Course Title: BIO 1 - Life Sciences
Institution: Irvine Valley College
Textbook used: *Biology: The Essentials* by Marielle Hoefnagels.
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Semester: Summer 2021
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Unit 1: Introduction to Life, Science & Biology

Defining characteristics of life

- Programmed by DNA
- Share chemical composition
- Are made of one or more cells
- Convert energy and matter in particular ways
- Are highly organized
- Grow and develop in predictable patterns
- Reproduce sexually or asexually
- Maintain internal constancy
- Change genetically as populations
- Are reliant upon other living things and particular environments

1. All organisms are operated from a “program” provided by DNA
    - DNA (Deoxyribonucleic acid) is a molecule that carries genetic information
    - All cells use DNA to produce mRNA molecules, which order the production of polypeptides, which will be modified into proteins
    - Individual units of DNA are called nucleotides
    - Nucleotides
        - Guanine
        - Adenine
        - Thymine
        - Cytosine
    - Electromagnetic charge: Axiomatic property of matter in which some particles are “negatively” charged, others “positively” charged
    - + and - attract, and each charge repels its own kind
    - Charges produce binary code (An information system based on 2 units of information)
    - The electromagnetic charges and the binary code could be used to order and produce polypeptides

2. All organisms share a specific, common chemical compositions in that they:
    - Consist of organic molecules
        - Organic molecules include: carbohydrates, lipids, proteins and nucleic acids
        - Whenever you see a carbon bonded to another carbon, you know you are dealing with organic molecule
    - Are mostly water
    - Run off of ATP (Adenosine Triphosphate; the ultimate energy source)

3. All organisms are made of one or more cells
    - Cells are basic units of life and every organism consists of one or more cells
    - Unicellular: Simple single-celled organisms
    - Multicellular: Consisting of many cells
    - Eukaryotic cells are much more complex than prokaryotic cells

4. Living things convert energy and matter in complex enzyme driven pathways
    - Everything obtains and converts energy; nothing produces or destroys energy
    - Autotrophs (producers): Manufacture their own food
        - Include plans, some protists, and many prokaryotes
    - Heterotrophs (consumers): Feed upon other organisms
        - Generally animals; some are protists and others are prokaryotes
    - Primary producers extract energy and nutrients from the nonliving environment
    - Decomposers are consumers that obtain nutrients from dead organisms and organic wastes
        - Fungi, some animals, protists, many prokaryotes
    - Energy is needed for
        - Keeping organized
        - Carrying out chemical reactions

    - Transporting molecules inside and among cells
    - Maintaining internal constancy
    - Reproducing, growing, and developing

5. Living things are organized (as the list descends, one is a member of the next classification)
    - Atom: Smallest chemical unit of a type of pure substance (element)
    - Molecule: A group of joined atoms (such as DNA)
    - Organelle: A membrane-bound structure that has a specific function within a cell (chloroplast)
    - Cell: The fundamental unit of life. Multicellular organisms consist of many cells; unicellular organisms consist of one cell (ex: leaf cell)
    - Tissue: A collection of specialized cells that function in a coordinated fashion (multicellular life only). (ex: Epidermis of leaf)
    - Organ: A structure consisting of tissues and carrying out specific functions (multicellular life only). (ex: leaf)
    - Organ system: Organs connected physically or chemically that function together (multicellular life only). (ex: aboveground part of a plant)
    - Population: A group of the same species of organisms living in the same place and time (ex: multiple acadia trees). (ex: populations or colonies)
    - Community: All populations that occupy the same region (ex: all populations in a savanna)
    - Ecosystem: The living and nonliving components of an area (ex: The Savannah)
    - Biosphere: The global ecosystem; the parts of the planet and its atmosphere where life is possible

6. Living things grow and develop in specific, predictable patterns

7. Organisms reproduce, either completely or partially
    - In asexual reproduction, only one parent is involved, and the offspring are genetically identical to the parent (complete reproduction)
    - Asexual reproduction is a successful strategy in unchanging environments
    - In sexual reproduction, two parents are involved, and the offspring are genetically different from the parent (partial reproduction)
    - Sexual reproduction is a successful strategy in changing environments since offspring are different from either parent

8. Living things maintain relatively constant internal conditions
    - Organisms maintain an optimal balance of temperature, mass, nutrients, salt, water, and other factors
    - To maintain organization, the cells need to be kept at a constant “steady-state”
    - The term for the maintenance of relatively constant internal conditions is “homeostasis”

9. All organisms (as populations) change genetically over time

- The genes in a population of bacteria have changed over time. A new gene, conferring antibiotic resistance, appears in the red bacteria. There are more bacteria with this new gene when antibiotics are present.
- Mutation: Alterations to the DNA program
- Evolution: Changes in gene frequencies in population over time

10. Living things are dependent on one another, and on their nonliving environment

Unit 2: Introduction to Life, Science & Biology (Part 2)

Science: A way of knowing in which facts are established by experimentation and probability analysis. Modern day science is characterized by scientific method

Scientific method

- 1. Empirical observations
- 2. Forming hypothesis
- 3. Experimentation
- 4. Conclusions
- 5. Publication
- 6. More testing
- 7. Theory building

List of senses

- Photic sense, Acoustic, Tactile, Taste (chemoreception), Smell (Chemoreception), Vestibular - linear, Vestibular - rotational, Balance, Tensile (weight) 1, Tensile 2, Thermal (hot & cold), Pressure, Humidity, Magnetic

Scientific Processes & Analysis

- Hypothesis: An idea that can be scientifically tested. Hypo = “below”, Thesis = “belief”
- Experiment: A set of controlled experiences used to test on hypothesis
- Variables: Unstable or changeable factors that can influence the experimental outcome
    - Experimental variable: factor that is being tested
    - Non-experimental variable: factors that are not being tested
- Scientific control: An experimental feature that is used to account for the effects of the non-experimental variables
- Statistics: The science dealing with the analysis and assessment of numerical data, based on probability
- Statistical analysis tests the data for statistical significance: the probability that the results did not arise purely by chance
- Confidence levels: How certain we can that the results indicate a difference from what random chance would produce
    - >95%+ confidence level: do not reject hypothesis

