SAT Biology E/M Subject Test Guide

From Simple Studies: https://simplestudies.edublogs.org &
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NOTE: ALL SAT SUBJECT TESTS ARE CANCELLED BUT YOU CAN STILL STUDY THIS CONTENT

- **Biology E or Biology M?**
  - It depends on what your strengths are!
    - **Biology E:** focuses on biological communities, ecosystems, populations, and energy flow
    - **Biology M:** focuses on biochemistry and cell processes/structure
  - Choose what YOU are the most confident in. You have until the day of the test to decide which one to take, so don't worry about this too much in the beginning. Try studying the concepts first and you'll most likely realize it along the way.
- **How is the test formatted?**
  - All questions on the Biology E/M subject test are multiple choice and are each worth 1 point. There are 80 questions total, which are divided into two parts:
    - The first 60 questions are general biology questions ("core" questions).
    - The next 20 questions differ depending on whether you take Biology E or M ("specialized" questions)
- **How to study for the test:**
  - **Use any and all resources on the College Board website!** After studying the material, use these to test yourself! These can be found at https://collegereadiness.collegeboard.org/sat-subject-tests/subjects/science/biology-em. Review your incorrect answers and be sure to find out WHY they were wrong.
  - **Watch free Khan Academy videos on YouTube.** These videos can be a great resource to use as well! Take notes on it (pause if you need to) and review them

again later. Here's the playlist: https://www.youtube.com/playlist?list=PLsaui3l-P1prBV4Owrc0SamLWBZF2KQlz

- **Prep books.** Prep books for SAT Biology E/M can be helpful, but aren't a necessity. If you do decide to buy one, I personally recommend the one by Barron's! Use all online tests provided.
- **Be prepared to make educated guesses.** It can be a great skill to use the process of elimination to make an educated guess when taking the test! If you really aren't sure, then skip to the next question to make sure you have enough time to finish.

****Study guide starts on the next page!****

Unit 1: Biochemistry

Structure of Atoms

- Atoms are made of:
  - *protons*: positive charge, mass = 1 amu, located in nucleus
  - *neutrons:* neutral charge, mass = 1 amu, located in nucleus
  - *electrons:* negative charge, mass = 0 amu, located outside nucleus
- Electrons can move from lower level of energy to higher level of energy (or **excited state**) by absorbing energy
  - **ground state** - lowest level of energy
- **isotopes** - atoms of same element that have different # of neutrons
  - **radioisotopes** - radioactive isotopes that decay with a **half-life**; used for medical diagnosis (**tracer**), research, and carbon dating

Types of Bonds

- **bond** - when the same electron (or electrons) is attracted by the nuclei of 2 atoms to become stable
  - To break one, energy is *absorbed*. To create one, energy is *released*.
- **ionic bonds:** electrons transferred; one atom (**anion**) gains electron(s) and the other (**cation**) loses electron(s)
  - Examples: anion: Cl^- , F^-; cations: Na^+, Ca^{2+}
- **covalent bonds:** electrons shared and a **molecule** is formed
  - 2 types of covalent bonds:
    - **nonpolar covalent bond** - electrons are shared equally between 2 alike atoms (ex. H_2 and O_2)
    - **polar covalent bond** - electrons are shared unequally between 2 different atoms (ex. CO and H_2O)
- **intermolecular attractions**: occur *between* molecules; Some are:

- **polar-polar attraction** - occur between polar molecules, which have stronger attractions towards each other
  - − end of polar molecule attracts + end of other polar molecule (ex. H_2O)

- **hydrogen bonding** - important to life because:
  - attaches 2 strands of DNA double helix together
  - causes water molecules to stick to each other, allowing for a variety of special characteristics
  - HF_4 is an example
- **nonpolar molecules** - weakest attractions (van der Waals), CO_2 is an example

Hydrophobic & Hydrophilic

- **hydrophobic** - "water hating"
- **hydrophilic** - "water loving"
- Polar substances dissolve in water, nonpolar substances do not
  - Ex. Plasma membrane is nonpolar so it only lets nonpolar substances diffuse easily, not large polar molecules

Special Properties of Water

- **High specific heat:** lots of heat needed to change water temperature, which creates stable ocean + coastal temperatures
- **High heat of vaporization:** lots of heat needed to evaporate water (ex. Sweat cools body efficiently)
- **Adhesion:** water sticks to other substances; allows for capillary action (water goes from roots → leaves) in plants
- **Cohesion tension:** water molecules stick to each other; allows for surface tension + **transpirational-pull cohesion tension** (water goes from roots → leaves of tree without energy)
- Universal solvent: water is very polar so it can dissolve other polar/ionic substances

- Ice = less dense than water: floating ice insulates water in winter and brings nutrients to surface in spring when ice melts

pH

- pH: used to measure how acidic or alkaline/basic a solution is; pH < 7 is acidic, pH > 7 is alkaline, pH = 7 is neutral
  - *is negative logarithm of H^+ ions in moles/liter
  - As H^+ concentration *increases*, pH *decreases*.
- Living cells maintain homeostasis; pH of ~7
  - They use buffers to regulate pH (ex. bicarbonate ion in human blood)

Organic Compounds

- Compounds that contain carbon; the types of organic compounds are:
- **Carbohydrates**
  - Made of C, H, O (carbon, hydrogen, oxygen)
  - Used for quick energy
  - 1 gram of carb = 4 calories of heat
  - **3 types of carbs:**
    - **monosaccharides ($C_nH_{2n}O_n$) -** glucose, galactose, fructose, etc.
    - **disaccharides ($C_{12}H_{22}O_{12}$) -** made of 2 monosaccharides that are bonded through dehydration synthesis/condensation; can be broken down through hydrolysis
      - dehydration synthesis *produces* water; hydrolysis *requires* water
      - Disaccharide examples: sucrose, lactose, maltose
    - **polysaccharides -** polymer made of many monosaccharides
      - Plant polysaccharides:
        - Cellulose - makes up cell walls in plants
        - Starch - how plants store carbs
      - Animal polysaccharides:
        - Chitin - makes up exoskeletons/mushroom cell walls
        - Glycogen - animal starch (stored in liver + skeletal muscle for humans)

- **Lipids**
  - Examples: fats, oils, waxes
  - Usually made up of 1 glycerol (an alcohol) + 3 fatty acids
  - **Fats:** hydrocarbon chain + carboxyl group at one end
    - **Saturated fats**
      - Usually from animals & solid at room temp (ex. butter)
      - Only have single bonds between carbons

- **Unsaturated fats**
  - From plants & liquid at room temp (ex. oil)
  - Have ≥1 double bond between carbons, meaning less hydrogens

➢ Some functions of lipids are:
- **Storing energy -** 1 gram of lipid = 9 calories of heat
- **Structure -** phospholipids make up cell membrane
- **Endocrine system -** certain lipids act as hormones

❖ **Proteins**

➢ Polymers (polypeptides) made of amino acids joined by peptide bonds
- Ex. enzymes

➢ Amino acids - carboxyl group, amine group, and variable (R) all bonded to one carbon in the center
- There are 20 different types of amino acids; each amino acid is unique due to its R group

➢ Necessary for growth + repair

➢ Made of sulfur, phosphorus, carbon, oxygen, hydrogen, nitrogen (CHNOPS)

➢ 1 gram of protein = 4 calories of heat

➢ 2 amino acids make up a dipeptide

➢ **Protein structure**
- Protein function depends on its shape/structure
- **primary structure** - amino acid sequence
- **secondary structure -** double helix or beta sheets that happen due to hydrogen bonding
- **tertiary structure -** directly influences specific 3D shape and function of a protein
- **quaternary structure -** more than 1 polypeptide chain present

- **Enzymes**
  - Large proteins that lower the energy of activation (E_a), which speeds up reactions
  - Only react with specific chemicals (substrates) and can be reused
  - Change shape a bit to let the substrate bind (induced-fit model)
  - Can become more/less efficient due to pH or temperature
- **Prions**
  - Misfolded proteins are infectious and make other proteins to misfold, causing brain diseases (ex. mad cow disease)

❖ **Nucleic acids**

- Polymers that contain genetic information that is inherited
- DNA and RNA
- Made up of nucleotides, which are made of a phosphate group, 5-carbon sugar (deoxyribose/ribose), and nitrogenous base
- **DNA bases:** adenine, cytosine, guanine, thymine
- **RNA bases:** adenine, cytosine, guanine, uracil
- Adenine {RNA+DNA} & guanine {RNA+DNA} = purines
- Cytosine {RNA+DNA}, thymine {only found in DNA}, uracil {only found in RNA} = pyrimidines

Unit 2: Cells

Cell Theory

- Every living thing is made of cells.
- The basic unit of life is the cell.
- Every cell comes from preexisting cells
  - Most cells are 10-100 micrometers (μm), but others are smaller (red blood cells = 8μm)
  - All cells have a membrane and nucleic acid.

