Study Guide for the Keystone Exam

You will be expected to take the Keystone Exam at the end of this course. This study guide contains the majority of the information that can be found on the Biology Keystone Exam. If you are attentive in class and study the information as we learn it, YOU should be fine!
Adapted from: http://www.whsd.net/userfiles/1605/Biology%20Keystone%20Review.pdf

- Describe the characteristics of life shared by all prokaryotic and eukaryotic organisms.
  - Made of Cells
  - Maintain Homeostasis
  - Maintain Metabolism
  - Reproduce
  - Heredity
  - Respond to Stimuli
  - Grow and Develop
- Compare cellular structures and their functions in prokaryotic and eukaryotic cells.
  - Prokaryotes
    - Lack organelles.
    - Contain ribosomes.
    - Lack a nucleus.
    - Single-celled.
  - Eukaryotes
    - Contain organelles.
    - Contains a nucleus.
    - Contain ribosomes.
    - Single and/or multi-celled.
  - Organelles:
    - Nucleus: Contains DNA, control cell's activities
    - Nucleolus: Site of ribosome synthesis (create), found in nucleus
    - Mitochondria: Breaks down carbohydrates to produce ATP (usable energy)
    - Rough Endoplasmic Reticulum: Transports proteins and other substances within cell
    - Smooth Endoplasmic Reticulum: Creates lipids
    - Ribosomes: Protein synthesis
    - Chloroplast: Synthesis carbohydrates using light energy
    - Golgi Apparatus: Protein packaging
    - Cytoplasm: Supports and protects organelles
    - Centrioles: Paired cylindrical organelles utilized in cell division
    - Cytoskeleton/Microtubules: Supports cell, provides shape, and used in cell movement
    - Lysosome: Breaks down food molecules, and old organelles
    - Vacuoles: Storage, digestion and waste removal
    - Contractile Vacuole: Pumps water out of cell
    - Vesicle: Moves proteins, lipids, and carbohydrates through cell
    - Cell Membrane: Protects contents of the cell, controls what enters and leaves cell
    - Cell Wall: Protects contents of cell and prevents cells from bursting
- Describe and interpret relationships between structure and function at various levels of biological organization
  - Organelles → cells → tissues → organs → organ systems → multi-cellular organisms
- Describe the events that occur during the cell cycle:
  - Interphase
    - G_1 Phase: Cell grows
    - S Phase: DNA is copied

        - G_2 Phase: Cell continues to grow, organelles are copied
    - Mitosis:
        - Prophase: Spindle fibers form, nuclear envelope dissolves, chromosomes become visible
        - Metaphase: Chromosomes align at the cell's equator, spindle fibers attach to chromosomes
        - Anaphase: Spindle fibers pull chromatids apart at centromere, chromatids move to opposite poles
        - Telophase
    - Meiosis
        - Prophase I: Chromosomes become visible, Nuclear envelope disappears, Crossover occurs
        - Metaphase I: Homologous chromosomes move to equator
        - Anaphase I: Homologous chromosomes move to opposite poles
        - Telophase I: Cytoplasm divides
        - Prophase II: New spindle fibers form around the chromosomes
        - Metaphase II: Chromosomes align up at the equator
        - Anaphase II: Centromeres divide, Chromatids move to opposite poles
        - Telophase II: Nuclear envelope reforms around each set of chromosomes, Cytoplasm divides
    - Cytokinesis: Splitting of the cell membrane into two separate cells.
- Compare and contrast the processes and outcomes of mitotic and meiotic nuclear divisions.
    - Mitosis
        - One division into two identical diploid cells.
    - Meiosis
        - Two divisions
        - After second division, 4 haploid cells is the result.
- Describe how the process of DNA replication results in the transmission and/or conservation of genetic information.
    - DNA replication: Process of making an exact copy of DNA
        - Occurs in the S phase of the cell cycle.
        - Produces two exact daughter strands of DNA from the parent strand.
            - One strand will be moved into each of the new daughter cells after cytokinesis occurs
- Explain the functional relationships among DNA, genes, alleles, and chromosomes and their roles in inheritance.
    - Chromosomes are long strands of DNA
    - DNA is the genetic material that codes for the hereditary traits of organisms.
    - Genes are segments of DNA that is located in a chromosome and that code for a specific hereditary trait.
    - Alleles are alternative forms of a gene that governs a characteristic, such as hair color
- Describe the unique properties of water and how these properties support life on Earth (e.g., freezing point, high specific heat, cohesion).
    - 70-75% of your body is made of water
    - Water can be found in all three states of matter: solid, liquid, and gas.
    - Due to water's polarity, it makes a great solvent.
        - Almost all polar molecules and ions can dissolve in water.

- Due to water's polarity – having a positive and negative end causes water molecules to tend to attract to each and pull water molecules together. This is called **cohesion.**
  - "Surface tension" is caused by the cohesion of water molecules.
  - Surface tension allows small items which are denser than water to be held on the surface of the water.
- Due to water's polarity, it tends to cling to other polar molecules.
  - Capillary movement involves three primary forces generated in liquid water by hydrogen bonding - adhesion, cohesion, and surface tension.
    - Adhesion is the attraction of water for a wettable surface.
    - Cohesion is the attraction of one water molecule for another water molecule.
    - Surface tension minimizes surface area. Inside a small diameter tube, water is attracted along the walls by adhesive forces.
    - As water is pulled along the tube surfaces by adhesive forces, surface tension and cohesion drag more water molecules along behind.
    - When the cohesive forces of the water, tube size resistance to movement, and gravity become too great, (or surface tension is reduced) water movement in the capillary stops.
- Water has a high specific heat.
  - The property of absorbing significant energy before showing temperature change is a measure called "specific heat."
  - Water boils at 212F (100C)
  - Water freezes at 32F (0C)
- As energy is added to water, the molecules tend to increase vibration and movement causing hydrogen bonds to break.
  - As water molecules are broken from all hydrogen bonds, they escape into the atmosphere in a process called evaporation.
    - When water evaporates from an organism, it permits the organism to cool down because it pulls heat from it.
- Water is a good hydraulic fluid.
  - Water is used to expand and hold cells rigid and erect.