    - <94.9% confidence level: reject hypothesis
- Publication
    - Forms of publication include: lecture, arcile, monogram, conference display, thesis, books, etc
- Fact: An idea that is believed to be true based on probability-based scientific testing (repeat testing)
    - Cold fusion experiment was proven to not be a scientific fact. The collective data could not show evidence of cold fusion
- Theory: A set of statements based on tested scientific facts that acts to describe, explain, or predict aspects of a given phenomenon
    - Theory is greater than fact in science
- Examples of scientific theories
    - Atom theory, germ theory, electromagnetic, evolution, quantum, big bang, cell, molecular, general relativity, special relativity, aether, etc

Aether Theory

- Speculated upon by Aristotle, Descartes, Newton
- Used by early chemist (16th century) Robert Boyle to explain the transmission of light through space
- Many scientists began to understand that light had wavelike properties, and interpreted this to mena that light carries through a background medium (like sound through air, or ripples over water)
- According to the theory the background medium for light would be aether
- Speed of light would appear to be faster when approaching the light source, and less when moving away from light source

Atom theory

- Kanada from India (philosopher), lived 2500-5000 years ago
    - He believed in entities (parmau ?) that combine in different ways to produce complex substances
- Democritus (460 - 370 BCE)
    - Believed all matter was made of indivisible particles, which he referred to as “uncuttables”, floating in a void
    - The Greek word for uncuttable is “atoms.”
    - All his works were burned by followers of Plato
- John Dalton (1766 - 1844)
    - Dalton noticed that in chemical reactions, given types of materials (hydrogen, nitrogen, oxygen, etc), they would always combine in fixed ratios (regardless of how small or large)
- “Corpuscle” → electrons: very small, negatively charged, subatomic particles
- Plum-pudding model (proposed by JJ Thomson)
    - Placed electrons within a positively charged matter

    - However, Hantaro Nagaoka pointed out that it would be more likely to have a positively-charged "core" than a diffuse positively-charged "field" (critical of plum-pudding model).
- Ernest Rutherford and the Rutherford Experiment
    - Shot subatomic particles to diffused field
    - Expected particle to go right through, but in reality it would sometimes bounce back
    - This led to discovery of proton, atomic nucleus
- Protons: "Large" positively charged subatomic particles
- Neutrons: Discovered when calculations of the mass of atomic nuclei were too small. A second nuclear particle, about the same size as a proton but neutral in charge was demonstrated to exist.
- Neils Bohr
    - Determined that electrons exist within quantum energy shells of greater and greater intensity the further they are from the nucleus
    - Orbitals: The space in which an atom's electron will be found at least 90% of the time.

Anti-Atom theory

- Plato (427 - 347)
    - Believed that matter was infinitely divisible
    - Demonstrated by continuing to divide gold leaf

Alchemy: The search for ways to to transform base metals to gold

Unit 3: Chemistry of Life

Atoms, molecules and molecular stability

- Matter: anything that takes up space and has mass
- Substances: Particular kinds of matter with identifiable physical and chemical properties

Elements essential to life

- Only 4 elements make up 96% or more (or close to 99%) of living matter: Carbon, Hydrogen, Oxygen, Nitrogen
- Minor three: Phosphorus, Potassium, Sulfur
- Trace elements (less than 1% in mass combined): Sodium, Magnesium, Iron, Zinc, Copper, Boron, Calcium, Cobalt, Selenium, Chlorine, Iodine, Molybdenum, Silicon, Manganese, Vanadium, Chromium, Fluorine, Nickel

Atom

- Smallest component of an element that retains the properties of that particular element
- Typically consists of a core (nucleus) of protons and neutrons, surrounded by electrons
- Protons are positively charged, electrons are negatively charged, neutron is neutral
- Isotopes: Varying atomic forms with difference in number of neutrons. Vary in neutron count, not protons count (since that would change the element)

    - Radiation (or radioactivity): The emission of subatomic particles from unstable nuclei. There are: Alpha radiation, Beta radiation, and Gamma radiation
    - Effects of radiation include: Cell death, tissue damage, death, cancer, damage to DNA
- Isotopes of Hydrogen: Protium (0 neutron), Deuterium (1 neutron), Tritium (2 neutrons)
- Half-life: The amount of time needed for half the amount of a given radioactive material to decay to a different form

Electrons

- Subatomic particle with a negative charge
- They have no known sub-components or substructure
- They are the major carrier of useable energy within living things
- Electron orbitals
    - Region of space in which an electron will most likely be found (90% of the time) around an atomic nucleus
    - Collective quantum states of the individual electrons in the "electron cloud"
- Quantum state: Probability outcome of measuring feature or a system, such as the system's energy or angular momentum
- Shell = energy level
- Octet "rule"
    - Holding 8 electrons to be stable (2 for helium / innermost shell)
- Electrons are most stable when
    - Paired with another electron
    - In a filled shell
    - In a "ground state" or in neutral atom

Chemical bonding

- Attraction between two or more atoms resulting from a sharing or transfer of valence electrons
- Valence shell is an atom's outermost shell
    - This shell may be filled with electrons, or it may have empty spaces (electron potential)
    - The number of empty spaces or available electrons in the valence shell is referred to as the valence number
    - The empty spaces can be filled by sharing electrons with, or passing electrons to, other atoms
- Chemical bonding: Attraction between two or more atoms resulting from a sharing or complete transfer of electrons
    - Covalent bonds: sharing of electrons, each atom donates an electron to share to produce new shells / orbitals
        - Non-polar: equal, even sharing of electrons
        - Polar: Unequal, unbalanced sharing of electrons
    - Ionic bonds: Complete transference of electrons
        - No sharing occurs
        - Formation of + and - ions (opposite charges attract)
- Hydrogen "bonds": A weak electromagnetic attraction between a partially positive-charged hydrogen of one molecule and a partially negative-charged atoms of another molecule