Prokaryotes vs. Eukaryotes

- **Prokaryotes:**
  - No nucleus or membrane-bound organelles
  - Have one circular chromosome, sometimes have plasmids
  - Small ribosomes are present
  - Can do anaerobic or aerobic respiration
  - No cytoskeleton; have cell walls
  - Unicellular and very small (1-10 μm)
- **Eukaryotes:**
  - Have nucleus and membrane-bound organelles
  - Have linear chromosomes (46 in human nucleus); no plasmids
  - Large ribosomes are present
  - Have cytoskeleton; most don't have cell walls (except plants and protists)
  - Sometimes unicellular, but usually multicellular and specialized; relatively large (10-100 μm)
- **Theory of endosymbiosis -** formation of first eukaryotic cells (~2.4 billion years ago) when smaller prokaryotes were phagocytosed by larger ones and became a part of them permanently
- Form relates to function when it comes to cells, and different types of cells have different functions and shapes. However, they still have (mostly) the same organelles.

Parts of the cell

- **Nucleus**
  - Is where genes are located (in the form of a chromatin network)
    - Chromatin is DNA wrapped around histones, or basic proteins, and it condenses to form chromosomes
  - Has a nuclear membrane that separates nucleus from cytoplasm
    - Contains pores that allow for transport out of the nucleus
- **Nucleolus**
  - Usually 1-2 are located inside nucleus of non-dividing cell
  - Does not have a surrounding membrane
  - Is where ribosomes are made
  - Made of chromatin + ribosomes that are being created
- **Ribosome**
  - Is where proteins are made
  - Consists of rRNA (ribosomal RNA) and protein
  - Can be free in cytoplasm or on endoplasmic reticulum
- **Endoplasmic Reticulum (ER)**
  - Membrane system in the cytoplasm
  - Two types of ER:
    - **Rough ER**
      - has ribosomes on surface
      - makes proteins + transports them
    - **Smooth ER**
      - makes lipids (ex. steroid hormones)
      - connects rough ER and Golgi apparatus
      - metabolizes glycogen and detoxifies cell
- **Golgi Apparatus**
  - System of flattened membrane pouches
  - Responsible for modification, storage, and packaging (into vesicles) of proteins/lipids

        - These proteins/lipids can then be transported to other locations

- **Vacuole**
    - Space without cytoplasm surrounded by a membrane
    - Responsible for storage
    - Example: contractile vacuoles
    - ***vesicles** are very small vacuoles
- **Lysosome**
    - Membrane-bound sacs filled with digestive enzymes
    - Responsible for intracellular digestion (digestion within cell)
    - Recycles cell parts + allows for apoptosis (programmed cell death)
- **Mitochondria**
    - Where cell respiration happens in all cells
    - Have a double membrane and inner membranes that are folded (cristae)
    - Have their own unique DNA
- **Plastids**
    - Have double membrane; only in plants/algae
    - Types of plastids:
        - **Chloroplasts**
            - Where photosynthesis occurs
            - Have chlorophyll (which makes them green)
            - Inner membrane is folded to create grana
            - Have their own DNA
        - **Leucoplasts**
            - Responsible for storing starch
            - Colorless and are in roots/tubers
        - **Chromoplasts**
            - Responsible for storage of carotenoids (which make carrots, tomatoes, and other plants red/orange/yellow)

- **Cytoskeleton**
  - Made of protein filaments that allow the cell to move/maintain shape
  - Two types of cytoskeletal elements:
    - **Microtubules -** thick tubes made of tubulin; make spindle fibers, flagella, cilia
    - **Microfilaments -** made of actin; maintains cell's shape
      - Examples of functions:
        - cleavage furrow when cell divides
        - pseudopods in amoeba
        - movement of skeletal muscles
- **Cilia/Flagella**
  - Consists of microtubules (9 pairs around 2 central ones)
  - Cilia = short, flagella = long
- **Centrioles/Centrosomes**
  - Made of 9 microtubule triplets
  - Responsible for organizing spindle fibers when cell divides
  - Only in animal cells
  - 2 centrioles = 1 centrosome; centrioles are perpendicular to each other
- **Cytoplasm & Cytosol**
  - **cytoplasm -** area from outside of nucleus to plasma membrane (includes organelles and cytoskeleton)
  - **cytosol -** only the liquid part of cytoplasm
- **Plasma Membrane**
  - Selectively permeable membrane made of phospholipid bilayer
  - Includes proteins, cholesterol, and carbohydrate chains attached to membrane
- **Cell Wall**
  - Only in plants, algae, and fungi (plants, algae = cellulose walls; fungi = chitin walls)
  - **middle lamella -** layer that attaches 2 plant cells after cell division

Plant vs. animal cells

- **Plant cells:**
  - No centrioles/centrosomes or lysosomes
  - Have chloroplasts + other plastids
  - Large vacuole in center of cell
  - Have cell wall and plasma membrane
- **Animal cells:**
  - Have centrioles/centrosomes and lysosomes
  - No chloroplasts + other plastids
  - Usually only small vacuoles
  - Only have plasma membrane

Transport in/out of a cell

- **Passive Transport**
  - When molecules move from high → low concentration *without* using energy
  - Examples of passive transport:
    - **Simple diffusion** - direct movement of molecules from high → low concentration; steeper gradient = faster diffusion
      - Ex. oxygen diffusion in human lungs (specifically in alveoli)
    - **Facilitated diffusion** - requires protein channels to move certain substances through a membrane
    - **Osmosis** - when *water* diffuses through a membrane to a place with more solute (hypertonic)
      - *Cell in hypertonic solution* - water moves from cell to solution
        - Cell shrinks (plasmolysis)
      - *Cell in hypotonic solution* - water moves into cell from solution
        - Animal cell bursts (lyses)
        - Plant cell swells (becomes turgid); plants lose turgor pressure/wilt when not watered
      - *Cell in isotonic solution* - water moves in + out of cell at same rate
        - Cell doesn't shrink or swell

- **Active Transport**
  - When molecules move against the concentration gradient using energy (ATP)
  - Types of active transport:
    - **Exocytosis** - when a cell releases molecules using energy (ex. Nerve cells release neurotransmitters into synapses through vesicles)
    - **Endocytosis** - when cells form new vesicles by absorbing molecules; the three types are:
      - **Phagocytosis** - when large particles/tiny organisms are engulfed by pseudopods
      - **Pinocytosis** - when small dissolved molecules are absorbed (cell drinking)
      - **Receptor-mediated endocytosis** - when specific substances bind to ligands (receptors on the membrane) + are enclosed in a vesicle
    - **Sodium-potassium pump** - protein pump in nerve cells that generates an ion gradient

Cell cycle

- Affected by signals (either internal or external), which control 3 checkpoints that strictly regulate cell division
- Cell cycle stages: G_1, S, G_2, mitosis, cytokinesis
  - Some cells (ex. neurons) remain in G_0 / don't divide.
- **Interphase** (>90% of cell's life)
  - In G_1 phase, cell grows and prepares for DNA replication
    - *G_1 checkpoint*
  - In S phase, DNA is synthesized
    - *S checkpoint*
  - In G_2 phase, organelles + other cellular components are produced
    - *G_2 checkpoint*

- **Mitosis** (division of nucleus) - for growth + repair
  - **Prophase**
    - Chromosomes are visible
    - Nucleoli disappear
    - Spindle fibers begin forming
    - Centrioles start moving to poles
  - **Metaphase**
    - Chromosomes line up on metaphase plate (single file)
    - Centrosomes at poles opposite to each other
    - Spindle fibers fully formed (connected to centromeres of chromosomes)
  - **Anaphase**
    - Sister chromatids are pulled apart by spindle fibers
  - **Telophase**
    - Chromosomes move to opposite ends of cell
    - Nuclear membrane forms
    - Chromosomes start to unravel back into chromatin
- **Cytokinesis** (division of cytoplasm)
  - Animal cells - cleavage furrow forms and daughter cells separate
  - Plant cells - cell plate forms in middle, cells don't separate; middle lamella keeps cells together

Meiosis

- Cell division that produces haploid gametes (sex cells)
- Stages of meiosis:
  - **Meiosis I** (reduction division)
    - Synapsis (pairing of homologous chromosomes) and crossing-over (homologous chromosomes swap genetic material) occur
    - *Homologous pairs* separate
    - Homologous chromosomes randomly line up in middle + separate independently of each other
    - Every gamete is genetically different

- **Meiosis II**
    - *Sister chromatids* separate
    - # of chromosomes stays haploid
    - Results in 4 genetically different daughter cells from one cell