- Explain how carbon is uniquely suited to form biological macromolecules.
  - Organic compounds are distinguished from inorganic compounds by the presence of both carbon and hydrogen.
  - Carbon, atomic number six, has six electrons.
    - Two are in the first electron shell and four are in the second electron shell.
    - **Carbon must share four electrons with other atoms to fill its outermost electron shell and attain a stable configuration.**
    - Carbon atoms can share electrons with a wide variety of elements also commonly found in organic compounds, the most notable being other carbon atoms, hydrogen atoms and oxygen atoms.
- Describe how biological macromolecules form from monomers.
  - Four Biological Macromolecules (Polymers) → Made of → Monomers
    - Carbohydrates: Monosaccharides (Monomer) →Disaccharides →Polysaccharides (Polymer/Macromolecule)
    - Proteins: Amino Acid (Monomer) →Polypeptide Chains → Protein (Polymer/Macromolecule)

        - Lipids: Tend to have a wide range of monomers depending on the type of lipid
        - Nucleic Acid: Nucleotide (Monomer) → DNA/RNA (Polymer/Macromolecule)
- Compare and contrast the structure and function of carbohydrates, lipids, proteins, and nucleic acids in organisms.
    - Carbohydrates – organic compounds made of carbon, hydrogen and oxygen with a ratio of 1:2:1
        - Key source of energy
        - Found in most foods especially fruits, vegetables and grains
        - Carbohydrates typically are sugars.
        - A complex carbohydrate known as cellulose that provides structural support for plants.
        - Monosaccharides: Examples include glucose and fructose
        - Disaccharides: Example: Sucrose
        - Polysaccharides: Examples include starch (found only in plants to store energy), cellulose (found only in plants used for structural support) and glycogen (found only in animals for energy storage)
    - Lipids – Nonpolar molecules that aren't soluble in water.
        - Fatty acids tend to be the monomer of the larger, more complex lipids.
        - There are different types of lipids each with different functions:
            - Phospholipids: make up the lipidbilayer of cell membranes.
            - Sterols: Tend to perform as hormones or signaling molecules include cholesterol, estrogen and testosterone.
            - Glycerol: stores large amounts of energy.
        - Fats found in foods:
            - Dietary fats: necessary to facilitate absorption of fat-soluble vitamins (A, D, E, and K) and carotenoids.
                - Omega-3 fatty acids: helps infant development, cancer, cardiovascular diseases, and various mental illnesses, such as depression, attention-deficit hyperactivity disorder, and dementia
                - Saturated fats:
                    - Increase the levels of bad cholesterol (LDL) in your body
                    - Clogs arteries
                - Unsaturated fats:
                    - Increases the amount of good cholesterol (HDL)
                    - Takes bad cholesterol (LDL) to liver to be broken down
                - Trans fats:
                    - Produced during production of vegetable oil
                    - Risk for cardiovascular disease.
    - Proteins – building block for many structures in the body.
        - Proteins: Amino acids (monomer) → Polypeptide chains → Proteins (Polymer/macromolecule)
            - 20 different amino acids make up 2 million different proteins in the human body.

        - Function of proteins:
            - Antibodies: travel through the blood stream and are utilized by the immune system to identify and defend against bacteria, viruses, and other foreign intruders.
            - Enzymes: referred to as catalysts because they speed up chemical reactions.
                - Most enzymes end with the suffix ase.
                    - Lactase – breaks down the sugar lactose.
                    - Fructase – breaks down the sugar fructose.
            - Hormones - messenger proteins which help to coordinate certain bodily activities.
                - Examples : insulin and oxytocin
            - Structural proteins - provide support.
                - Examples include keratin (hair and feathers) and collagen (tendons and ligaments).
            - Transport proteins: move molecules from one place to another around the body.
                - Example: Hemoglobin found in our bodies red blood cells
    - Nucleic acids – used for protein production and hereditary information storage.
        - Nucleotides (Monomer) → Nucleic acids (Polymer/Macromolecule)
        - Two different types:
            - DNA: Deoxyribonucleic Acid
                - Stores hereditary information
                - Consists of two strands of nucleotides twisted around each other.
            - RNA: Ribonucleic Acids
                - Used in the manufacturing of proteins.
                - Single strand of nucleotides that code for a specific protein to be made by the cell.
- Describe the role of an enzyme as a catalyst in regulating a specific biochemical reaction.
    - Function of enzymes:
        - When cells consume energy, the activation energy needed to start the chemical reaction is reduced by enzymes.
        - Enzymes also increase the speed of the chemical reaction.
            - Without enzymes chemical reactions would not occur quick enough to sustain life.
        - The molecule that an enzyme acts on is called the substrate.
            - Substrate molecules are changed, and product is formed.
            - *The enzyme molecule is unchanged after the reaction, and it can continue to catalyze the same type of reaction over and over.*
    - Enzymes are substrate specific.
        - The enzyme fits into the substrates **active site** like a key into a lock.
        - Each substrate has a different active spot which causes each substrate to have a different enzyme.
        - Starch can only be broken down into glucose with the enzyme amylase.
        - Lipase breaks lipids down into fatty acids and glycerol

