ZNOTES.ORG

UPDATED TO 2020 SYLLABUS

IB MIDDLE YEARS PROGRAM
BIOLOGY

SUMMARIZED NOTES ON THE THEORY SYLLABUS

1. Cell Structure

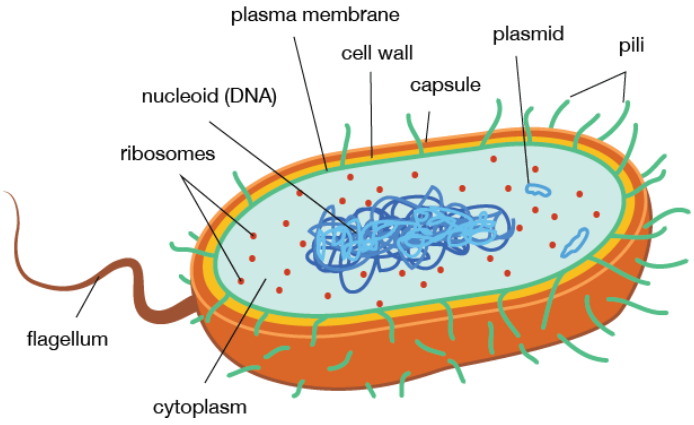
1.1. Cell Theory

- Original Cell Theory
  - All living organisms are composed of cells. They may be unicellular or multicellular
  - The cell is the basic unit of life
  - Cells arise from pre-existing cells
- Modernized ideas developed from cell theory
  - Energy flow occurs within cells
  - Hereditary information is passed from one cell to another
  - All cells have same basic composition
- Characteristics of Life: Nutrition, Respiration, Growth, Excretion, Homeostasis, Reproduction, Movement
- Young Cell → Cell Division → Cell Growth → Cell Specialization → Mature Cell
  - Programmed Cell Death

1.2. Cell organelles

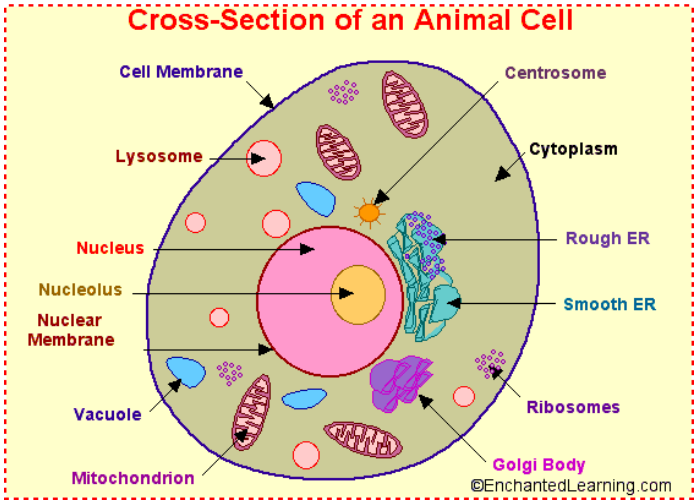
Prokaryotic Cells

- Cell wall
  - Gives cell rigid structure
- Plasma membrane
  - Controls what gets in and out of the cell
- Cytoplasm
  - Holds all organelles together, gives cell structure
- Nucleoid
  - Unbound clump of genetic matter
- Plasmid
  - Floating chunks of genetic matter
- Flagella
- Pili



Eukaryotic Cell

- Nucleus
  - Control center of cell
  - Replicates DNA
  - Transcription and modification of RNA
  - First is nuclear envelope which contains nuclear pores which send materials in and out
  - Then is chromatic which contains genetic matter (blobs)
  - Then is center which is nucleolus (the only thing that matters)
  - Chromatin = DNA
    - Stored in chromosomes
      - Chromosome: Long and thin, hard to see even with electron microscope. However, when it is cut or multiplies, it becomes short and thin, this is visible with a light microscope
  - the nucleolus is inside of the nucleus and produces ribosomes