Cellular Respiration

- Process where cells break down glucose and transfer its energy to molecules of ATP
    - *ATP (adenosine triphosphate) - made of adenosine (adenine + ribose) and 3 phosphate groups; stores lots of energy
- **Mitochondria structure**
    - 2 membranes:
        - Outer membrane
        - Inner cristae membrane (where electron transport chain occurs)
            - Outer compartment
            - Matrix - where Krebs cycle occurs
- **Two types of cell respiration**
    - **Aerobic respiration**
        - Has anaerobic phase (glycolysis) + aerobic phase (citric acid cycle/Krebs cycle + oxidative phosphorylation/chemiosmosis)
        - **Glycolysis**
            - Occurs in cytoplasm + controlled by enzymes
            - 2 ATP needed to start glycolysis
            - $1\ glucose + 2\ ATP \rightarrow 2\ pyruvate + 4\ ATP + 2\ NADH$
                - Net gain = 2 ATP

- **Citric acid cycle/Krebs cycle**
  - Pyruvate from glycolysis + coenzyme A = *Acetyl-CoA*, which enters Krebs cycle
  - Occurs in matrix of mitochondria
  - 1 turn of Krebs cycle = 1 ATP + 1 $FADH_2$ + 3 NADH
    - By-product: carbon dioxide
    - NADH produces 3 ATP, FADH produces 2 ATP
      - Oxidized forms: NAD^+ and FAD^+
      - Reduced forms: NADH and $FADH_2$
- **Electron Transport Chain (ETC)**
  - In cristae membranes (mitochondria)
  - Produces most ATP in aerobic cell respiration
  - $FADH_2$ + NADH transport energized electrons from Krebs cycle to ETCs
  - Energy from electrons is used to pump protons (H^+) from inner matrix to outer compartment through active transport
    - Proton gradient is formed and has lots of potential energy
    - H^+ can only flow down concentration gradient through ATP synthase channels, powering production of ATP from ADP + phosphate (chemiosmosis/oxidative phosphorylation)
  - Oxygen helps electrons move through ETC + is final electron/proton acceptor
    - Forms water as waste product by combining with protons + electrons

➢ **Anaerobic respiration**

- Does not require oxygen; evolved when no oxygen on Earth
- Glycolysis → *Fermentation
  - *Can be lactic acid fermentation (used by skeletal muscles) or alcohol fermentation (used by yeast)

Photosynthesis

- Series of reactions where plants use energy from light to create glucose
  - Formula: $6CO_2 + 12H_2O \rightarrow C_6H_{12}O_6 + 6H_2O + 6O_2$
- Photosynthesis is a reduction reaction (carbon in CO_2 gains electrons from hydrogen in H_2O)
- **Photosynthetic pigments**
  - Chlorophyll *a* and *b* - absorbs red-violet light; reflects green light
  - Carotenoids - absorbs green light; reflects orange, red, yellow light
  - Phycobilins - found in red algae, absorb wide spectrum of light

- **Light-dependent reactions & Light-independent reactions**
  - **Light-dependent reactions**
    - Requires light
    - Produces lots of ATP + provides protons for light-independent reactions
    - Occurs in grana of chloroplasts (in thylakoids)
      - Thylakoids have many photosystems, which have chlorophyll *a* (as well as chlorophyll *b* and carotenoids) to absorb light
    - Energized electrons in chlorophyll molecules escape and move into ETCs.
      - Energy is used to form proton gradient + power ATP production by ATP synthase (chemiosmosis; same as cell respiration)
    - Water is broken down into parts:
      - *Electrons* - replaces electrons that escaped from chlorophyll molecules
      - *Protons* - establishes proton gradient + used by ATP synthase to produce ATP; NADP takes them to stroma for use in light-independent reactions
      - *Oxygen* - released as waste product

- **Light-independent reactions**
  - Does not require light
  - Produces sugar (PGAL: 3-carbon sugar); uses lots of ATP
  - Occurs in stroma of chloroplasts
  - Consists of the Calvin cycle, which incorporates CO_2 into sugar (carbon fixation)
    - Important enzyme for Calvin cycle: rubisco

- **Leaf structure**
  - *photosynthesis mostly happens in palisade layer (tightly packed cells with chloroplasts)
  - Spongy mesophyll cells have chloroplasts + photosynthesis occurs
    - Less tightly packed and have air spaces (lets oxygen, CO_2, water vapor move throughout)
  - Epidermis layer - clear + no photosynthesis; protects cells underneath
    - Layer of cutin: above epidermis, prevents loss of water
  - Guard cells - makes stomata open/close, minimizing water loss

Unit 3: Heredity/Genetics

Probability

- *Remember that probability is only the likelihood that something will happen; it doesn't guarantee anything.
  - *Ex 1:* coin flip: 50% (½) heads, 50% (½) tails
    - Probability of 3 heads in a row: ½ x ½ x ½ = ⅛ (every flip is separate event)
  - *Ex 2:* birth: ½ daughter, ½ son
    - Probability of 2 daughters: ½ x ½ = ¼ (every birth is separate event)

Gregor Mendel's Laws

- Gregor Mendel analyzed inheritance patterns in plants by using probability
- Mendel's 3 laws were:
  - **Law of Dominance**
    - States that a cross between homozygous dominant (TT) and homozygous recessive (tt) will result in hybrid offspring (Tt) with 2 different alleles
      - The hybrid's phenotype (physical appearance) will be the dominant trait.
  - **Law of Segregation**
    - States that when gametes form, the 2 alleles from the parent cell separate
    - Can be proven by doing a monohybrid cross (cross between 2 hybrid/ Tt x Tt)
      - Monohybrid phenotypic ratio - **3:1**
      - Monohybrid genotypic ratio - **1:2:1**
    - ***Backcross** - can be used to find out unknown genotype (B_) by crossing it with homozygous recessive (bb)
      - If unknown genotype is BB, all offspring will exhibit dominant trait (Bb)
      - If unknown genotype is hybrid (Bb), ½ of offspring is predicted to exhibit recessive trait (bb)
      - *if phenotypic ratio = 1:1, the cross was **Bb** (hybrid) x bb

- **Law of Independent Assortment**
    - Applies when cross is between 2 hybrid organisms for 2 traits located on *separate* chromosomes
    - States that inheritance of one gene does not affect inheritance of another
    - Supported by a dihybrid cross (TtYy x TtYy); T = tall, t = dwarf, Y = yellow seed, y = green seed
        - Dihybrid phenotypic ratio - **9:3:3:1** (9 tall yellow, 3 tall green, 3 short yellow, 1 short green)

Non-Mendelian Inheritance

- **Incomplete Dominance** - blending inheritance (ex. Red x White = Pink)
- **Codominance** - both traits are fully expressed (ex. Person with both A allele and B allele will show both traits as someone with AB blood type)
- **Multiple alleles** - more than 2 alleles of a gene (ex. Blood type has 3 alleles: A, B, O)
- **Polygenic inheritance** - when multiple genes control one trait (ex. hair/skin color)
- **Sex-linked genes** - genes that are located on the sex chromosomes
    - mostly only considering X-linked since they are more common
    - Often recessive (color-blindness or hemophilia)
    - Affected fathers pass to all daughters but never to sons
    - Carrier mother = 50% chance of passing on gene to son
        - If son has affected X-linked gene, he has the trait
        - If daughter has one copy of affected X-linked gene, she is carrier (uncommon for her to inherit both affected X-linked genes)
- *gene expression is sometimes affected by the environment (ex. Fruit flies: vestigial wing gene is affected by temperature)
- *an individual's sex can influence inheritance patterns (different from sex-linked)
    - Ex. baldness being expressed differently in females and males

Karyotype

- Method used in the lab to check various qualities of chromosomes (can detect abnormalities in size, shape, or quantity of the chromosomes)
    - Humans have 44 autosomes and 2 sex chromosomes

Pedigree

- An organized family tree that shows the phenotypes of each family member for a certain trait
  - Circles = females, squares = males
  - Shaded in = expresses trait

Mutations

- Any random mistakes in the genome
- Can happen in both somatic cells (cancer) and germ cells (effects on future offspring)
- Can be caused by chemicals, radiation, etc.
- 2 types of mutations:
  - **Gene mutations** - change in the sequence of nucleotides in DNA
  - **Chromosomes mutations**
    - *Deletion* - when a chromosome fragment without a centromere is lost as the cell divides
    - *Translocation* - when a chromosome fragment attaches to a different (non-homologous) chromosome
    - *Inversion* - when a chromosome fragment attaches to its original chromosome in the reverse direction
    - *Polyploidy* - when a cell has extra sets of chromosomes
    - *Nondisjunction* - when homologous chromosomes do not separate properly during meiosis