- Explain how factors such as pH, temperature, and concentration levels can affect enzyme function.
    - pH effects on enzymes:
        - Each enzyme functions best in a specific ph range.
        - When the pH changes, the active site progressively distort and affect enzyme function. If the enzyme doesn't fit properly into the active spot, the enzyme works ineffectively.
    - Temperature effects on enzymes
        - Chemical reactions speed up as temperature is increased, so, in general, catalysis will increase at higher temperatures.
        - However, each enzyme has a temperature optimum, and beyond this point the enzyme's functional shape is lost.
        - Boiling temperatures will denature most enzymes.
    - Concentration effects:
        - Increasing substrate and/or enzyme concentration, increases the rate of reaction.
- Describe and/or predict observed patterns of inheritance (i.e., dominant, recessive, co-dominance, incomplete dominance, sex-linked, polygenic, and multiple alleles).
    - Punnett squares are used to predict the appearance of the offspring produced from two known parents.
        - Dominant genes are those that are always expressed if they are present in an organism's genotype.
            - The genotype is the pair of alleles that an organism receives from its parents. (Example: AA, Aa, aa)
                - Homozygous genotype: is a genotype that the alleles are the same (Ex: AA – Homozygous dominant, aa – Homozygous recessive)
                - Heterozygous genotype: is a genotype that the alleles are different (Ex: Aa – Heterozygous dominant)
            - The phenotype is the physical expression of the pair of alleles for a specific trait. (Example: Purple flowers or white flowers)
        - Recessive genes are those that are only expressed if dominant genes aren't present.
    - Exceptions to simple inheritance:
        - Polygenic traits: traits that are determined by the combined effect of more than one pair of genes.
            - The genes may be scattered along the same chromosome or located on different chromosomes.
            - All polygenic traits tend to have varying degrees of intermediate conditions.
            - Examples: Human hair color, eye color, height weight
        - Incomplete dominance: results in an intermediate expression of a trait in heterozygous individuals.
            - For instance, in primroses, snapdragons, and four-o'clocks, red or white flowers are homozygous while pink ones are heterozygous. The pink flowers result because the single "red" allele is unable to code for the production of enough red pigment to make the petals dark red.

- Multiple alleles: Genes with three or more alleles.
    - Even the traits controlled by genes with multiple alleles, an individual can have only two of the of the possible alleles for that gene.
    - Example: Human blood type – I^A, I^B, i^O
- Codominance: Two dominant alleles are expressed at the same time.
    - Both dominant phenotype are expressed at the same time.
    - Example: Human Blood Type – Parent one with I^AI^A blood type has a baby with parent two who has I^BI^B. They will have a child with AB blood type, because the A and B allele are both dominant.
- Sex-linked traits: A gene that is found only on the X chromosome and not the Y chromosome.
    - Because the gene controlling the trait is located on the sex chromosome, sex linkage is linked to the gender of the individual.
    - Usually such genes are found on the X chromosome.
        - The Y chromosome is thus missing such genes.
        - The result is that females will have two copies of the sex-linked gene while males will only have one copy of this gene.
        - If the gene is recessive, then males only need one such recessive gene to have a sex-linked trait rather than the customary two recessive genes for traits that are not sex-linked.
        - **<u>This is why males exhibit some traits more frequently than females.</u>**

- Describe processes that can alter composition or number of chromosomes (i.e., crossing-over, nondisjunction, duplication, translocation, deletion, insertion, and inversion).
    - Crossing Over: the exchange of genetic material between homologous chromosomes that results in recombinant chromosomes.
        - Occurs during Prophase I of meiosis.
        - Crossover usually occurs when matching regions on matching chromosomes break and then reconnect to the other chromosome.
        - This process shuffles the allele content between homologous chromosomes.
            - Creates more possible combinations of offspring outcomes.
    - Nondisjunction: is the failure of chromosomes pairs to separate properly during meiosis stage 1 and stage 2, specifically in the anaphase.
        - The result of this error is a gamete with an imbalance of chromosomes.
            - Loss of a single chromosome, in which the gamete with the defect will have one chromosome missing from one of its pairs, is referred to as a monosomy.
                - Other than Turner Syndrome (women who are missing one of a pair of X chromosomes), all other cases of full monosomy are lethal and the individual will not survive fetal development.
            - Gaining a single chromosome, in which the gamete with the defect will have one chromosome in addition to its pairs is referred to as a <u>trisomy</u>.
                - Examples:
                    - Trisomy 21 (Down Syndrome)
                    - Trisomy 18 (Edward's Syndrome)
                    - Triple X Snydrome
                    - XXY (Klinefelter Syndrome)

- Common chromosomal mutations:
  - Insertion: add one or more extra nucleotides into the DNA.
    - Alters the reading frame of the gene.
    - They are usually caused by errors during replication of repeating elements.
    - Example: Original strand ATCGAT New strand ATC**T**GAT
  - Deletion: removal of one or more nucleotides from the DNA.
    - Like insertions, these mutations can alter the reading frame of the gene.
    - Example: Original strand AT**CG**AT New strand ATAT
  - Duplication: leading to multiple copies of all chromosomal regions, increasing the dosage of the genes located within them.
    - Example: Original strand ATCGAT New strand ATC**ATC**GAT
  - Inversion: a segment of a chromosome is reversed end to end.
    - An inversion occurs when a single chromosome undergoes breakage and rearrangement within itself.
    - Example: Original strand ATCGAT New strand **CTA**GAT
  - Translocation: is a chromosome abnormality by rearrangement of parts between nonhomologous chromosomes.
    - A gene fusion may be created when the translocation joins two otherwise separated genes.
      - The occurrence of which is common in cancer.
    - Two types of translocation mutations:
      - Balanced: an even exchange of material with no genetic information extra or missing, and ideally full functionality
      - Unbalanced where the exchange of chromosome material is unequal resulting in extra or missing genes.