- Endoplasmic Reticulum
  - Rough
    - Many interconnected sacs with ribosomes attached to its membrane (it's what makes it rough)
    - synthesizes and packages proteins
    - folds protein molecules in sacs called cisternae
    - transport of synthesized proteins in vesicles to the Golgi apparatus
  - Smooth
    - contains enzymes that help synthesize lipids, phospholipids and steroids
    - detoxification
    - contains ions that the cell may need later such as sodium and calcium
- Golgi Apparatus
  - transports, modifies, and packages proteins and lipids into vesicles
  - takes products from rough ER (bulk flow), then the cisternae process, sort and label the chemicals
  - they are then dispatched to other parts of the cell or to the extracellular space
- Mitochondria
  - powerhouse of the cell
  - Production of energy via synthesis of ATP molecules
  - Important in cellular respiration

    - also contains strands of glycerol as reserve power
  - regulates cellular metabolism
- Lysosomes
  - waste treatment plants of the cell
  - breaks down cellular waste
  - transports undigested material to the cell membrane for removal
  - cell breaks down if the lysosome explodes
- Vesicles
  - Transports materials in or out of cells
- Vacuole
  - isolates materials that may be harmful/waste products
  - contains water
  - maintains turgor/hydrostatic pressure
  - maintains pH
  - exports unwanted substances
- Cell Membrane
  - Semi-permeable membrane, made of proteins and lipids
  - Semipermeable: Allows certain substances to enter
  - All Eukaryotic Cells have a cell membrane
  - Made of protein and lipids
- Cytoplasm
  - Site for all metabolic reactions & holds organelles
  - Metabolism: Sum total of all bodily reactions
  - Nearly all water
    - Some dissolved substances such as minerals
- Ribosomes
  - Site for protein synthesis
    - Amino acids used as material, and RNA as instructions
  - Attached to a network called the RER or scattered freely throughout the cytoplasm
  - Protein is needed for repairing damage or directing chemical processes
- Centrosomes
  - give structure to the microtubule
  - assemble microtubules
  - centrioles
- Cytoskeleton - gives structure
- Cell membrane
  - protects the cell and encloses its contents
  - monitors what enters and exits the cell
- Cell wall (plants only)
  - provides protection, structure and support
  - prevents water loss
  - protection from the environment
- Chloroplast (plants only)
  - sites of photosynthesis
  - contain chlorophyll (granum)

1.3. Difference between Prokaryotic and Eukaryotic Cells

Prokaryotic Cell	Eukaryotic Cell
Lacks a membrane bound nucleus	Membrane bound nucleus
Smaller and simpler	Specialized organelles
Bacteria and Archaea	Larger
Unicellular	Endomembrane System
	Mitochondria
	Plants, animals, Fungi and Protists

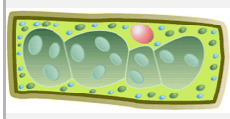
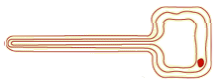
1.4. Difference between Animal and Plant Cell

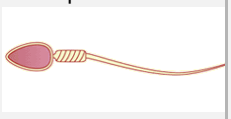
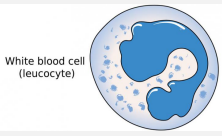
Plant Cell	Animal Cell
• Has a cell wall • Contains chloroplasts • Large vacoule • Stores carbs as starch or sucrose	• No cell walll • No chloroplasts • Small vacoule • Stores carbs as glycogen

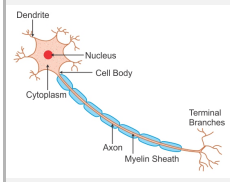
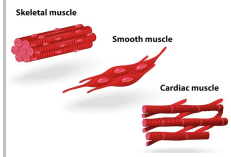
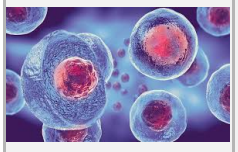
1.5. Levels of Organization