Examples of Human Disorders Caused by Gene/Chromosome Mutations

- **Genetic Disorders**
  - *Cystic fibrosis* - autosomal recessive; fluid builds up in digestive tract, lungs, etc.
  - *Tay-Sachs disease* - autosomal recessive; abnormal brain function due to shortage of enzymes that help break down lipids
  - *Phenylketonuria* - autosomal recessive; body can't break down phenylalanine, can cause mental disabilities
  - *Huntington's Disease* - autosomal dominant; affects nervous system, causes early death

- *Color blindness* - sex-linked recessive; inability to see certain colors
- *Hemophilia* - sex-linked recessive; blood doesn't clot normally

- **Chromosomal Disorders**
  - *Klinefelter's syndrome* - male with another X chromosome (XXY); small testes + sterile
  - *Down syndrome* - extra chromosome 21; higher risk of Alzheimer's + leukemia, possible mental disabilities

Experiments that proved DNA was inherited material

- 1927 - Griffith discovered that bacteria can absorb genetic material from their environment + add it to their own genes (bacterial transformation)
- 1944 - Avery, MacLeod, McCarty provided evidence for DNA being the genetic material in Griffith's experiment
- 1952 - Hershey and Chase did an experiment and provided evidence to prove that proteins were not genetic material, but DNA (nucleic acid) was.
- 1950 to 1953 - Rosalind Franklin used X-ray crystallography analysis to prove that DNA was a double helix
- 1962 - Watson and Crick described DNA as a double helix (and won Nobel Prize)
- 1953 - Meselson and Stahl provided evidence supporting that DNA replication is semiconservative

DNA Structure

- Is double helix + made up of 2 complementary strands that are in opposite orientations
- Is a polymer (monomers = nucleotides)
  - Nucleotides - 5-carbon sugar (or deoxyribose), phosphate group, nitrogenous base
    - 4 nitrogenous bases: adenine, thymine, cytosine, guanine (A, T, C, G)
    - A with T, C with G
- 2 DNA strands are held together by hydrogen bonds

DNA Replication (Eukaryotes)

- Semiconservative replication (each new DNA molecule = 1 old strand, 1 new strand)
- Happens during interphase (specifically the S phase)
- DNA polymerase starts DNA replication + proofreads new DNA strands for mutations

- Hydrogen bonds are broken to separate 2 DNA strands

- Each DNA strand is template for new strand
  - If template strand = AAATCGGAC, new strand = TTTAGCCTG
- Telomeres (nonsense DNA sequences) protect genes in chromosomes since DNA replication causes loss of nucleotides at the ends.

RNA Structure

- Has only one strand
- Is a polymer (monomer = nucleotides)
  - Nucleotides - 5-carbon sugar (or ribose), phosphate, nitrogenous base
    - 4 nitrogenous bases: adenine, uracil (not thymine), cytosine, guanine
- RNA types:
  - *messenger RNA (mRNA)* - made from template DNA strand during transcription; brings DNA sequence from nucleus to ribosomes to be translated
  - *ribosomal RNA (rRNA)* - are a part of ribosomes
  - *transfer RNA (tRNA)* - carries amino acids to mRNA (in ribosome) during translation to create a polypeptide (which is folded into a protein)

How DNA makes Proteins

- **Transcription**
  - mRNA sequence (codon sequence) is created from DNA template
    - DNA sequence: AAA TAA CCG GAC,
    - Transcribed mRNA sequence: UUU AUU GGC CUG
  - First, RNA polymerase binds to DNA strand at promoter region and separates the 2 strands.
  - Then, it keeps adding nucleotides and stops when a STOP codon is reached
  - Completed mRNA separates from DNA template strand and double helix reforms
- **RNA Processing**
  - Happens before mRNA strand moves out of nucleus
  - snRNPs remove noncoding regions (introns) and only coding regions (exons) remain

- exons are then spliced back together and the processed mRNA moves out of nucleus

- **Translation**
  - mRNA is translated into a sequence of amino acids which is folded into a protein
  - Occurs at a ribosome
  - tRNA carries specific amino acids in cytoplasm to ribosomes (the amino acid depends on codons of mRNA)
    - Codon chart will show what amino acid corresponds with what codon
  - A single amino acid can be encoded by multiple codons

Gene Regulation

- In humans, it is a complex process where cells turn off/on certain genes
- Basic model for gene regulation is the operon in bacteria
  - Group of functional genes + on/off "switches"
- 2 types of operons:
  - *Lac/inducible operon* - off until turned on when stimulated by environment
  - *repressible operon* - on until turned off when not needed
- Operon parts:
  - *promoter* - "on" switch; place where RNA polymerase binds and starts transcription
  - *operator* - place where the repressor binds and turns off the Lac operon
  - *TATA box* - sequence of adenine and thymine; helps RNA polymerase bind to promoter

Mutations

- **Types of Gene Mutations**
  - **Point mutation** - base-pair substitution; one nucleotide is switched for another (ex. Sickle cell anemia)
    - Can be detrimental, beneficial, or have no effect
  - **Insertion/Deletion** - deletion is adding a letter to DNA sequence, insertion is adding a letter; causes a frameshift, where everything after mutation is affected
    - Can cause abnormal/no polypeptide

- **Chromosome Mutations**
  - Abnormalities in # of chromosomes/chromosome structure
    - *Aneuploidy* - any abnormal chromosome # (ex. Trisomy-21 or Down syndrome); caused by nondisjunction
      - *Polyploidy* - type of aneuploidy with extra chromosomes sets

Genetic Engineering/Recombinant DNA

- *Recombinant DNA* - combination of DNA from two different sources into a single cell
  - Can be used for genetic engineering

Tools/Techniques for Genetic Engineering

- *Restriction enzymes* - tool that cuts DNA at specific places (recognition sequences)
  - Pieces of DNA cut by restriction enzymes = restriction fragments
- *Gel electrophoresis* - separation of DNA molecules based on size and charge
  - Smaller molecules = faster
  - DNA is cut into pieces by restriction enzymes before running a gel
- *Polymerase chain reaction (PCR)* - fast replication of DNA outside of a cell
  - DNA produced from this is used in labs to make comparisons/study

Unit 4: Evolution & Biodiversity

- Microevolution = changes in one population gene pool over many generations
- Macroevolution = creation of new species (speciation)
- ***Individuals don't evolve, but populations do.**
  - Populations - all members of a species in a certain location
- **Proof of Evolution**
  - **Fossil Record** - oldest fossils are of prokaryotes; transitional fossils exist that connect extinct fossilized species and modern ones
    - Fossils are dated through half-life of radioactive isotopes
  - **Comparative Anatomy**
    - **Homologous structures** - shows common ancestry (ex. In the bat wing, whale flipper, human arm, function varies, but bone structure is the same.)
      - Exemplifies divergent evolution
    - **Analogous structures** - similar ways of adapting; function is same, but structure is different (ex. Bat wing, fly wing)
      - Exemplifies convergent evolution
    - **Vestigial structures** - exemplifies evolution in anatomy (ex. appendix)
  - **Comparative Biochemistry**
    - Common ancestor = similar biochemical pathways
      - More closely related = more similarities
  - **Comparative Embryology**
    - Closely related = similar embryonic development
      - Ex. Every vertebrate embryo has gill pouches at some point.
  - **Biogeography**
    - Location of fossils can be evidence of common ancestor (ex. Marsupials)
  - **Molecular Biology**
    - More closely related = more similar cytochrome *c* amino acid sequence

Darwinian Theory of Natural Selection

- Populations of organisms often overpopulate until there are not enough resources
  - This causes competition in order to survive.
  - There is always variation in populations.
  - Individuals that have more useful phenotypes have a greater chance of surviving/reproducing (survival of the fittest). These traits are passed down to future offspring.
  - Evolution happens as the # of these helpful traits increase.
- *Example 1:* giraffe ancestors had short necks, with slight variations in length → giraffes with longer necks could reach more food and had greater chance of survival → more long-necked giraffes in population (individual giraffes didn't change, population did)
- *Example 2:* dark moths had greater chance of survival after Industrial Revolution; frequency of dark moths increased in population
- *Example 3:* antibiotics killed most bacteria and resistant individuals survived/reproduced; next generation of bacteria was resistant to antibiotic

Different Types of Natural Selection

- **Stabilizing Selection** - less extremes, more intermediate individuals (ex. Birth weight is mostly 6-9 pounds, not more or less since extremes are not as likely to survive)
- **Disruptive Selection** – more extremes, less intermediate individuals; causes ≥2 different phenotypes in a population (balanced polymorphism) and can create 2 new species.
- **Directional Selection** - one extreme dominates; a phenotype is completely replaced by another one (ex. Moths after Industrial Revolution)