    - Occurs between molecules, not within (inter, not intra)
    - Exist between water molecules and gives water special characteristics
    - Weak, but significant when very abundant
- Electronegativity: The tendency to attract electrons in a covalent bond
- Molecule: Two or more atoms united by chemical bonding
- Compound: Substances that consists of molecules that have two or more different elements bonded in a fixed ratio

Ions

- Anion: Negatively charged ion from gain of an electron
- Cation: Positively charged ion from loss of an electron
- Electrolytes: Dissociated, dissolved ions found in blood, cytoplasm, and the fluid between cells
- Sodium ions (Na+): Transmit nerve signals, help contract muscles, etc
- Potassium ions (K+): Transmit nerve signals, and contract muscles including the heart, etc
- Calcium ions: Transmit nerve signals, contract muscles
- Magnesium ions: Contraction, relaxing muscles
- Bicarbonate ions: Regulate the acidity or alkalinity of blood

Unit 4: Chemistry of Life (Part 2)

Organic Molecules

- Organic: referring to molecules comprised of one or more carbon-to carbon bonds
- Organic molecules include: Gasoline, DDT (Dichlorodiphenyltrichloroethane), Malathion, Sarin Nerve Gas, Toluene, Plastic, Acetone, Ethane, etc
- Isomers: Molecules with the same chemical content, but different structural arrangements
- 4 Organic Compounds: Carbohydrates, Lipids, Proteins, Nucleic Acids

Carbohydrates

- Monosaccharide (Single sugar molecule) - Hexose sugars (six-carbon sugars)
    - Glucose ($C_6H_{12}O_6$): Energy within the glucose is easily converted to ATP
    - Galactose
    - Fructose: Provides quick energy
- Disaccharide (Two sugar molecules linked)
    - Maltose
    - Sucrose: Provides energy transfer
    - Lactose: Provides energy transfer
    - Cellobiose
- Polysaccharide (Many sugar molecules linked)
    - Starch
    - Glycogen: Provides long-term energy storage
    - Cellulose: Used in plant cell wall structure, and provides dietary fiber
    - Chitin: Provides dietary fiber

Lipids

- Fats (Triglycerides)
    - Three Fatty Acid make Triglycerides
- Saturated Fatty Acids (Saturated with 2 Hydrogens)
    - Animal fats tend to be saturated fats
    - Single bonds, straight chains, stackable, and compressible
    - Solid at room temperature
- Unsaturated Fatty Acids
    - Tend to be vegetable
    - Double bonds, kinked / bent chains, unstackable, incompressible, and oily
    - Liquid at room temperature
- Functions of triglycerides
    - They store energy inside adipose tissue
    - Long-term energy storage
    - Cushioning of organs and bones
    - Insulation
    - Lubricants for skin, hair and feather
- Cis vs Trans Configuration
    - Cis: Substituents are on the same side of some plane
    - Trans: Substituents are on the opposite sides
- Phospholipids
    - Hydrophilic (water loving) head and hydrophobic (water fearing) tail
    - Amphipathic (both hydrophilic and hydrophobic)
    - Most organelles are made of the phospholipid bilayer
    - They are the major component of cellular membranes
- Steroids
    - Most steroids are hormones, but not all steroids are hormones
    - While use of anabolic steroids boost athletic performances, side effects include: Cancer, heart disease, liver failure, tendonitis, depression, and losing previous physique over time
    - Hormone: A compound produced by cells in one organ or tissue and transported within the organism to stimulate cells in another organ or tissue
    - Testosterone: Male sex hormone
    - Estrogen: Ovulatory sex hormone
    - Progesterone: Acts as pregnancy hormone
    - Cortisone: Reduces immune responses
    - Aldosterone: Increases fluid retention
    - Ecdysone: Molting hormone in insects
    - Cholesterol: Building block of all other steroids
- Cholesterol
    - Cholesterol is inserted between phospholipids, making the plasma membrane more fluid
    - Essential for making steroid hormones
    - The liver uses cholesterol to make bile, a fluid that helps in the digestion of fats
    - Used as insulation in nerve cells, forming a compound called “myelin”

    - Used as the precursor for Vitamin D
    - Helps protect the walls of the arteries from inflammation
        - Arteries become thinner as we age, which could lead to vulnerability to damage
        - However, if the cholesterol builds up too much, it could block blood flow entirely, and cause heart attack, etc

Proteins

- They perform wide variety of functions based on their shapes (often complex and convoluted) and their ability to move and interact with our body
- Cristallin: Protein in clear part of our eyes
- Lactase: Enzyme that breaks down lactose
- Immunoglobulin G: Antibody that bond onto bacteria and onto viruses, to signal to immune system
- Elastin: Protein used to hold structures of cells
- Collagen: Helps hold cells together
- Membrane protein: Hole in the middle to allow different kinds of compounds to pass in
- Human glyoxalase 1: Enzyme that helps break down toxic waste products that form from breakdown of food molecules
- Rhodopsin: Protein that receives purple light and activates neural passageways to the brain that allows us to see color purple
- Amino acids are divided into three groups: Nonpolar, polar and electrically charged
- Proteins are produced by ribosomes
- Peptide bonds: Covalent bond formed between the carbon end of one amino acid and the nitrogen end of another amino acid
- Polypeptide: What you get when you put amino acids together (can be in any way, with infinite configurations / possibilities)
- Structure levels
    - Primary: Linear sequences of amino acids
    - Secondary: Pleated sheets, random coils, helices
    - Tertiary: Globules and fibers
    - Quaternary: Compound polypeptide

Nucleic Acids

- DNA: Holds genetic information
- mRNA (messenger RNA): Carries genetic information to ribosomes
- rRNA (ribosomal RNA): Catalyzes the assembly of amino acids into protein chains
- tRNA (transfer RNA): Carries amino acids to ribosomes
- ATP -- The ultimate energy source
- NADH -- Carries electrons
- Each nucleotide is composed of phosphate, pentose sugar, and nitrogenous base
    - The phosphate group is always the same
    - Sugar can be either deoxyribose or ribose
    - Five types of nucleotides
        - Adenine

