomes are *cellular particles* made of ribosomal RNA, rRNA, and proteins. (These are *not* organelles… as <u>all</u> cell *types* have them so that <u>all</u> cells can make proteins and enzymes.)
   B. Ribosomes are the sites 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 <u>all</u> made here.
   C. Ribosomes are composed of two sub-units:
      1. Small sub-unit– Acts as a table or support structure for the actual protein "building process".
      2. Large sub-unit – Acts as the "factory" to make the actual proteins.
      3. *Both* must come together to work making proteins.
   D. Two types of ribosomes exist based on location:
      1. **Free Ribosomes**– These float "freely" in the cytoplasm of a cell. (They are found in <u>all</u> types of cells.)
         a. Free ribosomes make proteins that will stay *inside* the cell for use by the cell.
      2. **Bound Ribosomes** – These are attached to the endoplasmic reticulum organelle (RER). (These are <u>only</u> found in Eukaryotes because *only* they have the organelle.)
         a. Bound Ribosomes make proteins that will *leave* the cell to be used elsewhere. (Most are for communication between cells or for cell protection.)

Cell Structures – Part 3

I. Endoplasmic Reticulum (ER)

A. The Endoplasmic Reticulum is composed of a *network* of small tubes called **cisternae**. ("cisternae" means "tubes")
B. They are <u>always</u> found just outside and around the nucleus.
C. *Two types* of ER can exist inside Eukaryotic cells:
    1. **S**mooth **E**ndoplasmic **R**eticulum (SER)
        a. This structure helps with the *synthesis of lipids, phospholipids, and steroids*.
        b. It helps with carbohydrate breakdown. (Glycogen "stored sugar" to glucose "usable sugar".)
        c. It helps to detoxify the blood. (Liver cells are loaded with SER.)
        d. Liver cells and muscle cells have lots of SER.
    2. **R**ough **E**ndoplasmic **R**eticulum (RER)
        a. This structure helps with *protein synthesis*. (Provides a water free environment for protein folding.)
        b. Ribosomes are bound to the outside of the organelle and deposit 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.

II. Golgi Apparatus

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

III. **Lysosomes** (These act like a "stomach" for the cell.)

A. Lysosomes are involved in *digestion and recycling* (autophagy) of molecules.
B. Lysosomes are full of digestive enzymes. (**Lysozyme** is the name of the enzyme.)
C. The organelle is composed of a phospholipid *bilayer***.**

IV. **Vacuoles** and **Vesicles** (These act as "closets" for storage of materials.)

A. **Vacuoles** and **Vesicles** are *storage structures* for various products needed by the cell.
B. Various types can exist (Food, Contractile, Central)

V. **Endocytosis** – This is the process of bringing something *into* the cell. ("cyto" means "cell"; "sis" means "process of")

A. **Phagocytosis** – This is the process of cell "eating". ("phag" means "to eat")
B. **Pinocytosis** – This is the process of cell "drinking". ("pino" means "to drink")

VI. **Mitochondria** (Nicknamed the "Power House")

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, and enzymes inside it.
C. It has a "Room within a Room" appearance.
    1. Cristae – the folded inner membrane (The folding *increases the surface area* for making energy. This creates the inner-most "room" called the Mitochondrial Matrix – inner skeleton with ribosomes present. The matrix is the site for the Kreb's Cycle of cellular respiration.)
D. The space between the membranes is important in cellular respiration.
E. 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.)

VII. Chloroplasts

A. These organelles are the site of *photosynthesis* in plants and algae.
B. They are a type of plastid. (Plastid is a pigment containing molecule. These contain the pigments chlorophyll.)("phyll" means "pigment")
C. Has it's own DNA, ribosomes, and enzymes (ATP Synthase) too!
D. "Room within a Room" appearance too!
    1. **Thylakoid** – looks like a "green cookie room". (Site of the *light reaction of photosynthesis*. This is where sunlight energy is converted into "batteries". The "batteries" are ATP and NADPH. These "batteries" will be used to power the making of sugar in the Calvin Cycle.)
    2. **Grana**- is a stack of "green cookies" or thylakoids.

3. **Stroma**- This is mostly *watery space* in between the thylakoids and outer membrane (This is the site of the *Calvin cycle* of photosynthesis, where the sugar is made.)

E. Evolutionary Significance? (They also were believed to have been blue-green bacteria that entered into a symbiotic relationship for protection in return for energy.)

VIII. **Endosymbiont** Hypothesis

A. This hypothesis was proposed by Lynn Margulis in the 1960's.
B. It Defined symbiosis and introduced common types of symbiotic relationships.
C. 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 spanning hundreds of thousands of years.
    1. Smaller organism gained protection.
    2. Larger organism gained energy production or faster motility.

Cell Structures – Part 4

I. Cytoskeleton

A. The Cytoskeleton structure helps *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 – ligaments and tendons, smallest- muscle fibers)

1. **Microtubules** (largest)
   - These are *large, hollow tubes*.
   - They are composed of *Tubulin protein*.
   - Their main function is support or movement.
   - They also function as guide supports for organelle movement within the cell.
   - Important structures made of microtubules within a cell:
     i. Centrosomes/Centrioles (These act as anchors during cell division.)
     ii. Spindle Fibers (Act as guides or "tow ropes" for the chromosomes during cell division.)
       - Used to move chromosomes during the processes of Mitosis or Meiosis.
     iii. Cilia
       - These help with cell movement. Cells usually have *a lot* and they are *small in length*.
       - Cilia create a *wavelike* movement.
     iv. Flagella
       - These are also for movement. Cells usually have *few* and they are *very long* in length.
       - Flagella create an *undulating (whipping***)** movement.
2. **Microfilaments** (These are the *smallest* structures in the cytoskeleton.)
   - These are *solid rods*.
   - They are composed of *Actin or Myosin protein.*
   - They provide a *pulling force*.
     i. They are abundant in muscle tissue.
3. **Intermediate Filaments** (These are *medium* sized structures.) ("inter" means "between")
   - These are permanent *solid rods*.
   - They are mostly composed of *keratin protein*.
   - They help to *reinforce* and brace the large microtubules.

II. **Cell Wall** of Plant Cells

A. Plant cells create this structure for *protection and durability*. (Basically, weight bearing)
B. Composition of most plant cell walls:

1. **Primary Cell Wall** (Cellulose Sugar) (Found in all plant cells. It is not very strong by itself.)
2. **Middle Lamella** (Composed of Pectin Sugar.)
   a. The Pectin acts as super glue between cells to hold them firmly together. This helps them grow tall.
3. **Secondary Cell Wall** (Composed of Lignin sugar)
   a. The Lignin is found inside the primary cell wall allowing it to reinforce the primary wall. It is thickest on the corners. This also helps them grow really tall.

III. Extracellular Matrix (ECM)

A. This is the *outer protective "skeleton"* of the cell plasma membrane in *animal* cells. ("extra" means "outside of"; "matrix" means "skeleton")
B. It also functions in *communication* with other cells. (By using the glycoprotein like a blind man's hands.)
C. The ECM is composed mainly of Glycoproteins and Glycolipids ("glyco" means "sugar")

IV. Cellular Junctions (These act as stitching to "sew" cells together to make tissues.)

A. Cellular Junctions help to hold cells together so that they can work together. ("junction" means "connection")
B. Some are tunnels for cell-to-cell communication.

V. A cell is the <u>sum</u> of its parts. (It is the basic unit of life only when all the parts work together to make "*life*" possible.) (This is an example of the *theme* of *Emergent Properties*.)

A. *Characteristics* of living things:
   1. Composed of cells
   2. Responds and adapts to the environment
   3. Uses energy
   4. Grows and reproduces

Unit 1: Cell Structure and Function
Content Outline: Cell Membrane Structure (1.2)

I. Cells are said to be *Selectively Permeable* structures.
   A. The cell "*selects*" what materials enter or exit the cell through the membrane.
   B. The membrane also helps to *regulate (control)* **homeostasis** (stable internal environment) by "controlling" entry or exiting of certain molecules.

II. Membrane Structure—
   A. **Phospholipids** make up the *majority* of the membrane.
      1. These are **amphipathic** molecules. (It means there is a *hydrophilic* and *hydrophobic* component.)
         a. **Hydrophilic** means "water loving".
         b. **Hydrophobic** means "water fearing".
      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 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 hydrophilic and some are hydrophobic.)
      2. Two types of proteins are present on the membrane:
         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 <u>not</u> 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 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 "stiching" cells together to make tissues.)
         f. *Attachment points* for the cytoskeleton and ECM.

   C. Cholesterol
      1. This molecule helps keeps the membrane of all cells flexible.
      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 floors are water molecules. They keep you from moving up and down to some extent by their presence.

III. Why Models? Scientific Model
   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) Further, *the natural world is complex; it is too complicated to comprehend all at once. Scientists and students learn to define small portions for the convenience of investigation.*

IV. Cell-to-Cell Recognition
   A. This is vital to tissue formation, for example Red Blood Cells (RBCs) and White Blood Cells (WBCs).
   B. Glycolipids (sugar lipids) and Glycoproteins (sugar proteins) that function in this process *act as hands* on a blind person. Imagine cells are like blind, deaf, and mute individuals… how can they communicate with the environment around them?. By using their hands to identify molecules and other cells.

Unit 1: Cell Structure and Function
Content Outline: Movement Across Membranes (1.3)

I. Material Transport in general with regards to cells:
   A. CO_2 and O_2 (both gases) diffuse across the *wet* phospholipid bi-layer.
   B. Ions (charged particles) and water move through the proteins. (Hence the name Transport proteins.)

II. **Passive Transport** (No energy is required for this process to occur.)
   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 energy expenditure by the cell…which saves energy for *maintaining* homeostasis, repair, and reproduction.)

   B. **Osmosis** (The diffusion of water.)
      1. *Water always flows from **Hypotonic** to **Hypertonic** until **Isotonic***
      2. Terminology:
         a. Terms refer to the *material dissolved in the water, not the water itself. (That is "tonic".)*
            i. "Hypo" means "very little" is dissolved in the water.
            ii. "Hyper" means "a lot" is dissolved in the water.
            iii. "tonic" referring to the water.
         b. Water flows one way and the materials dissolved in the water flow in the *opposite* direction.
         c. Water molecules *never* stop moving across a membrane; even when isotonic state exists.
      3. The process of **Osmoregulation (water control)** is *crucial* for **all** cells to control.
         a. Pure water vs. normal water. *Pure* water is always the hypotonic.
         b. **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.
         c. **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.
         d. **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".)
      4. **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. We state that water is moving from *high potential* (hypotonic) to *low potential* (hypertonic).
            i. This is because we do not consider water to have varying water "concentrations". Water is water.

   C. **Facilitated Diffusion** ("Facilitate" means "to help".)
      1. This movement of molecules requires the *help* of a **Transport Protein**.
      2. It does not require energy to occur.

III. **Active Transport** (This process requires energy to occur**.**)
   A. This process is moving material *against the concentration [ ] gradient.* (Like pushing a car up a hill…it will require energy.)
      1. Some examples in organisms are: Proton pumps, and Na+/K+ Pumps of the nervous system.
         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.
         b. Electrons can also provide energy, such as in the Electron Transport Chain of Photosynthesis or Cellular Respiration.

IV. *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".)
   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".).

Unit 1: Cell Structure and Function
Content Outline: Cell Communication (1.4) – Part 1

I. Cell to Cell Communication
- A. It is *absolutely essential* for multi-cellular organisms to survive and function properly.
- B. Communication between cells 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.
- 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 is 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** - Chemical *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.
     b. In the phone answering example, 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, you 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.
     b. Now that I know what the phone message was; 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 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.

Cell Communication – Part 2

I. The most important receptor protein pathways in cells:
   A. **G- Protein Pathway** (This is the <u>most</u> common pathway used by cells.)
      1. **G- Protein Linked Receptor**
         a. This protein serves as the *attachment point* for the Ligand. (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.
      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 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.)
      2. This is a great example of structure = function. In repair, you need to get the *processes* going quickly to prevent possible cell or tissue death.
   C. *Intra*cellular 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. Protein **Kinase Cascades**
   A. *Kinases* turn <u>on</u> 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 <u>off</u> processes by *removing a phosphate* ion from the molecule.
   B. Same as "B" and "C" above.

IV. 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.)

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

Unit 1: Cell Structure and Function
Content Outline: The Cell Cycle (1.5) – Part 1

I. Reproduction by cells
- A. The main purpose is for *propagation (maintaining) of the lineage*.
- B. 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 cells)**.
     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 their *adult functions*.)
- C. This is also necessary for normal growth (Such as in size of organs) and repair (of existing structures).
- D. The process requires that **DNA Replication** 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 Protein Synthesis.
        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?)

II. **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 this is 46 chromosomes = 2n. (n= 23 in the egg; n=23 in the sperm)

III. **Histones**
- A. These are the *proteins* that help DNA *coil up "condense"* to form the chromosomes needed for division.

IV. **Sister Chromatids** ("Tid" means "portion"; Portion of the whole "duplicated" chromosome, after the DNA has replicated.)
- A. This term refers to *half* of a *replicated* chromosome. (One side of the "X" appearance…> OR<.)
- B. The two halves are held together at the **centromere** (means "center unit"), which is a *group of proteins*.

V. **Mitosis** – This process refers to *ordinary cell division***.** (Parent cell and daughter cells are exactly alike genetically.)
- A. Involves only <u>one</u> division after replication occurs in the S phase.

The Cell Cycle – Part 2

I. The Cell Cycle Phases are:

A**. Interphase**

1. Cells spend 90% of their *total 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. 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 replicated chromosomes "2n" + 46 original chromosomes ("2n"). *This is essentially two cells worth of DNA.*
      iii. The number of chromosomes is *still considered 46*, the replicated plus the original only counts as *one* chromosome as they are joined by the centromere.
   c. **G2** (Secondary or "second" growth)
      i. The cell and organelles mainly enlarge or replicate.
      ii. Second checkpoint occurs after this "part". (Do we have everything for <u>two</u> 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. **Pro**phase ("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. **Meta**phase ("meta" means "middle")
      i. The replicated chromosomes *line up on the metaphase plate* (middle of cell).
      ii. The *spindle apparatus attaches to the kinetochore* (a part of the centromere) <u>and</u> *centrioles* (the anchors).
      iii. Third checkpoint occurs here. (Are all the chromosomes attached and lined up and ready to "divide/separate" or "segregate"?)
   c. **Ana**phase ("ana" means "separate")
      i. Replicated chromosomes 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 chromosomes are "walked" toward the poles by the *motor protein* using ATP.
   d. **Telo**phase ("telo" means "last")
      i. The nuclear envelope is *rebuilt* by using broken down spindle apparatus pieces.
      ii. The chromosomes begin to *de-condense* back to their *chromatin* state.
      iii. A **cleavage furrow (indent)** 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. Cells that enter this phase, which is separate from the cell cycle, where Cyclin is <u>not</u> produced and essentially the cell cycle is shut down/turned off.

II. Spindle Apparatus

A. These structures are formed from the *broken down cytoskeleton* and nuclear envelope. *(recycled)*
B. The construction starts at the **centrosome** (where the centrioles are) and *works toward* the chromosomes.
C. They attach to the replicated chromosomes.
D. *Motor Protein* "walks" the 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 <u>do not</u> 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. **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 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 endosymbiant hypothesis occurred to produce "organelles". The two major steps are the same: synthesis and division.

Control of the Cell Cycle – Part 3

I. *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 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 replicated chromosomes in the middle of the cell and are they ALL attached to the spindle fibers?)

II. G0 (Zero growth phase)
   A. Cells that enter this phase, which is separate from the cell cycle, where Cyclin is <u>not</u> produced and essentially the cell cycle is shut down/turned off.

III. Cancer (*Abnormal* cell growth)
   A. *No checkpoints exist* within cancerous cells, so there is no **density-dependent inhibition**.
   B. Normal cells divide between 1 and 100X –It depends on the cell type.
   C. Cancer starts with *transformation of the DNA (mutation)* in a cell.
   D. **Tumor** – means "Abnormal growth"
   E. 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* of the tumor**.**
      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.

Unit 2: Biochemistry
Content Outline: Chemistry of Life (2.1) – Part 1

I. **Matter**
- A. Anything that takes up *space* and has *mass* to it.

II. **Element**
- A. The simplest *form of a substance* that cannot be broken apart and still have the properties of that element.

III. **Compound**
- A. *Two or more elements bonded together* resulting in *new* chemical properties to emerge for the compound.
- B. An example: Water (H_20) – a stable liquid and can sometimes be used to put out a fire. Hydrogen by itself is a flammable gas; Oxygen by itself is also a flammable gas.

IV. CHNOPS - The *most common* elements in <u>all</u> life forms.
- A. **Trace elements** – These are present in *very small* amounts.

V. **Atom**
- A. The smallest *unit of matter* with set chemical properties. Atoms *maintain* their original properties because the subatomic parts are all present.

VI. **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 <u>never</u> changes in an element. (This allowed the **Periodic Chart** 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 <u>can</u> 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 *outside the nucleus* in the "Electron cloud". Electrons are *moving*, which is called **kinetic energy**, and this is why they are associated with energy and batteries. It is **potential energy** when they are *bonded*.
  1. The number of electrons <u>can</u> change. (Atoms with *different numbers of electrons* than the normal amount for that element are called **Ions.**)
  2. The cloud is divided into *energy levels*. The first energy level holds *two* electrons. The second and third hold *eight* electrons.
- D. Atoms are *weighed* in units called **Daltons** or **Atomic Mass Units (AMUS).**
  1. Each proton or neutron (these are the *largest* sub-atomic particles) is equal to **1** Dalton or 1AMU. (Electrons are basically 1/1000 of a Dalton.)

VII. **Molecule**
- A. Two or more atoms bonded together. (They may be the *same* type of atom or they may be *different* atoms.)

VIII. **Atomic Number**
- A. This is usually shown as *subscript* on the Periodic Table.
- B. It refers to the *number of protons only in that element.*

IX. **Mass Number**
- A. Usually shown as *superscript* on the Periodic Table. ("Super" means "above" or "greater")
- B. It basically refers to the number of *protons and neutrons together in that element or molecule.*
  1. These are the two subatomic particles that have "*significant mass or weight*" associated with them. Remember, electrons have very little mass, so you can just add protons and neutrons.
  2. Mass Number can also be referred to as **Atomic Weight**.

X. **Isotopes**
- A. Atoms that possess *different numbers of neutrons* than the *normal* amount for that element and thereby have different *mass* numbers.
- *B.* These usually have *the same chemical properties* as the normal element, but the *physical properties may be different.*
- C. Most isotopes are *radioactive.*

Chemistry of Life – Part 2

I. **Energy** (represented by the symbol "E")
   A. Energy comes from the *rapid movement of electrons (e-) normally*, but it could also be neutrons.
   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.)

II. Chemical Properties
   A. An element's or molecule's properties are usually associated with the *number of electrons* it has.
   B. **Periods** (Run *horizontally* on the Periodic Table. **Horizontal** is "side to side")
      1. Elements behave *differently* as you go *across* a period.
      2. Think of it as a sentence, different words convey different things. Also what is usually at the end of a sentence… a period?
   C. **Columns or Families** (Run *vertically* on the Periodic Table. **Vertical** is "up and down")
      1. Elements behave *similarly* as you go down a column or family.

III. Chemical Bonds (These occur between elements or molecules.)
   A. **Covalent Bonds**
      1. This type is a *very strong* type of chemical bond.
         a. Results from *sharing electrons* between elements or molecules to fill <u>both</u> outer shells.
      2. They <u>always</u> 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 <u>not</u> have an electrical charge.*
   D. **Structural Formula** (Used to show the shape of the molecule)
   E. **Molecular Formula** (*Tells* the elements, and *number* of atoms of each, that make up a molecule)
      1. A.K.A. **Chemical Formula**
   F. **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 *gaining or losing electrons* between elements so that each element can fill its' outer most shell.
      3. When an ionic substance is dissolved in water Ions 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.
   G. **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 <u>most important</u> biological bonds.*

IV. Chemical Reactions
   A. To *make* a bond *requires* energy to be consumed. (The bond requires "catching" an electron.)
   B. To *break* a bond *gives off* energy. (The electrons are "released" to move again.)
   C. **Reactants** (Located on the *left side* of an equation.); **Products** (Located on the *right side* of an equation.)
      1. Demonstrates the **Law of the Conservation of Mass**
         1. *Matter is neither created nor destroyed just transferred or transformed.*
      2. If an element is on one side of an equation it <u>must</u> be on the other side too!
      3. Equilibrium (↔)
         a. Chemical reaction is going both ways at *equal* rates.

Unit 2: Biochemistry
Content Outline: Water Properties (2.2) – Part 1

I. Life and Water
   A. Water, mainly found *inside* of cells, makes up 70 –95% of the organisms body for *all* life forms on earth.

II. Water is a **Polar** molecule (It has a positive and a negative end.)
   A. Oxygen has a *slightly negative charge* because it is more **electronegative.** (It has a stronger hold on the electrons because it has eight positive protons as compared to Hydrogen's 1 proton.)
   B. Hydrogen has a *slightly positive charge* because it is less electronegative (it has a weaker hold on the electrons because it only has one positive proton).
   C. Water's polarity allows it to make **Hydrogen bonds** *easily*.
   D. This polarity makes it possible for water to conduct electricity very well. (Remember, electricity is flowing electrons.)
   E. This polarity allows for a single water molecule to bind to *4 other water molecules at a time*.

III. **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 how water moves up a plant.

IV. **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.**

V. **Surface Tension**
   A. This is the linking together of water molecules on the *surface of a body of water*.
   B. This property is made possible because of **Hydrogen bonds.**

VI. Water helps with *temperature regulation* in organisms and on the earth.
   A. Water is the <u>only</u> substance on earth to be found in all 3 states *naturally*. (solid, liquid, and gas)
   B. 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.)
   C. This property is made possible because of **Hydrogen bonds**.
   D. It takes tremendous amounts of E to break <u>all</u> four hydrogen bonds *at once* and turn liquid water to a gas.
   E. This is an important worldly effect as it helps to *keep the temperature of earth stable* (water absorbs the energy of sunlight, 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 remains stable.)
   F. Kinetic E terms associated with water.
      1. **Heat** – This measurement is the *total amount of kinetic E* in a substance.
      2. **Temperature** – This measurement is *the intensity* of all the heat *in a substance* as the molecules move. (The faster they move… the hotter it gets and the slower they move… the colder it gets.)
   G. 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**
   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% Celsius; after that, the colder it gets, the more it expands.
   B. Life was and still is able to survive under the *floating* ice that occurs at the poles and during winter.

Water Properties – Part 2

I. Water is the **Universal Solvent** (It can dissolve most things)
   A. **Solvent** – Liquid that is *doing the dissolving* of another substance.
   B. **Solute** – Substance *being dissolved* in the solute.
   C. **Solution** – Substance possessing *equal distribution* of material. (Kool-aid is a good example.)
   D. **Hydrogen bonds** of water make each situation possible.
   E. **Hydration shell** – Water *surrounding* a molecule. Substance is dissolved and "disappears".
   F. Oils, grease, and fat are *non-polar* and therefore water can't grab and dissolve. (They 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. 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 p**OH** scale.)
         a. On the pOH scale: < 7 – substance is a **base**; > 7 – substance is an **acid**

   B. Buffer
      1. A substance *that can resist changes in pH or pOH*.
      2. It can take on or give off an H+ or OH- to maintain the pH or pOH concentration.
      3. A good example is Human Blood –The buffer is Bicarbonate (HCO_3^-).
         a. Bicarbonate helps keep blood at a pH of 7.4 ideally
         b. It is needed because of the food, drink, air or other substances that we put into our bodies
         c. HCO_3^- can take on H^+ from the blood to become H_2CO_3 (Carbonic Acid) to *raise* blood pH.
            i. The H_2CO_3 then travels to the lungs where it is *converted* to H_2O (water) and CO_2.
         d. <u>OR</u> H_2CO_3 can give off a H^+ to become HCO_3^- and H^+ to *lower* blood pH.

   C. **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 that combines with water.
         a. Both are found in fossil fuels when burned. (Such as oil, gasoline, or diesel fuel)

Unit 2: Biochemistry
Content Outline: Carbon Properties (2.3)

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. (CO_2 in Photosynthesis)
- C. **Inorganic** refers to *most* compounds not containing Carbon. (CH_4 [Methane gas] and CO2 or CO are exceptions. They contain Carbon *but* are classified as inorganic.)