Causes of Diversity in a Population

- **Mutations** - random changes in DNA sequence
- **Genetic Drift:** change in available genes that happens because of chance

- **Bottleneck Effect** - reduction of population size without taking animal's fitness into account (ex. Natural disasters); abnormally high/low # of certain alleles for genes
- **Founder Effect** - when small part of a population colonizes a new location; proportion of alleles differs from original population

- **Gene Flow** - when alleles move in/out of a population (often caused by migration of individuals/gametes to other populations)

Requirements for Hardy-Weinberg Equilibrium

- Characteristics of NON-EVOLVING, stable population:
  - Large population
  - No gene flow / migration (isolated populations)
  - No mutations
  - Random mating
  - No natural selection

Hardy-Weinberg Equation

- Allows for calculation of allele frequency in a population (can be used for complex situations, but only simple (2 alleles) will be discussed.
  - $\mathbf{p + q = 1}$ or $\mathbf{p^2 + 2pq + q^2 = 1}$
  - p is dominant allele, q is recessive allele

Types of isolation that cause creation of new species

- **Geographic Isolation** - happens when species are separated (ex. Natural barriers like mountains, rivers, lakes, etc.)
- **Polyploidy** - mutation that happens due to mistakes during meiosis; polyploid individuals can only breed with other polyploid individuals
- **Habitat Isolation** - happens when organisms live in the same location but don't usually meet (ex. One lives in water, one lives on land)
- **Temporal Isolation** - happens when organisms live in same location but reproduce/are active at different times
- **Reproductive Isolation** - inability to mate because of anatomical limitations (ex. Size difference)

- **Behavioral Isolation** - happens when animals are isolated because of varying behaviors (ex. Female fireflies only respond to blinking patterns of their own species)

Evolution Patterns

- **Convergent Evolution** - is when unrelated species in similar environments have similar adaptations, or analogous structures (ex. Whale and fish)
- **Divergent Evolution** - is when a population is isolated and evolves into new species; the two species still have homologous structures (ex. human, bat, whale)
- **Coevolution** - is when two species that interact affect each other's evolution (ex. Bee and flower)
- **Parallel Evolution** - is when two related species develop similar traits to adapt to similar environments (ex. North American gray wolf and Tasmanian wolf of Australia)
- **Adaptive Radiation** - when many species evolve from one common ancestor (ex. Finches in the Galapagos Islands)

Various Theories of Evolution

- **Gradualism** - Darwin supported this theory; states that evolution happens over a long period of time and big changes happen when many small ones build up.
  - Was disproven by fossil record
- **Spontaneous Generation** - states that living things come from nonliving/inanimate things; disproven
- **Punctuated Equilibrium** - most widely accepted; states that the appearance of new species is sudden and happens after long period of time without any change

Important Facts

- *Earth is ~4.6 billion years old
- **Heterotroph hypothesis** - anaerobic heterotrophic prokaryotes were first cells
- **Theory of endosymbiosis** - eukaryotic cells formed when larger prokaryotes engulfed smaller ones and didn't digest them ~1.5 billion years ago; these small prokaryotes became mitochondria/chloroplasts
- **Mass Extinctions**
  - *Permian mass extinction (250 million years ago)* - happened when volcanic eruptions released lots of lava + carbon dioxide and almost wiped out life

- *Cretaceous mass extinction (65 million years ago)* - theory is that an asteroid crashed into Earth and caused a large debris cloud that blocked the sun (dinosaurs and many other animals went extinct).

Biodiversity

- Every organism (living or extinct) is classified using taxonomy
  - We still use binomial nomenclature, which was developed by Carl Linnaeus (ex. *Homo sapiens*); has genus name + species name
  - Taxonomy builds off of evolutionary history, or phylogeny
  - All organisms share certain traits, meaning that they all have a common ancestor that lived >3 billion years ago
- Most scientists today use the three-domain system (supported by analysis of DNA)
- Order of taxa (categories): domain, kingdom, phylum, class, order, family, species

Domains

- **Domain Archaea**
  - Single-celled + prokaryotic
  - Introns are only present in some genes
  - Extremophiles are in this domain:
    - *Methanogens* - get energy by making methane using hydrogen
    - *Halophiles* - can survive in places where concentration of salt is high
    - *Thermophiles* - can survive in places where temperatures are extremely high
- **Domain Bacteria**
  - Unicellular prokaryotes
  - Can be aerobic or anaerobic
  - Are decomposers that recycle organic material
  - Lots of them cause disease
  - Some reproduce sexually (through conjugation)
  - Can be heterotrophic or autotrophic
  - Have thick cell walls

- No introns

- **Domain Eukarya**
  - Have nucleus + organelles
  - Has 4 kingdoms

Kingdoms

- **Kingdom Protista**
  - All are eukaryotes but vary a lot
  - Most are unicellular, but others are simple multicellular organisms
  - Can be heterotrophic (amoebas, paramecia) or autotrophic (euglenas)
  - Move in different ways (amoeba = pseudopodia, euglena = flagellum, paramecium = cilia)
  - Some can reproduce sexually through conjugation
  - Includes seaweed + slime mold
  - Can cause diseases
- **Kingdom Fungi**
  - Eukaryotic heterotrophs
  - Can be single-celled OR multicellular
  - Releases digestive enzymes outside of cells to make nutrients easy to absorb
  - Are decomposers and saprobes (get nutrients from rotting organic material)
  - Cell walls made of chitin
  - Can combine with algae to create photosynthetic lichens
  - Reproduce asexually (budding, spores, fragmentation) and sexually
  - Examples: mushrooms, yeast, mold
- **Kingdom Plantae**
  - Multi-celled, autotrophic eukaryotes that can't move around
  - Cell walls made of cellulose
  - Are photosynthetic and have chlorophyll
  - Carbohydrates are stored as starch
  - Reproduce sexually (alternation of generations; can be haploid gametophyte or diploid sporophyte)
  - Some contain vascular tissue, some don't
  - Examples: flowering plants, ferns, moss

- **Kingdom Animalia**
  - Multi-celled + heterotrophic eukaryotes that can move
  - Usually sexual reproduction (often sperm and egg)
  - Often classified by homologous structures + development of the embryo
  - 35 phyla exist, but 9 are most common: **porifera, cnidarians, platyhelminthes, nematodes, annelids, mollusks, arthropods, echinoderms, chordates**

Important Trends in Evolution

- **Specialized Cells/Tissues/Organs**
  - Cell - basic unit of life (ex. neuron)
  - Tissue - group of similar cells that have one specific function (ex. nerves)
  - Organ - group of tissues that perform many functions (ex. brain)
    - *Porifera:* cells are not very specialized; don't have true nerve/muscular tissues
    - *Cnidarians:* only simplest tissue forms
    - *Flatworms:* have organs; no organ system
    - *Annelids + Arthropods:* more complex; have organ systems
- **Germ Layers**
  - Formed when embryo develops; eventually develop into tissues/organs
  - Complex phyla have:
    - *Ectoderm:* outer layer; becomes nervous system + skin
    - *Endoderm:* inner layer; becomes digestive system (viscera)
    - *Mesoderm:* middle layer; becomes bones, blood, muscles
  - *Porifera + cnidarians only have 2 cell layers (ectoderm and endoderm) which are connected by the mesoglea
- **Cephalization**
  - Development of head/anterior + rear/posterior
    - Anterior: brain/ganglia, nerves
    - Posterior: digestive, reproductive, excretory organs/tissues
  - No head is present in simpler animals (porifera, cnidarians)
  - Complex animals all have a head

- **Symmetry**
  - Most simple animals: radial symmetry
  - Most complex animals: bilateral symmetry (mirrored left and right sides)
    - Echinoderms have bilateral symmetry when young but radial symmetry when older
- **Formation of Body Cavity**
  - Coelom - cavity filled with fluid that is surrounded by mesoderm (is space for organ systems)
  - Simple animals: no coelom; are acoelomates
    - Have flat bodies so every cell is in contact is environment
    - *Nematodes/roundworms are pseudocoelomates since they have tube between endoderm and mesoderm (hydrostatic skeleton)
  - Complex animals: have coelom; are coelomates
    - Ex. Annelida, Mollusca, Arthropoda, Chordata

Phyla

- **Porifera (Sponges)**
  - Not symmetrical
  - No muscle/nerve tissues + don't move (are sessile)
  - Water is drawn into vacity in the center; nutrients are filtered from it
  - Have 2 cell layers (ectoderm + endoderm connected by mesoglea)
  - Specialized cells are present; no tissues/organs
  - Asexual reproduction (fragmentation) and sexual reproduction