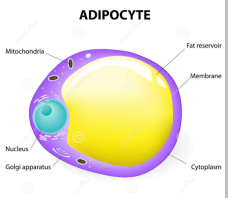
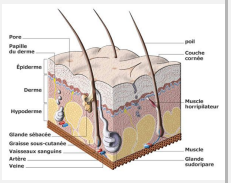
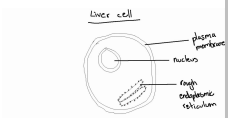
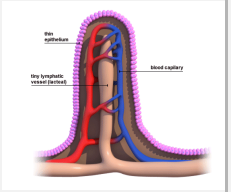
- Cells
- Tissues
- Organs
- Organ systems
- Organism

1.6. Specialized cells

Cell	Function	Adaption
Leaf cell 	Absorbs light energy for photosynthesis	Packed with chloroplasts. Regular shaped, closely packed cells form a continuous layer for efficient absorption of sunlight.
Root hair cell 	Absorbs water and mineral ions from the soil	Long 'finger-like' process with very thin wall, which gives a large surface area.

Cell	Function	Adaption
Sperm cell 	Fertilises an egg cell - female gamete	The head contains genetic information and an enzyme to help penetrate the egg cell membrane. The middle section is packed with mitochondria for energy. The tail moves the sperm to the egg.
Red blood cells 	Contain haemoglobin to carry oxygen to the cells. Remove CO2 from body by transporting it to the lungs.	Thin outer membrane to let oxygen diffuse through easily. Shape increases the surface area to allow more oxygen to be absorbed efficiently. No nucleus, so the whole cell is full of haemoglobin. Made in the bone marrow.
White blood cells 	Battle viruses, bacteria and other foreign invaders. Destroy harmful substances and prevent illness.	Made in the bone marrow and stored in blood and lymphatic tissue. Lifespan varies. Bone marrow is constantly producing WBCs. Can change shape to squeeze out of blood vessels and get to the site of infection. Can change shape to engulf bacteria.

Cell	Function	Adaption
Neurons/Nerve Cells 	Transmit and process information by sending electrical impulses.	Located in the brain and nervous system. 0.1 mm in diameter. Very long. Myelin sheath is a fatty layer that prevents the electrical impulses from affecting other parts of the body and increases the speed of conduction. Have extensions called dendrites and axons that bring information into and, release information from the cell itself. Some also contain structures and carry chemicals that are specialized for electrochemical communication
Myocytes/Muscle Cells 	Cardiac muscle cells comprise the middle muscular layer of the heart. Skeletal muscle cells are connected to the skeleton and help in locomotion. Smooth muscle cells are responsible for involuntary movement like digestion.	Have cylindrical organelles called myofibrils. Made up of banded fibers. Muscle cells can contract and this causes things to move. Energy is needed for this to happen so muscle cells contain lots of mitochondria.
Stem Cells 	Undifferentiated cells that can develop into different types of cells and have many potential scientific uses.	Unspecialized and can divide continuously. Could be used to treat diseases in the future.

Cell	Function	Adaption
Adipocytes/Fat Cells 	Store fat. Help the body maintain proper energy balance, store calories, mobilize energy sources in response to hormonal stimulation and command changes by signal secretion. Cushion and insulate the body.	White: contain large fat droplets and only a small amount of cytoplasm. Brown: contain fat droplets of differing size, a large amount of cytoplasm, numerous mitochondria, and round, centrally located nuclei.
Keratinocytes/Skin Cells 	Acts as a physical barrier between organism and environment. Prevents excess water loss. Protect from foreign invaders.	Epidermis, dermis, stratum, corneum. Dead skin cells break away making room for new ones. 16% of your weight is skin. You lose 1 million cells everyday. Contains melanin which gives color and protects from UV radiation. Renews itself every 30 days.
Hepatocytes/Liver Cells 	Involved in carbohydrate, fat and protein metabolism. Build proteins. Produce bile. Process molecules found in the body like hormones. Process foreign substances like medicines and alcohol.	Have abundant smooth ER and rough ER for protein and lipid synthesis. Have lots of mitochondria.They are filled with all sorts of other enzymes, and hence are the main space where drugs are metabolised.
Villi Cells 	Allows for absorption in the small intestine.	Microvilli increase the surface area for absorption. Thin epithelium = increased rate of diffusion. Extensive blood capillary network. Lacteals absorb fatty acids and glycerol.