II. Carbon's e- configuration
- A. Carbon has *versatility in four directions* because of the *four unpaired* electrons in its outer shell.
  1. It is said to have **tetravalence**. ("tetra" means 4; "valence" is the outer electron shell.)
- B. These four *unpaired electrons* allow carbon to act like *an intersection* in the building of an organic molecule by using those to form covalent bonds with other atoms.
  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)

III. 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.)

IV. **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. **Hydroxyls** (-OH)
  1. This group allows molecules to act as an *alcohol* or *polar* molecule.
  2. Name usually ends with "ol".
- C. **Carbonyls** only have *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 oxygen atoms*…one double bonded and one single bonded. (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 be polar too.
- E. **Amine** Contain Nitrogen
  1. Can act as bases by *picking up* free H+.
- F. **Sulfhydryl** Contain Sulfur
  1. Sulfur can make Di-Sulfide bridges for "pockets" in protein formation.
- G. **Phosphate** Contain Phosphorus
  1. These molecules are usually involved in *E Transfers*, such as associated with ATP. They can also act like an *Anion*, a negative ion.

Unit 2: Biochemistry
Content Outline: Molecules of Life (2.4) – Part 1

I. **Macromolecules**- "Macro" means "large"
- A. **Polymers** "poly" means 'many"; "mer" means "unit".
  1. Polymers 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.
  3. These are another example of the concept: Structure = Function.
- B. Macromolecules are formed by **Dehydration** or **Condensation Reactions.**
  1. Hydroxyl (OH) is removed from one molecule and Hydrogen (H) is removed from another. *This combination forms water.* This *orientation* of molecules and the making of a bond *requires E*.
  2. Enzymes (most are proteins) help *speed up the rate* of the reaction.
- C. Macromolecules are broken apart into individual monomers by **Hydrolysis reaction**. ("lysis" means "split".)
  1. This process *releases 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.

II. **Carbohydrates**- "Carbo" refers to Carbon; "hydrate" refers to water.
- A. These molecules are *mainly sugars.*
  1. **Monosaccharides** are the monomers or "building blocks". ("sacch" means "sugar".)
  2. **Disaccharides are** two monosaccharides linked together. ("di" means "two".)
  3. **Polysaccharides** are the polymers, many sugars linked together.
- B. The chemical composition is: Carbon = Oxygen; 2x as many Hydrogen atoms also present.
- C. The names usually end with "ose". Such as Fructose, Glucose, Sucrose.
- D. Polysaccharides are the primary E sources for cells.
- E. 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 of the bonded Hydrogen cause more energy to be released when they are broken off from the carbon.)
- D. Two main parts
  1. **Fatty Acid** tails (The Hydrocarbon unit.)
  2. **3 Carbon Glycerol molecules** (alcohol) to hold the whole molecule together.
- E. Major types of lipids
  1. **Triglycerols or Triglycerides –** *your basic fat or oil.*
     a. **Saturated fats are** fatty acids that are saturated with hydrogen atoms. The molecule has *no open bonds* to put any more Hydrogen on. (These are *solid at room temperature*. They usually are associated with *animals.*) Saturated fats 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. They usually are from *plants*, such as vegetable oil, sunflower oil, or peanut oil.)
     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. They are also usually from *plants*.)
     d. **Hydrogenated or Trans fats** (These are oils turned solid by *adding Hydrogen* by breaking the double or triple bonds in order to *transform* them 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 <u>not</u> attracted to water.)
     c. Phospholipid Bi-layers (having 2 layers) are common for cell and organelle membranes.

3. **Waxes**
    a. These lipids are made by *combining* alcohols with unsaturated oils. An example is lipstick which also has coloring added to make the different shades.
4. **Steroids, Cholesterol, and Hormones**
    a. A steroid has *4 carbon rings with the top ring looking like a house*.
    b. Cholesterol is also a steroid molecule and 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.
    c. Hormones are communication molecules.

F. Lipids are stored in Adipose Tissue in animals. This can lead to obesity or even **Atherosclerosis (Clogged Arteries).**

Molecules of Life – Part 2

I. **Proteins** (A. K.A. **Polypeptides**) and **Enzymes** (Enzymes are a *type* of protein.)

A. Proteins make up greater than 50% of an organism's *dry weight* (referred to as **biomass**).

B. This is another important example of the concept: Structure = Function. (Proteins are very large 3-D Molecules.)

C. The *monomer* "building blocks" are **Amino Acids** (There are 20 different Amino acids that can be involved in making proteins. Proteins usually have *hundreds* of Amino acids in their structure.)

D. Individual Amino acids (monomers) are bonded together by a **peptide bond**. When we put *many* amino acids together, we get a **polypeptide** or protein.

E. Proteins and enzymes are the "work horses" of a cell. They carry out *numerous* functions within cells.

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. Fredrick Sanger, in 1948, discovered the first protein Amino Acid sequence. It was for *insulin*.
   c. *Primary Sequence is* <u>*really important*</u>; 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 disease.
2. **Secondary Structure** (**2'**)
   a. **Hydrogen bonds** between *neighboring amino acids* allow for overlapping and coiling to occur. These help *fold up* the protein into its unique shape. It allows for *flexibility* too.
3. **Tertiary Structure** (**3'**) ("Tert" means "third")
4. A variety of bonds (covalent, ionic, hydrogen) between *distant* amino acids cause *large* folds in the protein. These help provide *stability* to the folded protein.
5. **Quaternary Structure** (**4'**) ("Quarter" means "fourth")
   a. This is when *two or more polypeptides are woven together*.
   b. Hemoglobin (Red Blood Cells have four proteins woven together.)
   c. Think, "multiple woven together" for Quaternary structure.

G. **Denaturation** (enzyme unfolding)

1. The "*unraveling*" of a protein or enzyme causing it <u>not</u> to function
2. Denaturing can be caused by pH *changes*, salt concentration *changes*, and temperature *changes*.
3. The most common bonds that have been affected during denaturation are the *weak* **hydrogen bonds** associated with **secondary structures.**

II. **Nucleic Acids**

A. *Monomers* are called **Nucleotides.**

B. *Polymers* are called **DNA or RNA**- It depends on the 5 Carbon sugars present in the monomer.

C. These are the *source* of genes and *hereditary* information primarily.

D. Two Types

1. **DNA** – This polymer is the "Master Million Dollar Blueprint".
   a. It is kept "safe" in the nucleus or nucleoid region. (Nucleus is like a vault designed 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. **C**ounting steps **T**akes you **U**p 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. "**A**labama is **Pure**ly **G**reater than **A**uburn" or "**A**uburn is **Pur**ely **G**reater than **A**labama" is an easy way to remember. It just depends on whom you like more.

G. It is <u>always</u> a pyrimidine paired with a purine.

H. The sequence <u>*determines*</u> *what protein or enzyme is made.*

1. Example of Structure = Function theme <u>and</u> Emergent Properties theme

2. That is why it (what is it? DNA RNA or Polymers) is the "*Blueprint*".

III. DNA Double Helix Structure
   A. James Watson and Francis Crick make the model in 1953.
   B. The two sides are said to be **complimentary.** (They fit together perfectly.)
   C. For a given stretch of DNA, only one of the two strands is read to obtain the instructions (Million Dollar Blueprint) for making proteins.

IV. 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.
      1. Time allows for the changes to occur… little time allows for less change <u>or</u> more time allows for greater change.

Unit 2: Biochemistry
Content Outline: Metabolism and Enzymes (2.5) – Part 1

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 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.*
     - c. Think **Cata**strophe; *breaking up* things.
  2. **Anabolism** –This is the *assembly 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*.
     - c. Think **Anabol**ic steroids; these *build* muscle.

II. **Energy** (represented by "E")
- A. Energy has the ability to *facilitate* transformation.
- B. There are two types of E mainly, as far as living organisms are concerned:
  1. **Kinetic E** (represented as "KE") - This is the energy of *movement*. In Biology this usually refers to the movement of electrons or protons.
  2. **Potential E** (represented as "PE") – This is the energy of *position*. (Usually referring to the chemical bonds associated with 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 *release* the E for use by cells.
  2. The sun is the source of all E for Earth. The process of photosynthesis allows plants to *store* 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** (Also called the **Principle of the Conservation of E.**)
  1. E cannot be created nor destroyed only transformed or transferred.
- **C. Second Law of Thermodynamics**
  1. Every E 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; E can't do work.

IV. **Gibbs Free E** (represented as "G")
- A. It is referred to as *"free"* because E is *available* to perform work. (Mainly making ATP or GTP in a cell.)
- B. Not all E is available. (Some is lost as waste…like when we defecate; we lose waste… cells also release waste.)
  1. Most E is *lost* as Heat as a byproduct of bonds being *broken*.

V. *Types of work* performed by living cells: (Most work is achieved by using *proteins and enzymes*.)
- A. *Mechanical* - work outside of the cell
- B. *Transport* - across the membrane
- C. *Metabolic* processes - Catabolism and Anabolism

VI. **ATP** (Adenosine Tri-Phosphate)
- A. Made from *Ribose sugar (RNA sugar)* and the nitrogen base Adenine.
- B. Has 3 *negative* phosphates linked together which makes it highly unstable like a "compressed spring". (*Unstable*, means it has the *capacity to perform work*.)
- C. ATP converting to ADP gives off energy; ADP being converted to ATP 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 therefore able to perform work. (Take the phosphorus off and it quits working.)

Metabolism and Enzymes – Part 2

I. **Enzymes**
- A. These molecules are *Biological* ***Catalysts***.
    1. Proteins that *speed up and control* the rate of a chemical reaction.
- **B.** *They are recycled***;** *they are <u>not</u> consumed by the reaction***.**
- 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.
- D. Enzyme names usually end with "ase".

II. **Free E of Activation**
- A. This refers to *the Free E used to start* a chemical reaction in motion. (Essentially is the energy needed to get 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. (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" means "more than one piece in the unit".)
- C. The two parts are mainly held together by *weak* ***Hydrogen bonds.***
- D. By *orienting* the substrate molecules, the reaction rate speeds up.

V. *Environmental 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 Heat causing it to **Denature** ("unfold").
- B. *pH* of the environment.
- C. *Salt* concentrations
- D. The **Optimal Conditions** for most human enzymes:
    1. 98.6˚F (35 - 40°C)
    2. pH usually between 7.2 and 7.6 (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. The limits of "life".

VI. **Inhibitors**
- A. The name implies that these molecules *negatively affec*t 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* causing the shape of the active site to *change s*o the substrate can't fit into it.
        a. These molecules cause the reaction to stop completely.

VII. ***Feedback*** **Inhibition**
- A. A **product** *in excess* shuts down the reaction that is taking place at *an earlier point in the pathway*.
- B. Prevents "waste" of precious materials and energy by not making more of what is not needed at that time.

Unit 3: Bioenergetics
Content Outline: Photosynthesis (3.1) – Part 1

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 "other")

III. **Chlorophyll** – A *light-absorbing pigment* found in chloroplasts of plants, algae, and blue-green bacteria.

A. Found mainly in the *mesophyll layer* of ground tissue in plant leaves. ("meso" refers to "middle")

B. "phyll" means "pigment"; ""chloro" means "green" (They *reflect* green light.)

IV. Chloroplast structure ("plast" means "container") (These are *organelles* like the ones in Eukaryotes.)

A. **Thylakoid** – Little green discs that *contain the pigment chlorophyll* found inside the chloroplast.

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

a. *Primary purpose is to make **ATP** and **NADPH**.* (Both are Energy molecules.)

B. **Grana** – a stack of thylakoids.

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

1. Site of the *light – independent reaction* (Dark or Calvin Cycle) of photosynthesis.

a. *Primary purpose is to use **ATP** and **NADPH** to make sugars using CO_2.*

V. Photosynthesis Chemical Reaction

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

B. Then takes the chemical E (ATP and NADPH) and uses that chemical *energy to power* the production of sugar (Sugars are chemical E *storage* molecules.)

B. 6 CO_2 +6 H_2O → (in the *presence* of sunlight) $C_6H_{12}O_6$ + 6O_2 + Heat (*Key Number* is 6 in balancing.)

C. Sugar is *stored chemical energy* for cellular respiration.

D. *H_20 splits*; *<u>not</u> CO_2*.

E. Two processes involved in the conversion of sunlight energy to sugar:

1. **Light reaction** (light dependent) – It *changes* sunlight into ATP and NADPH. (*Usable* chemical energy.)
2. **Calvin cycle** (A.K.A. **light independent reaction**) – Makes sugar using CO_2, ATP , and NADPH.

a. Melvin Calvin discovered the working process.

F. NADP+ is *converted* to NADPH by picking up 2 negative electrons (The *first* cancels the charge; the *second* makes the NADP molecule negative which allows for H+ to attach and thus create NADPH.)

G. ADP is *phosphorylated* (Add a phosphate) to make ATP. This *requires the free E of electron transport chain*.

VI. Sunlight (It is *high quality* E. Remember, High quality means it *can perform work*.)

A. Sunlight travels in *waves* with different wavelengths. (The **Electromagnetic spectrum** shows all the Wavelengths/colors found in sunlight.)

1. *Red Light*– Has the *longest* wavelength. (It also has the *least E* of "white light".)
2. *Blue Light*- Has the *shortest* wavelength. (It has the *most E* of "white light".)
3. **Spectrophotometer** – This *measures light wavelengths* not absorbed by a *specimen*.

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

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

D. **Absorption** vs. **Reflection**

1. **Absorbed** –These colors are *usable* light E.

a. *Plants use Reds and Blues*; *but* *not green.*

b. **Chlorophyll A** – *Main 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 E. (B *funnels* E to A.)

d. **Carotenoids** – These are *accessory pigments* that help Chlorophyll A. (They *funnel* E to A too.) (These are red, orange, or yellow pigments.)

e**. Photosystem** – *Group* of light absorbing pigments in thylakoid membrane. (Chlorophyll A would be in the reaction center.) ("system" means "group of").

i. Photosystem I (P700) – Responsible for *ATP and NADPH production*.

ii. Photosystem II (P680) – Responsible for *ATP production only*.

3. **Reflection** – These colors are *not usable*. (They provide the *color* of an object in *your* vision.)

a. *This is why plants appear green to you.* Green light is *reflected* back toward *your* eyes.

Photosynthesis – Part 2

VII. **Light Reaction** of Photosynthesis

A. This process is used for *converting* sunlight into *usable* chemical Energy molecules. (These molecules are: **ATP** and **NADPH**)

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

C. There are *thousands* of these Photosystems (I and II) on *each* Thylakoid membrane.

Step 1: Sunlight hits and *splits* the water in the stroma. It also hits the photosystems I (P700) and II (P680).

Step 2: *2 Excited electrons* travel down the electron transport chains. They came from the Mg in the Chlorophyll A molecule. (The 2 excited electrons were able to leave the Mg because the sunlight *heated them up* and made them move much faster. Fast enough to escape the pull from the nucleus' positive protons) As the *excited electrons* go down the electron transport chain, their *excited kinetic E (also called **Free E***) is *being used to power* the proteins called **Proton pumps**. (Remember, a proton is a Hydrogen ion and is shown as H^+) As the electrons go down their chain, their excited kinetic E *decreases.*

A. P680's *2 excited electrons*

1. ***Free E** of the electrons* is used to **actively transport** protons (H+) into the *confined* thylakoid space. (As the [H+] goes up inside the space. The [H+] goes down in the stroma. So a concentration gradient is *created*. This is a *source* of potential E now. It would be like blowing air into a balloon. The pressure builds as more air is blown in. This is also an example of potential E.)

B. P700's *2 excited electrons* combine with NADP+, to make it negative so that NADPH can be generated.(This is the ending point for *non-cyclic electron flow*.)

OR

Cyclic electron flow – P700 loses *2 excited electrons* to the electron transport chain, but they **return** to P700. (Remember this makes *extra* ATP.)

Step 3: The *trapped H+,* inside the Thylakoid, are *released through the **ATP Synthetase Complex***. This is the group of enzymes in the Thylakoid membrane that helps make ATP. Just look at its name. (This release of kinetic H+ *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+ produces a *large amount of ATP***.**

B. This is an example of **Energy Coupling** (*Two* processes *working together* to make ATP. The *first* process was **Active transport** to pump the H+ into the Thylakoid to make the concentration gradient. The *second* process is a type of **diffusion**. The H+ going from high [ ] to low [ ]. The kinetic movement of the H+ fuels the production of ATP.) This is **Chemiosmosis** again.

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

Photosynthesis – Part 3

I. **Calvin Cycle** (A.K.A **light independent reaction**)

A. This part *uses the ATP and NADPH* of light reaction to make sugar using CO_2.

B. There are 4 steps to *making* a single sugar molecule:

Step 1: 3 CO_2 molecules will be used, in the chloroplasts stroma, by the enzyme Rubisco to convert RuBPs into G3P molecules. (Remember, these were the 2 halves of a sugar molecule that were seen in Glycolysis.) The *energy to power the conversion* comes from ATP and NADPH.

Step 2: 1 G3P will be to *removed to put toward* making sugar.

Step 3: The remaining G3P will be reconverted back into RuBP using the extra ATP from the light reaction.

Step 4: Repeat steps 1 → 3 to make the *second half* of the sugar molecule.

C. These sugars will be needed to *feed* the whole plant or algae. The sugars will be *consumed* in the process of cellular respiration or *stored* to be used later or passed to consumers in a food chain.

Unit 3: Bioenergetics
Content Outline: Cellular Respiration (3.2) – Part 1

I. Cellular Respiration
- A. This is the process of *releasing energy* contained in *organic molecules* (mainly Glucose) to do work. (This is an example of catabolism.)
  1. The process is for *making ATP* using oxygen, if available.
  2. The process releases heat (Remember, heat is *Low Quality E*) and free electrons. (Remember that electrons are a source of *Kinetic Energy*.)
- B. *With O_2 present* in the cell – Cellular Respiration can occur in the mitochondria.
- C. *Without O_2 present* in the cell – Fermentation will occur in the cytoplasm of the cell.
- D. 6 02 + C6H12O6 → 6CO2 + 6H2O + Free E +Heat E
  1. *The Free E is used to make ATP from ADP by phosphorylation*

II. Cellular Respiration is a *Three Step Process:*
- A. Step 1: **Glycolysis** (This is the *breaking of* Glucose into 2 molecules of G3P.) (<u>All</u> 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.)
- C. Step 3: **e- Transport Chain** (This is where the *Free E of the electrons is used to help make ATP*.)
- D. The whole process yields a *maximum of 38 ATP*/ 95% of time only 36 are produced.

III. The Process of Glycolysis
- A. In this process, Glucose (C_6 H_{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*.
- B. There are two phases in 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.)

  2. **E Payoff Phas**e
     a. The 2 molecules of G3P will then be *converted* to 2 molecules of Pyruvate.
     b. This phase *will yield 4 ATP + 2 NADH*. (2 ATP and 1 NADH per molecule) The cell *pays back* the two it *used* for the first phase. 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. <u>All</u> organisms do it as it occurs in the cytoplasm of a cell.

Cellular Respiration – Part 2

I. If Oxygen is present within the Eukaryotic cell ("**Aerobic**" means "With Oxygen"), the Eukaryotic cell *can* perform the other two parts of Cellular Respiration – Kreb's Cycle and Electron Transport Chain.

A. In order to enter the *inner* Mitochondrial space, where the Kreb'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. The final product is Acetyl Coenzyme A. (*Each* molecule is now located in the *inner* mitochondrial space.)

B. **Kreb's Cycle** (This occurs in the *inner* mitochondrial space where there is *room* to work.)
Remember, the *main purpose* of the Kreb's Cycle is to make Electron Carriers by tearing Hydrogens and attaching them to the Electron carriers. Remember, each Hydrogen has one electron with it. See how many it makes per Acetyl Coenzyme put into the cycle.

1. **EACH** Acetyl Coenzyme A that goes through the cycle will produce:
   a. 3 NADH, 1 FADH2, 1ATP, and CO2.
   b. Each Electron carrier can carry 2 electrons to the Electron Transport Chain.
      i. The *first* negative electron cancels the positive charge on either NAD+ or FADH+.
      ii. The *second* negative charge makes the FADH or NAD negative.
      iii. So a *positive* H^+ will be able to attach to a *negative FADH or NAD.*

C. **Electron Transport Chain**

1. This occurs on the *inner Mitochondrial membrane.*
   a. This membrane is folded (*the folds increase surface area =more ATP can be produced as there is room for more Electron Transport Chains.)*
2. 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*.
3. The *whole* process is a *controlled release of E*.
   a. Electrons move 2 at a time *down* the chain toward *Oxygen***.** *(Make H2O at end.)*
   b. *Energy (electrons) from NADH and FADH2 is used to produce ATP***.**
   c. *Free Energy*, from the electrons, fuels the *active transport* of H+ into the inner mitochondrial space.
      i. H+ (ions/protons) are *pumped* into the space between the membranes *using the Free E released from electrons* as they go down the chain.
      ii. The concentration of H+ 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+ are released* using ATP Synthesizing Complex. (It would be like pulling the cork in the sink.)
      iv. The H+ rush out (going from High [ ]–>Low [ ]) allowing the **ATP Synthesizing Complex** to use the *Kinetic E* to turn ADP → ATP in large amounts by *phosphorylation*.
      v. This is another example of **Energy Coupling** – two processes working together to make ATP. One process is Active transport and the other is facilitated diffusion. Also known as **Chemiosmosis.**
      vi. The Electron Transport Chain can *make 34 or 32 ATP*
      vii. *Add it all up now*:
      2 Net ATP from Glycolysis
      2 ATP from the Kreb's Cycle
      34 **OR** 32 from the Electron Transport Chain (Using all the NADH or FADH2)
      38 Maximum OR 36 Normal

Cellular Respiration – Part 3

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 2 Pyruvate to 2 molecules of **Ethanol** by cutting off CO_2 and filling the open bond with H from the electron carriers. (This freed up the electron carrier to keep Glycolysis going thereby allowing some ATP to *stay alive.)*

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

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

i. *Converts* Pyruvate into **Lactic Acid** by breaking a double bond with O_2 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 to *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* oxygen – because it produces more ATP.)

Unit 4: Molecular Genetics
Content Outline: DNA History and Replication (4.1) – Part 1

I. Alfred Hershey and Martha Chase (in 1952)
- A. They worked with the T2 **Bacteriophage** (A virus that infects bacteria.) and E. Coli bacteria.
- B. Over time this became known as the Hershey-Chase Experiment.
    1. They used *radioactive Sulfur-35* to label the virus's *protein* outer capsid in one container.
    2. They then used *radioactive Phosphorus-32* to label the *DNA* inside the virus in *another* container.
    3. The radioactive viruses were then exposed to bacteria. The viruses infected the bacteria.
    4. In the radioactive Sulfur container, the radioactive Sulfur did <u>not</u> 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 <u>not</u> radioactive.
    5. 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 <u>were</u> radioactive from the Phosphorus they possessed.
    6. This *proved with 100% accuracy*, that DNA was the "*transformation agent"* and that it carries the information "blueprint" from one generation to the next.

II. Erwin Chargaff (in 1947)
- A. He developed what became known as **Chargaff's Rule**.
- B. The rule states that, for <u>all</u> organisms**,** [A] = [T] and [C] = [G].
    1. For example: If you know a species has 32% Thymine; then it must ALSO have 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÷ 2 = 18) The percentage is 18% Cytosine and 18% Guanine.

III. Rosalind Franklin (in the 1950's)
- A. She performed X-ray Crystallography on DNA. This picture was *extremely* important in helping James Watson and Francis Crick develop their model of DNA. (See below.)
    1. The picture *indicates the Double Helix*. 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 <u>always</u> one pyrimidine (C or T) and one purine (A or G).
        a. Purines (A&G) are *larger* nitrogenous bases. Pyrimidines (C&T) are *smaller* nitrogenous bases.
    3. The large areas *around* the "X" are the sugar phosphate backbone of DNA.

IV. 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 Base. (A=T and C=G)
- 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.

DNA History and Replication – Part 2

I. DNA **Replica**tion
- A. The process of making 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.
- 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. Matthew Meselson and Franklin Stahl propose this model, in 1958.
    2. It shows one original DNA side serving as a *template (guide)* for making the *other* DNA side.
    3. Easy as A = T and C = G.
    4. 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. There 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 *spaces* to do the actual building work of making the *new complimentary side* of the new DNA molecule by other enzymes.)