- Describe how genetic mutations alter the DNA sequence and may or may not affect phenotype (e.g., silent, nonsense, frame-shift).
  - **Point mutations**: often caused by chemicals or malfunction of DNA replication, exchange a single nucleotide for another.
    - Various types of point mutation:
      - **Silent mutations**: are DNA mutations that do not result in a change to the amino acid sequence of a protein, or that **do** result in amino acid change but **do not** result in radically different properties of the changed amino acids.
        - Because silent mutations do not alter protein function they are often treated as though they are evolutionarily neutral.
      - **Nonsense mutations**: is a point mutation in a sequence of DNA that results in a premature stop codon.
      - **Missense mutations:** is a point mutation in which a single nucleotide is changed, resulting in a codon that codes for a different amino acid.
        - tends to make the resulting protein nonfunctional.
  - **Frameshift mutations:** will in general cause the reading of the codons after the mutation to code for different amino acids.
    - The frameshift mutation will also alter the first stop codon ("UAA", "UGA" or "UAG") encountered in the sequence.

        - The polypeptide being created could be abnormally short or abnormally long, and will most likely not be functional.
- Explain how genetic mutations may result in genotypic and phenotypic variations within a population.
    - A mutation is a change in DNA, the hereditary material of life.
        - An organism's DNA affects how it looks, how it behaves, and its physiology.
        - So a change in an organism's DNA can cause changes in all aspects of its life including the organism's genotype.
    - New phenotypic expressions arise from mutations in the genes.
    - This is an important source of variation that allows organisms to adapt to new environments.
- Describe how the processes of transcription and translation are similar in all organisms.
    - The process of transcription and translation occurs in all organisms.
        - While the overall process is similar, the lack of a nucleus makes the process somewhat different in prokaryotes and eukaryotes.
            - In prokaryotes, both transcription and translation take place in the cytoplasm.
        - In eukaryotes, transcription occurs in the nucleus and translation in the cytoplasm.
    - Transcription = DNA → RNA Translation = RNA → protein
    - RNA is chemically very similar to DNA, except that the sugar component of RNA is ribose instead of deoxyribose, and it contains the base uracil in place of thymine.
        - The RNA that is transcribed from DNA for the purpose of protein synthesis is called a messenger RNA or mRNA.
        - The mRNA is then transported out of the nucleus, where it is translated into a specific protein molecule in the cytoplasm.
    - <u>Translation</u> - mRNA produced by transcription is decoded by the ribosome to produce a specific amino acid chain, or polypeptide, that will later fold into an active protein.
        - Prokaryotes - translation occurs in the cell's cytoplasm, where the large and small subunits of the ribosome are located and bind to the mRNA.
        - Eukaryotes - translation occurs across the membrane of the endoplasmic reticulum in a process called vectorial synthesis.
            - The ribosome facilitates decoding by inducing the binding of tRNAs with complementary anticodon sequences to that of the mRNA.
            - The tRNAs carry specific amino acids that are chained together into a polypeptide as the mRNA passes through and is "read" by the ribosome in a fashion reminiscent to that of a stock ticker and ticker tape.
- Describe the role of ribosomes, endoplasmic reticulum, Golgi apparatus, and the nucleus in the production of specific types of proteins.
    - Ribosomes: are found in both prokaryotes and eukaryotes.
        - The ribosome is a large complex composed of many molecules, including ribosomal RNAs and proteins.
        - The ribosome molecules translate the mRNA genetic code to a specific sequence of amino acids that make up a protein is called translation.
        - It is the "factory" where amino acids are assembled into proteins.

        - tRNAs (small noncoding RNA chains) that transport amino acids to the ribosome.
        - tRNAs have a site for amino acid attachment, and a site called an anticodon.
        - The anticodon is an RNA triplet complementary to the mRNA triplet that codes for their cargo amino acid.
    - Endoplasmic reticulum: only found in eukaryotic cells.
        - the ribosome binds to the outer membrane of the rough endoplasmic reticulum
        - the polypeptide chain that is produced by the ribosome is then released into the endoplasmic reticulum.
        - The ER then transports the polypeptide chain to the area of the cell where it will be used.
    - Golgi Apparatus: is composed of flattened fluid-filled sacs that controls the flow of molecules in a cell.
        - Produces a product called glycoprotein.
            - Carbohydrates are added to freshly translated proteins to complete its production.
            - These newly formed glycoproteins (proteins with added carbohydrates) are used in a variety of ways, and in light of this, there is a wide variety of proteins in relation to their function.
        - This finished product, glycoprotein, is 'pinched off' the Golgi apparatus, and is transported by a vesicle of the cell membrane.
        - When this vesicle reaches the cell membrane, it binds to a receptor on the surface and excretes the protein, where it can then undergo its function.
    - Nucleus: directs protein synthesis by synthesizing messenger RNA (mRNA) according to instructions provided by the DNA.
- Explain how genetic engineering has impacted the fields of medicine, forensics, and agriculture (e.g., selective breeding, gene splicing, cloning, genetically modified organisms, gene therapy).
    - <u>Selective Breeding</u>: is the process of breeding plants and animals for particular traits.
        - Benefits:
            - high crop yields
            - resistance to disease
            - high growth rate
            - improved medicinal production
        - Negative impacts:
            - The other animals or plants become redundant and un-necessary.
            - Could cause genetic problems and the animal may become sick easier.
            - If it is a plant that needs more water then it would be creating an environmental issue.
            - Disrupts the food chain and the natural order of life, there is already a law of nature in place to choose the best aspects (survival of the fittest).
    - <u>Gene splicing</u>: cutting the DNA from one organism and attaching it to the DNA of another organism causing the host organism to demonstrate a new phenotype.
        - Example: attaching the insulin gene to bacteria to mass produce the drug.
    - <u>Cloning</u>: is the process of producing similar populations of genetically identical individuals that occurs in nature when organisms reproduce asexually.
        - Benefits:
            - Cloning body parts can become a life-saver.

- Cloning can also provide a viable solution to infertility in organisms.
- Cloning technologies may help to understand the composition of genes and their effect on traits and behavior in a more comprehensive and elaborate manner.
- Genetic alteration of plants and animals can also be enabled by cloning.
- It can also help to replicate animals that can be used for research purposes by scientists.