    - Guanine
    - Cytosine
    - Thymine
    - Uracil (only in RNA. Replaces Thymine)

Unit 5: Chemistry and Physics of Water

Heat: total molecular motion (total molecular kinetic energy) in a system
Temperature: The average molecular motion (average molecular kinetic energy) of a system

Water

- Polar; Partial positive charge in hydrogen, partial negative charge in oxygen
- Polarity water produces makes water versatile solvent abilities
- Substances that dissolve well in water: Hydrophilic (polar, ionic)
- Substances that do not dissolve so well in water: Hydrophobic (nonpolar)

Hydrogen bonds' impact on the character of water

- Cohesion: The ability of substance to stick to itself
- Adhesion: The ability of a substance to stick to *similar* substances.
- Resistance to vaporization (wants to stay in liquid state. Due to cohesion): Vaporization is a movement of a substance from the liquid or solid phase into the gaseous phase. Two types of vaporization
    - Evaporation: The formation of vapor at the surface of a liquid
    - Boiling: The formation of vapor pockets within a liquid
- Even though water has small molecular weight, its boiling point is significantly high due to hydrogen bonds

Evapotranspiration: The heat-driven movement of water from root to tree

- Xylem tissue: straw like cells that carry water

Surface tension

- Water molecules at the surface experience a net inward force resulting in a "lamination effect"

Resistance to freezing

- Water has relatively high freezing point
- When water is a solid, the particles are pushed quite further from each other, by the hydrogen bonds, leading to lower density when water is solid (ice)
- Water is more dense as liquid than as solid (which is why solid water, ice, will float over liquid water). Water freezes at the surface, providing insulation (organisms such as fishes can live underneath the ice during winter)

Unit 6: Energy and Matter

Energy: The ability to move matter through space

- Work: Movement of matter through space
- Forms include: Atomic, Gravitational, Electromagnetic, Chemical Bond, Kinetic, Potential, etc
- Energy can be converted into another form of energy
    - Example: As you use up gasoline on a vehicle to drive your car to destination, you are converting chemical bond energy (in gasoline molecules) to kinetic energy.
- In terms of living things, the two prominent energies:
    - More useable: More organized, more predictable, more concentrated, less random
    - Less useable: Less organized, less predictable, less concentrated, more random
- First Law of Thermodynamics
    - Energy can be converted from one form to another, but never created nor destroyed
- Second Law of Thermodynamics
    - Every time energy is converted, some of it is converted to less usable form
    - Entropy: A measurement of the disorderliness of a system
- Photons: Massless, or near massless, particles of light energy

Photosynthesis

$6\ CO_2 + 6\ H_2O \rightarrow (photon) \rightarrow C_6H_{12}O_6 + 6\ O_2$

- Light reactions → Light independent reactions (Calvin cycle).
- Light reactions
    - Electron is pulled from water molecule (which splits apart), and oxygen is being produced as waste product, while ATP and NADPH are produced
    - Takes place in Grana.
- Light Independent Reaction (Calvin cycle)
    - Enzyme now use energy ATP and NADPH to start putting water and CO2 together, to produce sugar (glucose)
    - Takes place in the stroma.

Cellular Respiration

$C_6H_{12}O_6 + 6\ O_2 \rightarrow 6\ CO_2 + 6\ H_2O + 36\ ATP$

- Glycolysis (Glucose → Pyruvic acid) → Citric acid cycle (Kreb cycle) → Electron transport chain
- Glycolysis
    - A systematic, enzyme-mediated set of reactions that occurs in the cytoplasm
    - Converts glucose to pyruvate, stripping off valuable electrons in the process
    - Yields energy products: 2 ATP, 2 NADH and 2 pyruvates
    - Waste products: 2 pyruvates are waste products if there is no mitochondrial function
- Krebs cycle (citric acid cycle)
    - A systematic, enzyme-mediated set of reactions that occurs in the mitochondrial matrix
    - Converts pyruvate to carbon dioxide, stripping off valuable electrons in the process
    - Yields energy products: 2 ATP; 8 NADH, and 2 $FADH_2$
    - Waste products: 6 CO_2
- Electron Transport System

    - Creation of ATP using electron-powered hydrogen-ion pumps in the mitochondrial cristae
    - Converts electron energy from NADH and $FADH_2$ to a hydrogen ion gradient
    - ATPase then sues the hydrogen gradient to put phosphate onto ADP
    - Yields energy products: 32 ATP
    - Waste products: 6 H_2O
    - The other reactant: oxygen

Aerobic respiration: the conversion of organic matter energy to ATP, using oxygen and an electron transport system

Fermentation (Anaerobic process)

- Creation of ATP from glycolysis in the cytoplasm under anaerobic conditions (either no mitochondria, no oxygen, or no neither of either)
- Converts glucose to pyruvate and then to one of several possible waste products
- Yields energy products: 2 ATP
- Waste products: Ethanol, lactic acid, carbon dioxide, acetone

Environment

- Calorie: The amount of energy needed to raise the temperature of 1g of water (or 1 CC, 1 ml) by 1 degree of Celsius
- Trophic Efficiency: Energy gained / Energy Available
    - Remaining energy besides the trophic efficiency is released as “heat” (highly random energy)

Unit 7: Cells, Domains, Kingdoms

3 Domains of living things (3 types of cells)

- Bacteria
- Archaea
- Eukaryota

    Bacteria

    - 1 strand of DNA is found in cytoplasm
    - Ribosome is smaller than ours
    - Bacteria are found everywhere where living things could be found
    - Not all bacteria have cell wall (not made of cellulose, but made of peptidoglycan)
    - Unicellular (one cell), although many cells are found together (colonial)
    - Their simplicity allows them to reproduce quickly
    - Blue green algae has chains of cells of different size (not exactly a multicellular organism, however)
    - Most bacteria are heterotrophs; some are autotrophs