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" in Polymerase tells you it is an enzyme.)
    1. The enzyme works at a rate of about 500 nucleotides being added *per second*.
- B. The two sides of the Double Helix are said to be **Anti-parallel.** (This means that the DNA information runs in *different directions… anti, but the sides are next to each other*…parallel.)
    1. DNA is <u>always</u> *read and made 5'→3'.* (Remember this <u>important fact</u>!)
        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.)
- C. **Helicase** enzyme causes the Double Helix to *unwind.*
- D. **Single-strand binding protein** keeps the two sides *apart and stable*. (Look at the name and "*see"* the function.)
- E. **Leading strand** of the *replication fork* (Remember, there are <u>two</u> forks going in <u>opposite</u> directions.)
    1. *This strand runs, as it is being constructed, 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.) using **Primase** enzyme and go! (A "primer" is a *starting segment* of nucleotides.)
- F. **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. *The Okazaki fragments are "stitched" together using the enzyme **Ligase**.*

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.
- B. For errors that are created (what are called Mutations) <u>after</u> the DNA has been made – **Nucleotide Excision Repair** is used to correct these, if possible
    1. Step 1: **Nuclease** –*cuts around the faulty 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.

C. So What?

1. Errors in proofreading can result in some forms of cancer. For instance, some individuals are genetically predisposed to skin cancer because they have a mutation in the gene that codes for the excision repair enzyme. They can't fix damage caused by UV light on skin cells.

Unit 4: Molecular Genetics
Content Outline: Protein Synthesis (4.2) – Part 1

I. George Beadle and Edward Tatum (1934)
   A. They developed *the one gene-one enzyme hypothesis*. This *hypothesis* proposed 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 *recyclable, workable copy* of DNA but in the form of **RNA.** (The recyclable copy will become known as **mRNA – messenger RNA**. It is a *recyclable copy* of the "Million Dollar DNA Blueprint".)
      1. mRNA is synthesized (made) by an *enzyme* called **RNA Polymerase.**
      2. The *message* (mRNA) will be sent to the *construction site (ribosomes)* for *building* the protein.
      3. RNA nucleotides use Ribose instead of Deoxyribose as the *five carbon sugar*.
      4. 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.)
      5. mRNA is a single-stranded molecule, therefore it is *less stable* than DNA.

   B. DNA serves as a *template (guide)* for making the mRNA. A = U and C = G. (Still can use Chargaff's Rule.)
   C. Transcription is considered the *first part* of Protein Synthesis.

III. **Translation** (Means "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 using the *copied "blueprint"* that was provided.
   C. Translation is considered the *second part* of Protein Synthesis.

IV. **Codon** ("A.K.A Triplet Code") - This is the *RNA language* that will be translated into polypeptides.
   A. Codons are a "three letter" or three-nucleotide sequence of RNA. (It is *determined* by the template strand of DNA/ Important Blueprint Information, but is *read on the RNA*! The mRNA is being translated; <u>not</u> the DNA.)
      1. The codons <u>must</u> 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. There are four essential things you need to know about the genetic code (RNA Codon Chart)
         a. The RNA referred to is *mRNA* and it <u>must</u> be read in a **5' →3** orientation.
         b. Each 3 letter codon (e.g. GCU) *codes for* one, and only one, amino acid.
         c. *Most* amino acids have more than one codon.
         d. Therefore the genetic code is *redundant*, but it is not ambiguous.
      2. 61of the 64 possible codons ($4^3 = 64$) 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** and is also the codon for the amino acid Methionine. (It depends on the *position* of Methionine in the mRNA. The first codon on the 5' end that is AUG, 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. *This chart is <u>universal</u> for <u>all</u> living organisms and viruses.* **(**Viruses are *not considered* living.) (This hits on the theme of Unity and Diversity. Unity in that it indicates Common Ancestry among <u>all</u> organisms and viruses. Diversity is in the *differences* of the sequences of amino acids strung together to make a protein.)
      6. The codon will *match* the anti-codon sequence in the translation phase of protein synthesis.
   C. **Reading Frame** - This term refers to a set of **3** *consecutive nucleotides*. (They are read in 5' → 3' <u>Direction.</u>)

Protein Synthesis – Part 2

I. **Transcription – (A.K.A mRNA 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 recyclable copy* of the DNA sequence.)

A. Three Phases of *production* to **a transcription unit** (A piece of mRNA.):

1. **Initiation -** This is building our *factory to make* mRNA basically.
    a. A protein called a **Transcription Factor** attaches to *promoter* sequence of the gene being transcribed. Then additional transcription factors (proteins and enzymes) are added in the building process.
    b. 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 involved in making the structure.)
2. **Elongation** This refers to the *actual making* of the mRNA molecule.
    a. This <u>must</u> be made in the 5' → 3' direction!
    i. The RNA polymerase must begin work on the 3' end of the DNA strand though.
    b. RNA Polymerase II separates the DNA Double Helix to make *room to work*, and also *adds nucleosides* to the growing molecule.
    c. 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. Often, termination occurs as soon as the polymerase reaches a specific series of nucleotides along the DNA template, known as the **termination sequence.**
    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".)
2. *Back end (3') modification* of the mRNA molecule.
    a. A Poly A Tail added. ("poly" means "many"; 50-250 Adenines will be added onto the tail. The more As the *longer* the mRNA will last.)
    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.
    a. During this step, remove the **non-coding introns** (These act as "spacers") using **Spliceosomes**. A spliceosome is a type of enzymes that act as *scissors.*
    b. Generally, the **coding exons** are joined together into *one continuous sequence.*
        i. At times, "alternative splicing" can occur, when the order of the exons may need to be rearranged. This process allowing for *different proteins to be formed.*
    c. Spliceosomes "Stitch" the pieces together to make the *finalized* **secondary mRNA** transcript that is now ready for transport to the ribosomes for translation into proteins.

Protein Synthesis – Part 3

I. **Translation** - This is the process *of actually making (synthesis) 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. Remember, that the **anticodon** is found on the **tRNA** molecule, <u>not</u> the mRNA.
      2. The Anticodon *"matches"* the codon on the mRNA molecule ensuring the *proper amino acid* is brought to the construction site of the Ribosome. If they do <u>not</u> match … it is the *wrong* Amino Acid!
      3. 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).
   D. 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 recycled.)
      3. The ribosome **translocates (**"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.
      4. *Remember, these are <u>not</u> membrane-bound organelles. <u>All</u> cells possess ribosomes.*
   E. 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 *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 the protein.
         c. 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 primary (1') sequence of amino acids.
         a. The ribosome **translocates** ("walks") down the mRNA one codon at a time
      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 protein *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.
         a. **Polyribosomes** (many ribosomes) can also occur on a single 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.)

II. Post (means "after") Translation Modification (This is the *protein folding* that <u>must</u> occur for the protein to be functional.)
   A. If the 1' sequence enters a **Chaperonin** to fold, the protein *will stay inside* the cell.
   B. If the 1' sequence enters the Rough Endoplasmic Reticulum (RER) to fold, the protein *will be exported out of the cell.*

Protein Synthesis - Part 4

I. **Mutations**

A. *Change in the nucleotide sequence* of DNA or mRNA that code for a protein.

B. Caused by **Mutagens** (Means to "**gen**erate a **muta**tion".)

1. These are *physical or chemical interactions* that change 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.)*
   b. **Missense Point Mutation** – The mutation *changes the amino acid* coded for. (MIStake) (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.) (NONsense)
2. **READING FRAMESHIFT** Mutation (The whole DNA "sentence" is *changed behind the mutation*.)
   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 B**O**I 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 by mutation and *this is a cause of evolution*. *Change in the DNA over time*.

Unit 4: Molecular Genetics
Content Outline: DNA Control Mechanisms (4.3)

I. DNA control mechanisms in Prokaryotic cells only:
   A. **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.

II. DNA *control mechanisms in* all *cells* (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 the1940's. She worked with Maize. She won a Nobel Prize for this work.
      2. The most common type of transposon is :
         a. Basic Insertion
            i. This is the *simplest* form.
            ii. **Transposase** – the enzyme that allows the DNA *to "jump" from location to location.*
      3. This is another example helping to show *common ancestry* among all the life forms on Earth.

III. DNA *control* mechanism in Eukaryotes mainly:
   A. DNA that is *wound up*, like for Mitosis, is not able to be transcribed. The enzyme transcription "factory" can't be built because it *cannot* get access to the DNA strand.
   B. DNA that is *unwound*, like in G1 of Interphase, is able to be transcribed. The enzyme transcription "factory" *can* be built because it *can* get access to the DNA strand.
   C. Remember, Eukaryotic cells can also control the *removal of introns and rearranging of exons* in post translation modification.
   D. Lastly, did the protein require a **chaperonin** or the **Rough Endoplasmic Reticulum (RER)** for folding up into its 3D shape?
      1. Proteins that use **chaperonins** stay *inside* the cell, such as enzymes or cytoskeleton parts.
      2. Proteins that use **RER** *exit* the cell, such as for communication or protection by the Extra Cellular Matrix (ECM).

IV. *The genes that are transcribed help determine what the cells will mature into over time.* In other words, when cells "grow up" they will carry out "adult" functions. We call "adult" cells **specialized** or **differentiated**. They can carry out special or different functions. What do you want to be when you grow up?

Unit 4: Molecular Genetics
Content Outline: DNA Biotechnology (4.4) - Part 1

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 joined into *one* molecule.
- **B. Biotechnology** (This term refers to the use of living organisms to develop new organic products.)
  1. DNA gene cloning is an example.
     a. This process involves the bacterial **plasmids** and another DNA source.
     b. A **plasmid** is a small ring of DNA found in bacteria *in addition* to the main large circular DNA strand found in the nucleoid region.

II. **Bacterial Cloning** Process: (This is used for *inserting single genes* into bacteria.)
- A. Step 1: **Restriction Enzymes** are used to cut a DNA plasmid and DNA from other donor source.
  1. Restriction enzymes cut DNA at *specific nucleotide sequences*.
     The specific DNA sequence is referred to as the **Restriction Site**.
  2. Genes of interest (and antibiotic resistance genes) are cut into **Restriction Fragments.**
  3. When the DNA is cut, "Sticky Ends" or single-stranded DNA ends are created.
  4. *The same **restriction enzyme** must be used on both the plasmid and the DNA donor source*.
     a. Therefore, the "sticky ends" of the plasmid and the genes of interest *will match and can be joined.*
- B. Step 2: Create conditions for bacteria to take up *recombined* plasmids. (Bacteria are now **transformed**)
- C. Step 3: Incubate transformed bacteria in the presence of antibiotic to select for *only* transformed cells.
- D. Step 4: *Transformed* bacteria reproduce by binary fission to achieve a *large working population*.
- *E. Outcome: Transformed cells that have antibiotic resistance can express the gene of interest.*

III. **Polymerase Chain Reaction (PCR)** – This process requires *no organism* in the production of new DNA molecules.
- A. Kary Mullis won a Nobel Prize in 1993 for the development of this process.
  1. The process is used to turn a single molecule of DNA into a *large, workable sample of 100% identical DNA molecules*. This is widely used in criminal forensics (Murder cases).
  2. Nobel Prize is the *top award* a scientist can receive for their research. It would be like an MVP award in sports or an Oscar for actors or a Grammy for singers.
- B. Process
  1. The DNA sample is placed in a **PCR Thermal Cycler** machine.
     a. The machine uses *heat, DNA Primers, enzymes and a constant supply of nucleosides* to build *new* DNA molecules that are *identical* in nucleotide sequence to the original molecule.
     b. Step 1: *Heat* is used to *separate the DNA double helix* so that replication can occur.
     c. Step 2: The *attachment of a DNA Primer* to the template DNA strand will start replication.
     d. Step 3: The *DNA polymerase enzyme works 5'→3'* attaching nucleosides to the growing "new" side of the replicated DNA molecule.
     e. Step 4: *Cool* the mixture to recombine and stabilize the DNA back into a double strand.
     f. *Repeat the cycle (steps 1-4) many more times* to get large, workable sample of the DNA.
     g. Analyze the amplified DNA fragments.

Part 2

I. **Gel Electrophoresis** - This process is used to create a "*DNA fingerprint*".
   A. *Different individual's DNA samples,* but from the *same region* of a chromosome are exposed to the *same* restriction enzyme.
      1. This creates **Restriction Fragment Length Polymorphisms (RFLP's)**
         a. These are fragments of DNA having *different lengths* that were created using restriction enzymes. (Can you *see* that in the term?)
   B. Step 1: The DNA RFLP's are loaded into an agarose gel.
   C. Step 2: 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 should flow from the Black → Red strips when performing this process.)
   D. The RFLP's will *separate according to length/size* of the fragments.
      1. Big pieces move *slowly* through the gel.
         Small pieces move *quickly* through the gel.
   E. The DNA fragments are stained for ease of viewing.
   F. The DNA bands create a *unique "fingerprint"* of the individual's DNA.

II. **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. The human genome contains approximately 20,000 different genes. .
   D. These 20,000 genes only make up about *2% of the total genome*. That is amazing! Only 2%!
   E. Some of the other 98% are *regulatory/control sequences, about 10%*.
   1.The other 88%, is yet to be fully understood by science.

III. **Transgenic Organisms**
   A. DNA from two different organisms is recombined to make *one* organism that possesses traits from *both* "parent" organisms. These traits will be passed on through reproduction as the traits are in the DNA nucleotide sequence.

IV. Applications ("uses") of DNA Technology:
   A. Gene Therapy
      1. This uses a virus to introduce a new gene into a body cell's DNA.
      2. Somatic cells vs. Germ cells (Somatic cells only affect you; germ cells affect future generations.)
      3. Currently, only somatic cell gene therapy is legally allowed.
   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.
         Bacteria that can clean up Oil Spills or breakdown Plastic by eating the oil compounds.
      2. Organisms helping clean up heavy metals (such as Mercury) from mining or waste collection.
   E. Agriculture
      1. Engineering organisms to produce more and larger food.
      2. Genetically engineering organisms able to produce hardier food for easy transport across the world.
      3. Having organisms that can produce healthier foods.
      4. Having organisms that can produce food during winter. (Referred to as "Winterized".)
   F. Livestock
      1. Organisms that are "meatier".
      2. Organisms that are "leaner". (Having less fat.)
      3. Organisms that are disease resistant.

Unit 5: Mendelian Genetics
Content Outline: Mendel and Mendelian Genetics (5.1)

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**
   A. An *inheritable physical feature* is a *characteristic* such as eye color or hair color.

III. **Trait**
   A. This requires inheriting *two* alleles, one from *each parent.*
   B. A trait is a *variation of a character* such as *blue* colored eyes or *black* colored hair.

IV. **Alleles**
   A. This term refers to *different versions of a gene*. Remember, a gene is a *distinct DNA sequence* that can make one protein or enzyme. (Brown, blue, green eye color. There 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. If a dominant allele is present, the trait it codes for is expressed.
   D. **Recessive** alleles are given *lower case letters*. These are like books or recipe cards with *missing words* or no words– little information is on them on *how* to make the dominant version of the protein or enzyme. The "blueprint" is lacking.

V. **True "pure" breed**
   A. These organisms only have one *type* of alleles for that trait. (BB or bb for example.)
   B. A.K.A. **Homozygous alleles**. ("Homo" means "same".)

VI. **Hybridization**
   A. This is the process of "creating" an organism with two *different* types of alleles for that trait. (Such as Bb.)
      1. Referred to as **Hybrid** or **Heterozygous alleles**. ("Hybrid" and "hetero" mean "different".)

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 **Testcross** 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* dominant allele.

IX. Punnett Square
   A. This is a chart showing the *possible* genotypic outcomes for a *mating cross* based on parent's genotypes.
   B. **Monohybrid** – This chart displays *one* trait. It has *4* squares. ($4^1 = 4$ squares)
   C. **Dihybrid** – This chart displays *two* traits. It has *16* squares. ($4^2 = 16$ squares)
   D. **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. This states that *alleles on homologous chromosomes* move *independently* of one another. They "walk" to opposite poles of the germ cell during Anaphase I.
   B. This occurs at Anaphase I in Meiosis.

XI. Mendel's **Law of Independent *Assortment*** (This law describes the behavior of pairs of homologous chromosomes during Metaphase I.)
   A. This law describes how each pair of homologous chromosomes moves to the metaphase plate during Metaphase I independently of any other chromosome pair, and the *random placement* of the chromosome pair along the Metaphase plate.

XII. **Probability** "Chance"
   A. This refers to the *likelihood of a certain outcome* actually happening. (What are the chances of…occurring?)
   B. Probability is measured on a scale between 0 and 1.00. (From 0% to 100% essentially. 0.5 is 50% and so on.)
   C. On a monohybrid Punnett square, each square *represents a 25% chance of an outcome.*
   D. All boxes that have the same genotypes are added together to get the total probability.

Unit 5: Mendelian Genetics
Content Outline: Mendelian Genetics (5.2)

I. **Complete Dominance**

A. The dominant allele has information and it is *expressed*, even if there is only one copy. Geneticists call this "100% penetrance".

II. **Incomplete Dominance**

A. Information from *both alleles is expressed* in the cell. Neither phenotype is *completely* penetrant, therefore the heterozygous phenotype appears "blended". (Red + White = Pink)

III. **Codominance**

A. Information from *both alleles* is expressed in the cell. They are both *equally present* in terms of phenotype. (For example, black and white coats in animals, AB blood type in humans.)

IV. **Multiple Alleles**

A. There are *multiple (more than 2)* versions of the *same basic allele*.
B. The glycoprotein "hands" of red blood cells are a classic example. These "hands" (antigens) identify blood types. One dominant allele results in the presence of A antigens on the surface of red blood cells. Another dominant allele results in the presence of B antigens on the surface of red blood cells. A *third* allele results in no antigen and is a recessive allele. This condition is referred to as Type O. Since it is recessive, the gene or stretch of DNA that codes for these proteins has no code for A or B antigens, so *neither is made*.
C. **Universal Donor** – Can **give** blood to anyone. Since the O type blood has neither A nor B antigens, it does not cause a reaction in the bodies of people who have A, B, AB or O blood types.
D. **Universal Recipient**- Can **receive** blood from anyone. Since the AB type blood have both A and B antigens, there is no reaction if those cells are mixed with A, B, AB, or O blood types.

V. **Pedigree**

A. This is a *family history* of trait occurrence in chart form.
B. Pedigrees help tell the *past occurrences* of traits and can be useful in *predicting the future occurrence* of traits.
C. The power of pedigrees is their ability to predict possible genotypes and thus phenotypes of future generations.

VI. **Recessive** Disorders

A. Only occur in the *homozygous recessive* state.
B. **Carriers** – These are organisms that are *heterozygous* in genotype. (They are 50/50 in terms of passing on an allele for the trait.) These organisms usually *appear normal* for the trait as they possess one dominant allele.
C. Human recessive disorders:
    1. **Cystic Fibrosis** (Also referred to as "CF'.)
        a. This is the *most common lethal genetic disease* among people of European descent.
        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 thick mucus to build up in the lung tissues.
            i. The mucus impairs breathing.
            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 mucus cleared from the lungs periodically for their *entire* life. There are medicines to help *reduce the number of times* this has to occur.
    2. **Sickle-cell Disease**
        a. This disorder is the *most common genetic disorder among people of African descent*.
        b. It affects 1 in 400 births.
        c. The 6^{th} *Amino Acid* in the hemoglobin molecule is changed (Glutamic Acid → Valine) in the **primary sequence** needed to make red blood cells.
        d. **Sickle-cell trait** ("Trait" is used to refer to individuals who 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 **Heterozygote 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 sickle-cell disease to contend with.*
        e. These sickle shaped cells have *reduced oxygen carrying ability*. They can also cause pain if they block small blood vessels and capillaries.

i. This blockage causes Oxygen deprivation down stream.

f. Treatment? Since it is *genetic* there is no cure. Some medicines help with the pain or low oxygen levels.

VII. Dominant Disorders

A. Only need *one* allele for these disorders to be present or "expressed".

B. If an individual is homozygous dominant, usually the disease is much worse and often fatal.

C. Human Dominant Disorders:

1. **Achondroplasia** (This is referred to as **Genetic** Dwarfism.)
   a. This disorder affects 1 in 10,000 adults.
   b. Most people are *homozygous recessive* and therefor much taller than individuals with Achondroplasia.

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 gene is located on tip of Autosome 4. And the *mutation* behaves in a *dominant* fashion.
   d. Family history is important in diagnosis of this disorder and pedigrees can help.
   e. It is a slow *degenerative disorder affecting the brain* that is almost always fatal.

VIII. Genetic Counseling and Counselors

A. Genetic Counselors, a well-paying career in high demand, are health care professionals that work as part of a team, providing information and support to families who have members with birth defects and to families who may be at risk for a variety of *inherited conditions*.

B. *Remember, chance has no memory***.** Each mating can potentially have a different outcome.

C. Sometimes there is a need to various genetic tests to help with confirming diagnosis.

Unit 5: Mendelian Genetics
Content Outline: Meiosis (5.3)

I. Heredity

A. Heredity 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).

II. Genetics

A. Genetics is the science that deals with *the transmission of information in the form of DN*A. 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. It leads to better disease diagnosis, stronger crops, forensic analysis for crime scenes and missing persons, and technologies involving genetic engineering.

III. Gene

A. A *unit of hereditary information* in the form of a DNA sequence of nucleotides.

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 in a *set* of chromosomes. *All* of the DNA within a cell is *two sets of chromosomes*. (One set would be like the "blueprint" for making the entire functioning car.)

B. A *set* of the DNA comes from the *mother ("half" is represented by "n");* another set of the DNA comes from the *father (n). Therefore, a set plus a set equals 2 sets which is equal to 1 organism.*
(n + n) = 2n. ("Half" is also called **haploid/monoploid** and "two sets" is called **diploid.**)

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 in living organisms:

A. Asexual Reproduction

1. This involves only *one* parent. The parent is producing *genetic clones* of itself. 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.) It is a simple process. You only need one parent.
3. Risks – Every organism is the same. So if a disease affects one; it will affect <u>all</u>. (*There is <u>no</u>* <u>variation</u>!) 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, the fungus wiped them out quickly causing the famine to occur.

B. Sexual Reproduction

1. This involves *two parents* contributing DNA. This process *"creates" variation*, which is important in terms of *survival in the environment*.
2. Benefits – Sexual Reproduction 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.
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 and involves a more complicated process to create the gametes that have *half* the DNA content.

Unit 5: Mendelian Genetics
Content Outline: Meiosis Process (5.4)

I. Human Life Cycle is *Diploid Majority.*
   A. **Somatic cells** – These make up *most of our body*. ("Soma" means "body".)
      1. These cells possess *46 chromosomes* inside them. (They are **2n – diploid**.)
      2. **Karyotypes** will display all 46 chromosomes. A **karyotype** is basically pictures of the chromosomes. ("Kary" refers to "nucleus".)
      3. **Homologous** ("same") **Chromosomes** can be seen. (These are called **Autosomes.**) 44 = 22 *pairs* exist in all human cells. If female, the two sex chromosomes are the same … two X chromosomes.
         a. **Heterologous** ("different") **Chromosomes** *can* be seen in males. These may be the 2 sex chromosomes. In males, there is one X and one Y chromosome. Female (XX); Male (XY).
   B. **Germ cells** (A.K.A. **gametes**) – These are your sex cells. ("Germ" means "beginning".)
      1. They are **n – haploid**. (**Egg**-come from females; **sperm**- comes from males.)
      2. **Fertilization**, which is the *fusion* of egg and sperm together, *must* occur to be able to reproduce sexually.
         a. This fusion between egg and sperm produces a single **diploid** cell called a **zygote**.
         b. The **zygote,** through *repeated mitosis,* produces the *new organism*.

II. **Meiosis** - means "The process of *Gamete Formation*".
   A. Meiosis *occurs in the sex organs of the organism.* Sex organs are called **Gonads.**
   B. This process has 1 DNA replication followed by *2 cell divisions;* therefore, the result can be 4 haploid cells.
      1. Remember, that the S phase, starts with a diploid cell and then *doubles the amount* of DNA. In humans, when all 46 chromosomes are *replicated* the parent cell has 46 original and 46 replicated chromosomes, twice the DNA of a non-dividing cell. "Chromosome" becomes "chromatid" to *represent* the fact it was *replicated.*
      2. **Meiosis I** - This division is the separation of 46 homologous *pairs***.** This takes the cell to 46 chromosomes, some are original, some are *replicated*, but most are now *different due to crossover*.
      3. **Meiosis II** - This division is the separation of **sister chromatids.** In humans, 46 → 23 chromosomes.
   C. In this process, *Males produce **4** haploid sperm* with each having 23 chromosomes.
   D. In this process, *Females produce **1** haploid egg* with 23 chromosomes. The other three cells degrade.
   E. Stages in 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* exists.)
         a. **Crossover** ("genetic swapping") occurs in Prophase I. (*Creates variation*.)
         b. Chromosome *pairs* independently sort as they line up in Metaphase I (*Creates variation.)*
         c. **Sister Chromatids** separate in Anaphase II. (*Creates Variation*.)