- **Cnidarians (Hydra, Jellyfish)**
  - Have radial symmetry
  - Vase shaped (polyp) body which usually doesn't move or medusa body which usually moves
  - Some are have a larva stage and 2 reproductive stages:
    - Asexual (polyp) and sexual (medusa)
  - 2 cell layers (ectoderm + endoderm connected by mesoglea)
  - Digest food in a gastrovascular cavity (extracellular) or in lysosomes (intracellular)
  - No transport system
  - Have cnidocytes (stinging cells)
- **Platyhelminthes (Flatworms/Tapeworms)**
  - Simple but have bilateral symmetry, a head, and 3 cell layers
  - Only one opening for both eating + getting rid of waste
  - No digestive/respiratory systems, so body is flat (nutrients/wastes can diffuse directly)
- **Nematodes (Roundworms)**
  - Unsegmented
  - Have bilateral symmetry
  - Often parasitic
- **Annelids (Segmented worms)**
  - Bilateral symmetry
  - Tube for digestive tract (different parts are crop, gizzard, intestine)
  - Excrete wastes through nephridia
  - Has closed circulatory system
  - Blood has hemoglobin + can carry oxygen
  - Oxygen + carbon dioxide diffuses through skin

- **Mollusks (Squids, Clams, Octopuses)**
  - Soft body (usually has hard shell)
  - Open circulatory system
  - Bilateral symmetry; three "zones" of body are:
    - Head-foot
    - Visceral mass - has digestive, excretory, and reproductive organs
    - Mantle - creates shell
  - Has radula (functions similar to a tongue)
  - Usually have gills + nephridia
- **Arthropods (Insects, Crustaceans, Arachnids)**
  - Have joints
  - 3 segments: head, thorax, abdomen
  - Relatively large amount of sensory apparatus
  - Have chitin exoskeleton
  - Have open circulatory system
  - Excretes nitrogenous wastes through malpighian tubules)
  - Trachea (air ducts) bring in air
- **Echinoderms (Sea stars, Sea urchins)**
  - Usually don't move/move slowly
  - Bilateral symmetry when young, radial symmetry as adult
  - Reproduce sexually (fertilization outside body) or asexually (fragmentation or regeneration)
  - Some have endoskeleton (sea stars)
- **Chordates (Fish, Reptiles, Birds, Mammals, etc.)**
  - Have notochord
  - Have a nerve cord that is hollow + dorsal
  - Some have tail that helps animals move/balance
  - Birds and mammals = homeotherms (stable body temperature)
  - Other chordates = usually cold-blooded; sometimes endotherms

Mammals

- Phylum is Chordata
- Provide milk to offspring (from mammary glands)
- Have hair + are warm-blooded
- Usually placental mammals (embryo develops in uterus + connected to mom by placenta)
    - Marsupials are born extremely early
    - Some mammals lay eggs (monotremes)

Primates

- Includes humans
- Ancestors probably ate insects
- Have opposable thumbs
- Have nails and sensitive nerve endings in hands/fingers
- Eyes face forward + are close together
- Usually have few offspring per birth and care for them for long time
- Examples: humans, chimpanzees, gorillas, orangutans, etc.

Cladograms/Phylogenetic Trees

- Branching diagram
- Represents hypothesis about evolutionary history of certain organisms

Unit 5: Organismal Biology

Plants

Plant Classification

- **Bryophytes**
  - No vascular tissue and are very small
  - Live in wet environments
  - Examples: mosses, liverworts, hornworts
- **Tracheophytes**
  - Have vessels (xylem and phloem)
  - Can be seedless (ferns; use spores to reproduce) or have seeds
  - Ones that have seeds are divided into gymnosperms and angiosperms
  - **Gymnosperms** - have cones
  - **Angiosperms** - flowering plants

Traits that Allowed Transition from Sea to Land

- Cell walls for support (made of cellulose)
- Stomates to let gases in
- Roots + root hairs to increase nutrient absorption from soil
- Waxy cuticle to prevent dehydration

Root Layers

- **Zone of cell division** - has meristem cells that divide constantly + make new cells
- **Zone of elongation** - cells elongate + push root cap down
- **Zone of differentiation** - cells here are specialized + create 3 tissue systems (xylem/phloem, ground tissue, epidermis)

Root Structure

- **Epidermis** - covers root surface + specialized for absorption
- **Cortex** - has parenchyma cells which have lots of plastids to store starch + other things
- **Stele** - also called vascular cylinder; xylem and phloem, which transport water and nutrients
- **Endoderm** - decides what minerals can enter the vascular cylinder + plant body

Types of Roots

- **Taproot** - one large root that branches into smaller lateral roots; usually in dicots
- **Fibrous root system** - common in monocots; holds plant in place
- **Adventitious roots** - roots above ground such as:
  - **Aerial roots** - in mangroves (stick out of water) or ivy to let it attach to buildings
  - **Prop roots** - support plant (ex. corn)

Stem Structure

- In monocots, vascular bundles (xylem on inside, meristem tissue in middle, phloem on outside) are scattered in the stem
- In dicots, vascular bundles are organized into a ring around stem edge

Leaf Parts

- **Epidermis** - for protection
- **Waxy cuticle** - prevents loss of water
- **Guard cells** - controls opening/closing of stomata
- **Palisade mesophyll** - photosynthesis
- **Spongy mesophyll** - photosynthesis + diffusion of gases in/out of cells
- **Veins** - transport water/nutrients from soil to leaves + carry sugar from leaves to rest of plant

Stomates

- Responsible for taking in gases (oxygen or carbon dioxide) and giving off water vapor; controlled by guard cells
  - Must be closed at times to avoid water loss
  - Guard cells control them through osmosis

Plant Reproduction

- **Asexual** - vegetative propagation (ex. Graftings, bulbs, etc.)
- **Sexual** - flower is the sexual organ
  - **Flower parts:**
    - Petals - bright colors to attract pollinators
    - Sepals - encloses and protects flower before it opens, are green

- Pistils/carpels - produces female gametophytes (has ovary, stigma, and style)
    - Ovary - contains ovule where meiosis produces ova (female gametophytes)
    - Style - long and thin stalk
    - Stigma - sticky top part of style where pollen can land
- Stamen - male flower part (made of anther + filament)
    - Anther - pollen (sperm) is produced here
    - Filament - threadlike; supports anther

➢ After plant is pollinated + fertilized, ovule becomes the seed and ovary becomes the fruit

Seed

❖ Made of
    ➢ Seed coat
    ➢ cotyledon/endosperm (food for embryo)
    ➢ Embryo

❖ Embryo consists of:
    ➢ Hypocotyl - becomes lower part of stem + roots
    ➢ Epicotyl - becomes upper part of stem
    ➢ Radicle - first organ to erupt from a germinating seed

❖ Monocot seed does not split in half, dicot seed does

Alternation of Generations

❖ Sexual life cycle where haploid (gametophyte) and diploid (sporophyte) generations alternate

❖ Gametophyte produces gametes by mitosis and these combine to make diploid zygotes
    ➢ These zygotes develop into sporophytes which produce haploid spores
    ➢ Haploid spores then produce new gametophyte

Plant Hormones

❖ **Auxins** - cause tropisms (growth toward/away from a stimulus like light)

❖ **Cytokinins** - stimulate cytokinesis + cell division

- **Gibberellins** - promote elongation of the leaves + stem
- **Ethylene gas** - promotes ripening of fruit
- **Abscisic acid (ABA)** - stops growth + makes seeds dormant

Human Physiology

Digestive System Organs

- **Mouth** - Mechanical (tongue and teeth) + chemical digestion (salivary amylase)
- **Esophagus** - No digestion occurs
- **Stomach** - hydrochloric acid (pH = 2-3) activates enzyme pepsinogen into pepsin, which breaks down proteins
- **Small intestine** - contains amylases, lipases, proteases (all digestion is finished in the duodenum, or first 10 inches)
    - Has villi and microvilli (fingerlike projections that absorb nutrients efficiently)
- **Liver** - has many functions
    - Produces bile
    - Neutralizes acids in food from stomach
    - Makes cholesterol, nitrogenous waste, and urea
    - Detoxifies the blood (alcohol + drugs)
- **Gallbladder** - stores bile for liver
- **Pancreas** - makes digestive enzymes for small intestine + makes sodium bicarbonate to neutralize stomach acid
- **Large intestine** (colon) - no digestion
    - undigested waste is removed
    - Water is reabsorbed
    - Vitamins (B, K, folic acid) are produced
- **Rectum** - temporarily stores feces until it is removed from the body

Gas Exchange

- Happens in tiny air sacs in lungs (alveoli)
- Negative pressure lets humans breathe (expanding chest decreases pressure in lungs + draws air in)

- Hemoglobin molecules transport oxygen in the blood; carbon dioxide dissolves into blood plasma