    Archaea

- Soviet biologists (although they weren't taken seriously initially) discovered archaea (means old ones)
- 1 strand of DNA is found in cytoplasm
- Ribosome is smaller than ours
- Group of organisms that had completely different DNA from Bacteria
- Extreme environments (boiling water, acidic environments, etc)

Eukaryota cells

- Structurally complex
- 4 "kingdoms"
    - Protista
    - Plantae
    - Fungi
    - Animalia

Protista

- Amoeba (doesn't have much of a cell wall)
- Diatoms (has silica, glass cell walls)
- Colonial _____ (Cellulose cell walls)
- Some are Non-motile
- All protestants are unicellular
- Seaweeds are protista (multi-cellular)
- Eukaryotic
- Single celled
- Autotrophs (photosynthetic), heterotrophs (absorptive, engulfment)
- Typically motile
- Cell walls of cellulose or silica, if any
- No where near abundant as bacteria

Plants

- Eukaryotic
- Multicellular
- Autotrophs (photosynthetic; some few heterotrophic)
- Non-motile
- Cell walls of cellulose
- Have chlorophyll
- Chloroplasts

Fungus

- Eukaryotic
- Multicellular
- Heterotrophs (absorptive)
- Non-motile
- Cell walls of chitin

Animals
- Eukaryotic
- Multicellular
- Heterotrophs (ingestive)
- Motile
- No cell walls

Viruses
- Non-cellular
- Non-living
- Protein capsule: no cell wall
- Typical diameter: < 0.1 microns
- DNA or RNA strand, possibly enzymes, or some other materials, within the protein capsule
- Notable viruses
    - HSV (Herpes Virus)
    - SARS-CoV-2 (“Coronavirus”)
    - HPV Human Papillomavirus
    - HIV
- It is difficult to produce vaccines for viruses, because viruses have protein codes, and protein codes are difficult to target, since the code is constantly changing

Antibiotic
- Fight off bacterial infections
- Antibiotics target peptidoglycan cell wall of the bacteria, keeping it from being able to reproduce
- Other antibiotics target ribosomes of bacteria

Unit 8: Eukaryotic cells

Nucleus
- Double membranes of nuclear envelope (to protect the DNA)
- You do not have chromosomes in most of the cells; You have DNA in every cell. Most of the time you don’t have DNA in the form of chromosomes; rather, you have them in the form of chromatins (long strand-like condition).

Nucelolus
- Holds the DNA that codes for ribosome (rRNA and associated proteins) production
- Not condensed all the way
- Believed to be oldest portion of the Nucleus

Pore complexes
- To get messenger RNA information out of the nucleus, the nucleus is equipped with pore complexes.

- Built with polypeptides, ane embedded in double membrane structure
- Polypeptides put together is referred to as pore complex
- It allows certain things in and out, specifically mRNA
- mRNA is built using the template
- mRNA leaves pore and goes to the ribosome, or endoplasmic reticulum

Transcription: Process of producing mRNA from DNA
Translation: Production of protein using the mRNA and assembling amino acids

Endoplasmic Reticulum

- Smooth ER (SER)
    - Manufacturers phospholipids that make up the transport vesicles
    - Enzymes inside smooth ER that help produce phospholipids
    - Other enzymes that detoxifies the cell are found here
- Rough ER (RER)
    - Studded with ribosomes
    - mRNA tends to go out to RER when it is coding for proteins to be used for outside the cell
    - Feeds information to ribosomes, and ribosomes produce protein. The protein is inserted into ER lumen (inside ER)

Transport Vesicle

- Transport polypeptides to new destinations
- “Pinch off” the membrane is released
- Heads off towards Golgi body

Golgi body

- Enzymes within the golgi body help build the protein body attaching necessary elements, etc
- Golgi body manufactures polypeptides to turn them into proteins
- When produced, it is packaged into secretory vesicles, which hold finished proteins. It leaves the golgi apparatus and releases it to the outside world (secreting)

Endomembrane system (“interior membrane system”)

- Lysosome
    - Lysosomes also break down materials within the cell such as mitochondria, and recycle old materials
- Caterpillar
    - Cells are broken down and breaks down caterpillar cells for it to become butterfly
- “Suicide bags”
    - The level of ATP to sustain lysosome drops (mitochondria isn’t able to continue feeding the lysosome??) and in result lysosome breaks apart
    - This is why older people shrink up, because their cell breaks apart
- Centrioles
    - Play role in process of cell division (cell reproduction)

    - Helping pull DNA apart

Cytoskeletons
- Made out of proteins
- Hold together organelles
- Hold together cells, keeping organelles in place, attaching to different cells (cell structure)
- Beside cell structure, also cell mobility

Neurons (Nerve cells)
- Transmit electric information
- Long and thin
- Coded by myelin (holds electric information in place)
- Attaches in synapse to another neuron, releases chemical neurons (neurotransmitters substance)
- Cytoskeleton connects neurons
- Neural pathways are built every time you learn information

Muscle cells
- Cytoskeleton allows muscle cells to contract, allowing entire organism to move

Cell wall
- Plants have both cell wall and plasma membrane
- Central vacuole
    - Higher pressure keeping rigidity of the cell
    - Allows cells to store water, minerals, nutrients
- Plants have both mitochondria and chloroplast
- Chloroplast (site of photosynthesis)
    - Grana (looks like stack of coins): Stacked thylakoids
    - Thylakoids: Individual “coins” that are sacs
    - NADPH (electron carrier) and ATP are produced here, and they are transported out the thylakoids to Stroma to be used in glucose production
    - Pigment: A molecule which functions to absorb light

Unit 9: Membrane Dynamics Structure and Functions

Liposome
- Forms the basic structure for every cell in body
- Water in the center

Cholesterol
- Is attracted to phospholipid fatty acids, thereby solidifying the membrane
- Major function: Cholesterol helps maintain the proper viscosity of the membrane (A fluid’s viscosity is a measure of how resistant it is to deformation)