III. **Crossover (**"genetic swapping") between *homologous* chromatids.
   A. This occurs to *create variation from the parent's genome*. (They are then called **Recombinant Chromatids**.)
   B. **Synapsis** – Chromatids 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".)

IV. *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" [identical] daughter cells; Meiosis – variable haploid gametes.)
   C. Crossover, in Prophase I of Meiosis, creates variation. (No crossover in Mitosis.)

V. Evolution
   A. The genetic variation within individuals, produced during meiosis (both prophase – crossing over, and metaphase – segregation and independent assortment), along with random fertilization (the recombination of two haploid genomes) between individuals emerges as genotypic and phenotypic variety within a population. Natural selection seizes upon this variety, and drives the adaptation of a population over time.

Unit 5: Mendelian Genetics
Content Outline: Non-Mendelian Patterns of inheritance (5.5)

I. Linked Genes

A. This term is used to describe genes found on the Autosomes (1 – 22). Linked Genes are usually inherited as a *linked unit* because they are found on the *same* chromosome. These genes are not independently assorted but rather they are inherited as a package.

B. **Genetic Recombination** occurs at Crossover in Prophase I when chromosome *segments are exchanged* between *homologous paired chromosomes*.

II. Sex-Linked Genes

A. This term refers to genes *found on the sex chromosomes;* 95% of the time it 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 (sex determining region of Y) gene goes active to convert estrogen to testosterone to finish development of the male.
   2. After development is complete testosterone production is turned off until puberty. At puberty it is turned back on 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 color absorbing protein in cones of the retina of the eye.
      b. The most common type is Red/Green Color blindness. (Red and Green appear gray.)
   2. **Hemophilia** (Means "love of bleeding")
      a. These individuals cannot make Anti-Hemolytic Factor. (AHF for short.)
      b. They experience problems with excessive bleeding, including bleeding to death.
      c. This was a disorder associated with the "Royal Blue-Bloods of Europe" – They were attempting to keep the crown " In the Family" by arranging close relative marriages. The "carrier" is traced by to Queen Victoria.
      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** 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. They tend to pass the recessive X on to their sons. The son will develop the disorder, if he inherits the recessive X from his carrier mother. *These disorders appear to "skip" a generation, because the mother is a carrier and the sons are showing the disorder*.

Unit 5: Mendelian Genetics
Content Outline: Abnormal Chromosome Number (5.6) "When Meiosis Goes Wrong"

I. Chromosomal errors than can occur:
   A. Chromosomal errors can occur *during Mitosis or Meiosis*.
      1. They often occur during the *Anaphase* Stages where *chromosomes are moving*.
      2. They could also occur during *Crossover* where gene *DNA segments are moving*.
      3. Some often occur spontaneously.
   B. Two *types* of errors can occur:
      1. **Chromosomal *Number*** (**Aneuploidy** means "*Abnormal number* of chromosomes" See Part II below)
         a. This is the result of **non-disjunction**. (*Failure to separate* during Anaphase.) Can you "see" a possible definition in the term?
         b. **Trisomic** (*Three* of 1 *kind* of chromosome.)
         c. **Monosomic** (*Missing one***,** the other half of the pair.)
         d. **Polyploidy** (*Many extra sets* of chromosomes.)
            i. 3n (triploid) Three "sets" are in this cell.
            ii. 4n (tetraploid) Four "sets" are in this cell.
            iii. *Deadly in most animals; Plants not really affected.*
      2. **Individual Chromosome *Structure***
         a. These occur because *of faulty crossover, faulty repair, or breakage.*
         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*".
         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 abnormal chromosomal number (#) or structure:
      1. **Down's Syndrome** (#)
         a. This affects about 1 in 700 births.
         b. This individual possess an *Extra 21 Autosome* (A.K.A. **Trisomy 21**)
         c. General syndrome features: flattened face, short stature, learning disabled, infertile.
      2. Turners Syndrome (XO) (#)
         a. General characteristics: These individuals have generally typical characteristics, although they often experience infertility as adults. Sometimes they have mild learning bilitiesThese individuals are usually raised as females.

Remember, there are no cures for any of these disorders; only treatments because the problem is genetic!

Unit 6: Ecology
Content Outline: Ecology Introduction (6.1) – Part 1

I. **Ecology** - the study of the *interactions occurring between organisms and their environment*. This is another level to the theme of open systems.
   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)

II. Levels of Ecology:
   A. **Organismal** – looks at *morphology* (bodily structure), *behavior*, and *distribution* of organisms.
   B. **Population** – looks at *abundance* within an area. (At the same time and showing signs of reproduction.)
   C. **Community** – looks at *species interacting*. (Predation, competition, symbiosis)
   D. **Ecosystem** – looks at the *biotic factors interacting with the abiotic factors*. (E flow and cycling of nutrients)
   E. **Landscape** - looks at the *arrangement of ecosystems* within a given area. (Mountains capes and seascapes)
   F. **Biosphere** – looks at *global interactions* between biotic and abiotic factors.

III. **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** – species that evolved in the defined area. (Also referred to as **indigenous** or **native species**.)
   B. **Transplant species** - species *from another area* living in a foreign environment.
      1. Some *accidental* transplant species – Zebra Mussels and Fire Ants
      2. Some *human purposeful* transplant species – African "killer" honeybees and Kudzu
   C. Abiotic Factors:
      1. Temperature
      2. Water availability
      3. Sunlight amount (Photosynthesis rates and 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.)

IV. **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 see the weather for the day.)

Ecology Introduction (6.1) – Part 2

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

A. Biomes 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 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^o latitude= tilt of Earth) (North –Tropic of Cancer; South- Tropic of Capricorn)
   b. Equator - 0^o; Poles 90^o; Arctic or Antarctic circle – 66.6^o

2. Local effects

a. Oceans – These act as *heat banks*. (Coastal/island areas generally warmer than interior areas.)
- Oceans absorb 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 - Create the *rain shadow effect*. This creates deserts on the *backside of mountains*.
- As 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.)
- Wind increases with altitude. (Plants tend to be smaller and animals furrier.)
- Temperatures on average drop 6^o 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 O2. 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.

d. **Thermocline** - These are temperature gradients (layers) that occur within a body of water as water heats or cools.

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

Ecology Introduction - Part 3 (Aquatic Biomes of Earth)

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 O_2 production and CO_2 consumption. (Due to Phytoplankton performing photosynthesis.)

II. Regions in 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".)

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.)

D**. Abyss** – These are the *deepest parts* of the Benthic Zone. (Deep sea trenches mostly.)

E. **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.

F. **Coral Reef** – These are *very* rich in biodiversity. (They are often called "the Rainforests of the ocean.")

- They are *endangered and therefore protected by laws*.
- They are found in *warm water climates*.

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

A. **Littoral Zone** – The shallows. (*"Literally* where you find most of the organisms".) Light is present for plants.

B. **Benthic Zone** –The bottom area. (It may or may not have plants; it depending on the depth of light penetration.)

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

A. **Oligotrophic** –These are *nutrient poor* ("oligo"- 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* ("eury" – 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 abundant nutrients are within reach.

C. **Mesotrophic** – These lakes are in between conditions. ("meso" means "middle")

1. Moderate plant and animals present; mostly around the edge areas of the lake.

V. Streams and Rivers

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

1. Waters are cold, clear, fast, narrow, nutrient poor, *high dissolved O_2* 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 O_2. (Plants and animals are *moderate oxygen demanding* such as bass or catfish.)

C. **Estuar**y – 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. (Estuaries are 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** (Define by having trees.) and **marsh** (Defined by having reed grasses only.)
2. They are *very* rich in biodiversity. (These areas are protected by law and serve as Game lands and wildlife refuges.)
3. These help to *reduce flooding* by holding rainwaters or hurricane waters. (VERY IMPORTANT!)

Ecology Introduction - Part 4 (Land Biomes of Earth)

Land Biomes –Students need to know the following:

A. General climatic conditions (Graphs showing precipitation and temperature)
B. General plant characteristics
C. General animal characteristics
D. General soil conditions as it relates to nutrients

In the following Biomes:

A. Tropical Rain Forest
B. Savannah
C. Desert – Hot
D. Desert - Polar
E. Taiga
F. Tundra
G. Temperate Deciduous Forest
H. Grasslands
I. Chaparral

Unit 6: Ecology
Content Outline: Population Ecology (6.2) – Part 1

I. **Population Ecology**
- A. Population Ecology is a field of Biology that 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 8 BILLION.
- D. Population Ecology 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* the organisms are located.

II. Patterns of Dispersion:
- A. **Clumped** – This usually results from a need for nutrients, mating, or employment.
- B. **Uniform** (evenly) – This usually results from territoriality or favorable environment.
- C. **Random** – There is no apparent reason seen for the dispersion pattern.

III. **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 Curve**s
  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 and organism is usually at top of food chain and there seems to be extensive parental care and E investment.
     b. **Type II** (*Constant decline*) (Type of environment?)
        This indicates that the environment is relatively favorable but organism may be a food source for another organism. The parental care is modest.
     c. **Type III** (Many young → few middle and old) (Type of environment?)
        This indicates a harsh environment because most of the population dies 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.

Population Ecology (6.2) – Part 2

I. Population Growth Models:

A. **Exponential Growth Models** (*Ideal Growth*)

1. Involves **r-selection species.** ("r"… think rapid growth.)
2. These species are also referred to as **Density – independent species.**
   a. Their population size is related to *resources* not number of organisms.
3. Produces **a J curve graph.**
4. Their environment has *unlimited resources*. (Good for ideal growth.)
5. Occurs mainly in *new* environments with **pioneer species** such as bacteria, lichens, and mosses. 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' species arrived and began to make soil. The soil enabled plants to grow. The seeds of the plants arrived in the 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.
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.** (K refers to a population that is hovering around the **carrying capacity** "which is represented by "K".)
2. These are referred to as **Density – dependent species**.
   a. These species numbers are about the number of organisms in a given area because of *limited resources* therefore the species is near the carrying capacity for that environment.
3. Produces an **S curve graph.** ("Snakes" around the carrying capacity line.)
4. 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? → It depends on the *amount* of damage to the environment and K.)
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.)

Density Dependent are mostly living (biotic) things. (Competition, predators, prey, food, disease)

Density Independent are mostly non-living (abiotic) things. (Sunlight, soil nutrients, wind, rain)

Population Ecology – Part 3

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, 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. (Like personality issues with humans.)
- E. Carrying capacity for the given environment.

II. **Boom-Bust cycles** of Growth (This mainly describes a Predator/Prey relationship.)
- 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 <u>is</u> occurring has changed the dynamics of Earth tremendously.
  1. Environmental degradation and over-consumption of resources <u>is</u> occurring.
  2. Species loss (extinction) <u>is</u> occurring at a fast rate.
  3. Overpopulation <u>is</u> being seen in India, China, and some other Island nations.
- B. Freedom/Control
  1. China and India and The United States

     China has imposed laws control 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. The size of the U.S.'s **Ecological Footprint** is enormous.
- C. Human Growth History
  1. The human species started as a Hunter/Gather society. (Also called **nomads**.)
  2. **Agricultural Revolution** and the plow.

     With the invention of the plow, the availability of more food and not having to travel to find food increased health and energy reserves. These energy reserves could be put toward reproducing… so the population begins to climb. The Agricultural Revolution also led to the formation of towns and villages.
  3. **Industrial Revolution**

     The Industrial Revolution also helped to increase the popularity of 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 E to put toward reproduction. Health care also improved for most people.
  4. **Technology Revolution** and Medicine

     Better health care is causing people to live longer and the survival of babies is increasing. Women, in general, are having more children because families are becoming more affluent. Technology, while mostly good for society, can make people less active and put even more E toward reproduction and obesity.

IV. **Ecological Footprint**
- A. A measurement that takes into account the amount of water and land *needed* to produce *all used products* (resources) and *dispose of all generated waste* as a result of that same product (trash in landfills).

Unit 6: Ecology
Content Outline: Community Ecology (6.3) – Part 1

I. **Community** – This 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.

II. **Interspecific Interactions** - Are *interactions between* two different species. ("Inter" means "between".)
   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 smaller.)
      3. Two species <u>cannot</u> occupy the *same* niche.
   B. **Predation** (+); (-) Considered a *positive – negative relationship*.
      1. Normal predation - Carnivore or Omnivore eats an herbivore.
      2. **Herbivory** - Eating plants is also considered predation…since they are a different species.
      3. **Parasitism** – Death does not occur; but *harm is done* to another species.
         a. Two types: 1) **Ectoparasites** – These attack from the outside. (Like a mosquito.)
            2) **Endoparasite** – These attack from the inside. (Like a tapeworm.)
      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** – This is camouflage. (Sounds 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.
            Műllerian 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.

Community Ecology (6.3) – Part 2

I. Trophic Structure (*Feeding* Relationships) ("Troph" means "to feed".)

A. *Matter Cycles* -Materials (matter) get recycled within the environment. This is related to the **Law of Conservation of Matter**… Matter is neither created nor destroyed… only transferred and transformed.

B. *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, which is when the heat energy leaves the earth. (Demonstrates the **Second Law of Thermodynamics**…All Energy proceeds towards a state of Entropy [disorder] with each transfer.)

C. **Food chains** –Food Chains demonstrate an *orderly flow* of who eats whom. (Producers eaten by consumers, consumers and producers broken down by decomposers.)

1. Most food chains only have *four to five* trophic levels in them, because you run out of energy to transfer and support life.
2. **T**he **10 % rule of E** (90 % of all energy is lost as heat 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 (Mouse)
   1000 joules of E (Grasshopper)
   10,000 joules of E (Grass/flower… producers) – START HERE

   Each time only 10% of the E gets passed on to the next higher level in the chain. 90% is lost on the metabolism maintaining the life of that organism before it is eaten or as waste.

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

Community Ecology (6.3) – Part 3

I. **Stability** – A community at equilibrium. (Very little disturbance/change occurs over time.)

II. **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 plush, Tropical Island.
    b. Pioneers make the dirt needed for the plants and 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 the specific area.
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

Unit 6: Ecology
Content Outline: Ecosystem Dynamics (6.4) – Part 1

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** (*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 storing 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 occur 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 along the chain.

C. **Decomposers** (A.K.A. **Detritivores**) – These organisms feed on *dead organic material* - which is 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 <u>*cannot*</u> perform work.)
3. The **10% rule** applies from trophic level to trophic level. The 10% rules states that only 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. This will be seen in the Biogeochemical cycles in the next section.

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 to helping the temperature of the Earth rise.
4. The absorbed E by water will be released at night to help keep the unlighted side of the Earth warm.

Ecosystem Dynamics (6.4) – Part 2

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 returns to land, makes its way to plants or to 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** - CO_2 is removed from the air by photosynthesizing organisms such as plants, phytoplankton and bacteria. They use the CO_2 to aid in the development of sugars during photosynthesis. These sugars, which contain the carbon ($C_6H_{12}O_6$), are then passed from organism to organism through the food chain. All organisms then release the carbon, in the form of CO_2, 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 CO_2 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 <u>not</u> the nitrites.) Some other bacteria in the soil can also eat the nitrates. These are called **Denitrifying Bacteria**. They consume the nitrates and break them 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 smell bad. 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. 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 causes 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.)

Ecosystem Dynamics (6.4) – Part 3

I. Human Impact on Ecosystems

A. Agriculture

1. Harvesting (Promotes a *loss* of nutrients from that area.)

a. Fertilizers can be good in that it replaces nutrients, due to harvesting/removal or bad because it could hurt the environment *when in excess*.)

b. **Critical Load** - Refers to the *maximum amount of nutrients that plants can absorb*. (The *extra* fertilizer damages the ecosystem.)

B. Fossil Fuels

1. Burning these can cause **Acid Precipitation** (It is Rain/snow/sleet/ice with a pH of < 5.6.)

a. Sulfur and Nitrogen oxides are the main causes and they are released by burning fossil fuels.

b. Effects? It kills plants and **leaches** (nutrients moved *away from* the roots) the soil.

C. **Biological Magnification** - the *buildup of poisons* and heavy metals in organisms. The higher up the food chain you get, the more concentrated the poisons get, which causes health and reproductive problems.

1. DDT and PCB, to name a couple, use has led 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 population. The DDT caused the bird's eggs shells to be paper-thin. So when the mother sat on the eggs to keep them warm; she ended up crushing them instead.

D. Rising Atmospheric CO2 levels

1. Caused by deforestation and fossil fuels. (No trees to pull CO_2 out of the air and fossil fuels releasing it.)

E. The Greenhouse Effect and Greenhouse Gases increasing will help *raise the Earth's average temperature*.

F. Ozone Depletion and CFC's (**C**hloro-**f**luro-**c**arbons are propellants found in aerosol cans and refrigerants.)

1. *Each* CFC can destroy up to *100,000 Ozone molecules.* (It is a chain reaction.)

2. Ozone helps block out harmful radiation from the sun, so we don't burn up.

2. Ozone holes in Antarctica and Northeastern Canada exist. These holes are causing ice to melt faster and also causing more health related issues, such as skin cancers.

Unit 7: Evolution
Content Outline: History of Darwin's Theory of Evolution (7.1) – Part 1

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. 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 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 in that environment or moves "migrates" to a different more favorable environment, if possible.

Darwin's Predecessors:

II. Plato (427 B.C. – 347 B.C.) develops the first attempted organization of nature.
   A. Plato believed that two distinctly *different worlds* existed based upon the Gods of Olympus and Earth.
      1. The Real and Perfect world exists, this is the World of the Gods.
      2. The other that exists is the Illusory and Imperfect world; this is Earth… where you can see birth defects in all species, including man.)

III. Aristotle (384 B.C. – 322 B.C.) is a student of Plato who modifies Plato's organization.
   A. He develops the **Scala Naturae**. (It means "scale of nature".)
      1. Aristotle believes that each species has its own "rung" on the "ladder of life".
      2. The species' position is permanent and perfect. (Man is at the top, just below the gods.)

IV. 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 names" 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 <u>not</u> 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 are 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.

V. 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 and settle to the bottom of that body of water, they get covered up by *layers* of sediment (eroded earth). The weight (pressure) 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 fossils are still hidden in the dirt.

1. Must have water, pressure, and lots of time to create a fossil.
2. The term “Strata” means “layer”.
3. 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. Cuvier 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.

VI. Jean Baptiste Lamarck (1744 – 1829)

A. He proposed 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.) His theory 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, his or her 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. (This is also incorrect.)

History of Darwin's Theory of Evolution (7.1) – Part 2

I. Charles Darwin was born on February 12, 1809 in Shrewsbury, England. (Abraham Lincoln was also born on that date.)
   A. Darwin attended the University of Edinburgh at age of 16 to become a doctor. (Like his father and grandfather.)

II. December 1831
   A. Darwin 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 for 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 to England in 1836.)
   C. Darwin collects plants, animals, and fossils at every stop on this journey and sends them back to England.

III. 1840 London
   A. Darwin has a working manuscript on his Theory of Natural Selection.

IV. 1844
   A. Darwin's manuscript is completed. He will continue to tinker with it until its publication.

V. 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. 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".

VI. **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 an 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* and "nature" ultimately decides who gets to survive and reproduce and who doesn't by excessive environmental "forces" killing them off.
   E. This concept came to Darwin while reading Thomas Malthus's *Principles of Populations.*
      1. The book basically states that more organisms are born than nature can allow to survive.
      2. Remember, carrying capacity? So "who" chooses… nature… based on the traits an organism possesses. Remember variation is important.

VII. **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 "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.

VIII. **Populations**
   A. Four items that define a population:
      1. *Same species* of organism.
      2. In the *same place***.**
      3. At the *same time.*
      4. and *showing signs of reproduction.* (Young are visible within the group.)

IX. Supporting evidence for Common Ancestry among organisms includes:

A. **Homologous** (means "same') **Structures** - Examples include skeletal structure, limb structure, or cephalization. (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** - Seen as common stages of development that embryos go through. (Darwin wrote about these in his book too.)

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.

X. **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.

XI. 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.

Unit 7: Evolution
Content Outline: Evolution of Populations (7.2) – Part 1

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 is 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 acquire 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. The 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. **Population** is defined by four criteria:
- A. *Same species* of organism.
- B. Located in the *same location.*
- C. At the *same time.*
- D. And showing *signs of reproduction.* (Offspring are present within the group.)

IV. **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, such as blue or brown for eye color.)
     - a. "Frequency" refers to "how many" are present at that time within the population (gene pool).
     - b. Is considered *fixed*, if there is no change in frequency—no evolution is present. (A state of *equilibrium* is occurring.)
     - c. Is considered *evolving*, if frequency is changing— evolution is occurring. (A state of *change* is occurring over time.)

Evolution of Populations (7.2) – Part 2

I. **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: $\mathbf{p^2 + 2pq + q^2 = 1}$(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* (Frequency *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 in the population at this time. (Nature *favors all equally* in terms of fitness.)

Evolution of Populations (7.2) – Part 3

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. If there is no variation or "option" to use, 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 these 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 of 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").
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.

IV. 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.

Evolution of Populations (7.2) – Part 4

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.
         a. 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 (have many alleles) Characters.
      1. Skin color is basically based upon how many different alleles you inherit from your parents. Albinism (A recessive genetic condition.) occurs when the individual inherits mutations in both copies of a protein pigment-producing gene. These individuals lack pigment in their skin, hair, and the iris of their eyes. So basically, "race" is a man-made construct that tries to group individuals based on geographic origin or degree of skin pigmentation, but we are <u>all</u> human (*Homo sapiens)*. 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.

III. Evolutionary *flow:* (Modes or 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 <u>same</u> time.*
   C. **Stabilizing** – the "bell curve" moves to the *"stable"* center.
   D. These are <u>all</u> related to some trait that is beneficial for survival within that changing environment.

IV. **Neutral Variation**
   A. No survival benefit or harm (That is why we call it neutral.) from the trait.
      For example, Fingerprints … everyone's is different but it doesn't help us or hurt us in survival and reproduction. Fingerprints only help in crime solving.

V. **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 population's organisms.
      1. **Intrasexual selection** ("Intra" means "*within* one same sex".)
         a. Males mainly "fight" for reproductive rights. (It becomes "Survival of the fittest".)
      2. **Intersexual selection** ("Inter" means "*between* the two sexes".)
         a. Males strut to attract the female's attention. (Mostly seen in birds with bright coloration.)
         b. Females choose based on "fittest" looks. (This indicates good health.)
   C. Competition between individuals makes sure that the "best or most fit" genes get passed on to the next generation.

Unit 8: Diversity of Life

Content Outline: Characteristics and Hierarchy of Life (8.1)

I. Characteristics of living things:
- A. All living things are composed of cells.
- B. Living things possess differing levels of complexity (For example, a cell has a membrane. This is only one complex part of a cell. Cells have ribosomes for making proteins, another part.)
- C. Living things use energy (E) in metabolic processes.
- D. Living things respond to their environment,
- E. All living things adapt to their environment.
- F. All organisms reproduce to keep the lineage going.
- G. All organisms grow and develop.

I. Hierarchy of life:
- A. **Cells** – This is the *basic unit of life*. (Either Prokaryotic or Eukaryotic.)
- B**. Tissues** – These are composed from cells with *common structure and function.*
- C. **Organs** – This functional structure is a collection of *similar tissues working together*.
- D. **Organ Systems** – These are composed of *organs working together*. (There are 11 systems in animals.)
- E. **Organism** – This is when all the organ systems are working together to create a multi-cellular organism. (This is a great example of Emergent Properties.)
- F. **Population** – A group of the *same species, in the same place, at the same time, and showing signs of reproductio*n.
- G. **Community** – A group of *interacting populations* in the same area at the same time.
- H. **Ecosystem** – Groups of *interacting communities,* all experiencing common *abiotic factors*.
- I. **Biosphere** – The entire part of the planet that can support life.