Blood Clotting

- Starts when clotting factors are released
- Platelets release thromboplastin which changes prothrombin into thrombin
  - This causes fibrinogen to change into fibrin; fibrin makes up the clot

Path of Blood

- Right atrium
- Right atrioventricular valve (also called tricuspid valve)
- Right ventricle
- Pulmonary semilunar valve
- Pulmonary artery
- Lungs
- Pulmonary vein
- Left atrium
- Left atrioventricular valve (also called bicuspid valve)
- Left ventricle
- Aortic semilunar valve
- Aorta
- All cells in body
- Returns to heart through vena cava
  - *Arteries transport blood away from heart (high pressure), veins transport blood toward heart (low pressure)

Hormones

- **Steroid hormones** - can pass through cell membrane + bind to receptor inside cell
  - This creates a hormone-receptor complex that triggers a response from nucleus
- **Polypeptide hormones** - cannot pass through cell membrane; binds to receptor on surface of cell
  - 2nd messenger is triggered in cytoplasm, which finally triggers a response from nucleus

Feedback Mechanisms

- **Negative feedback** - maintains homeostasis
- **Positive feedback** - enhances a response that already exists

Nervous System

- In vertebrates:
  - Central nervous system (CNS) - brain + spinal cord
  - Peripheral nervous system (PNS) - all nerves outside of CNS
    - Sensory: carries information from nerve endings/sensory receptors
    - Motor: consists of 2 systems
      - Somatic system - controls voluntary muscles
      - Autonomic system - controls involuntary muscles
        - Sympathetic:
          - Increased heartbeat + breathing
          - Glycogen converted to glucose by liver
          - Fight-or-flight response
          - Adrenaline raises blood sugar levels
          - Increased gas exchange
        - Parasympathetic:
          - Opposite functions of sympathetic
          - Decreases heartbeat + breathing
          - More digestion
          - Calms body down
- Basic unit of nervous system: neuron
  - When axon is polarized (at rest) sodium and potassium stay on opposite sides of membrane
  - impulse/action potential passes through an axon and causes a wave of depolarization (makes sodium flow in, potassium flow out).
  - The sodium-potassium pump then restores neuron's resting potential during the refractory period.
- Impulse travels along axon electrically; across synapse chemically

➢ Vesicles release neurotransmitters that travel across synapses

Eye Parts

- **Cones** - photoreceptors that can detect differences in color; located in retina
- **Cornea** - clear covering that protects eye + lets light into eye
- **Humor** - fluids that the eyeball is filled with; maintains eye shape
- **Iris** - controls amount of light that enters eye
- **Lens** - focuses light directly onto retina
- **Pupil** - hole in middle of iris
- **Retina** - turns light into nerve impulses that carry information to brain through optic nerve
- **Rods** - photoreceptors that are sensitive but don't detect color; located in retina

Ear Parts

- **Auditory canal** - the ear canal (where sound enters the ear)
- **Cochlea** - part of the inner ear that is filled with fluid; sends nerve impulses to brain
- **Ear bones** - includes stirrup, hammer, anvil
- **Eustachian tube** - makes sure pressure between environment and inner ear is equal
- **Oval window** - sends pressure waves to cochlea
- **Semicircular canals** - helps maintain balance, filled with fluid
- **Tympanum** - eardrum that vibrates when sound waves hit it

Excretion

- Basic unit of kidney: nephron
- Nephron functions:
  - **Filtration** of glucose, salts, vitamins, urea, etc. from the blood; happens in Bowman's capsule + is nonselective
  - **Secretion** is active and selective uptake of molecules that were not filtered into Bowman's capsule
  - **Reabsorption** is when water + nutrients filtered into nephron are absorbed into capillaries, both passive and active transport, happens in the tubule, loop of Henle, and collecting tubule
  - **Excretion** is when metabolic wastes are removed from the body

Reproduction/Development

Asexual Reproduction

- Genetically identical offspring
- Can quickly make many copies of itself
- Advantageous when in stable environment

Sexual Reproduction

- Advantageous over asexual because of genetic variation in offspring
- Increases chances of survival in unstable environment

Human Male Reproductive System

- **Testes** - where sperm is produced (male gonads)
- **Vas deferens** - carries sperm from epididymis to penis during ejaculation
- **Prostate gland** - secretes semen into urethra; is a large gland
- **Scrotum** - sac that holds testes
- **Urethra** - tube; carries sperm + urine

Human Female Reproductive System

- **Ovary** - meiosis happens here; is also the place where the secondary oocyte forms before birth
- **Oviduct or fallopian tube** - fertilization happens here; egg moves from here to the uterus after ovulation
- **Uterus** - where the embryo implants/develops when fertilization happens
- **Vagina** - birth canal (baby passes through here during delivery)
- **Cervix** - lowest part of uterus
- **Endometrium** - uterine lining

Menstrual Cycle Phases

- **Follicular Phase** - follicles in ovary respond to follicle-stimulating hormone (FSH) by growing and releasing more estrogen
- **Ovulation** - ~Day 14, luteinizing hormone (LH) levels surge, which makes the secondary oocyte rupture out of ovaries

- **Luteal Phase** - corpus luteum forms after ovulation and it releases estrogen and progesterone which thickens the uterine lining
- **Menstruation** - happens if embryo doesn't implant to the uterus; uterine lining breaks down and is expelled through the vagina

Spermatogenesis

- Sperm production begins during puberty; FSH + testosterone stimulate production of sperm by the testes
- Every diploid spermatogonium cell divides (mitosis) and creates 2 diploid primary spermatocytes.
  - Each primary spermatocyte goes through meiosis I and produce 2 haploid secondary spermatocytes.
  - Finally, each secondary spermatocyte goes through meiosis II which results in 4 genetically unique haploid sperm cells.

Oogenesis

- Production of ova starts before birth; All of the eggs a female will have throughout her life will be present when she is born.
- In embryo, diploid oogonium cell divides (mitosis) to make 2 diploid primary oocytes. These are not activated until puberty.
  - During puberty, meiosis I happens and haploid secondary oocytes are produced. These are released every time a female ovulates.
  - Meiosis II only happens if a secondary oocyte is fertilized
  - *During meiosis I and II, the cytoplasm divides unequally to create 1 active ovum + 2 small polar bodies

Development of the Zygote

- The zygote goes through very quick mitotic division after fertilization (cleavage) and forms a blastula full of fluid.
- After this, the blastula continues to go through mitotic division (gastrulation) and forms a 3-layered embryo (gastrula)
  - Three embryonic layers:
    - **Ectoderm** - becomes nervous system + skin

- **Endoderm** - becomes the viscera (digestive organs, lungs, liver, etc.)
- **Mesoderm** - becomes blood, bones, and muscle

Extraembryonic Membranes (Bird Embryo)

- **Chorion** - located under the shell; facilitates diffusion of gases between atmosphere and inside of the egg
- **Yolk sac** - contains the yolk (food for embryo)
- **Amnion** - surrounds the embryo with amniotic fluid
- **Allantois** - similar to mammalian placenta (where embryo receives certain gases + gets rid of wastes

Human Immune System

Nonspecific Defense

- **1st Line of Defense** - mucous membranes, cilia in lungs, skin
- **2nd Line of Defense**
  - *Inflammation* - increased body temperature + swelling
  - *Histamine* - increased blood flow to affected area
  - *Interferons* - chemicals that can stop viral infections
  - *Phagocytes* - a kind of white blood cell that engulfs foreign invaders

Specific Defense (3rd Line of Defense)

- **B lymphocytes** - create antibodies that are effective against a specific antigen
  - Antibodies can only bind to one type of antigen; they form antigen-antibody complexes that can be engulfed by phagocytes
- **T lymphocytes** - fight pathogens directly (cell-mediated response)

Clonal Selection

- An antigen that enters the body activates a very specific B/T lymphocyte
  - The selected lymphocyte clones itself thousands of times and become:
    - **Plasma cells** - short-lived; immediately neutralize antigens
    - **Memory cells** - stay in the body for much longer; neutralize antigens

Types of Immunity

- **Passive Immunity:** temporary; antibodies are borrowed and don't remain for long (ex. Maternal antibodies given to baby)

- **Active Immunity:** permanent; antibodies are made by the person after being sick/getting a vaccine

Blood Types

- Blood type depends on what type of blood cell antigen someone has (A, B, O)
- Type O is said to be a universal donor since it has no antigens.