  - Disadvantages:
    - Since cloning creates identical genes and it is a process of replicating a complete genetic constitution, it can significantly hamper the much needed DNA diversity.
      - The lessening of genes diversity will weaken organism's adaptation ability.
    - Cloning raises a concerning probability of deliberate reproduction of undesirable traits in organisms.
    - On the moral and ethical front as well, cloning raises several serious questions.
- Gene therapy: DNA can be used to supplement or alter genes within an individual's cells as a therapy to treat disease.
- Stem cell therapy: an intervention strategy that introduces new adult stem cells into damaged tissue in order to treat disease or injury.
  - Highly controversial here in the US!
  - Will soon be able to treat cancer, Type 1 diabetes mellitus, Parkinson's disease, Huntington's disease, Celiac disease, cardiac failure, muscle damage and neurological disorders, and many others.

- Describe the fundamental roles of plastids (e.g., chloroplasts) and mitochondria in energy transformations.
  - Plastids: only found in plants.
    - Is composed of stacks of thylakoid sacks.
    - Chlorophyll covers each stack.
    - With a combination of water and carbon dioxide, the light is converted into glucose, where it is then used by the mitochondria to make ATP molecules
      - This chemical process of producing glucose is called photosynthesis.
  - Mitochondria: found in all eukaryotic cells.
    - Where adenosine triphosphate (ATP) molecules are produced and stored.
      - ATP is a result of cellular respiration and requires a food source
    - How does the mitochondria function:
      - It is covered in cristae created by multiple folds of the membrane to maximize surface area.
      - The mitochondrion uses the vast surface of the inner membrane to perform many chemical reactions.
      - The chemical reactions include filtering out certain molecules and attaching other molecules to transport proteins.
      - The transport proteins will carry select molecule types into the matrix, where oxygen combines with food molecules to create energy.

- Compare and contrast the basic transformation of energy during photosynthesis and cellular respiration.
    - Photosynthesis: the process by which plants use solar energy to convert the raw materials carbon dioxide (CO_2) and water (H_2O) into glucose ($C_6H_{12}O_6$) for use as an energy source.
        - Oxygen gas is produced as the byproduct
        - The general chemical equation for photosynthesis is:
            - $6\ H_2O + 6\ CO_2$ + solar energy ----------> $C_6H_{12}O_6 + 6\ O_2$
        - Occurs in the chloroplasts of plants.
    - Cellular respiration: is the release of energy from energy-storing compounds (i.e. glucose, fructose, starch).
        - The cells of all organisms, and therefore, all organisms, require a continuous supply of energy for the performance of their daily, vital activities.
        - Respiration It is represented by the chemical equation:
            - $C_6H_{12}O_6 + 6\ O_2$ ----> $6\ CO_2 + 6\ H_2O$ + energy (heat, light, ATP, etc.)
                - You should be careful to notice that the process of cellular respiration is essentially the reverse of photosynthesis.
        - The catabolic breakdown (burning) of glucose requires the presence of oxygen and yields energy and carbon dioxide
        - Releases carbon dioxide as a byproduct, which may then be used by plants in the photosynthetic process.
        - Occurs in the mitochondria of eukaryotes.
- Describe the role of ATP in biochemical reactions.
    - ATP (Adenosine Triphosphate) is a nucleotide used for energy storage
        - Composed of:
            - Adenine nitrogen base
            - Ribose sugar molecule
            - Phosphate group(s)
                - Number of phosphate groups determines the power of the nucleotide:
                    - AMP: Adenosine monophosphate – 1 phosphate group – acts like a very weak battery
                    - ADP: Adenosine diphosphate – 2 phosphate groups – acts like a dollar store battery (has power but not the best)
                    - ATP: Adenosine triphosphate – 3 phosphate groups – acts like a Duracell lithium battery
    - ATP is fuel for cells – it is consumed by a variety of different processes.
        - Once it is spent, it reverts back to adenosine diphosphate and adenosine monophosphate.
    - ATP transports chemical energy within cells for metabolism.

        - ATP is produced in:
            - Photophosphorylation
            - Cellular respiration
            - Fermentation
        - ATP is used by:
            - Enzymes function
            - Structural proteins in many cellular processes,
                - Including metabolism, motility, and cell division.
- Explain how natural selection can impact allele frequencies of a population.
    - Natural selection can increase the frequencies of alleles if they are advantageous to a species' survival and reproductive abilities.
        - If they somehow produce a phenotype that is not a selective advantage, their frequency will decrease.
        - The change in allelic frequencies is one way of defining evolution.
        - A population evolves as "better" alleles increase in frequency in the gene pool
- Describe the factors that can contribute to the development of new species (e.g., isolating mechanisms, genetic drift, founder effect, migration).
    - **Prezygotic mechanisms**: Factors which prevent individuals from mating.
        - Geographic isolation: Species occur in different areas, and are often separated by terrestrial and aquatic barriers.
        - Temporal isolation: Individuals do not mate because they are reproductively active at different times. This may be different times of the day or different seasons. The species mating periods may not match up. Individuals do not encounter one another during either their mating periods, or at all.
        - Ecological isolation: Individuals only mate in their preferred habitat. They do not encounter individuals of other species with different ecological preferences.
        - Behavioral isolation: Individuals of different species may meet, but one does not recognize any sexual cues that may be given. An individual chooses a member of its own species in most cases.
        - Mechanical isolation: Copulation may be attempted but transfer of sperm does not take place. The individuals may be incompatible due to size or morphology.
        - Gametic incompatibility: Sperm transfer takes place, but the egg is not fertilized.
    - **Postzygotic isolating mechanisms**: Genomic incompatibility, hybrid inviability or sterility.
        - Zygotic mortality: The egg is fertilized, but the zygote does not develop.
        - Hybrid inviability: Hybrid embryo forms, but is not viable.
        - Hybrid sterility: Hybrid is viable, but the resulting adult is sterile.
        - Hybrid breakdown: First generation (F1) hybrids are viable and fertile, but further hybrid generations (F2 and backcrosses) are inviable or sterile.
    - **Genetic Drift**: In each generation, some individuals may, just by chance, leave behind a few more descendents (and genes, of course!) than other individuals.