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 <u>not</u> 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).
     - b. There exists much debate over how many kingdoms actually exist.
     - c. The two most commonly accepted are:
       - i. **Five Kingdom**- Animalia, Plantae, Fungi, Protista, and Monera (old term for bacteria.)
       - ii. **Six Kingdom** – Animalia, Plantae, Fungi, Protista, Archaebacteria, Eubacteria
  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 are 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.

Unit 8: Diversity of Life
Content Outline: Viruses (8.2)

I. Wendell Stanley (1935)
- A. First person to isolate a virus. The virus was **T**obacco **M**osaic **V**irus - **TMV**

II. 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 have 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**. ("mere" means "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 <u>not</u> living organisms. They <u>cannot</u> be "killed". They can be broken apart using chemicals though.

III. Viral Reproduction
- A. Viruses <u>must</u> 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.
- D. **Restriction enzymes** – These enzymes, *found in bacteria*, act as primitive *defense* against viruses. These enzymes *cut up the viral 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.

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. Major viruses:
- A. HIV/AIDS, Ebola, Influenza, SARS
- B. **Epidemic** – Big Outbreak in one area; **Pandemic** – Global Outbreak
- C. Plant Viruses (Over 2,000 are known to exist. Plant viruses cause big financial losses for farmers because of destroyed crops.)

VI. **Viroids** (These are naked, infectious *RNA molecules*.) They attack plants only. ("oid" means "like"… they are "like" viruses as they are infectious.)

VII. **Prions** (These are infectious *proteins*) Mad Cow is one example. It destroys brain cells thus driving the cow "mad" until it dies. The human version is Kruetzfeldt-Jacob Disease (KJD).

Unit 8: Diversity of Life
Content Outline: Bacteria Kingdoms (8.3) – Part 1

I. Prokaryotes (Bacteria) are the *oldest organisms* and most adaptive organisms on the planet.
   A. Some famous bacteria include Plague, TB, Cholera, Botulinum, and Anthrax.
   B. Most bacteria are harmless though.
   C. Bacteria are <u>essential</u> for life to exist. They are involved in nutrient recycling – they are decomposers.

II. Two **Domains** of Bacteria exist:
   A. Bacteria (common) and Archaea (extremophiles)
   B. The genetic difference is located in the *small subunit of the ribosome's RNA sequence*.

III. Bacterial Structure
   A. All prokaryotes are *unicellular*.
   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 <u>not</u> 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 water.)
      3. The cell wall is mainly composed of proteins and sugars. These 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 posses a *thin* peptidoglycan layer *between* phospholipids 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.
   E. Some prokaryotes have flagella, or cilia/fimbraie, or a helix body shape for movement.
   F. Some prokaryotes can move by "sliming". ("Spitting" out a layer of mucous in front of them to slide on.)

IV. **Taxis** - refers to movement in *response to a stimulus*. (These terms could be used with *any* organism.)
   A. (+) indicates movement "toward"; (-) indicates movement "away".
   B. The prefix tells the type of stimulus. (photo-light; geo-gravity; rheo-current; chemo-chemical)

V. Bacterial Genome
   A. A prokaryote genome is about $1/1000^{th}$ the amount of a Eukaryotic cell genome.
   B. It consists of a single *circular* strand located in the nucleoid region. (It is not *linear*, like in Eukaryotes.)
   C. The Domain Archaea has histones to help DNA coil up; the Domain Bacteria does <u>not</u> have histones.
      1. More evidence for *common ancestry with Eukaryotes*, which also have histones.
   D. Prokaryotes also have plasmids for exchanging. (Most plasmids contain resistance information.)

VI. Bacterial reproduction is accomplished by the process of **Binary Fission** to create clones. (It is asexual reproduction.)
   A. It is like Mitosis, except there is no G2 phase or Mitosis phases… just G1, S, and cytokinesis.

VII. Means of Nutrition (feeding):
   A. **Saprobes** - The eating of dead material. (These are decomposers.)
   B. **Parasites** - These harm other organisms.
   C. **Nitrogen Fixation** - Feeding on Ammonia– NH_3 to make Ammonium – NH_4.
   D. **Nitrification** - Feeding on Ammonium and producing Nitrite – NO_2 as waste <u>OR</u> feeding on NO_2 and producing Nitrate – NO_3 as waste.
   E. **Photosynthesis** - Using sunlight energy, CO_2, and H_2O to make sugar.
   F. **Chemosynthesis** - Using Hydrogen Sulfide – H_2S for energy instead of sunlight energy in making sugars.
   G. **Heterotroph** - Feeding on another organism.

Unit 8: Diversity of Life
Content Outline: Bacteria Kingdoms (8.3) – Part 2

I. Oxygen Demands (These terms can be used with other organism too.)
   a. **Obligate Aerobes** - These must intake oxygen to utilize their primary source of energy. ("Obligate" means "must"; "Aerobe" means "with oxygen".)
   b. **Facultative Anaerobes** - These organisms can be both. They can "function" with OR without oxygen.
   c. **Obligate Anaerobes** - These must be *without oxygen*. (They die in the presence of oxygen.)

II. Terms used with Archaea (extremophiles) with regards to their living environments:
   A. **Methanogens** - Produce Methane gas – CH_4. These are mainly associated with ruminants. (Animals with a rumen as part of the "stomach".) Swamps, waste disposal, and trash dumps also produce methane. (You have them too… living in your large intestine. These are the organisms that cause us to release gas or "fart".)
   B. **Halophiles** - These are salt lovers. ("halo" means "salt"; "phile" means "lover of".) These bacteria are associated with places like the Dead Sea in Israel or Great Salt Lakes of Utah.
   C. **Thermophiles** - These are heat lovers. (These bacteria are found in hot springs or volcanoes.)

III. Ecological Impact of Bacteria
   A. They are *important recyclers of nutrients*. (They are **decomposers/saprobes**.)
   B. Some can perform *Nitrogen Fixation* that makes Nitrogen available for plants → animals eat the plants.

IV. Symbiotic Relationships with Bacteria
   A. Three types of relationships can exist:
      1. **Mutualism** (+;+) *Both* organisms benefit. (For example, E. Coli in the intestines of most animals. They help with reabsorbing water from the process of digestion.)
      2. **Commensalism** (+; 0) *Only one* organism benefits. (These are rare.)
      3. **Parasitism** (- ; +) One organism is *harmed* and the other organism benefits. (For example, Strep Throat in humans.)

V. Pathogenic Bacteria (Disease causing)
   A. These prokaryotes account for more than half of all non- genetic diseases in humans.
   B. **Opportunists** (such as streptococcus) become a problem when the body is busy fighting something else, such as a cold virus. (They see an *opportunity* to reproduce and take over.)
   C. **Exotoxins** – These are secreted proteins that cause disease. (These are mostly Gram + bacteria.)
   D. **Endotoxins** – Proteins of the capsule/membrane/cell wall. (These are mostly Gram – bacteria.)
   E. **Antibiotics** – These are substances that kill bacteria. (They usually end with "mycin". The name means *"substance against life".)*

VI. **Bioremediation** – This term refers to cleaning up the environment using living organisms.

Unit 8: Diversity of Life
Content Outline: Kingdom Protista (8.4)

I. Protista
- A. Most of these organisms are *uni-cellular*.
- B. Means of *nutrition (feeding*) for these organisms:
  1. **Heterotroph** - Feeds on other organisms. ("Trophe" means "feeding".)
     a. Includes the animal- like prtotists. These are protozoa or zooplankton. ("Zoa" means "animal".)
     b. Also includes the Fungus – like protists.
  2. **Photoautotroph** – These are the Photosynthesizers.
     a. Includes the plant -like protists. (These are the algae and phytoplankton.)
  3. **Mixotroph** - These organisms can obtain energy either way listed above.
- C. Most organisms are motile.
  1. They use flagella or cilia to move through water or other liquid.
     a. *These are <u>not</u> homologous structures with bacteria – it is an analogous structure, remember.*
     b. These are an *extension* of the cytoplasm in protists, so they are considered organelles; They are part of the plasma membrane in prokaryotes and are therefore not considered organelles.
- D. The flagella are believed to have been a helical prokaryote that entered into a *symbiotic relationship.*
- E. Reproductive Means
  1. Most are *sexually reproducing* organisms. (Remember, this method *favors variation*.)
  2. Some are asexual. (This is a *faster process* but produces <u>*no*</u> *variation*; the resulting offspring are <u>*all*</u> *clones*.)
- F. Habitats of these organisms
  1. These are mostly aquatic organisms. (Most are important parts of aquatic food chains or webs.)
  2. Some Protista are symbiotic parasites.

II. **Endosymbiotic Hypothesis**
- A. This was proposed by Lynn Margulis in 1960.
- B. It proposes that smaller prokaryotes entered into a *symbiotic relationship* with larger prokaryotes for protection. In return, the smaller prokaryote provided the ability to produce energy or motility for the larger organism. This relationship would have given the "new" organism an *evolutionary advantage* over the existing prokaryotes. This advantage led to the evolution of the Domain Eukarya and eventually over hundreds of millions of years to the Kingdoms Fungi, Plantae, and Animalia.
- C. Supporting evidence – Mitochondria, Chloroplasts, Flagella

III. The main examples of protists that exists:
- A. **Euglenozoa**
  1. These are *Bi-flagellated* organisms.
  2. Most of these organisms are **Mixotrophic.** (They can photosynthesize and also are heterotrophic.)
     a. They have a *red eyespot* that helps in detecting sunlight.
- B**. Alveolata**
  1. These organisms *contain small air-filled chambers called* **alveoli**.
  2. Dinoflagellates
     a. Most are phytoplankton.
     b. Example - **Red Tide** (These are toxic to most mollusks, fish, and humans.)
- C. **Diatoms**
  1. Produce a *yellow-brown, energy rich oil.*
  2. Have a strong outer *shell composed of silica*. (Silica look like stained glass.)
  3. *Important phytoplankton. (In food chains, they are major producers.)*
- D. **Phaeophyta** ("Phaeo" – means "brown".)
  1. A.K.A. Sea weed or kelp
  2. Produce *a brown, light absorbing pigment that contains Iodine.*
- E. **Animal- like Protists** (A.K.A. **protozoa**.) ("Proto" means "first"; "zoa" means "animal".)
  1. Most move using **Pseudopodia** "oozing". ("Pseudo" means "false"; "poda" means "foot".)
  2. These *catch and eat other organisms*, just like animals.
  3. Amoebas
     a. Most are free-living organisms and have no "real shape".
- F. **Fungus- like Protists** (A.K.A. **Mycetozoa** – fungus animals) ("Mycota" means "fungus".)
  1. These feed on *decaying organisms,* as they are decomposers.
- G. **Plant- like Protists**
  1. These organisms *perform photosynthesis*, just like plants.

Unit 8: Diversity of Life
Content Outline: Kingdom Fungi (8.5)

I. About 500 MYA, Fungi (Mycota) began to colonize the land to break down the abundant dead plant material that existed.
   A. This Kingdom is composed mainly of *soil dwelling decomposers*.
   B. The Kingdom evolved from unicellular flagellated protists.
   C. Fungi only resemble plants; but are more closely related to animals.
      1. Fungi are Heterotroph by *absorption* using exoenzymes. (Animals are heterotroph by *ingestion.*)
      2. Fungi cell walls are composed of **Chitin.** (Same substance found in the exoskeleton of Arthropods.)
         a. Remember, plant cell walls are composed of Cellulose.
   D. Most Fungi have symbiotic relationship with plants roots. (Referred to as **mycorrhizae.**)
      1. The Fungi help to *increase the surface area* for water uptake by the roots. The plant provides sugars for food.
      2. **Endomycorrhizae** - The fungus enters into the root cells of the plant.
      3. **Ectomycorrhizae** - The fungus covers over the surface of the root of the plant.

II. Fungi Body Structure
   A. **Hyphae** - These are tubular filaments.
      1. Hyphae are intertwined to form a **Mycelium.** (Mycelium means "Fungus body".)
         a. The mycelium extends above and below ground.
      2. Fungi can grow extremely fast. This reduces competition. They just need moisture (rain) to grow.

III. Classification of Fungi
   A. Most fungus are *classified according to the sexual reproductive structure* they produce.
   B. Six Major Phylum exists:
      1. **Chytridomycota** (The sexual structure is the Chytrids.)
         a. Produce *flagellated spores called zoospores*. (Similar to sperm of the animal kingdom.)
      2. **Zygomycota** (The sexual structure is the Zygosporangium.)
         a. Examples - Mycorrhizae, *Rhizopus stolonifer* (black bread mold), *Penicillium* (green bread mold).
      3. **Glomeromycetes** (The sexual structure is glomerulus.)
         a. Most are endomycorrhizae called **arbuscular**. (A *tree shaped* connection with plant cells.)
      4. **Ascomycota** (The sexual structure is the ascus - means "sac".)
         a. Ascus are found on the large **ascocarp** mycelium.
         b. Spores are small and dust like structures called **Conidia.**
         c. Examples - Lichens, plant pathogens, mycorrhizae, yeast.
      5. **Basidiomycota** (The sexual structure is the **Basidium** - means "club".)
         a. Basidium found on the large **Basidiocarp** mycelium.
         b. These fungi are important decomposers. They can break down lignin of plant cell walls.
         c. Examples - Mycorrhizae, food mushrooms, Fairy Rings, Death Cap, Toad Stool, Puff balls.
      6. **Deuteromycota** (These are the Imperfect Fungi - No known means of sexual reproduction; thus imperfect.)
         a. Humans use Yeast for bread and alcohol production.
         b. *Candidia albicans* – this fungus causes a yeast infection of the vagina. (**Mycosis** – means "a fungal infection". A Fungicide is prescribed for treatment.)

IV. Ecological Impact of Fungus
   A. They are important *decomposers*. (A.K.A. Saprobes) They recycle vital nutrients back to the environment.
   B. Some fungus plant pathogens – wheat rust, corn smut, Dutch Elm Disease, Chestnut Blight.
   C. Some fungus human pathogens – ringworm, athletes foot, jock itch, yeast infections, dandruff.
   D. Some fungus are used as medicines and food.

Unit 8: Diversity of Life
Content Outline: Plant Kingdom (8.6) – Part 1

I. About 500 Million Years Ago (MYA), plants begin to leave the watery environment for land.
   A. This was in an attempt to *avoid competition for resources in the oceans* from protists, animals, and fungi. Plants are believed to have started around the moist coastal areas.
   B. Plant-like protists (algae) are believed to have been the original source.
   C. Four major groups of plants will evolve over millions of years in response to the changing environment.
      1. Bryophytes (mosses) - these are non-vascular.
      2. Pteriodophytes – these are vascular, non seed plants.
      3. Gynmosperms - these are vascular, naked seed plants.
      4. Angiosperms – these are vascular, flowering plants.

II. The following *adaptations will evolve over time* in plants to enable them to survive on land in a dryer environment:
   A. *Waxy cuticle* on the surface of the leaves. (This helps to avoid dehydration.)
   B. *Vascular tissue* evolves. (This will transport water and nutrients.)
   C. A *Protective seed* evolves. (This helps the survival of the embryonic plant during harsh dry times.)
      1. An added benefit of seeds is that *dispersal increases*. (Seeds can be "moved" into new territory – away from competition.)
   D. *Flowers and fruit develop*. (These structures help moving to new areas or reproducing by *using animals*.)

III. Unifying traits that support all/most plants common ancestry.
   A. The "basic" structure – **Root** (below ground portion) and **shoot** (above ground portion).
   B. **Apical meristematic tissue** at the *tips* of roots and shoots. (Where plants grow in height and length.)
   C. Produce a waxy **Cuticle** on herbaceous parts. ("Herb" means "soft, fleshy".)
   D. There are **Stomata** (openings) on the leaves for *gas exchange* to occur during photosynthesis.
   E. Most plants possess vascular tissue. (<u>Not</u> found in Bryophytes.)
      1. **Xylem-** Carries *water up* the plant towards the leaves. (These are *dead, hollow* cells.)
         a. Two types of xylem cells: **Tracheids** (They are small.) and **vessel elements**. (These are large.)
      2. **Phloem-** Carries *sugar water down* to feed the plant or store in the roots. (These are *living* cells)
         a. Two types of phloem cells: **Sieve-tube members** and **Companion cells**.

IV. **Bryophytes Phylum** (Name ends with an "e")
   A. There are three major groups that exist presently:
      1. Hepatophyta (Liverworts) ("Hepta" means "liver"; "wort" is old English for "plant".)
      2. Anthocerophyta (Hornworts) ("Cero" means "horn".)
      3. Bryophyta (True mosses) (Name ends with an "a".)
   B. These are *very small* in size. (There is only cellulose in the cell wall…so it is very weak.)
   C. Gametophyte generation is the *Dominant generation*. (The dominant is always present visually.)
      1. Due to the presence of water *often* in the environment. (This is good for swimming, flagellated sperm.)
      2. Possess leaf-like structures called **microphylls**. (They have no veins in them, like true leaves.)
      3. They possess structures *similar to roots* called **Rhizoids.** They *support* the gametophores upwards.
      4. The *dependent* sporophyte generation will be produced *on top* of the dominant gametophyte.
         a. **Foot** - This is the support base for the sporophyte generation.
         b. **Seta** (Stalk) - This is for rising up *away from the water* for *greater dispersal of spores*.
         c. **Capsule** - This is the s**porangium**. (It contains the spore cells that undergo *meiosis* to become haploid.)
         d. **Calyptera** - This is the removable protective cap on the capsule.
         e. **Peristome** - This structure is for *discharging or shooting the spores outward* away from the parent plant.
   D. They move water and other materials by *diffusion and osmosis* because there is <u>no</u> vascular tissue present.
      1. Therefore the plant can <u>only</u> be a couple of cells thick/wide.

V. Ecological and Economical Importance of Bryophytes
    A. They are a major food source (producers) in the Tundra. (Such as upper Alaska.)
    B. Peat Moss (A.K.A. *Sphagnum*) is a fuel source and also a CO_2 bank. (Remember, CO_2 is a greenhouse gas.)
    C. They can be used as a soil conditioner – as they can hold up 20x their weight in water. (Used by gardeners/farmers.)

Unit 8: Diversity of Life
Content Outline: Plant Kingdom (8.6) – Part 2

I. About 420 MYA, the first *vascular* plants evolve as plants *moved farther away from water sources*.
   A. The first group of vascular plants to evolve is *seedless in terms of reproduction*. (Sperm still need to swim in water.)
   B. They have moved farther inland to *avoid competition* with Bryophytes.
      1. The sporophyte will become the *dominant generation*. (Due to the environment being less "swampy".)
      2. The gametophyte will remain very small, but now it is *dependent* on the larger sporophyte.

II. Evolutionary adaptations needed for a *drier environment* farther away from water:
   A. *Lignified* cells to increase *cell wall strength*. (Needed to allow roots to burrow through the soil to find water.)
      1. Lignin is a stronger, stickier sugar used to reinforce the cellulose cell wall.
   B. *Pectin* to help reinforce the *weight bearing* of cells. (Need to grow taller.)
      1. Pectin also is a stronger, stickier sugar.
   C. *Vascular tissues evolve to move fluids*. (No longer dependent on osmosis/diffusion from the environment.)
   D. *Real roots* evolve from rhizoids. (This allows for absorbing and transporting water and nutrients.)
   E. *Real leaves* (megaphylls) begin to evolve from an increasing microphyll. ("Phyll" means "leaf".)
   F. Reduced gametophyte generation; increased sporophyte generation. (Environment is becoming drier.)

III. Modern **Pteridophytes Phylum**
   A. Two different phyla exist:
      1. Lycophytes
         a. Most went extinct about 250 MYA. (Pangaea formed - causing swampy areas to dry up.)
            i. These formed the first real forests. (They decomposed to make crude oil or coal "fossil fuels".)
         b. Existing species are mostly tropical.
         c. Some are **Epiphytes**-air plants. They grow in the branches of trees.
         d. Sporophylls (leaves) are rich in oil. (They were the source of first flash photography.)
      2. Pterophyta
         a. Psilophyteas
            i. Characteristic "y" branching.
         b. Sphenophytes (A.K.A. horsetails or ***Equisetum***)
            i. Characteristic jointed stems with Whorls (rings) of megaphylls (leaves).
            ii. Hollow stem moves oxygen to the roots for cellular respiration. (Similar to Bamboo.)
            iii. Silica embedded megaphylls have a sandpaper texture.
         c. Ferns
            i. Characteristic megaphylls called **Fronds.**
            ii. Develop from **Fiddleheads.** (As seen on front of the book.)
            iii. Spores develop on the underside of the megaphylls in groups called **Sori.**
            iv. Produce a tiny heart–shaped gametophyte generation.

Unit 8: Diversity of Life
Content Outline: Plant Kingdom (8.6) – Part 3

I. About 300 MYA, Gymnosperm Phylum of plants begins to evolve.

II. Adaptations needed for much drier and cooler environments:
   A. A greatly reduced gametophyte generation. (It becomes a single, microscopic cell.)
   B. Reduced size of leaves. (The leaves of pines are called needles.)
   C. Thick, waxy cuticle on the leaves.
   D. The leaves remain all year, hence the term "evergreens". (They shed a little at a time, like a dog sheds hair.)
   E. Large plants with thick bark.
   F. Cones for reproduction. The female cones (large and hard) contain the seeds. Males (small and yellow) contain the pollen grains that contain the sperm.
      1. The wind and rain carry the pollen grains to the female cones for fertilization.
      2. Seeds have a food source for the developing embryo inside.

III. **Gymnosperms** "Naked Seed Plants"
   A. Most Gymnosperm species produce cones. (A.K.A. conifers)
   B. Four phyla exist today:
      1. Ginkophyta
         a. Only one species still exists – *Ginko biloba.*
         b. Characteristic *oriental fan shaped leaves*. (They turn bright yellow in fall.)
      2. Cycadophyta
         a. Possesses a large cone in the center of palm like leaves. (These are similar to fronds.)
         b. Mainly used as yard ornamentation.
      3. Gnetophyta
         a. These are extreme desert plants.
         b. *Welwitschia* – Among largest leaves of all plants. (It grows in African deserts.)
         c. *Ephedra* – Produces ephedrine. (Used in diet pills); Become tumbleweeds when they die. (This "tumbling" helps to scatter the seeds.)
      4. Coniferophyta
         a. Two types of cones are produced:
            i. Male cones – these appear long, narrow, and yellow. (Pollen grains are yellow.)
            ii. Female cones – These are large and wide. (If green – unfertilized; if brown – fertilized.)
         b. Evergreen needle leaves
            i. Very thin leaves reduce water loss through the stomata and make food all year long.
            ii. Very thick, sticky cuticle on the leaves.
         c. Thick and sticky sap to keep animals from eating the plant. (Sap is used to make turpentine.)

Unit 8: Diversity of Life
Content Outline: Plant Kingdom (8.6) – Part 4

I. About 200 MYA, Angiosperms begin to evolve due to increased water availability.
- A. Angiosperms are the flowering plants. (Called Anthophyta.)
- B. They are seed producing, vascular plants.
- C. The sporophyte is the *dominant generation*. The gametophyte generation remains a single cell.