1.7. Additional Structures in Cells

- Glycogen granules (glycosomes) - found in the cytoplasm
  - Independent metabolic unit composed of a highly branched polysaccharide and various proteins involved in its metabolism
- Microtubules - provide structure and shape to the cytoplasm
  - Transport: act as routes for various cell organelles to move
  - Also help in cell division; pull the spindle and cell apart once chromosomes have been replicated
- Keratin fibre - structural protein
  - Very important for epithelial cells which make up the skin
  - Filaments anchor to each other which stops cells from pulling apart
  - Found in extensively skin, nails and hair
- actin filaments - found in the cytoplasm; composed of actin polymers
  - A kind of cytoskeletal filament that is important for cell shape, muscle contraction, and cell adhesion
- Myosin filaments - prototype of a molecular motor (a protein that converts chemical energy in ATP to mechanical energy)
  - Help form myofibrils which are key in muscle cells and muscle contraction
- Pseudopodia - temporary finger like projections from the cell membrane that aid in movement and ingestion; filled with cytoplasm
- Vesicles - a structure consisting of a liquid enclosed by a lipid bilayer
  - Form naturally during the processes of secretion, uptake and transport of materials within the plasma membrane
- Microvilli - microscopic cellular membrane protrusions that increase the surface area for diffusion, minimize any increase in volume, and are involved in a wide variety of functions, including absorption,secretion, and cellular adhesion
- Flagella - a long, whip-like structure that helps some single celled organisms move
  - Composed of microtubules
- Cilia - slender protrusion that project from the much larger cell body
  - Motile - found in the lungs, respiratory tract and middle ear
    - Rhythmic waving or beating motion
    - Make sure airways are clean so we can breathe easily
  - Primary - single appendages on surface of cells
    - Ex: kidney tubules; cilia bend with urine flow and send a signal to alert the cells that there is a flow of urine

2. Biomolecules

2.1. Diffusion

- Occurs when particles spread
- Move from a region where they are in high concentration to a region where they are in low concentration.
- Occurs when the particles are free to move
  - True in gases and for particles dissolved in solutions
- Passive; no energy used
- Experiment: Potassium Manganate VII crystal in a jar of water
  - It is a purple solid
  - When placed in water, we observe the purple color spreading through diffusion
  - After a while, the color is consistently purple throughout the water

2.2. Osmosis

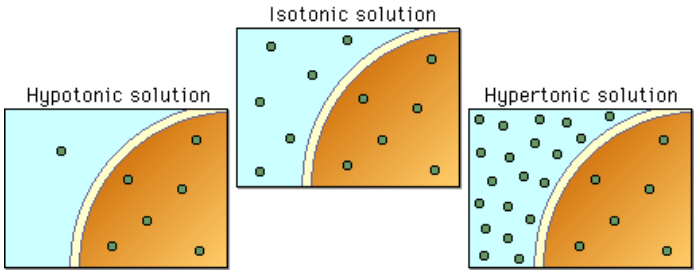
- Water can move across cell membranes because of osmosis. For osmosis to happen you need:
  - Two solutions with different concentrations
  - A partially permeable membrane to separate them
- Partially permeable membranes let some substances pass through them, but not others.
- Water moves from high to low concentration
- Water potential: The pressure/concentration of water
  - Water potential judged by how dilute a solution is
    - A more dilute solution has more water potential
      - Eg. A solution of 10 mg of solute per 100 ml (10 mg/100 ml0 of water has more water potential than a solution of 20mg solute per 100 ml water (20 mg/100 ml)
    - Water potential is inversely proportional to amount of solute
- Experiment: Potato Cylinders in NaCl solution
  - Take 9 thin potato sticks (three per solution), weigh them, measure their length, and put them in solutions of NaCl of varying concentrations (20%, 10%, 0%)
  - Leave undisturbed for 20 minutes
  - Take them out and gently blot with tissue paper and then weigh them and measure them again