- The genes of the next generation will be the genes of the "lucky" individuals, not necessarily the healthier or "better" individuals.
- Effects of genetic drift:
    - Drift reduces genetic variation in populations, potentially reducing a population's ability to evolve in response to new selective pressures.
    - Genetic drift acts faster and has more drastic results in smaller populations. This effect is particularly important in rare and endangered species.
    - Genetic drift can contribute to speciation. For example, a small isolated population may diverge from the larger population through genetic drift.
- Types of genetic drift:
    - Bottleneck effect: occur when a population's size is reduced (by natural events or by human destruction) for at least one generation.
        - Reduced genetic variation means that the population may not be able to adapt to new selection pressures, such as climatic change or a shift in available resources, because the genetic variation that selection would act on may have already drifted out of the population.
        - Example: cheetahs have been overhunted by humans. With conservation efforts, the cheetah population has rebound; however, the cheetah's gene pool is now very limited.
            - If the cheetahs gene pool was once illustrated by all the letters of the alphabet; after the human hunting to near extinction, the cheetah's gene pool is now represented by maybe 5 letters of the alphabet
    - Founders effect: occurs when a new colony is started by a few members of the original population.
        - This small population size means that the colony may have:
            - reduced genetic variation from the original population.
            - a non-random sample of the genes in the original population.
        - Example: the Afrikaner population of Dutch settlers in South Africa is descended mainly from a few colonists. Today, the Afrikaner population has an unusually high frequency of the gene that causes Huntington's disease, because those original Dutch colonists just happened to carry that gene with unusually high frequency.
- Interpret evidence supporting the theory of evolution (i.e., fossil, anatomical, physiological, embryological, biochemical, and universal genetic code).
    - Fossil: show a pattern of development from early ancestors to modern descendants.

        - Most direct evidence that evolution takes place.
        - Provide an actual record of Earth's past life-forms.
        - Change over time can be seen in the fossil record.
    - Anatomical: comparisons of the different types of organisms often reveal basic similarities in body structures even though the structure's function may differ between organisms.
        - Different anatomical structures:
            - Vestigial structures: structures present in organisms, but are reduced in size and either have no or little function than in other related species.
                - Examples: Human appendix, whale hip bone
            - Homologous structures: structures derived from a common ancestor or same evolutionary or developmental origin.
                - Examples: The forearm of the crocodile, cat, bat and bird
            - Analagous Structures: Structures of different species having similar or corresponding function but not from the same evolutionary origin.
                - Examples: The wings of a bat and a butterfly.
    - Embryological:
        - At some time in development, all vertebrates have a tail, buds that become limbs, and pharyngeal pouches.
    - Biochemical:
        - With the increase of anatomical differences, protein and DNA differences also increase.
- Distinguish among the scientific terms: hypothesis, inference, law, theory, principle, fact, and observation.
    - Hypothesis: is a proposed explanation for a phenomenon.
        - Is an idea about the solution to a problem utilizing knowledge & research.
        - "An educated guess"
        - Used to help guide scientists through the experimental process.
    - Inference: is a conclusion drawn from specific observations.
    - Law: Is the summarizing statement of observed experimental facts that have been tested many times and is generally accepted to be true.
    - Theory: It represents a hypothesis or group of related hypotheses, which has been confirmed through repeated experimental tests.
    - Principle: A basic truth, law, or assumption.
    - Fact: Something demonstrated to exist or known to have existed.
    - Observation: An inference or a judgment that is acquired from or based on observing.
        - Typically, the first step in a scientific process.
- Describe how the structure of the plasma membrane allows it to function as a regulatory structure and/or protective barrier for a cell.
    - Plasma membranes are sheet-like structures composed mainly of lipids and proteins.

        - **Membrane lipids** are organized in a bilayer (two sheets of lipids making up a single membrane).
        - **The proteins**, on the other hand, are scattered throughout the bilayer and perform most membrane functions.
        - Both lipids and proteins are constantly moving within the membrane.
    - The cell membrane is selectively permeable to ions and organic molecules and controls the movement of substances in and out of cells.
        - Controls what enters and leaves the cell
    - The basic function of the cell membrane is to protect the cell from its surroundings.
    - Other functions of the cell membrane:
        - cell adhesion
        - ion conductivity
        - cell signaling
        - serve as the attachment surface for several extracellular structures
- Compare and contrast the mechanisms that transport materials across the plasma membrane (i.e., passive transport -- diffusion, osmosis, facilitated diffusion; active transport -- pumps, endocytosis, exocytosis).
    - The cell employs a number of transport mechanisms that involve biological membranes:
        - Passive Transport: substances move from an area of high concentration to an area of low concentration.
            - No energy is required to move from high to low concentrations.
            - Types of passive transport:
                - Diffusion: Some substances (small molecules, ions) such as carbon dioxide (CO_2), oxygen (O_2), and water, can move across the plasma membrane
                    - Osmosis: is the diffusion of water from areas of high concentration to areas of low concentration.
                - Facilitated diffusion: is the spontaneous passage of molecules or ions across a biological membrane passing through specific trans-membrane integral proteins.
                    - The facilitated diffusion may occur either across biological membranes or through aqueous compartments of an organism.
                    - Polar molecules and charged ions are dissolved in water but they cannot diffuse freely across the plasma membrane due to the hydrophobic (water fearing) nature of the fatty acid tails of phospholipids that make up the lipid bilayers.
                    - Only small nonpolar molecules, such as oxygen can diffuse easily across the membrane.