II. Adaptations for a "new and wetter" environment:
- A. Vessel element xylem tissue evolves to transport more water to the leaves. (Tracheids were too small.)
- B. More water leads to larger leaves to perform more photosynthesis. (More sugars lead to fruit production.)
- C. **Flower** (It is a *specialized shoot* (stem) for pollinator attraction. Floral identity genes are responsible.)
  1. Flowers have four circles of specialized, modified leaves:
     - a. **Sepals** – These are the green protective leaves. (Forms the bud. They are *non-reproductive*.)
     - b. **Petals** – These are the colored attractant leaves. (They are fragrant and also *non- reproductive*.)
     - c. **Stamen** - This is the male sporophyll. (Site of pollen grains. It is *reproductive*.)
       - i. **Anther** - Part with the yellow pollen grains and **filament** - It is a support stalk.
       - ii. Pollinator to transport pollen grain. (Example of co-evolution and also *reduces* competition.)
     - d. **Carpel/Pistil** – Site of female sporophyll, (It is *reproductive*.)
       - i. **Stigma** (sticky top), **Style** (the neck), **ovary** (Contains the ovules and eggs.)
- D. **Fruit** (It is a ripened ovary.) Developed to promote seed dispersal by animals eating the fruit.
  1. Green fruit (unripened, hard, unscented, and sour – no sugar.)
  2. Colored fruit (ripened, soft, scented, and sweet – lots of sugar.)(**Pericarp** – skin of the carpel/fruit.)
  3. After fertilization, the ovary wall thickens to become pulp of the fruit. (The seeds are inside.)
  4. Fruit structures for seed dispersal:
     - a. **Kites** - These fruits are carried by the wind.
     - b. **Burrs** - These fruits are carried by the fur of animals.
     - c. **Edible** - Animal digestive tract weakens the seed coat and seed deposited with fertilizer in new area.
  5. Fruit types:
     - a. **Simple** - Possesses one ovary. It will have a single seed. (A.K.A. pits.) (Such as a Peach.)
     - b. **Aggregate** - one flower with several carpels. It will have several seeds. (Such as a Blackberry.)
     - c. **Multiple** - Several flowers fused together to produce "one" fruit. (Such as a Pineapple.)
     - d. **Dry** - These are grains and nuts.
  6. Seedless Fruits? (This is an example of hormonal trickery.)
- E. **Double fertilization** (**Zygote** [organism] AND **endosperm** ["food"] will be produced.)
  1. Pollen tube is created by the 1 "digger" sperm.
  2. The other 2 enter through the micropyle (small pore). One fertilizes the egg; the other the polar nuclei.
  3. **Cotyledons** - are embryonic leaves. (1 leaf – **monocot**; 2 leaves – **dicot/eudicot.**)

III. Types of **Angiosperms** (There are over 200,000 species. They make up 90% of all plants.)
- A. Basal Angiosperms-are the oldest species. (They lack vessel elements xylem.)
- B. Magnoliids-are transitional species mainly. They are evergreens like Gymnosperms, but make flowers.
- C. Monocots
- D. Eudicots "true dicots"

IV. Angiosperm Plant uses
- A. Sources of *food and medicines*.
- B. Perfumes and decorations

Unit 8: Diversity of Life
Content Outline: Animal Characteristics (8.7)

I. About 800MYA (In the Pre-Cambrian Era), multi-cellular animals evolved from the Protist kingdom.
   A. They would have evolved from a group of multi-cellular Protists.
   B. About 360 MYA, animals (fish) begin to colonize land.
   C. About 250 MYA, Pangaea forms causing mass extinctions of fish and amphibians. (Reptiles survive dry climate.)
   D. About 180 MYA, Pangaea breaks apart.
   E. About 65 MYA, an asteroid collides with Earth causing mass extinction of reptiles/dinosaurs. (Mammals survive.)

II. Animal Traits
   A. They are all *multi-cellular heterotrophes by ingestion*.
   B. Animal cells have *no cell walls.* (They are held together by junctions and collagen fibers.)
   C. Most have muscle and nervous tissue for *movement and responding* to a changing environment.
   D. They exhibit *diploid dominant life-styles***.**
      1. Reproduce sexually using flagellated sperm (males) and non-motile eggs (females) that are both *haploid*.
      2. Haploid gametes fuse together to make *diploid* zygote.
      3. The diploid zygote will continue to grow, by mitosis, and develop into the organism.

III. Body Structure Evolution ("**Grade**" means "organizational complexity".)
   A. **Parazoa** (like animals) vs. **Eumetazoa** (true animals) ("Para" means "like"; "eu" means "true"; "zoa" is "animal".)
      1. Parazoa organisms are asymmetrical, have no true tissues, and are non – motile; BUT are heterotrophic.
   B. **Radial** vs. **Bilateral**
      1. Two tissues (diploblastic…no muscle tissue), nerve net vs. Three tissues (triploblastic), with a nervous system.
         a. Three tissues – **Ectoderm** (Makes skin and nervous tissue.); **Mesoderm** (Makes Muscles, Bones, heart.); **Endoderm** (Makes the digestive organs/tract, liver, and lungs.)
      2. **Dorsal** (Back/top), **ventral** (front/bottom), **anterior** (toward the head), **posterior** (toward the tail)
      3. Cephalization-the accumulation of *senses* in the head region of an animal.
   C. **Acoelomates** - These are "without a cavity" animals. (They tend to be *very small* – diffusion/osmosis is main transport system.)
   D. **Pseudocoelomates** - These are the *false cavity* animals (The space/cavity is *between two different tissues***.** The fluid filled space acts as a *hydrostatic skeleton*.)
   E. **Coelomates** - These are the *true cavity* animals. (The space *is within one tissue* – the mesoderm. It is for organ spaces and protection from the digestive tube.)
   F. **Deuterostomes (***Second* opening animals**)** vs. **Protostomes (***first* opening animals**)**
      1. Look at Blastula shape. (Is it Radial <u>OR</u> Spiral.)
      2. Anus (second opening) first development vs. Mouth (first opening) first development of the digestive tract.
         a. It is what the *Blastopore makes first.*
      3. Dueterostomes are Echinoderms and Chordates. (This includes humans…sorry.)
      4. Protostomes are Mollusks, Annelids, and Arthropods.

IV. Organ Systems present in most animals:
   A. Nervous System – uses senses to detect environmental stimulus and cues as well as control bodily function.
   B. Muscular/Bone System – moves the organism about the environment.
   C. Circulatory System – moves oxygen and nutrients through an organism's whole body.
   D. Respiratory system – performs gas exchange with the environment. (O_2 in; CO_2 out.)
   E. Digestive system –breakdowns food to the cellular level for providing nutrients to the cells.
   F. Excretory System –disposes of liquid nitrogenous waste.

Unit 8: Diversity of Life
Content Outline: Basic Anatomy and Physiology (8.8) – Part 1

I. **Anatomy** – This is the study of structure; **Physiology** – This is the study of function.

II. Hierarchy of multi-cellular organism's structure:

A. **Cells** – These are the *basic unit of life*.

B**. Tissues** – These are composed from cells with *common structure and function*. (There are 4 tissue types in most animals.)

1. **Epithelial Tissue** - This tissue forms *protective coverings* of structures, such as organs, cavities, and skin.
    a. They act as a *barrier* for various molecules. (This tissue relies heavily on the cell junctions to function.)
2. **Connective Tissue** - This tissue is for *binding together and supporting the other tissues* of the body.
    a. Types of connective tissue cells:
        i. **Loose connective tissue** - This is the most abundant. (It basically acts as "filler material".)
        ii**. Adipose tissue** (Fat cells) - These are for insulation, Energy storage, and padding.
        iii. **Fibrous Connective tissue** – These are composed of dense collagenous fibers.
            - **Ligaments** - For connecting *bone to bone.*
            - **Tendons** - For connecting *bone with muscle*.
        iv. **Cartilage** - This is a *flexible support* material.
            - Cartilage is also the initial framework for making bone.
        v. **Bone** (Osteo Tissues) - This is made from cartilage that has undergone **ossification.**
            ("Ossification" means "The process of making bone".).
            – These cells build bone by depositing Calcium and Magnesium salts in cartilage.
        vi. **Blood Tissue** - This tissue connects the *whole organism* transporting gases, nutrients, and wastes.
            - **Plasma** - This is the watery component containing dissolved substances.
            - **Hematocrit** - This is the cellular component- RBC's, WBC's, and platelets.
            - **"Erytho"** means "red"; "**Leuko"** means "white"; "cyte" means "cell".
3. **Nervous Tissue** - This tissue *senses stimuli and relay messages*.
    a. The basic structure is called a **neuron.**
        i**. Dendrites** – This part of the cell *receives stimulus* from the environment or another cell.
        ii. **Body** – This part *collects and bundles* the stimuli into *one* message. (Contains the organelles)
        iii. **Axon** – This part takes the information away from body toward the brain/muscle/gland.

4. **Muscle Tissue** -This tissue provides a *pulling* force within the body.
    a. Cells of this tissue are referred to as **muscle fibers** due to their long spindly shape.
    b. These cells are mostly composed of **actin** and **myosin microfibrils.**
    c. This tissue is the *second largest consumer of energy* in animals. (First is homeostasis.)
    d. Three types of muscle tissue in animals:
        i. **Skeletal** - This is striated (means "striped") muscle. (It is voluntary, meaning *you control it.)*
        ii. **Cardiac** - This is striated muscle. (It is involuntary, meaning the *brain controls it*; not you.)
        iii. **Smooth** - This is unstriated muscle. (It is involuntary. It functions in **peristalsis** - *-rhythmic* contraction of the digestive tract or in moving blood through blood vessels.)

C. **Organs** – This functional structure is a collection of *similar tissues working together*.

1. They are positioned in two different cavities:
    a. **Thoracic Cavity** - This is above the diaphragm. It contains the heart and lungs and is protected by ribs.
    b. **Abdominal Cavity** - This is below the diaphragm. It contains the digestive, urinary, and reproductive organs.

D. **Organ Systems** – These are composed of organs working together. (There are 11 systems in animals.)

E. **Organism** – This when all the organ systems are working together to create a multi-cellular organism.
(This is a great example of Emergent Properties.)

Unit 8: Diversity of Life

Content Outline: Basic Anatomy and Physiology (8.8) – Part 2

I. **Homeostasis** - Maintaining a *steady* internal state.
   A. **Negative Feedback Loop** – This *stops a process already in motion and reverses the effect.*
   B. **Positive Feedback Loop** - *Enhances* a process that is already in motion.
   C. To constantly monitor all the chemical processes occurring within an organism every second of everyday it is alive, requires *a tremendous amount of energy*. Therefore this is the number one energy expenditure by animals. The amount of energy needed to stay alive will be related to the amount of food they eat.

II. **Metabolism** - The sum of all the chemical reactions occurring within an organism.
   A. Heat Production vs. Food Intake vs. Activity
      1. **Endotherm** – These organisms generate their body heat *from within* by breaking down their food; therefore they need to eat more to keep their bodies warm; therefore they are more active anytime of the year.
      2. **Ectotherm** – These organisms obtain heat *from the surrounding environment*; therefore they need less food; therefore they are less active most of the time, especially when it is cold out.
      3. Metabolic Rate vs. body size
         a. Small animals→need more Energy (E)→to counter their large loss of body heat.
         b. Large animals→need less E→as they lose less body heat.
         c. Birds→require massive amounts of E→to counter the massive amount of body heat lost and needed to keep their giant breast muscles warm.

III. **Thermoregulation** in Animals
   A. **Regulator**-Organisms that *monitor* temperature and adjust in a changing environment. This *requires energy*.
   B. **Conformer**-Organisms that *match* their body temperature to the environmental temperature. (Requires No energy.
      1. These are incorrectly referred to as "cold" blooded animals.
   D. Adaptations in animals to aid in thermoregulation:
      1. Insulation (hair, feathers, fat)

Unit 8: Diversity of Life

Content Outline: Nervous Systems (8.9)

I. Evolution of a Nervous System

A. Start with the evolution of an organism wide Nerve Net in Cnidarians.

B. The evolution of a brain (a mass of neurons) leads to control of the system. It uses a nerve cord to control the body.

C. The evolution of other sensory organs in the head region, called **Cephalization,** allows for *reception* and *response* to stimuli from the environment.

II. Overview of the Nervous System:

A. **Sensory Input** - Stimulus sent into the brain or spinal cord. (From the body to the brain or spinal cord.)

1. Sensory Receptors receive a stimulus from the environment. A **stimulus** is a form of energy such as electromagnetic (light), mechanical (pressure), and 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** (Exiting out of the brain or spinal cord to the body.)

1. The response is carried out by **Effector Cells.**
    a. Effectors are Muscles or Glands. (These can have an *effect* on your body.)

D. **Peripheral Nervous System (PNS)**

1. This includes the Sensory Receptors and Motor Nerves.

III. Neuron Structure (Nerve Cell)

A. **Cell Body** - This takes stimuli from different dendrites and compiles the energy into one signal. (Like a funnel.)

B. **Dendrites** -These collect and carry stimuli 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.

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.)

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.

IV. **Reflex Arc** (The simplest neural pathway.)

A. A stimulus energy is detected by a **Sensory 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.

Unit 8: Diversity of Life
Content Outline: Sensory Mechanisms (8.10) – Part 1

I. Sensation of **Hearing**

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

B. Structure of the human ear:

1. Outer Ear - This part is for the *collection of sound waves from the external surrounding environment*.
    a. **Pinna** - This cartilaginous structure acts like an antenna *for collecting sound waves*.
    b. **Auditory canal** - This *concentrates the energy* as it moves toward the middle ear.
    c. **Tympanic Membrane** (A.K.A. ear drum) - This structure *converts* the sound wave energy into vibrations.
2. Middle Ear - This part is for the *amplification of energy* traveling toward the inner ear.
    a. **Malleus** (A.K.A. the hammer)*
    b. **Incus** (A.K.A. the anvil)* *smallest bones in the human body
    c. **Stapes** (A.K.A. the stirrup)* (This bone bangs on the oval window to *create ripples* inside the cochlea.)
        i. These bones are responsible for *amplifying* the vibration energy.
    d. **Eustachian tube** – These tubes, that connects with the throat, acts as a *pressure valve* for the ears.
    e. **Oval window** - This structure *converts the amplified vibration energy* into fluid wave energy.
3. Inner Ear - This part is where the transduction of fluid waves into electrical energy occurs – the type of energy that the brain can understand.
    a. **Cochlea** ("snail shell shaped") - This organ is located in the temporal bone of the skull.
        i. It is filled with a fluid called perilymph. (This fluid is used to make ripples.)
        ii. The **Vestibular Canal** runs on top of the Cochlear duct. (A "vestibule" is a covering.)
        iii. The **Tympanic Canal** runs on the bottom of the Cochlear duct. It ends at the **round window**.
        iv. The **Cochlear Duct** contains the **Organ of Corti.** (Where the hairs are located.)
            - **Basilar membrane** - This contains the mechanoreceptor hairs.
            - **Tectorial Membrane** - This *bends the hairs* as the ripple energy passes over top.
            - *Hairs bend causing neurons of the auditory nerve to create an action potential. (Electrical energy).*
    b. **Round Window** - This structure *absorbs the ripple* so as not to create waves in opposite direction.

C. **Volume** (A.K.A. loudness)

1. This term refers to the **sound wave height** – (Tall = *loud*); (Small = *soft*)

D. **Pitch** (A.K.A. Frequency) This term refers to the *"number" of sound waves* to hit the tympanic membrane per second.

1. It is measured in **hertz** (Hz). (20 -20,000 – human hearing. Most animals can go much higher than humans.) Evolution? Humans have lost some hearing because of life style – blind people not so.

II. Sensation of **Balance** and **Motion**

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

B. **Vestibule** - This is the covering of the **Utricle** and **Saccule** – These structures are perilymph *reservoirs*.

C. **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^o -detects up/down; 45^o - detects horizontal/vertical; 0^o -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 hairs causing depolarization in neurons and the energy of motion is converted to electrical energy.*

III. Sensation of **Taste**

A. This is accomplished using receptors in the nose and mouth.
("**Gustatory"** – means "taste"; "**Olfactory"** – means "smell".)

B. Chemicals are detected by different neurons upon contact.

1. The five taste senses are: sweet, sour, bitter, salty, and umami (means "savory"… applies to meat taste.).

Taste is 80 % SMELL and 20 % TASTE – What if you have a cold? Food seems tasteless.

Unit 8: Diversity of Life
Content Outline: Sensory Mechanisms (8.10) – Part 2

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

A. Types of light detecting structures:

1. **Oscilli** – As seen in Cnidarians and Bi-valves.
2. **Eye cup** – As seen in Platyhelminthes.
3. Eyes *with a lens* as seen in most other animals.
    a. **Compound Eye** – Found in invertebrates, such as insects.
        i. Made of many **ommatidia** working together. (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. Anatomy (structure) of the Human Eye:

1. **Sclera** – This is referred to as the eye white.
2. **Choroid** – This layer contains the blood vessels and black pigment for reducing sun light glare.
3. **Conjunctiva** – This layer is involved with mucous production to keep the eye cells moist. (**Conjunctivitis**… is the *inflammation* of this tissue layer.)
4. **Cornea** – This layer is the clear part of the sclera. (It also acts as a fixed lens and prevents debris from entering.)
5. **Iris** – This is the "colored" choroid. (It controls the *amount of light* entering the eye through the pupil.)
    a. It is operated by smooth muscle automatically for you. (Autonomic nervous system.)
6. **Retina** – This layer of the eye is the site of the photoreceptors. (It appears yellow upon dissection.)
    a. **Rods** - These receptor cells are for seeing black, white, and shades of grey.
        i. They are the *most abundant* in all animals having these structures.
        ii. They possess **Rhodopsin Pigment**.
    b. **Cones** - These receptor cells are used *for seeing color*.
        i. They are outnumbered 20 :1 by the rods.
        ii. They are found in vertebrates: but not all.
        iii. They possess **Photopsin Pigments** (red, blue, green) (Color-blindness is sex linked recessive. The genes for making these pigments were never in the parent's gametes.)
7. **Lens** – This structure focuses light. (It is made of a transparent, stretchable protein called crystalline.)
    a. **Accomodation** - This is the "focusing" of the eye for near vs. distant vision. (This requires it to stretch.)
        i. **Stigmatism** – This term refers to a misshaped lens.
        ii. **Myopia** – (A.K.A. nearsighted…You can't see far away objects clearly.)
        iii. **Hyperopia** – (A.K.A. farsighted…You can't see close up objects clearly.)
        iv. **Presbyopia** – Term refers to *lens degeneration* associated with old age.
        v. **Cataract** – This term refers to a "cloudy lens".
        vi. **Glaucoma** – Condition of having too much vitreous humor; results in too much pressure in the eye.)
8. **Ciliary Body** – These are the muscles that stretch the lens.
9. **Aqueous Humor** – This is the fluid in the **front** of the eye. (It is mostly water… "aqueous"; humor means "fluid".)
10. **Vitreous Humor** – This is the fluid in the **back** of the eye. (It is jelly-like… "vitreous". It gives the eye its shape.)
12. **Optic Nerve** – There is one for each eye. (It takes the action potential to the brain.)
13. **Optic Chiasm** – Collects rights and lefts in to one side of brain. (Located in the base of the brain.)
14. **Lateral Geniculate Nuclei** – These groups of neurons make the right or left "side" picture.
15. **Primary Visual Cortex** of the Occipital lobe of cerebrum - The site of integration of "halves" into 1 picture.

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Unit 8: Diversity of Life
Content Outline: Sensory Mechanisms (8.10) – Part 3

I. **Locomotion** – (A.K.A. movement) This term refers to *active* movement of an organism or object using *muscles and skeleton*.

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. It is accomplished by the use of *the skeleton*.

1. The is a skeleton made of bones, such as in Starfish, fish, amphibians, reptiles, birds and mammals.
2. There are skeletons made of water pressure (hydroskeleton), such as in earthworms.
3. There skeletons on the *outside of the body*, called **exoskeletons**, such as on insects and other arthropods.

C. It is also accomplished by the *use of muscles*.

1. The muscles associated with movement are called **skeletal muscle.** They are striated ("striped").
    a. The striations (strips) are created by the proteins microfilaments **Actin** and **Myosin.**
    b. These muscle cells all run in the *same direction*. This gives them *greater pulling strength.*
        i. Muscles can only pull on skeletons. They cannot push on skeletons.
    c. These are the only muscle *you can control*. This is called **voluntary movement**. (You must think it.)
2. The muscles of your heart are called **cardiac muscle.** (They are also striated.)
    a. They have a crisscrossing "net-like" structure. This gives it *greater compression (squeezing) strength.*
    b. You cannot control the movement. It is called **involuntary movement.** (You do not think about it.)
3. The muscles of your digestive tract or iris are operated by **smooth muscle**. They have no striations (stripes.)
    b. You cannot control the movement. It is called **involuntary movement.** (You do not think about it.)

C. 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.

Unit 8: Diversity of Life
Content Outline: Circulatory and Immune Systems (8.11)

I. Circulatory System - Responsible for connecting all the cells of the *whole* organism.
   A. The Circulatory System *distributes* nutrients, oxygen, hormones, and functions in waste retrieval.

II. Evolution of the Circulatory system:
   A. It started with a **Gastrovascular Cavity**. (As seen in Cnidarians and Platyhelminthes.)
   B. **Open Circulatory** system is one type that evolved. (Arthropods and some Mollusks possess.)
      1. Blood *bathes* the organs by moving through sinuses (spaces).
      2. The system has a *tubular heart* with directional arteries to distribute blood.
   C. **Closed Circulatory** system (Annelids, some mollusks, and vertebrates possess.)
      1. Blood is confined to traveling through blood vessels under pressure.
      2. A muscular *chambered heart* mostly (Not in annelids.)(2, 3, 4 chambered hearts exist)
         a. **Atriums** – These chambers *receive blood* coming *into* the heart.
            i. They are composed of a *thin* layer muscle tissue.
         b. **Ventricles** – These chambers *pump blood away* from the heart.
            i. They are composed of a *thick* layer of muscle tissue.
      3. Mammals, birds, reptiles, and amphibians have a **Double Loop system**.
            i. One loop for getting oxygen; one loop for delivering oxygen.
   D. Echinodermata have a **water vascular system** with three parts: madreporite, Tube feet, and canals.

III. Blood Vessel types of the body:
   A. **Arteries** – These are large blood vessels carrying blood *away* from the heart.
   B. **Arterioles** – These are medium sized vessels carrying blood *away* from the heart.
   C. **Capillaries** – These are the smallest blood vessels where nutrients and oxygen *diffuse out.*
   D. **Venules** – These are small blood vessels that *collect waste* materials from the tissues.
   E. **Veins** – These are large blood vessels that carry blood *toward* the heart.

IV. Blood distribution
   A. **During digestion of food** – The blood mainly is in the digestive organs.
      1. Swimming? The blood is not in the muscles, which are needed to swim, so you cramp if you go swimming right after eating. So wait 30 minutes.
   B. **During Exercise** – The blood is mostly in the muscles and skin, not the digestive organs.

V. Types of Blood cells:
   A. **Erythrocytes** - These are red blood cells RBC's ("Erythro" means "red"; "cyte" means "cell".)
      1. **Hemoglobin** uses iron (Fe) to hold oxygen. ("Heme" means "iron".)
         a. Each RBC can hold *1 billion* oxygen molecules.
   B. **Leukocytes** - These are white blood cells- WBC's ("Leuko" means "white".)
      1. They protect our bodies against invading organisms or materials.
      2. Some of these cells (**B-Lymphocytes**) make **antibodies** to help clean up your blood of pathogens (disease causing agents, such as bacteria and viruses.)
      3. Some of these cells (**T-Killer Lymphocytes**) kill *infected cells.*
   C. **Platelets** – These are pieces of RBC's used for making clots.

VI. **Immunity**
   A. This term refers to our white blood cells being able to attack pathogens.
   B. There are two types of immunity:
      1. **Innate Immunity (A.K.A. General Immunity)** ("Innate" means "To be born with".)
         a. These are defenses you are born with, such as skin, tears, mucus in your nose and ears.
         b. For plants, it is bark, thorns, spines on a cactus, or terrible tasting chemicals.
      2. **Specific Immunity**
         a. This uses the Lymphocytes to attack *specific pathogens*, such as Chicken Pox.
         b. This type of immunity is *acquired (received by you)* in two ways:
            i. **Active immunity**
               - You have to get and then fight the pathogen. (Chicken Pox is an example.)
               - You make **memory cells** to fight *future* infections. It takes *less time* to get better.
            ii. **Passive Immunity**
               - You have to get a shot (immunization) to make the memory cells.
               - The shot contains weakened viruses, so you hopefully do not get sick.
               - Some immunizations only last a couple of months or years.

Unit 8: Diversity of Life
Content Outline: Respiratory Systems (8.12)

I. Respiratory Systems - These are for *gas exchange* with the environment.
   A. Gas exchange (Oxygen *in* and Carbon dioxide *out*.)
      1. Oxygen is need for *cellular respiration*; Carbon dioxide is the waste product of cellular respiration.
   B. **Respiratory Medium** - This term refers to *where the oxygen molecules are located*. (It is water, air or blood.)
   C. **Respiratory Surface** - This term refers to *where the gas exchange occurs*.
      1. Diffusion must occur across a *wet* surface. *Gases do not diffuse across dry surfaces.*
      2. A *large surface area* is needed to get *large amounts* of gas exchange to occur.
         a. *Folds* in the surface *increase surface area* within a small space.
      3. Gills, Lungs, Tracheal tubes, Skin, and membranes are *all* respiratory surfaces.
         a. *Works with the circulatory system; that is why they are always located together*.