Fluid Mosaic model

- Mosaic is made out of individual pieces
- Plasma membrane is composite of different pieces that when put together, become plasma membrane

Permeability

- The quality of a material that allows liquids, gases, or particles to pass (or permeate) through it
- Semi-permeable: capable of being penetrated (permeated) by some things, not others

The structure of the membrane gives it at least 3 important qualities

- A barrier capability
    - Larger molecules are blocked by the tight-packing of the phospholipids
    - Charged molecules are repelled by the hydrophobic core, and are interfered with by the electromagnetic charges on the phospholipid heads
- A permeability based on the phospholipids
    - Smaller, non-charged molecules can easily pass through the tight-packing of the phospholipids
    - Even some larger, non-polar molecules can pass through due to their chemical similarity to the hydrophobic core
- A permeability based on the integral proteins
    - Specific molecules can pass through the integral proteins, which act as channels, gates, or pumps

Passive Transport

- Does not require input of energy
- Simple Diffusion: The net random movement of solutes from an area of *their* higher concentration to an area of their lower concentration
- Facilitated diffusion: The net random movement of solutes from an area of *their* higher concentration to an area of their loewe concentration through an integral protein
- Osmosis: The net random movement of *solvent* from an area of its higher concentration to an area of its lower concentration through a semipermeable membrane.

Active Transport

- The movement of solutes from an area of their lower concentration to an area of their higher concentration through an integral protein using ATP
- Going against concentration gradient

Tonicity

- Tonicity: The relative solute concentration of a solution
- Hypertonic: refers to a solution that is relatively higher in solute concentration
- Hypotonic: refers to a solution relatively lower in solute concentration

Unit 10: Enzymes

Reactions

- Metabolism: The totality of all chemical reactions occurring within a biological unit
- Catabolic reactions: Reactions that break apart large reactants to form smaller products
- Anabolic reactions: Reactions that combine smaller reactants to form larger products
- Activation energy: The energy needed to push a given molecule to its transition state (in other words; the energy needed for a chemical reaction to occur)

Examples of enzymes: Sucrase, Lactase, Amylase, Hexokinase, Lipase, Pepsin, Ribulose bisphosphate carboxylase

Examples of substrates: Sucrose, Lactose, Starch, Glucose, Triglycerides, polypeptides

Functions of enzymes

- Determine *which* bonds will break and which products will form
- Speed up reaction rates
- Product inhibition: Enzymes often have built-in mechanisms by which they can be shut off. There are two major mechanism:
    - Competitive Product Inhibition
    - Non-competitive Product Inhibition
- Competitive Product Inhibition
    - The product molecule of the enzyme-driven reaction bonds INTO the active site, thus blocking substrates
    - Competitive inhibition interferes with active site of enzyme so substrate cannot bind
- Non-competitive product inhibition
    - The product molecule of the enzyme-driven reaction bonds AWAY from active site (the "inhibition site" thus altering the enzyme's shape, and *eliminating* the active site)
    - Non-competitive inhibition change shape enzyme so it cannot bind to substrate
- Denaturing: Changes to protein shape that inhibit or destroy protein functioning
- Conditions that can denature enzymes: pH, temperature, product inhibitions

Active site: the specific region on an enzyme where substrates bind to the enzyme, and therein enter into a transition state

Transition state: A molecular structure's maximum point of instability as it begins to undergo a chemical reaction

Unit 11: Cell Respiration, Glycolysis

All relevant information has been moved to Unit 6: Energy and Matter. See cellular respiration section.

Unit 12: DNA, Genes, Protein Synthesis

Nucleotides

- Made of three different components: phosphate, pentose sugar, and nitrogenous base
- A with T (in RNA, U replaces T). C with G.
- Codons: Sequence of three nucleotides, unit of coding that codes for amino acids. Initiator codon helps process of assembling ribosome

Protein Synthesis

- Transcription → Translation → Protein
- Transcription: The development of the mRNA chain according to the DNA nucleotide sequence
- Translation: The development of the growing polypeptide chain according to the mRNA codon sequence
- Promoter site (usually TATA): A sequence of DNA nucleotides that accepts a transcription factor, and guides the RNA polymerase enzyme to the gene. Cell puts out transcription factor, signaling too the RNA polymerase this is the specific site it should begin
- Transcription factor: A protein that binds to a promoter site to regulate mRNA production

Gene

- A sequence of DNA nucleotides that encodes for a specific polypeptide or mRNA sequence

Unit 13: Mitosis

Cell Cycle

- Interphase (G1, S, G2)
    - G1: Growth
    - S: DNA synthesis. The strand is replicated through the S phase
    - G2: Growth and preparation for mitosis. DNA exists in the form of Dyad
- Mitosis: The process in which a single eukaryotic cell replicates its DNA and divides into two new identical cells
    - Prophase
    - Prometaphase (Late Prophase)
    - Metaphase
    - Anaphase
    - Telophase
- Cytokinesis

Functions of Mitosis

- Allows a single-celled organism to grow and develop into a multi-celled organism
- Allows for the repair of damaged tissue (NOT repair of damaged cells)
- Allows for the replacement of cell types that routinely die

Unit 14: Mendelian Genetics

Genetics: Scientific study of how biological traits are passed from one generation to the next

- Genetics explains why organisms usually give rise to organisms very similar to themselves

Gregor Mendel

- Studied patterns of characteristic inheritance in pea plants in the mid 1800s
- An Augustinian Friar and Abbott who was very interested in science, especially physics, math, genetics, and plants
- Mendel used the pea plants to study. Basic patterns of genetic inheritance

Patterns of inheritance

- Gregor Mendel was the first person to scientifically analyze patterns of inheritance, and perhaps the first person in the West to perform experiments on organisms
- To deduce the fundamental principles of genetics, Mendel examined the "blending" hypothesis vs the "particulate" hypothesis
- Blending hypothesis
    - Example: Blond hair + Black hair would result in brown hair offspring
    - Intermediate blend
- Particulate Hypothesis
    - Example: Blond hair + Black hair → Particles are passed down to offspring, so it could result in offspring of blond, black, or brown (intermediate blend)