2.3. Active Transport

- Dissolved molecules move across a cell membrane from a lower to a higher concentration
- Particles move against the concentration gradient - and therefore require an input of energy from the cell.
- Sometimes dissolved molecules are at a higher concentration inside the cell than outside, but, because the organism needs these molecules, they still have to be absorbed. Carrier proteins pick up specific molecules and take them through the cell membrane against the concentration gradient.

2.4. Types of Solutions

- Isotonic Solution: A solution with the exact same concentration of solute as mass (Eg. cell) in question
  - Can be determined by examining the line of best fit. Where the line intersects the X axis (X intercept) is the solute concentration of the cell, and the solute concentration in a isotonic solution
  - Isotonic Solution has equal water potential as well
- Hypotonic Solution: A solution with a higher solute concentration than the cell
- Hypertonic Solution: A solution with a lower solute concentration than the cell
- An Animal Cell:
  - In an Hypotonic Solution
    - The water will move into the cell as it has less water potential than the solution. Due to the water entering the cell, the cell will expand and eventually burst
  - In a Hypertonic Solution
    - Water will leave the cell as the solution has less water potential. The cell will shrink and eventually shrivel up
- A Plant Cell:
  - In Hypotonic Solution
    - Water moves into the cell (reason stated in animal cell) and the plant cell becomes turgid, however it does not explode due to its cell wall
  - In a Hypertonic Solution
    - Water moves out of the cell, and the cell moves away from the cell wall. This is called plasmolysis
      - The cell wall remains in place and doesn't shrink
        - The solution between the cell and its cell wall will have the same solute concentration as the Hypertonic solution
- Plasmolysis: The shrinking of the cell membrane away from the cell wall, when a plant is placed in a Hypertonic solution

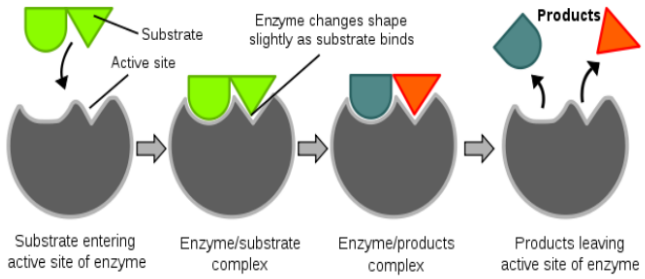


2.5. Enzymes

Properties

- Proteins which act as biocatalysts and speed up metabolic reaction
- Enzymes play an important role in
  - Metabolism, Diagnosis, and Therapeutics.
- Metabolism: The sum of all biochemical reactions in our bodies'
- Anabolism
  - Reactions which combine smaller molecules and create bigger molecules. Eg. Photosynthesis

    - Photosynthesis Equation: 6CO2 + 6H2O —> C6H12O6 + 6O2
- Catabolism
    - Reactions which break down bigger molecules. Eg. Respiration
        - Equation for Respiration: C6H12O6 + 6O2 —> 6CO2 + 6H2O + Energy
- All biochemical reactions are enzymes catalyzed in the living organism.
- Enzyme can be used therapeutically such as digestive enzymes.
    - are proteins that increase the rate of reaction by lowering the energy of activation
- They catalyze nearly all the chemical reactions taking place in the cells of the body.
- Not altered or consumed during reaction.
- Reusable
- Most enzymes end with “ase”
    - Eg. _____ ase,
- The blank spot is for the substrate
    - Substrate is the compound to be broken down.
        - Each enzyme has its own specific substrate
            - Enzymes remain inactive/inert until they interact with their substrate
- lock and key mechanism
- Active site:



Factors that affect rate of production

- Denatured: When an enzyme has lost its shape
    - Enzymes have optimum temperature and PH
        - If the optimum temp is exceeded, they start to look like their melting, and lose their definite shape, which makes it impossible for their substrate to fit within their active site
            - Bodily enzymes usually have an optimum temp of 35-40 celsius
- Extremely high temperatures are very dangerous for enzymes
    - Can denatured active site
- Extremely low temps lead to very low amount of kinetic energy
    - Very few enzyme/substrate complexes found
    - Active sites become inactive
- pH level (6-8 near neutral) is optimal
    - Few enzymes prefer acidic or basic conditions
        - Pepsin - 2
        - Amylase - 7
        - Lipase - 12
- Higher concentration of substrates means faster rate of production

Real-life Applications of Enzymes

- Treating Disorders
    - Ex: dissolving internal blood clots, dissolving hardened walls of blood vessels, etc.
        - Streptokinase, Urokinase
        - Taken as medicine to help spinal or brain injury patients who are prone to life threatening blood clots
        - Serratiopeptidase used to treat atherosclerosis (hardening and thickening of blood vessel walls)
- Assist metabolism
    - Used for old or geriatric patients
    - When old, human body cannot secrete digestive enzymes
    - Instead consume enzymes in the form of medicine (papain)
- Laundry Detergent
    - Protease dissolves proteins like blood and sweat
    - Lipase dissolves lipids- butter, oil, grease stains
    - Amylase dissolves carbs - chocolate, other foods
- Leather industry
    - To create leather, hair, fat, and protein must be removed from cow’s hide
    - This is done by protease and lipase

2.6. Biomolecules

Introduction

- All living things get energy that they need to function from food in the form of biomolecules
- Categories
    - Carbohydrates
    - Proteins
    - Lipids
    - Nucleic acids
    - All are composed of carbon, hydrogen, and oxygen
- Polymers: long molecules which are made of repeating monomers
- Momer: an individual piece that repeats

Carbohydrates

- Are made of sugars
- Each part is a simple sugar
- The molecules is a complex carbohydrate
- Carbs give energy

$$C_6H_{12}O_6$$

- Aka saccharides

- Monosaccharides - a single piece
  - Single unit of sugars
  - Water soluble
  - Sweet
    - Eg. Glucose and Fructose
- Disaccharides - 2 pieces
  - 2 units together
  - Sweet
  - Water Soluble
    - Eg. Sucrose and Maltose
- Polysaccharides - many pieces
  - Many units joined together
  - Not Sweet
  - Not Water soluble
    - Eg.
      - Starch: Stored food in Plants
      - Glycogen: Stored food in animals
      - Cellulose: Cell wall of plant
- Carbs are also used in cell walls of plants

Proteins

- C, H, O, N and sometimes S
- Proteins made of Amino acids (20 different types known) in different combinations to form a protein
- Protein mo. made of 100s of amino acids joined together
- Amino acids (single units) to Peptides (chains) to polypeptides (multiple chains
  - Some proteins made if 1 pp chain or more

Fat/Lipids

- C, H, and O
- 2 types:
  - Unsaturated: Liquids at room temperature
  - Saturated: Solid at room temperature
- Consist of 1 Glycerol and 3 Fatty Acids