II. Mammalian Respiratory system
   A. It is located in the Thoracic Cavity (Chest).
   B. **Nostrils** and **Nasal cavity**
      1. These cavities *warm, moisten, and clean the air* using mucous and hairs.
   C. **Pharynx** (This is the *back* of mouth.) and **Larynx** (This is the *top* of trachea.)
      1. **Epiglottis** - This muscular flap covers the trachea by bending over the opening.
         a. Helps to prevent food and drink from entering the trachea/lungs.
      2. True and false vocal cords - These vibrate to make sounds. (You can only talk while exhaling because the moving air is causing the *vibration* by "catching" the wind; much like a parachute catches air.)
   D. **Trachea (A.K.A. windpipe)**
      1. It is protected by C- shaped cartilage rods on the front side.
   E. **Bronchi** - There is one for each lung. (Cartilage keeps them open for air to travel through.)
   F. **Bronchioles** - These carry air into each lobe of each lung.
      1. **Bronchitis** – This is an *inflammation* of the airways. ("itis" means "inflammation of".)
      2. **Asthma** – This medical condition causes trouble with breathing due to airways swelling shut.
   G. **Alveoli** ("Alveoli" means "small air sacs".)
      1. This is the site of gas exchange by diffusion. (*If it is a wet surface*.)
      2. They are only one cell layer thick which allows for *rapid diffusion* of gases.
      3. They are surrounded by capillary beds. (This makes it 2 cell layers thick, which leads to rapid diffusion of gases in and out.)
      4. WBCs keep these areas clean. (Smoking? Kills the WBCs.)

Unit 8: Diversity of Life

Content Outline: Digestive Systems (8.13)

I. **Food**

A. It is the *source of chemical energy* used to create ATP (molecule of cellular work) in the process of cellular respiration.

B. It can also serve as the *raw building materials* for "making" the organism.

II. **Undernourishment** - This condition is caused by a *lack of food*.

III. **Overnourishment** - This condition is caused by *too much food* in the diet.

A. Condition can cause Obesity and heart problems.

IV. **Malnurished** - This condition is caused by eating *poor quality food*.

V. Feeding Types:

A. **Herbivore** – These are plant eaters.

B. **Carnivores** – These are meat eaters.

C. **Omnivores** – These are plant and meat eaters. ("Omni" means "all".)

VI. Feeding Mechanisms:

A. **Suspension/filter feeding** (Examples, whales, sponges, bivalves.)

B. **Substrate feeding** (Example, maggots.) Substrate refers to "surfaces". They live in or on their food source.

C. **Deposit feeders** (Example, earthworms.) They eat substances deposited in the soil.

D. **Fluid feeders** (Examples, mosquitoes, hummingbirds.) Feed on fluids such as blood or plant nectar.

E**. Bulk feeders** (Examples, Humans and most other animals.) Bulk refers to "large quantities at one time".

VII Food processing basics:

A**. Ingestion** - This is the putting of food *in the mouth*.

B. **Digestion** - This is *the breakdown of food*.; **indigestion** - This refers to trouble breaking down food.

1. Digestion is accomplished through *enzymatic hydrolysis* primarily.
2. The process is aided by mechanical (grinding/chewing) digestion as well.

C. Food molecules then undergo **absorption** into the circulatory system or diffusion into the surrounding tissues.

D. Elimination of waste (About 10% of what is eaten.) occurs at the end of the tract (anus) or out the mouth/anus for primitive animals.

VIII. Where Digestion Occurs:

A**.** It starts as a single opening osculum (as in sponges), and evolves over time into a single opening mouth/anus of a gastrovascular cavity (as in Cnidarians and Platyhelminthes).

B. Gastrovascular cavities evolved into a two opening digestive tracts (A.K.A. **Alimentary Canal**) over millions of years. (As seen in all other phyla of animals.)

1. Organs of the digestive tract:
   a. **Mouth/Teeth** - Starts digestion by breaking food up into smaller pieces.
   b. **Pharynx** - This muscular tube sucks food up into the tract.
   c. **Esophagus** - This structure lubricates food for passage through the tract.
   d. **Crop** (food storage) → These two evolve over time to become one organ – **stomach.**
   e. **Gizzard** (food breakdown)→
   f. **Small intestines** - This organ finishes food breakdown and also food absorption.
   g. **Large intestines** - This organ is for waste collection and water reabsorption.
   h. **Anus** - Where waste material exits the body.

IX. **Adaptations to the digestive tracts of Mammals:**

A. Teeth types – These structures are directly related to an organisms diet. (Just like beaks for birds.)

B. Increased stomach size for carnivores.

C. Length of digestive tract – Carnivores have short digestive tracts; herbivores have long digestive tracts.

D. **Rumens** in herbivores - This structure contains cellulose-digesting bacteria. (Animals are ruminants. They chew cud.)

Unit 8: Diversity of Life
Content Outline: Excretory Systems (8.14)

I. **Osmoregulation**

A. This is the *continuous control* of water and solute concentrations within an organism. (A part of **homeostasis.**)

B. Regulation occurs across a **transport epithelium** (membrane).

1. Nephridia (mammals, birds, reptiles, amphibians, fish); Metanephridia (annelids); Malpighian tubules (Insects); Green glands (Crustaceans), flame cells (Platyhelminthes) are all examples of transport epitheliums.

D. They help in *the removal of nitrogenous waste***.** (Ammonia is created from using amino acids for Energy production.)

1. **Ammonia** – This form requires *lots* of water to dispose. (Fish and other aquatic invertebrates live in water.)
2. **Urea** – This form requires *moderate* amounts of water in disposal – Good for dry land. (Evolution of Mammals & Amphibians.)
    a. This form combines ammonia and carbon dioxide together. (Two waste products as one.)
3. **Uric Acid** – This form requires *very little* water – Good for desert climates. (Evolution of Birds and reptiles.)
    a. Ammonia and carbon dioxide in a paste like state. (Car paints? It is an acid… so it destroys them.)

II**.** Adaptations for Water Conservation:

A. Keratinized skin - As seen in reptiles, birds, and mammals. (This skin type is related to the formation of Pangaea.)

B. Exoskeleton Seen in insects – These were the first animals on land.

C. Being nocturnal - Animals move around *at night* to avoid possible dehydration by the sun. (Desert animal mainly.)

D. Storage cells or vacuoles - to store extra water. (Desert animals- camels: plants – central vacuole.)

E. Waxy Cuticle – Seen on plant leaf surfaces.

III. Urine Production Basics for <u>all</u> animals.

A. It is a basically a two step process:

1. **Filtration** - This is achieved by the "liquid" portion of blood being *separated* from the blood cells and platelets.
    b. The liquid portion now becomes "filtrate" upon leaving the blood vessel.
    c. The collected filtrate is then filtered, to remove nitrogenous waste and other excess molecules.
2. **Tubular reabsorption** -This is the reabsorbing of "good materials" from the filtrate – leaving "bad" behind.
    a. Reabsorption collects all or most of the "good materials" and puts them back in the blood.
    b. This leaves behind the "bad materials" to be collected and disposed of in the form of Urine.

IV. Osmoregulation in Mammals – This occurs in the Kidneys. (Your kidneys are a collection of *1 million* nephrons per kidney.)

A. Structures of the Urinary system:

1. **Renal Artery** – This blood vessel brings "polluted" blood *into* the kidneys.
2. **Renal Vein** – This blood vessel takes "purified" blood *away* from the kidneys.
3. **Renal Cortex** – This is the *outer part* of the kidney where the nephrons are located. (Site of *urine production.*)
4. **Renal Medulla** – This is the *middle part* of the kidney. (Site of *urine collection* from the nephrons.)
5. **Nephrons** – These are the structures where blood is actually "purified".
6. **Collection Tubules** – These are where urine is collected from the nephrons.
    a. Tubules converge to create **Renal Pyramids.** (These are triangular shaped structures in the medulla.)
    b. All tubules lead to the **Renal Pelvis.**
7. **Renal Pelvis** – This is the main collection area (In the center of the kidney.) for the collection tubes.
    a. **Calyxs** – These are the extensions (inlets) off the central pelvis that connect to the pyramids.
8. **Ureter** – These two tubes take the urine from the kidneys to the bladder for storage until release.
9. **Bladder** – This is the expandable urine storage organ. (It is composed of transitional epithelium.)
10. **Urethra** – This is the tube leading from the bladder to outside of body. (It is the urinating tube.)
    (Urine should be yellowish to clear... it depends on the amount of water to be released.)

V. Diseases associated with Kidney function:

A. **Diabetes** (means "Sweet Urine") – There is *too* much sugar in the blood; the body is trying to get rid of it in the urine.

B. **Cirrhosis of Liver** – Condition leads to *too* much ammonia and bile in the blood causing Jaundice (yellowing) of skin.

1. Most common cause of Cirrhosis is alcoholism.

Unit 8: Diversity of Life
Content Outline: Animal Kingdom – Invertebrates (8.15) – Part 1

I. **Invertebrates** – These are animals without a backbone. (These are lower grade animals.)
   A. Most of these are aquatic life forms.
   B. They account for *95% of all known animal life forms* existing today.

II. **Parazoa** (like-animals) ("Para" means "like"; "zoa" means "animal"… like a zoo is where we see animals.)
   A. Phylum: Porifera - These are pore bearers. (The common name is Sponges.)
      1. Porous – **porocytes** (Where water enters in to the organism.); **Osculum** (Where water exits the organism.)
      2. *No true tissues are present*; there are no muscle or nerves either.
      3. They are all sessile (means "non-moving") **filter feeders.**
      4. **Hermaphrodites** – Organism contains both sexes.

III. **Radial** Eumetazoa ("True" animals; "eu" means "true")
   A. Phylum: Cnidaria - These are Jellyfish and Sea Anemones.
      1. **Diploblastic** - Means "*two* germ layers"; An **Endoderm** (for digestion) and **ectoderm** (outer protective layer).
      2. **Mesoglea** (middle jelly) - This provides *buoyancy* and *shape* to the organism.
      3. These are mostly marine (means "salt water") animals.
      4. Two Life Stages:
         a. **Polyp Stage** (It is sessile.) - This stage is similar to the sponges *in appearance*.
         b. **Medusa Stage** (This is motile…can move.)
            i. Moves using a **nerve net** to *shock* the mesoglea.
            ii. **Bell** (top portion) has **statocysts** (Cells that detect gravity.) and **oscilli** (Cells that detect light.).
            iii. Tenticles contain **Cnidocytes.** (These are stinging cells.)
      5. **Gastrovascular cavity** - Functions in digestion and food distribution. (Possesses *one mouth/anus opening*.)
      6. Sexual (Medusa stage) and asexual (Polyp stage) reproduction can occur in these organisms.

IV. **Bilateral** Eumetazoa ("Bi" meaning "two"; "lateral" means "parallel sides".)
   A. Phylum: Platyhelminthes (Flatworms)
      1. **Triplobastic** – having *three* germ layers – **ectoderm, mesoderm** (makes muscles), and **endoderm.**
      2. **Acoelomates** – (means "without a cavity")- These are small animals that *move materials by osmosis/diffusion*.
         a. They can only be a *couple of cells thick*; just like the bryophytes of plants.
      3. **Nervous System** - Has a ganglia/brain and nerve chords. Responds to the environment and helps in movement.
         a. **Eyespots** - These are structures for detecting light. (They are *recessed* oscilli.)
         b. This is the beginning of **cephalization** - The accumulation of sensory tissue in a "head" region.
      4. **Gastrovascular cavity** - Extends the length of the body. (Still a single mouth/anus opening.)
      5. **Flame cells** – These are for excreting *nitrogenous waste* associated with protein breakdown.
         a. They are similar to your kidneys.
      6. Four classes exist:
         a. Turbellaria (planarians)
            i. These are free-living, marine, carnivorous flatworms.
         b. Trematodes (flukes) and Monogeneans
            i. These are internal or external parasites associated with feces water.
            ii. Most common is Schistosomysis (Blood/liver fluke). Kills 200 Million people/year – third world.
         c. Cestoidea (Tapeworms)
            i. These are parasites of the intestines. (They cause *extreme* weight loss quickly upon infection.)
            ii. **Scolex** (the head) - it has sucker cups with hooks to hold on in the intestine as food moves past.
            iii. **Proglottids** - These are the reproductive segments. (Hermaphroditic)(Larger sections – older.)
            iv. Can be acquired by contaminated feces water or feces eating, such as with dogs and cats.

Unit 8: Diversity of Life
Content Outline: Animal Kingdom – Invertebrates (8.15) – Part 2

I. Phylum: Mollusca (mollusks)(means "soft body")

A. Most have a protective shell (Either external or internal.) made of chitin or Calcium Carbonate.

B. All mollusks have three soft body parts:

1. Foot – A *muscle* for movement, swimming, or grabbing prey.

2. Mantle – This is a *tissue flap* that can produce the protective shell.

3. Visceral Mass – Area that contains the *vital organs* (heart, gills/lungs, stomach, gonads, and nephridia)

C. Mantle Cavity – This cavity (space) contains the gills (if aquatic) or lungs (if terrestrial).

D. Radula – This is a barbed, shredding tongue that goes back and forth.

E. **Beaks** – Eagle-shaped structure found in the cephalopods for killing and eating prey. (These are razor sharp.)

F. Separate sexes exist in most groups. (Except in snails, which are *still* hermaphroditic.)

G. Four classes of Mollusks exist:

1. Polyplacophora (Chitons)
   a. These are flat worm- like organisms; but with 8 hard protective plates of Calcium Carbonate.
2. Gastropoda (means "Stomach-foot"; "poda" means "foot") - These are Snails and slugs.
   a. These are mostly marine; but some are terrestrial.
   b. The head has eyestalks that possess retractable eyespots.
   c. Some have a twisted shell of Calcium Carbonate. (Except the slugs, which have <u>no</u> shell.)
3. Bivalvia (means "**possessing two shells"**) - These are oysters, scallops, and clams.
   a. These organisms possess a protective shell, having two halves, of Calcium Carbonate.
   b. The shell is *controlled* by large adductor muscle.
   c. These are *filter feeders* and possess gills for gas exchange.
4. Cephalopoda (means "Head-foot") - These are squid, octopus, and nautilus.
   a. Most are aerodynamic; all are *carnivorous predators* with beaks.
   b. They all have tentacles with strong suction cups to hold prey.
   c. They move by *jet propulsion using siphons*. (Move by swimming backwards.)
   a. **Shell** – external – nautilus (These are living fossils); internal – squid(pen); non-existent in octopus
   b. *Closed circulatory system and digestive tract* - this affords a larger size organism.
   c. *Very well developed nervous system and senses.* (They have eyes and brain because they are predators.)

Unit 8: Diversity of Life
Content Outline: Animal Kingdom – Invertebrates (8.15) – Part 3

I. Phylum: Annelida - These are the *segmented* worms. (" Annelid" means "fused rings".)
- A. They have a septated (segmented) coelom. (This allows for *specialization* of each segment to occur.)
- B. They possess a true digestive tract with different organs:
  1. **Pharynx** - This structure sucks up food.
  2. **Esophagus** - This structure lubricates the food so it can slide by **peristalsis**… rhythmic contraction.
  3. **Crop** - This structure is for food storage.
  4. **Gizzard** - This structure is for food breakdown. (Crop and gizzard will evolve into a stomach later in time.)
  5. **Intestines** - This structure is for food absorption. (Food molecules are passed into the circulatory system.)
- C. They have a **closed circulatory system.** The system runs dorsally and ventrally for the whole length of the organism. The system has 5 muscular *tube hearts* for pumping hemoglobin. (**Hemoglobin** is iron rich blood.)
- **D.** **Nervous system** has *anterior ganglion brain* with ventral nerve cord possessing segmental ganglia.
- **E.** **Excretory system** (removes nitrogenous waste) is composed of segmental **Metanephridia** (2 per segment.)
- **F.** Reproduction - They perform *cross-fertilization* even though they are hermaphrodites. (Structure = Function, Take and stick out your thumb and index finger on both hands. Then rotate one hand so that you have one palm side and one topside facing you. Point each hand toward the other hand. Now move them together. Each thumb [male organ] is touching an index [female organ]. So they can cross-fertilize each other.)
  1. They are **hermaphrodites**. (This is due to life style – living in dirt… might be hard to *find* a mate)
  2. **Clitellum**- It is the one enlarged segment.
     a. This segment makes a *protective case to collect the eggs* in. The eggs are laid in front of the clitellum and then "scooped up" as the worm moves forward.
- **G.** Three classes of annelids exist:
  1. Oligiochaeta (Earthworms)
  2. Polychaeta (Sea worms)
  3. Hirudinea (Leaches) - These are fresh water worms. (They are also parasites.)
     a. They have a blade like jaw and anesthetic saliva. (So you can't feel them until you see them.)
     b. **Hirudin** - This protein in the saliva is an anti-coagulant; so it keeps blood from clotting while it feeds. (Hirudin is used to help break up blood clots that are causing a heart attack or stroke.)

II. Phylum: Nematoda - These are the round, *unsegmented* worms.
- A. They are free-living decomposers or parasites.
- B. Have a thick **chitinous skin** (called the **cuticle**) that has to undergo **ecdysis** (means "shed") periodically to grow larger.
  1. This skin protects against **desiccation** (means "water loss").
- C. These are p**seudocoelomates**.
- D. There are **separate sexes.**
- E. For example, *Tricinella spiralis* "trichinosis" (Can be caught by eating undercooked pork.)

Unit 8: Diversity of Life
Content Outline: Animal Kingdom – Invertebrates (8.15) – Part 4

I. Arthropods ("Arthro" means "jointed"; "poda" means "foot".)
   A. These are the *most abundant group of animals* on Earth. (Insects are the most abundant arthropods.)
   B. They are also *segmented* animals. (Remember, this allows for specialization of segments.)
   C. They all display a high degree of **cephalization**. (Brain, antenna, eyes, mouthparts all in the head.)
   D. **Exoskeleton** *of Chitin* - protects against desiccation and harm.
      1. It serves as an *attachment point* for muscle tissue. (Replaces the need for bones.)
      2. It too must undergo **ecdysis** to grow larger, unfortunately for the organism…they become exposed.
   E. All have an **open circulatory system.** (There are <u>no</u> blood vessels to get pinched in the exoskeleton.)
      1. **Hemolymph** (similar to hemoglobin) travels through sinuses (spaces).
      2. Hemolymph *bathes* the organs instead.
      3. They possess a large *one-chamber heart* with directing tubes.
   F. Use **gills, lungs, or tracheal tubes** (for insects) for gas exchange. (It depends on where they live…water or land.)
   G. Four subphylum exist in nature:
      1. Cheliceriforms -These are the *fanged* arthropods. ("Chelicera" means "fang".)
         a. These are Ticks, Spiders, Mites, Scorpions, and Horseshoe Crabs.
         b. They have <u>*no*</u> antenna, they have 8 legs, and a body with two parts: **Cephalothorax** and abdomen, they have multiple eyes (simple and compound), book lungs, spinnerets (Cephalothorax is a *combined head and thorax*.)
      2. Myriapods ("Myria" means "*multi"…multi-legged* animals.)
         a. Millipede belongs to the class: Diplopoda - They have *2 pairs* of walking legs per segment. (These are harmless decomposers.)
         b. Centipedes belong to the class: Chilopoda - They have *1 pair* of walking legs per segment. (These are poisonous carnivores and they have a pincher on the tail end like a scorpion.)
      3. Hexapoda (means "**six legged**" animals) - These are the Insects.
         a. Most can fly using one or two pairs of *wings*. (Wings are an extension of the cuticle. They are basically air-filled tubes with a thin layer of Chitin covering the open spaces.)(They are *analogous* to bird wings…<u>not</u> homologous.)
         b. Possess *one pair of antenna*.
         c. Possess **Malpighian tubules** (like kidneys) - collect nitrogenous waste and empty it into the intestine for disposal.
         d. Possess a **Tracheal tube system** with spiracles (openings in abdomen) for gas exchange.
         e. **Incomplete Metamorphosis** – Insect grows from nymph to adult. (They look alike though.)
         f. **Complete Metamorphosis** – Insect grows from Larva to pupa to adult. (Each looks different.)
         g. Mate *once* in the lifetime; then die. Males usually killed after mating. Females – after laying eggs.
         h. *Important pollinators* of angiosperm plants.
         i. Some are disease carriers (For example, mosquitos carry Zika virus.)
         j. Some are considered by man to be pests. We use pesticides/insecticides to kill them.
      4. Crustaceans (These are *aquatic* arthropods.)
         a. They possess *2 pair of antenna*. (A long pair – for finding obstacles; a short pair – for finding food)
         b. Possess walking legs on thorax and swimmerets on abdomen.
         c. Possess a **Carapace** (this covers the visceral mass). It is a part of the exoskeleton.
         d. Usually has two large *pincers* as first set of legs.
         e. **Green gland** (like kidneys) collects nitrogenous waste. (They are under the eyes – the location acts as a defensive location. They urinate as they *retreat* backwards.)

Unit 8: Diversity of Life
Content Outline: Animal Kingdom – Invertebrates (8.15) – Part 5

I. Phylum: Echinodermata (means “spiny skin”; “derm” means “skin”)
   A. These are the Starfish, Sea urchins, Sea cucumbers, Sand dollars, and Sea biscuits.

   B. They have an *internal calcium carbonate skeleton.* (It grows as the organism grows, so it is composed of living cells; just like yours.) It is **Homologous** to vertebrates.

   C. They use a **water vascular system** for movement and transport.
      1. It has three parts to it:
         a. **Madreporite** – This is the “mother pore” or opening to the inside.
         b. **Tube feet** – These are for suction and walking.
         c. **Ring canal** – This connects the five legs and madreporite.

   D. They start as bilateral larva → grows into radial adult.

   E. They are carnivores. (They eat bivalves.)

   F. They can regenerate lost limbs.

   G. **Deuterostome** like the vertebrates in development (*Common ancestry* with the high grade animals.)

Unit 8: Diversity of Life
Content Outline: Animal Kingdom - Vertebrate Animals (8.16) – Part 1

I. Phylum: Chordata -These are animals *possessing a **notochord***. (These are the higher-grade animals.)
   A. Four general characteristics of all Chordates:
      1. They possess a **notochord.** - This is a flexible support rod running dorsally. (It reduces to intervertebral discs.)
      2. They also possess a *dorsal, hollow nerve chord*.
         a. This structure develops into the Central Nervous System (CNS) – brain and spinal cord.
      3. **Pharyngeal slits** -This allows water passage to bypass the digestive tract.
      4. They possess a *muscular post-anal tail***.** (This, over millions of years, has reduced to tail bones in humans and great apes.)
   B. These are all **Deuterostome** development. (Blastopore makes the anus first organisms.)

II. **Vertebrates** - These are chordates that possess a hard *backbone surrounding and protecting the nerve cord.*
   A. These are mostly large and active animals.
   B. They possess a very high degree of **Cephalization**.
   C. They have an *axial skeleton* supported by the backbone. (This helps lead to larger size and better movement.)
      1. There are ribs to protect the visceral mass.
      2. The skeleton *grows as the organism grows.*
      3. Axial refers to "central" that all appendages come off of in an outward fashion.
   D. The skeleton has *two pair of appendages***.** (There is one anterior pair and one posterior pair.)
   E. Notochordal Discs in between vertebrae. (They are jelly filled *cushions* that provide greater flexibility.)
   F. They have an *advanced respiratory system***.** (This means *more oxygen can be obtained* which then leads to larger and more active bodies.)
   G. They have an *advanced circulatory system.* (A better way to *move nutrients, oxygen, and waste* → bigger body.)
   H. They have an *advanced digestive system***.** (This allows for organisms to be able to eat different foods → get more nutrients → more active and larger bodies.)
   A. They have an *advanced nervous system*. (This allows them to control larger more active body quickly when responding to the environment.)

<u>FISH</u>

III. Jawed Fish
   A. Class: **Chondroichthyes** - These are the cartilaginous fish such as Sharks and Rays. ("Chondro" means "cartilage; "icthye" means "fish".)
      1. The teeth are the only bones; the body is made of cartilage.
      2. They have scaled skin. (Prevents **desiccation** "water loss".)
      3. They have muscular fins and powerful jaws. (This is great for predators.)
      4. They have highly advanced vision and olfaction (sense of smell). (This is also great for predators.)
      5. They have a **lateral line system** used for hearing. (It detects water vibrations.)
   B. Class: **Osteoichthyes** - These are the boney fish, such as bass, catfish, and trout. ("Osteo" means "bone".)
      1. These are the most abundant vertebrates.
      2. They have an *endoskeleton made of calcium carbonate*, just like humans.
      3. They have a **lateral line system** for hearing.
      4. Gills with an **operculum** covering. (This structure allows them to breath while being still as it creates water movement and thus keeping the gills constantly exposed to fresh oxygenated water.)
      5. They have a **swim bladder for buoyancy**. (This makes for more versatile movement in an obstacle-ridden environment, such as a swamp or river.)
      6. The female's eggs are laid outside the body and then fertilized by the male's sperm.
      7. Fish have a *two-chambered* heart in close proximity to the gills.