Genes & Alleles

- A sequence of DNA nucleotides that encodes for a specific polypeptide (protein)
- Genotype: Allelic content of a gene pair
- Phenotype: The characteristics encoded for by genes (appearance)
- Gene pairs: Mendel determined that the "factors", or genes, come in pairs
- Locus: The specific location along a DNA molecule at which a given gene is located
- Alles: Alternate members of given gene pair
- Law of Allelic segregation: Alleles of the same gene pair will separate from one another during gamete formation
- When symbolizing alleles: dominant is given in upper case, while the recessive is given in lower case. When shown together in a gene pair, dominant is written first

Punnett Square

- Used to determine genetic probability states for a given offspring of a given set of parents
- Homozygous
    - Possessing identical alleles in a given gene pair
    - Homozygote: An individual who possesses identical alleles in a given gene pair
- Heterozygous
    - Possessing two different types of alleles in a given gene pair
    - Heterozygote: An individual who possesses two different alleles in a given gene pair
- Genotypic ratio
    - Homozygous Dominant : Heterozygous : Homozygous Recessive

    - For example, when crossing Gg x Gg, the genotypic ratio is 1:2:1 (GG:Gg:gg)
- Phenotypic ratio
    - Dominant trait : Recessive trait
    - For example, when crossing Ff x Ff, the phenotypic ratio is 3:1
- Simple Dominance
    - An inheritance pattern in which there is a dominant allele in a gene pair that can completely override the recessive allele
- Incomplete Dominance
    - An inheritance pattern in which neither allele in a gene pair can completely override the expression of the other allele
    - Two different alleles, both of which are simultaneously expressed

Unit 15: Meiosis

Functions of Meiosis

- To produce gametes (sperm cells and egg cells) for the purpose of sexual reproduction
- The purpose of sexual reproduction is to create genetic diversity in offspring

Meiosis

- Takes place in the gonads (where gametes are made): Testicles, ovaries
- There are two meiosis stages; Meiosis I and Meiosis II.
- Prophase I → Metaphase I → Anaphase I → Telophase I → Cytokinesis → Prophase II → Metaphase II → Anaphase II → Telophase II → Cytokinesis
- Haploid
    - Having only one member of each homologous pair (one copy of each chromosome)
    - (whereas diploid is two members of each homologous pair)
- Crossing Over
    - Creates new combinations of genes on chromosomes (A major source of genetic diversity)
    - Occurs at Prophase I
    - Crossing over does not cause mutation
- Random Alignment
    - Creates different combinations of paternal and maternal chromosomes in gametes (Another major source of genetic diversity)
    - Occurs in Metaphase I
- Syngamy
    - The fusion of gametes to create a zygote
    - It’s not part of the meiosis
    - Creates new combinations of genes in organisms (recombination)
    - The final source of genetic diversity

Unit 16: Molecular, Human, Non-Mendelian Genetics

Pleiotropic: One gene pair or allele having multiple phenotypic effects

Sex

- XY (23rd pair) → Male
- XX (23rd pair) → Female

Syndromes, Disorders and other conditions

- Achromatism (or Albinism)
- Marfan syndrome
    - Caused by an altered allele that results in increased production of a protein called transforming growth factor beta, or TGF-β
    - The increase in TGF-β causes breakdown in connective tissues. It destroys tendons, ligaments, collagen
- Autosomal Disorders
    - Autosomes are the non sex chromosomes -- those *other* than X and Y
- Tay-Sachs Syndrome
    - People with Tay-Sachs syndrome are missing an enzyme that digests nerve cell gangliosides
    - Gangliosides are fatty bodies found in the nerve cells of all developing humans, and are broken down to provide energy to the cells
- Cystic Fibrosis
    - Cause buildup of mucus
    - No cure, only treatment.
- Huntington's Disease
- Achondroplasia (dwarf)
    - Dominant gene
    - It *can* sometimes be lethal
- Fragile X
    - Fragile site
    - Cartilage growth
    - Leading genetic cause of mental retardation
    - More commons in males than in females
- Klinefelter's Syndrome
    - 2 X's and Y
    - Wide hips, poor beard growth, narrow shoulders.
    - Unlikely to reproduce
    - Some identify as males, some as women. (Usually regarded as female in African cultures).
- Trisomy: Possessing three chromosomes in a pair
    - Triple X - XXX: Taller, sometimes perform worse in standardized tests / intelligence tests
    - Jacobs Syndrome - XYY: little bit taller, worse performance on intelligence tests
    - Found on the autosomes
    - Down Syndrome: Trisomy of chromosome #21

    - Edwards Syndrome: Trisomy of chromosome #18
    - Patau Syndrome: Trisomy of chromosome #13
- Monosomy: Possessing only one chromosome in a pair
- Turner's Syndrome (XO)
    - Short, unusual neck, Small fingernails, short stature
    - No menstruation

Polygenic Conditions

- Dependent upon alleles in two or more gene pairs
- Eg: Aa Bb CC Dd ee Ff gg Hh Ii Jj etc

Multi-allelic

- Referring to a single gene pair in which there are more than 2 possible alleles
- The gene pairs for HLA (Human Leukocyte-associated Antigen) have hundreds of possible alleles

Nondisjunction

- The failure of homologous chromosomes to separate properly during meiosis (results in one cell with two monads)

Chromosomal disjunction: The normal separation of homologous chromosomes from one another during gamete formation (i.e, during meiosis)

Chromosomal nondisjunction: Failure of homologous chromosomes to separate from one another during gamete formation (i.e, during meiosis)

Unit 17: Community Ecology

Ecology: Scientific study of how organisms interact with each other and with their non-living environment