        - This process does NOT use energy – molecules travel from areas of high to low concentration.
    - Active transport: moves molecules from areas of low concentration to areas of high concentration.
        - This movement uses energy (typically ATP).
        - Types of active transport:
            - Sodium-potassium pumps: is responsible for cells containing relatively high concentrations of potassium ions but low concentrations of sodium ions.
                - The pump, while binding ATP, binds 3 intracellular Na^+ ions.
                - A change in the pump exposes the Na^+ ions to the outside, so they are released.
                - The pump binds 2 extracellular K^+ ions - transporting the K^+ ions into the cell.
                - The pump has a higher affinity for Na^+ ions than K^+ ions, so the two bound K^+ ions are released.
                - ATP binds, and the process starts again.
            - Endocytosis: is the process in which cells absorb molecules by engulfing them.
                - The plasma membrane creates a small deformation inward, called an invagination, in which the substance to be transported is captured.
                - The deformation then pinches off from the membrane on the inside of the cell, creating a vesicle containing the captured substance.
                - Two types of endocytosis:
                    - Phagocytosis - cell eating -small molecules and ions
                    - Pinocytosis - cell drinking
            - Exocytosis: occurs in various cells to remove undigested residues of substances brought in by endocytosis.
                - Secrete substances such as hormones and enzymes, and to transport a substance completely across a cellular barrier.
- Describe how endoplasmic reticulum, Golgi apparatus, and other membrane-bound cellular organelles facilitate transport of materials within cells.
    - Endoplasmic reticulum: the transportation system of the eukaryotic cell.
        - Secretory proteins are moved across the endoplasmic reticulum membrane.

        - Proteins that are destined for places outside the endoplasmic reticulum are packed into transport vesicles and moved along the cytoskeleton toward their destination.
    - Golgi apparatus:
        - The vesicles that leave the rough endoplasmic reticulum are transported to the Golgi apparatus, where they fuse with the Golgi membrane and empty their contents into the lumen.
            - The Golgi complex modifies many products from the ER including proteins and phospholipids.
            - The complex also manufactures certain biological polymers of its own.
            - Once modifications have been made and molecules have been sorted, they are secreted from the Golgi via transport vesicles to their intended destinations.
                - Some of the molecules are destined for the cell membrane where they aid in membrane repair and intercellular signaling.
                - Other molecules are secreted to areas outside of the cell.
                - Still other vesicles contain enzymes that digest cellular components.
                    - These vesicle form cell structures called lysosomes.
- Explain how organisms maintain homeostasis (e.g., thermoregulation, water regulation, oxygen regulation).
    - The human body is regulated by mechanisms that involve organs, glands, tissues and cells.
        - Internal body temperature of humans should be around 98.6 F
            - We maintain body temperature by:
                - Behavioural - where we consciously change our behavior
                - Physiological - where our body automatically alters its functioning without conscious control.
                    - Shivering
                    - Sweating
            - The body relies upon a constant fluid level to ensure metabolic reactions within cells can proceed.
                - Gases, nutrients, ions, hormones and wastes are carried in body fluids.
            - Water is continually being lost from the body in a variety of ways, for example through sweat and urine.
                - When water is lost from any of the body fluids, dissolved solutes (typically waste products) become more concentrated and water is less concentrated.
        - Single-celled organisms really upon their cell membrane to regulate diffuse of essential molecules.

- Describe the levels of ecological organization (i.e., organism, population, community, ecosystem, biome, biosphere).
    - In order from smallest to greatest:
        - **Organism:** individual living creature.
        - **Population:** A group of organisms of one species that interbreed and live in the same place at the same time (e.g. muted swan population).
        - **Community:** An group of organisms or a population of different species occupying a particular area.
        - **Ecosystem:** A system that includes all living organisms (biotic factors) in an area as well as its physical environment (abiotic factors) functioning together as a unit.
        - **Biome:** A major ecological community of organisms adapted to a particular climatic or environmental condition on a large geographic area in which they occur. (Ex: Savanna, Tropical rainforest)
        - **Biosphere:** The part of the earth where living things exist.
- Describe characteristic biotic and abiotic components of aquatic and terrestrial ecosystems.
    - **Biotic:** are the living things (such as plant, animal, fungus, *etc.*) in an ecosystem as well as their products (e.g. secretions, wastes, and remains)
    - **Abiotic:** is a nonliving (NEVER has lived) physical and chemical attribute of a system, for example light, temperature, wind patterns, rocks, soil, pH, pressure, etc. in an environment.
- Describe how energy flows through an ecosystem (e.g., food chains, food webs, energy pyramids).
    - **Food Chains:** A feeding hierarchy in which organisms in an ecosystem are grouped into trophic (nutritional) levels and are shown in a succession to represent the flow of food energy and the feeding relationships between them.
    - **Food Webs:** A food web is many food chains linked together to show a more accurate model of all possible feeding relationships of organisms in an ecosystem.
    - **Energy Pyramids:** A graphical model that is shaped like a pyramid to show how the energy flows through a food chain, how the amount of energy is decreasing and becoming less available for organisms as it enters each trophic level, and how much of the energy in the ecosystem is lost to the atmosphere as heat.
- Describe biotic interactions in an ecosystem (e.g., competition, predation, symbiosis).
    - **Symbiosis:** a long-term relationship between two different species.
        - Examples of symbiosis:
            - **Competition:** A symbiotic relationship between or among living things for resources, such as food, space, shelter, mate, ecological status, *etc.*
                - **Ex:** Two male lions fighting for a mate.
            - **Mutualism:** in this type of symbiosis, both organisms of different species rely on one another for nutrients, protection and other life functions, hence, they are usually found living in close proximity.