Unit 8: Diversity of Life
Content Outline: Animal Kingdom - Vertebrate Animals (8.16) – Part 2

AMPHIBIANS

I. Class: Amphibians
   A. These are all **tetrapods.** (means "organisms with four legs")
   B. They are *scaleless*. (They *must keep skin moist to breath*; therefore they live in moist environments.)
   C. They have webbed feet for swimming.
   D. They have a *three-chambered heart*. Two – **atriums** (receives blood) and **one ventricle** (pumps blood out).
   E. They *must have water for eggs to be laid in, just like the fish.*
   F. They *undergo complete metamorphosis*.
      1. The Larva form is a water *herbivore* & the adult form is a terrestrial *carnivore*.
   G. About 250 MYA, most species go extinct due to Pangaea forming and displacing the water.
   H. Three orders of amphibians exist:
      1. Urodela (means "first tail")
         a. They are either aquatic or terrestrial organisms.
         b. These are salamanders and newts.
      2. Anurans (means "no tail")
         a. They have powerful hopping legs and a long tongue. (Great for catching insects.)
         b. These are frogs and toads. (Frogs stay in water mostly; toads on land mostly.)
      3. Apodans (means "no feet") (They look similar to snakes.)
         a. They are legless and blind organisms.
         b. They are cave-dwelling or ground-dwelling.
   I. Amphibians are important *environmental indicators* of water quality. (Due to the eggs needing clean water.)
      1. Acid rain and pollution are causing large species extinction in our time.

II. Amniotes -These are organisms that *produce a fluid-filled developmental structure* called the **amnion**.
   A. This includes reptiles, birds, and mammals.
   B. These *organisms thrived during Pangaea* because they are less dependent on the presence of water.
   C. **Amniotic egg**
      1. Most have a shell of Calcium Carbonate around the egg to prevent desiccation (water loss).
         a. The egg contains four extra embryonic *membranes* and the Albumin:
            i. **Amnion** - This is the fluid-filled membrane that the embryo floats in.
            ii. **Allantois** - This membranous sac is for waste collection.
            iii. **Chorion** - This membrane functions in gas exchange. (Oxygen inward and carbon dioxide outward.)
            iv. **Yolk Sac** - This structure is a food source in eggs. (It makes the gonads in mammals.)
            v. **Albumin** - This is the egg white protein. (It is an extra food source should the yolk sac get depleted.)

Unit 8: Diversity of Life

Content Outline: Animal Kingdom - Vertebrate Animals (8.16) – Part 3

REPTILES

I. Class Reptila
   A. General Characteristics of reptiles:
      1. Body covered by *scales of keratin*. (Prevents desiccation.)
      2. They have *true lungs* (possessing **alveoli**… small air sacs) and a *three-chambered heart*.
      3. They are **Ectothermic. -** They absorb heat from the surrounding environment. (This keeps their metabolism low… so they do not have to eat as often as birds and mammals.)
   B. Three Sub-classes exist:
      1. Testudines – These are Turtles/Tortoises. (They lay their eggs on land.)
      2. Lepidosaurs - These are Tuataras and Squamata. (These are common lizards and snakes.)
      3. Crocodilia - These are Alligators and Crocodiles. (Alligators have a wide snout; crocodiles have a narrow snout.)

II. Class: Aves (Birds)
   A. This group evolved from Archaeopteryx.
      1. It was a feathered, solid boned, teeth, vertebrate tail, claws on the wing, 6 feet tall predator. (It was not a good flyer, as it was too heavy. Compare modern birds characteristics below to see how the weight was reduced.)
   B. General characteristics of birds:
      1. They have *scales on the feet and face*.
      2. **Feathers** are modified scales of keratin, and located on an aerodynamic wing and body.
      3. They have hollow bones.*
      4. They lay eggs with the developing embryo inside the egg.
      5. They have a reduced number of organs. (For example, only 1 gonad.)*
      6. Toothless beak of fused keratin. (The shape dictates diet.)*
      7. **Endothermic** - They generate heat *within* from food breakdown. (They have fat tissue to help retain the heat.)
      8. Lungs have *secondary air sacs***.** (2x as much oxygen in one breath.)*
      9. They have a *four-chambered heart***.** (Allows for increased activity.)*
      10. They have excellent eyesight. (Most are predators.)

      * **Exaptions** that eventually lead to flight.
   C. Two sub – classes exist:
      1. **Ratites** - These are the *flightless* birds.
      2. **Carinates** - These are birds of *flight*.
         a. Types of Carinates:
            i. **Passeriformes** (song birds)
            ii. Aquatic
            iii. **Raptors** (birds of prey)

Unit 8: Diversity of Life

Content Outline: Animal Kingdom - Vertebrate Animals (8.16) – Part 4

MAMMALS

I. Class: Mammalia

A. Mammal general characteristics:

1. They possess **mammary glands** in the breasts to feed the young high protein milk.
2. They have **hair** of keratin and a *sub-cutaneous fat layer*, both act as insulation to trap heat. (Endothermic)
3. They have a *four-chambered heart* and most have a *large brain* capable of some level of learning.
4. Most give live birth. This needs a **placenta** – connection with the mother.
5. Possess different types of teeth. (The organisms diet indicates the type of teeth they possess.)
    a. Incisors (cutting tissue)
    b. Bicuspids (puncture and hold prey)
    c. Premolars and molars (grinding food)
6. Most show a high level of parental care. The number of offspring is proportional to energy spent on rearing.

B. Three orders of mammals exist:

1. Monotremes - These are *egg-laying* mammals.
    a. Duck-billed Platypus and Echidnas (Australia/New Guinea)(They are poisonous, like some reptiles.)
2. Marsupials - These are the *pouched* animals, such as kangaroos.
    a. Mother gives early birth and the embryo goes to the marsupium to suckle and finish developing.
    b. Found mostly in Australia and North America.
3. Placentals - Most furry animals and humans.
    a. They have long pregnancy because of placenta. (Greater protective development can occur.)

Unit 9: Botany
Content Outline: Plant Structure and Growth (9.1)

I. **Plant "Organs":**
- A. Most plants live in *two different environments*: air and soil. (Each is *interdependent* on the other for survival.)
- B. The two organ systems of plants:
  1. **Root System** - This system functions in the soil environment.
     - a. It helps to *anchor* the plant to the ground or base.
     - b. It helps to *absorb water and nutrients* for use by the plant.
     - c. It helps *store food*. (Starch – glucose monomers strung together.)
     - d. Three types of roots exist:
       - i. **Tap Root** – There is *one large root* that dominates, like a carrot.
       - ii. **Fibrous** – There are *many, equal-sized* roots, like in grass.
       - iii. **Adventitious** – These are *above ground braces* for tall plants, like corn.
     - e. **Root hairs** – These dermal tissue extensions *increase surface area for maximum water and nutrient absorption*.
       - i. They are usually covered with **mycorrhizae** - a fungus **symbiant**.
  2. **Shoot System** - This system functions in the air environment.
     - a. **Stems** (This includes the branches and plant trunk.)
       - i. **Nodes** and **internodes** (These are growth and environmental indicators.)
         * Longer internodes indicate it was a "better" growing conditions that year.
       - ii. **Auxillary buds** – These buds are located on the *sides* of branches.
       - iii. **Terminal Buds** – This *one* bud is located at the *tips* of branches.
     - b. **Modified Stems**:
       - i. **Stolon** – These are *above ground runners* for asexual reproduction.
       - ii. **Rhizomes** – These are *below ground runners* for asexual reproduction.
       - iii. **Tubers** – These are *stems for starch (food) storage*. (Like a potato.)
       - iv. **Bulbs** – These are *starch storage leaves.* (Like an onion.)
     - c. **Leaves** (These are the site of photosynthesis.)
       - i. **Blade** – This part of a leaf is the *green fleshy part* between the veins.
       - ii. **Vein** – Site of the xylem and phloem tissues.
         **Monocot veins – run parallel; Eudicot veins – branch out.*
       - iii. **Petiole** – This is where the leaf *connects* to stem of the branch.
       - iv. **Petiole-less** – This is a sheath like structure for a new leaf, like in grass.
       - v. Leaves are very useful in identifying a species of plant.
         Types of leaves: *Simple, compound, double compound.*
     - d. **Leaf Modifications**–Things like **spines** (for protection) and **flowers** (for reproduction).
     - e. **Leaf Stomata** (stomate –singular) - These openings are created by the *two Guard cells.*
       - i. Stomata control the rate of **Transpiration** (water *loss*), CO_2 entry, O_2 release.
- C. Monocot traits vs. Eudicot traits

II. **Plant Tissues:**
- A. These tissues *run continuously through the entire organism.*
- B. Three types of plant tissues exist:
  1. **Dermal (epidermis) -**The "skin" basically.
     - a. It serves as *protection* for the plant against pathogens.
     - b. It can contain root hairs, if it is on the underground portion of the plant.
     - c. It can produce the cuticle (A waxy covering preventing dehydration, if it is above ground.)
  2. **Vascular** - This tissue carries fluids.
     - a. **Xylem** → It carries *water up to the leaves* through *dead, hollow cells*.
     - b. **Phloem** → It carries *sugar water down toward the roots* through *living cells.*
  3. **Ground Tissue** - This is basically "filler" material. Just storage mostly.
     - a. **Pith** - Ground tissue located *inside the vascular bundles*.
     - b. **Cortex** - Ground tissue located *outside the vascular bundles.*

III. **Growth** – This term refers to the *increase in mass due to cell division.*

IV. **Development** – This term refers to the *sum of all the changes* that occur within an organism.

V. Plant Growth
- A. **Flowering plant** growth periods:
  1. **Annuals** – These plants live, flower, reproduce, and die within *one year*.

2. **Biennials** – These live, flower, reproduce, and die within *two years*. (First year they store energy; The second year they reproduce.)
3. **Perennials** – These plants live for many years provided no infection or trauma occurs.

B. Plants grow *their entire lives so long as the environment is favorable* and no trauma.
   1. Plants go *dormant ("slow" metabolic activity period)* during the winter months.

VI. Meristematic Tissues:
   A. **Apical meristem** – This tissue is responsible for **primary growth**. (Growth *in length*.)
      1. It is found in herbaceous and woody plants.
   B. **Lateral Meristem** – This tissue is responsible for **secondary growth**. (Growth in *width*.)
      1. It is found only in woody plants.
   C. **Pith** – *dead* filled cells of ground tissue *inside* the vascular bundle ring.
      1. **Early wood (Spring growth)** – These are the *light rings*. These cells are larger and less compact cells that carry more water. (Think Spring Rains.)
      2. **Late wood (Summer/Fall growth)** – These are the *dark rings*. These cells are smaller and more compact cells and therefore carry less water. (Water won't be needed once the leaves fall off.)
      3. Early + Late = 1 Growth ring (year). (These rings are Environmental indicators of years past.)
         i. Wide ring – good growing conditions; thin ring - bad conditions.
      4. **Heartwood** – This wood is used to make lumber and telephone poles. (It is filled in xylem.)
      5. **Sapwood** – This wood is used to make paper. (It comes from functional xylem.)

Unit 9: Botany
Content Outline: Fluid Transport in Vascular Plants (9.2) – Part 1

I. The three levels of fluid transport that occurs in plants:
- A. Cellular level (This occurs in the roots and leaves mainly.)
- B. Tissue level (Accomplished by the xylem and phloem mainly.)
- C. Organismal level (The entire plant.)

II. *Cellular* Level Fluid Transport
- A. This transport involves the "selectively" permeable cell "plasma" membrane.
  - 1. *Passive and active transport* are the means of transport accomplished across the membrane by the cells.
    - a. It may involve **transport proteins**.
- B. Water moves through **aquaporins** (water transport proteins) by passive **diffusion**. (It involves *no energy*.)
- C. Active transport proteins involved. (These are mostly proton pumps and *require energy*.)

III**. Water Potential** (represented by the symbol **"Ψ**"…Trident, as carried by the Greek God of the water Poseidon.)
- A. *Water always travels hypotonic to hypertonic until isotonic, with <u>no</u> pressure***. (VERY IMPORTANT TO REMEMBER!)**
- B. Plants have cell walls, which creates restrictive pressure. (Ψ_P - Pressure)
- C. **$\Psi_T = \Psi_P + \Psi_S$ (**Total water potential = water potential under pressure + water potential of solutes.)
  - 1. Water moves High potential → Low potential. (Just like diffusion.)
  - 3. **Pure water = 0 potential.** (There is no *concentration gradient of dissolved molecules.)*
  - 4. Solutes, such as ions or sugars, *added* to pure water *lowers* potential.
  - 5. Pushing (+ pressure) *raises potential*; Pulling (- pressure) *lowers potential*.
- D. Just *add the pressures on each side of the membrane* and then *remember, it moves high to low.* For negative numbers, they become *lower* the farther *past zero* you go.

IV. **Flaccid** – The term refers to plant cells that *do not have enough water* in them. (Plant appears limp or wilted.)
- A. This can lead to **plasmolysis** – a cell membrane ripping away from cell wall. (This creates holes in the cell … so the plant cell dies.)

V. **Turgid** – The term refers to plant cells that *have plenty of water* inside and therefore the cell membrane is pushing against the cell wall. (The plant appears stiff and rigid.)

VI. **Central Vacuole** and **Tonoplast Membrane** – This structure acts as a *water/ion reservoir for plant cells*. (This structure can take up 90% of a plant cell's inner membrane space. It stores water needed for photosynthesis.)

VII. **Bulk Flow** – This term refers to moving large quantities (Bulk) of fluid.
- 1. **Sink** – Refers to where the fluid is *being put to be stored or used.* (The *final* destination for the fluid.)
- 2. **Source** – Refers to where the *fluid is being generated or originating*.
- 3. Fall vs. Spring? Summer and Fall: The roots are the sink and the leaves are the source.
  Spring: The leaves become the sink and the roots are the source.

Unit 9: Botany
Content Outline: Fluid Transport in Vascular Plants (9.2) – Part 2

I. Transpiration – This term refers to the process of *water loss occurring at the stomata* on leaves. (This is like "pulling" on the "water chain" of molecules… remember **cohesion** of water molecules**.**) This is mainly a solar powered process, but wind and humidity can affect it.

II. **Cohesion – Tension Principle** in Xylem tissue

A. **Cohesion** - A *water molecule binding to another water molecule*. (This allows for the making of a water "chain".)

B. **Adhesion** – A *water molecule sticking to some other molecule*, like the sides of the xylem cells. (This ALSO helps move the "chain" of water molecules upward toward the leaves.)

C. **Transpiration Pull** – This force provides the tension or "pulling strength" on the water "chain".

1. The *rate of transpiration* occurring at the stomata *is affected by the surrounding environment.*
   a. Heat (increases); Wind (increases); Humidity (decreases).
   b. **Guard cells** operate the stomata. These cells try to *compromise* between water loss and CO_2 intake.
2. **Water Potential (Ψ)** becomes *more negative* as you ascend (go up) the plant.

D. **Cavitation** – This is an *air pocket that forms* in the xylem because the "chain of water" broke. (The *cavity* is permanent.)

E. The Cohesion – Tension Principle *process requires <u>no</u> ATP* ***– as it is solar powered*****.**

F. Transpiration process also provides the leaf with an **evaporative cooling effect.** (Keeps leaves cool.)

III. Guard Cell operation

A. Guard cells are stimulated by the *presence of sunlight or the lack of CO_2* within the leaf.

B. *To open – Actively Transport K+ (potassium ions) into the guard cell*. (Water follows "free" of charge making the cells turgid and bloated open.)

1. Water is going from *Hypotonic to hypertonic*.
2. Water and ions are stored in the central vacuole.

C. *To Close – Actively transport the K+ out of the guard cells* (Water follows "free" of charge and the cells go limp or flaccid.)

D. Desert vs. Normal plants? Desert plants open up the stomata at night; *too* much water loss would occur during the day and the plant would dehydrate and die. The stomata are also located on the green stems, since most deserts plants have no leaves. Remember, the leaves are the needles to protect the watery stem.

IV. **Pressure – Flow Hypothesis** in Phloem tissue

A. Pressure builds up in the leaf from the continuous production of sugar via photosynthesis. (This is Positive Pressure.)

B. The sugars are "pushed" (positive pressure) out of the leaf into the phloem tissue. (Gravity then does the rest.)

C. Source vs. sink (These are time of year dependent.)

1. **Loading** – This is the putting of the sugar water into the Phloem tissue for **translocation.**
2. **Unloading** – This is taking the sugar out of the water and converting it to starch for storage.
   a. The water is recycled back into the xylem to be reused.

D. *This also requires <u>no</u> ATP… as it is also solar powered via photosynthesis.*

Unit 9: Botany
Content Outline: Plant Hormones (9.3)

I. Plant Hormones

A. **Auxin** (A.K.A. IAA- Indoleacetic Acid.) (This is the *most important* plant hormone.)

1. It is produced by the *apical meristem cells of shoots* in the terminal bud.
    a. **Apical Dominance** – IAA in *high concentrations* inhibits lateral buds from growing.
2. It is also responsible for **phototropism** (growing toward light) *in plant tips***.**
    a. IAA accumulates on the *"dark" side* of the stem causing cells to elongate on that side.
3. In the roots, Auxin *promotes lateral root growth.* (Plants need more support → because plant is taller.)
4. It also *promotes fruit development when produced by seeds* after double fertilization has occurred.

B. **Cytokinin**

1. It is *produced by the apical meristem cells at the tips of roots*. (It is an **antagonistic hormone** to Auxin.)
2. It also *promotes lateral stem growth* when in high concentration. (Cytokinin: Auxin *ratio* affects the *type* of growth that occurs at a place within the plant.)
3. It *also retards aging of plant cells***.** (This hormone is in the little packet that comes with cut flowers.)

C. **Gibberellin**

1. It is *produced in the seeds***.**
2. It is also responsible for **"bolting"** (rapid seed embryo growth) and *breaking dormancy in seeds (*called **germination**). (The hormone is *activated by water* imbibing (means "coming into") the seed.)
3. *Promotes gigantic fruit production***.** (Bigger, heavier fruit means more $ for farmers and grocery stores when you buy it.)

D. **Abscisic Acid (ABA)**

1. It *promotes seed dormancy*. (The hormone accumulates during *seed development* and is *inactivated* by water.) (ABA : Gibberellin *ratio* determines what the embryo in the seed will do.) (It is **antagonistic** to Gibberellin.)

E. **Ethylene gas** (This is the "Death" hormone.)

1. It promotes the rotting ("ripening") of the fruit. (It is a positive feedback loop. Fruit storage? Fruit is stored in cold coolers until needed. The cold *inactivates* the ethylene gas.)
    a. "One bad apple spoils the bunch" and potatoes and onions produce a lot too.
    b. Cold storage and CO_2 are used for international and long food transportation and storage.
2. It is also responsible for the **Triple Response**.
    Step 1: Gibberellin gets temporarily "turned off". (Due to an obstacle in the way of growth.)
    Step 2: Ethylene gas hormone gets "turned on". (The plant grows *sideways* to avoid the obstacle.)
    Step 3: Ethylene gas hormone gets "turned off" and Gibberellin is "turned back on". (Obstacle cleared.)

Unit 9: Botany
Content Outline: Plant Environmental Responses (9.4)

I. Plants responding to the environment
- A. Plants respond to changes in the environment by changing their *growth and development*.
- B. A stimulus sets in motion a *signal transduction pathway* causing the plant cells to respond accordingly.
  1. For example, **Bolting** – This process is triggered by water (ligand) entering the seed.
  2. For example, **Greening** – The plant begins producing chloroplasts in response to sunlight.
- C. Hormones are released to target tissues to relay information. (Remember, only need small amounts → cell amplifies.)
- D. **Tropisms** – These are *movements by plants* in response to a stimulus. (+ - towards; (-)-away from)
  1. *Prefix* tells the *type of energy* stimulus (photo - light, gravi - gravity, thigmo – touch)
  2. Darwin's experiment shows phototropism and Auxin production in the tip (apical meristem).

II. **Photomorphogenesis** – The term refers to changes in *growth and development* due to *light influences*.
- A. Plants respond to red and blue wavelengths of light. (Remember, green is reflected back toward your eyes.)
- B. "Photo" means "light"; "morph" means "shape/form"; and "genesis" means "start/creation of".

III. **Photoperiodism** – The term refers to responses to a *24-hour period of time*. (Measuring light-time vs. night time lengths.)
- *A.* Example, Flowering – *It is about the total amount of <u>uninterrupted</u> nighttime "beauty sleep" length.*
  * Lightning storms can *interrupt* the nighttime beauty sleep and throw off plant timing.
  1. Short day/*long night plants***.** (Require long periods of night/"sleep".)
  2. Long day/*short night plants.* (Require short periods of night/"sleep".)
  3. Day neutral plants (The amount of night time does <u>not</u> matter.)

IV. **Gravitropism** – This is responding to the "pull" of *gravity*.
- A. In Shoots (stems) – Plants are negatively gravitropic; In roots – they are positively gravitropic.
- B. Gravity is detected by the *accumulation of starch granules* on the plasma membrane bottom of a cell.

V. **Thigmomorphogenesis** – This is responding to touch "pressure". (For example, a Venus Fly Trap.)

VI. Plant defenses against herbivory (plant eating):
- A. Production of thorns or spines. (These are just modified leaves.)
- B. Production of distasteful substances/poisons. (These are called **canavines** or **tannins**.)

Unit 9: Botany
Content Outline: Angiosperm Plant Reproduction (9.5)

I. Flower Structure:

A. Male part (**Stamen**) – There are *two parts* to this one structure - The **anther** and **filament** are the two parts to the **stamen**.

1. The **anther** contains the pollen grains and the **filament** holds up the anther so it can touch pollinators.
2. The pollen grain has *3 haploid sperm inside*. (The protective casing is made out of **sporopollenin**.)

B. Female part (**Carpel**) – There are *three parts* to this one structure - The **stigma**, **style**, **ovary** are the three parts to the **carpel** or **pistil.** (The ovary contains the **ova** – means "egg".)

C. **Receptacle** – This is where the flower *attaches to the stem*.

D. **Petals** – These are for *attracting pollinators*.

E. **Sepals** – These are the green *protective leaves* of the "bud" that curl up, under the flower, after blooming has occurred.

II. **Pollination** and **Double Fertilization**

A. A pollen grain lands on the sticky stigma. This is called **pollination**. It can be caused by wind, rain, or animals.

1. The animals' importance in pollination is an example of **coevolution**.

B. The "digger" sperm creates the pollen tube through the style to the ovule opening, called the **micropyle.**

1. The other two sperm follow to perform **Double Fertilization.**
   a. The *first sperm* fertilizes the ova to create the diploid zygote.
   b. The *second sperm* fertilizes the **polar nuclei** to form the **endosperm** (It is 3n. It will be food for developing zygote during germination.)

V. Embryo Development:

A. **Germination** – The seed coat is worn away (by time, fire, acid, water) and water enters "imbibes" the seed.

1. **Breaking Dormancy** – The seed inactivity (usually in the winter) that is no longer occurring.

B. The first cell division is <u>*always*</u> *asymmetrical.* (This determines the root "end" and the shoot "end" of the new plant.)

C. **Suspensor** – This structure is the *connection* between the root and the shoot.

D. **Hypocotyl** – This is the part of the embryo attached to seed (below the epicotyl). It is responsible for **"bolting"**.

1. Responsible for "bolting" – *Rapid period of growth* to breach the surface and photosynthesize.
   a. As there is only a *limited amount of nutrients* in the endosperm available to the developing plant.
2. **Hypocotyl Hook** – This structure is responsible for "pushing" through the dirt. (It protects the **cotyledons**.)

E. **Epicotyl** – This is the part of the embryo below the **cotyledons** (embryonic leaves) or the **scutellum** (sheath) in grasses.

F. **Radicle** – This is the part of the embryo that will *become the roots* of the new plant.