- Physical adaptations: Genetically-inherited characteristics that enable a given organism to survive and reproduce using a given niche
- Niche is not a physical place, but rather how organisms use the space
- Ecological niche: The manner in which an organism uses the resources in, and is influenced by the conditions of, its habitat
- Fundamental niche: The largest array of resources an organism can utilize
- Realized niche: The actual set of resources utilized
- Habitat: The physical place, or type of place, where an organism lives
- Conditions: background features of the habitat; temperature, humidity, salinity, altitude, irradiance, pH, etc.
- Competitive Exclusion principle
    - "Gause's Principle": No two species can use the same niche in the same habitat
    - One, or the other, or both, will inevitably be outcompeted

- Competition: Antagonistic struggle for a common resource
    - Win -- the resource
    - Lose: time, energy, other opportunities, tissue, life
- Indirect (exploitive) competition
    - Quicker or more efficient use of a resource
- Direct (physical) competition
    - A fight or attack
- Niche Partitioning
    - The division of niches between species so as to cut down on competition
    - May be permanent or temporary
- Competition
    - Interspecific: between different species (e.g: Lions vs Hyenas)
    - Intraspecific: Within a species (e.g: Lions vs Lions, bacterium vs bacterium, oak vs oak, human vs human). Far more common and far less avoidable
- Populations:
    - A group of organisms of the same kind that actually or potentially interbreed
    - Individual within a species interact with each other as members of a population or colony
    - A group of organisms that interbreed so as to produce viable offspring
- Population growth
    - Exponential: J-shaped growth curve
    - Logistic: S-shaped growth curve
- Biotic potential: Maximum reproductive capacity of a population in the absence of environmental resistance
- Environmental resistance: ecological features that inhibit population growth
    - Density-independent: Drought, hot spells, cold snaps, fires, floods
    - Density-dependent: Predators, disease, food shortages, water shortages, build-up of wastes, lack of space, nesting sites, etc
- Carrying Capacity: The environment's ability to hold (or "carry") a specific number of individuals for a prolonged period of time
- Environmental selection: Differential survival of individuals in a population, which leads to differential survival of genes
- Gene pool: All of the inheritable alleles found within a given population

Unit 18: Population Genetics

Hardy-Weinberg Equilibrium Rules

- 1. There must be no random events that differentially eliminate alleles
- 2. There must be no migration into or out of the population
- 3. There must be no reproductive or survival advantage to any gene or genotype
- 4. All mating must occur at random (no selection criteria for mates)
- 5. Mutations may not occur

- Genetic Drift

    - Changes in gene (allele) frequency owing to random factors
    - A violation of rule 1
- Gene Flow
    - Movement of genes (alleles) into or out of population resulting from migration
    - A violation of rule 2
- Environmental (natural) Selection
    - Conditions of habitat create differential survival and replication of specific alleles
    - Environmental selection can create trends in allele frequency shifts
    - A violation of rule 3
- Sexual Selection
    - Mate pairing criteria create differential survival and replication of specific alleles
    - A violation of rule 4
- Mutation: Alteration to the nucleotide sequence of a gene
    - Factors causing mutations
        - 1. Exposure to radiation -- gamma rays, X-rays, UV light
        - 2. Exposure to toxins -- heavy metals, organic poisons, ionic compounds
        - 3. Random replication errors in DNA synthesis
    - A violation of rule 5

Evolution: Changes in gene frequencies in populations over time

Evolutionary Fitness: The ability of an organism or allele to survive and reproduce relative to other individuals or alleles within a population

Unit 19: Environmental Selection

Genetic Diversity
- The variety of genes and genotypes in a gene pool
- Environmental selection acts to eliminate genes
- Only certain genes can survive in a given environment

Selections
- Stabilizing Selection
    - No genetically-related change in population mean over time
    - Selective pressure keeps population centered around an average
- Directional Selection
    - Genetically-related change in mean over time follows a progressive trend
    - Selective pressure moves population from one average to another
- Disruptive Selection
    - Genetically-related change in mean over time produces two “means” (modes)
    - Selective pressure splits population around two “averages” or modes

Species: A population of organisms which is reproductively isolated from other populations of organisms

Speciation

- The evolution of reproductive isolation in two populations which previously interbred
- Disruptive selection is the only selection pattern that can produce speciation
- Patterns of speciation
    - Allopatric
    - Sympatric
    - Parapatric

- Allopatric Speciation
    - Speciation occurs in two separate areas
    - Usually involves some geographic barrier; river, canyon, open ocean, mountain range
- Sympatric Speciation
    - Speciation occurs in the same area
    - Usually involves some sudden mutation
- Parapatric Speciation
    - Speciation occurs in two adjacent areas

Unit 20: Isolation

Reproductive isolation

- Pre-zygotic (no zygote ever forms)
    - Habitat
    - Temporal
    - Behavioral
    - Mechanical
    - Gametic Incompatibility
- Post-zygotic (zygote forms, potential of offspring)
    - Hybrid (zygote) mortality
    - Hybrid Sterility
    - Hybrid Inviability

- Pre-zygotic isolation
    - The two species do not mate with each other such as to produce a fusion of gametes
    - Includes habitat, temporal, behavioral, mechanical and gametic incompatibility-based isolation
- Habitat isolation
    - Two species reproduce in different habitats
- Temporal isolation
    - Two species mate at different times of the year, or the day
    - The Maryland Giant Blue Tobacco is one example
- Behavioral isolation
    - Songs

    - Dance behaviors
    - Visual cues
- Mechanical isolation
    - Breeding is prohibited due to anatomical constraints
- Gametic Incompatibility
    - Egg and sperm cells do not chemically recognize each other
    - Textbooks may call this “post-zygotic”, but it is obviously not
- Post-zygotic isolation
    - Isolation occurs even after the egg and sperm have fused; after mating, fertilization, and syngamy have occurred
    - Includes hybrid (zygote) mortality, hybrid sterility, and hybrid inviability mechanisms
- Zygote (hybrid) mortality
    - Sperm and egg fuse, but the offspring fail to develop
- Hybrid sterility (hybrid infertility)
    - The two species mate, produce offspring, but the offspring are not fertile
- Hybrid inviability
    - The hybrid offspring cannot survive long enough to reproduce