Extra Information

- When immune system fails, allergies + autoimmune diseases happen

Animal Behavior

- Behavior - way organism responds to changes in internal/external environment
  - Can be learned or innate
  - Triggered by stimuli (changes in environment)

Fixed action pattern (FAP)

- Stereotypical innate behavior caused by external stimuli (sign stimuli)
  - Releasers - stimuli exchanged between members of a species

Learning

- Complicated process where the way an organism responds changes due to experience
- **Habituation** - simple kind of learning where animal ignores a constant stimulus
- **Associative learning** - a type of learning where a connection is made between one stimulus and another through experience. Two types of this are:
  - **Classical conditioning** - Pavlov's experiment where dogs associated food with a bell ringing and salivated every time they heard it (even without seeing food)
  - **Operant conditioning (Skinner)** - animal learns to behave a certain way to receive reward/avoid being punished; animals are trained this way
- **Imprinting** - learning that happens during a certain (sensitive) time in an organism's life (ex. Geese hatchlings following scientist instead of mother goose)

Social Behavior

- Usually between ≥ 2 members of same species

- **Cooperation** - allows individuals to be more successful doing certain tasks (ex. Wolves hunting in a pack)
- **Agonistic behavior** - aggressive behavior (either threats or combat) to settle conflicts
  - Usually because of food or mates + will often have a dominance hierarchy (or pecking order)
- **Territoriality** - use of agonistic behaviors to defend territories from rivals
- **Altruism** - behavior that reduces an individual's fitness but improves the fitness of the group overall (ex. Worker bee sacrificing itself for the hive is advantageous because of kin selection)

Other Famous Scientists

- Karl von Frisch studied honeybee communication; Niko Tinbergen studied the fixed action pattern

Ecology

- Ecology - study of how organisms interact with each other/their environment
- **Basic Vocab:**
  - *Population* - group of individuals (same species) that live in the same area; can breed + interact with one another
  - *Community* - all organisms that live in same area
  - *Ecosystem* - all organisms + nonliving (abiotic) factors that they interact with
  - *Abiotic factors* - nonliving (ex. Soil, rocks, wind, water, temperature, sunlight)
  - *Biotic factors* - all organisms that a certain organism can react with (ex. Birds, parasites, insects, prey, predators)
  - *Biosphere* - ecosystem on a global scale
  - *Niche* - what organism eats/needs for survival

Population Properties

- *Size* - total # individuals in population (limited by # of births, # of deaths, immigration, emigration)
- *Density* - # of individuals per unit area/volume; sampling techniques (ex. Mark and recapture) are used to count them

- *Dispersion* - how individuals are spaced out in the area the population lives in, Three types are:
  - **Clumped** - most common pattern (ex. Schools of fish)
  - **Uniform** - evenly spaced out
  - **Random spacing** - happens when nothing pressures individuals to live in groups/along (ex. Trees in forest)

Population Growth

- Population grows exponentially until carrying capacity (max that environment is able to support) is reached
  - Carrying capacity sometimes changes when the changes happen in the environment itself

Strategies of Reproduction

- *R-strategists:*
  - Lots of small young
  - Little/no parenting
  - Matures rapidly
  - Reproduces only once
  - Ex. insects
- *K-strategists:*
  - Fewer but larger young
  - More nurturing/involved parenting
  - Matures slowly
  - Reproduces multiple times
  - Ex. mammals

Community Structure & Interactions between Populations

- Communities are various populations and their interactions with each other/the environment

- 3 main categories of interactions:
  - **Competition** - G. F. Gause made the competitive exclusion principle (states that 2 species cannot exist together in a community if they compete for the same resources)
    - Two possible outcomes for competition of same resources within community:
      - Extinction/evolution by natural selection (resource partitioning)
      - Divergence in evolution to avoid competition (character displacement)
  - **Predation**
    - Is when animal eats animal or animal eats plant
    - Prey evolved defense mechanisms to protect themselves from predators
      - *Plants* - spines, thorns, poisonous chemicals
      - *Animals* - active defense (hiding, running) and passive defense (camouflage or mimicking poisonous animals)
  - **Feeding** - relationships between organisms based on feeding
    - **Mutualism** - (+/+) relationship; beneficial to both organisms (ex. Gut bacteria and humans)
    - **Commensalism** - (+/o) relationship; beneficial to one organism, neutral to the other (ex. Whales and barnacles)
    - **Parasitism** - (+/-) relationship; beneficial to one organism, harmful to the other (ex. Tapeworms and humans)

Food Chain

- *Food chain* – sequence of organisms where energy is transferred from trophic/feeding level → another level
- Energy moves through food chain from producers → herbivores → carnivores
  - ~10% of energy in a trophic level changes to organic matter in trophic level that follows (shown in food pyramid)
  - **Producers**
    - Convert light into chemical energy + have largest biomass

        - Ex. phytoplankton, photosynthetic algae, green plants
    - **Primary Consumers**
        - Consume producers (are herbivores)
        - Ex. zooplankton, grasshoppers
    - **Secondary Consumers**
        - Consume herbivores/primary consumers (are carnivores)
        - Ex. small fish, frogs
    - **Tertiary Consumers**
        - Consume secondary consumers (are carnivores)
        - Have least biomass; unstable population size
        - Ex. hawk
- **Productivity** - how fast producers make organic matter
    - **Gross primary productivity:** amt. of energy changed to chemical energy per unit time
    - **Net primary productivity:** `gross primary productivity – energy used (for respiration)`
- **Biological Magnification** - more accumulated toxins in organisms at top of food chain than in lower organisms
- **Decomposers** - bacteria + fungi; break down organic material so nutrients can be recycled

Ecological Succession - when disturbed ecosystem is rebuilt

- **Primary ecological succession** - no life or soil; pioneer organisms (lichens) arrive first to a disturbed ecosystem; soil building is also seen in this type of succession
    - When ecosystem becomes stable again, is the climax community
- **Secondary succession** - disturbed ecosystem but still has soil

Biomes - large areas that are classified by amt. of rainfall + temperature

- **Marine**
    - Largest + most stable biome
    - Responsible for majority of food/oxygen on Earth
    - Further subdivided based on amt. of sunlight, depth, etc.

- **Desert**
  - < 10 inches rainfall annually
  - Very extreme temperature difference between day and night
  - Many plants are drought resistant + often have shallow roots
    - Ex. cacti, mesquite, sagebrush
    - Some plants only grow after rain and die soon after
  - Many animals move around during night, early morning, or late afternoon to avoid extreme heat
    - In the daytime, they stay underground/in shade
    - Ex. snakes, lizards, rodents, insects
- **Tropical Rain Forest**
  - Near equator where there is lots of rain (humid) + have stable temperatures all year long
  - 4% of land on Earth, but 20% of food production on Earth
  - Extremely diverse; contain the most species of plants and animals
  - Tall trees create canopy at the top
- **Temperate Deciduous Forest**
  - Located in North America (northeast direction)
  - More plant species diversity than taiga
  - Trees here lose their leaves in winter
    - Decomposing fallen leaves create fertile soil
  - Animal examples: squirrels, foxes, bears, deer
- **Temperate Grasslands**
  - Large areas of land in tropical + temperate zones
  - Low/unstable rainfall, so trees can't survive
  - Grazing mammals (bison) and burrowing mammals (prairie dogs) live here
- **Conifer Forest (Taiga/Boreal Forest)**
  - Located in northern Canada + other northern regions

- Largest land biome
- Have some evergreen forests + lakes/ponds
- Lots of rainfall, extremely cold in winter (snows a lot)
- More animal species diversity than tundra

- **Tundra**
  - Located even farther north in North America, Europe, Asia
  - Very little rainfall; very cold (ground is frozen)
  - No trees, many lakes/ponds
  - Many insects, which attract birds in summer

Chemical Cycles

- **The Water Cycle**
  - Water evaporates from oceans, lakes, or plants through transpiration
  - Water vapor forms clouds which causes water to rain down again
  - Some water becomes groundwater, other water enters rivers/lakes/oceans
- **The Carbon Cycle**
  - Cell respiration releases carbon dioxide and uses up oxygen
  - Burning fossil fuels releases carbon dioxide
  - Carbon dioxide is removed from atmosphere and oxygen is released by plants (photosynthesis)
- **The Nitrogen Cycle**
  - *Nitrogen-fixing bacteria* live in roots (legumes) + convert free nitrogen to ammonium ions (NH_4^+)
  - *Nitrifying bacteria* change ammonium ions into nitrites (NO_2^-) and finally into nitrates (NO_3^-)
    - Plants absorb nitrates and are eaten by animals
  - *Denitrifying bacteria* change nitrates back into free nitrogen
  - *Decomposers* break down organic matter into ammonia (NH_4^+)

Impact of Humans on the Biosphere

- Humans disturbed/destroyed/changed countless ecosystems through

- ➢ Deforestation
- ➢ Depleting/contaminating groundwater
- ➢ Destroying habitats
- ➢ Minimizing biodiversity
- ➢ Destroying ozone layer
- ➢ Climate change
- ➢ Acid rain
- ➢ Invasive species/toxins

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