        - **Ex:** *E. coli* living in the intestines of humans help break down the fiber we eat, while they get food to survive.
    - **Commensalism:** A form of symbiosis between two organisms of different species in which one of them benefits from the association whereas the other is largely unaffected or not significantly harmed or benefiting from the relationship.
        - **Ex:** between the epiphyte orchids on branches of trees. These orchids benefit from the trees by the trees rendering support to the orchids. The orchids can gain more light and air in this way. The trees are neither drastically harmed nor benefiting from the orchids attached to their branches.
    - **Predation:** A form of symbiotic relationship between two organisms of unlike species in which one of them acts as predator that captures and feeds on the other organism that serves as the prey.
        - **Ex:** An owl killing a mouse for food.
    - **Parasitism:** A form of symbiosis in which one organism (called parasite) benefits at the expense of another organism usually of different species (called host). The association may also lead to the injury of the host.
        - **Ex:** A tick on a dog.
- Describe how matter recycles through an ecosystem (i.e., water cycle, carbon cycle, oxygen cycle, nitrogen cycle).
    - Water cycle:
        - Within this cycle, <u>energy is supplied by the sun</u>, which drives evaporation whether it is from the ocean surfaces or from treetops and leaves.
        - The sun, with the help of wind, also supplies the energy, which drives the weather systems, which moves the water vapors, in the form of clouds, from one place to another, or else it would only rain over oceans.
            - **Precipitation** occurs when water condenses from a gaseous state in the atmosphere and then falls to earth.
            - Gravity pulls the water underground (**seepage**) or groundwater across the surface of the terrain (also called **runoff**), either way gravity goes on to pull water lower and lower until it reaches the oceans.
            - Water returns to the atmosphere by:
                - **Evaporation** is the reverse process where liquid water becomes gaseous. Once water condenses, gravity takes over and the water is pulled to the ground.
                - In plants, water is drawn in at the roots and moves to the gas exchange organs, the leaves, where it evaporates quickly.
                    - This special case is called **transpiration**.
        - As the water vapor moves higher in altitude, the water cools and and forms clouds in a process known as **condensation**.

- Carbon Cycle: the key events of this cycle are the complementary reactions of respiration and photosynthesis.
  - **Respiration** takes carbohydrates and oxygen and combines them to produce carbon dioxide, water, and energy.
  - **Photosynthesis** takes carbon dioxide and water and produces carbohydrates and oxygen.
    - This might sound a little confusing but, the outputs of respiration are the inputs of photosynthesis, and the outputs of photosynthesis are the inputs of respiration. The reactions are also complementary in the way they deal with energy.

  - The chief reservoirs for carbon dioxide are in the oceans and in rock.
    - Carbon dioxide dissolves readily in water (also known as **erosion**).
      - Once there, it may precipitate (fall out of solution) as a solid rock known as calcium carbonate (limestone).
    - Animals acquire all their carbon in their food, and, because of this, all carbon in biological systems ultimately comes from plants (autotrophs).
    - Through **combustion** of organic material, which oxidizes the carbon, it contains, producing carbon dioxide (as well as other things, like smoke).
      - Burning fossil fuels such as coal, petroleum products, and natural gas releases carbon that has been stored in the geosphere for millions of years.
- Nitrogen Cycle:
  - Nitrogen is critically important in forming the amino portions of the amino acids, which in turn form the proteins of your body.
  - The principal reservoir of nitrogen is the atmosphere, which is about 78% nitrogen.
    - Nitrogen gas in the atmosphere is composed of two nitrogen atoms bound to each other.
      - It is a non-reactive gas meaning it takes a lot of energy to get nitrogen gas to break up and combine with other things, such as carbon or oxygen.
    - Nitrogen gas can be taken from the atmosphere (fixed) in two basic ways:
      - Lightning provides enough energy to "burn" the nitrogen and fix it in the form of nitrate, which is a nitrogen with three oxygens attached.
      - The other form of nitrogen fixation is by nitrogen fixing bacteria.
        - They use special enzymes instead of the massive amount of energy found in lightning to fix nitrogen.
      - Most plants can take up nitrate and convert it to amino acids.
      - Animals acquire all of their amino acids when they eat plants (or other animals).
      - When plants or animals die (or release waste), the nitrogen is returned to the soil.

        - The usual form of nitrogen returned to the soil in animal wastes or in the output of the decomposers, is ammonia.
            - Ammonia is toxic, but fortunately, there are nitrite bacteria in the soil and in the water, which take up ammonia and convert it to nitrite.
            - Nitrite is also somewhat toxic, but another type of bacteria, nitrate bacteria, will take nitrite and convert it to nitrate, which can be taken up by plants to continue the cycle.
- Describe the effects of limiting factors on population dynamics and potential species extinction.
    - Populations grow at exponential rates in the presence of unlimited resources.
        - Exponential populations grow continuously, with reproduction occurring at any time, such as among humans.
        - All populations begin exponential growth in favorable environments and at low population densities.
            - Because of this, exponential growth may apply to populations establishing new environments, during transient, favorable conditions, and by populations with low initial population density.
    - However, geometrical or exponential growth cannot continue indefinitely.
        - In nature, population growth must eventually slow, and population size ceases to increase.
        - As resources (ex: food, water, shelter) are depleted, population growth rate slows and eventually stops: This is known as logistic growth.
            - The population size at which growth stops is generally called the carrying capacity (K), which is the number of individuals of a particular population that the environment can support.
            - At carrying capacity, because population size is approximately constant, birthrates must equal death rates, and population growth is zero.
    - No population can increase without limitation.
        - Instead, populations in natural ecosystems increase or decrease in response to the changes in the factors that restrict growth.
        - Many factors influence population densities and growth, and these factors may lead to oscillations in population size over time.
    - Factors that decrease population growth can be defined as environmental stress including limitations in food, predation, pollutants in the environment, and climate extremes, including seasonal cycles such as monsoons.
        - In addition, catastrophic factors can also impact population growth, such as fires and hurricanes.