Nucleic Acids

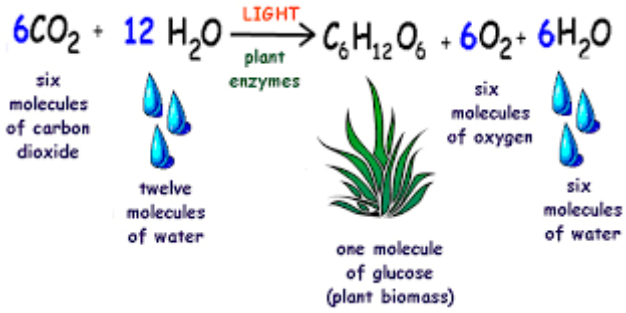
- DNA (DeoxyriboNucleic Acid)
  - Hereditary material in all living organisms
  - Structure of DNA
    - Double Helix
    - Consists of 2 antiparallel polynucleotide chains
      - Antiparallel: Parallel but going in the opposite direction
      - Each chain consists of Nucleotides. Made of:
        - Deoxyribose sugar
        - Phosphate
        - Nitrogenous base. 4 types
          - A - Adenine (Heavy)
          - T - Thymine (Light)
          - G - Guanine (Heavy)
          - C - Cytosine (Light
            - A pairs with T
            - G pairs with C
- RNA (RiboNucleic Acid)
  - No T, T replaced by U
  - Used as instructions for creating proteins. Amino acids are material

Tests for Various Biomolecules

- Proteins: Biuret reagent, protein turns from blue to purple (violet to be precise)
- Carbs: Iodine, Starch turns blue-black
- Sugars: Benedict's Reagent, sugar end up brick red
  - Blue → Green → Orange → Red
- Fats: Emulsion test, dissolve fat in alcohol, add water. Milky white means presence of lipids/fats

3. Plant Biology

3.1. Photosynthesis



- photosynthesis - the process by which green plants and some other organisms use sunlight to synthesize nutrients from carbon dioxide and water
  - energy is stored as starch
- key events:
  - absorption of light energy by chlorophyll
  - converting light energy into chemical energy
    - water is split into oxygen and hydrogen
  - reduction of CO2 into carbohydrates

Factors Affecting Rate of Photosynthesis

- Light
- Water
- Carbon Dioxide
- Temperature (optimal is 37 degrees C)

Experiments

1. Chlorophyll
    1. Take a plant with variegated leaves and put it in a dark room for 3 days (destarching)
    2. Place it in sunlight for 6 hours
    3. Take a leaf and place it in boiling water and then immerse it into alcohol
        1. Take the leaf in the beaker of alcohol and place it in a bath of boiling water until the alcohol begins to boil

2. The hot water kills the leaf, and the alcohol kills the chlorophyll, removing it from the leaf
4. Place iodine on the leaf - the parts with chlorophyll will turn a blue-black; other parts will be a yellow/brown

2. Light - repeat chlorophyll experiment but with two different normal plants; place one in the dark and one in the light
3. Carbon Dioxide
    1. Destarch two plants
    2. Cover both plants with bell jars
        1. In one, place a dish containing KOH (this absorbs CO2)
        2. Leave the other one as it is
        3. Seal the bottom of the bell jars
    3. Keep the plants in sunlight for two hours
    4. Try starch test

Light and Dark Reactions

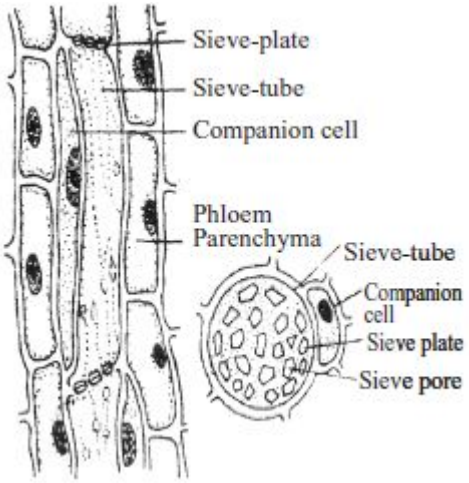
- Light Reaction
    - Requires light
    - Occurs in the thylakoids
    - When the light energy from is trapped inside the thylakoid, it excites the electron moving along the electron transport chain
    - As a result, NADP+ is converted into NADPH
    - Additionally, ADP is joined to another phosphate group and becomes ATP
    - Water molecules are split into hydrogen and oxygen
    - The byproducts of this reaction are ATP, NADPH and O2
- Dark Reaction
    - Also known as the calvin cycle
    - Does not require light
    - In this process, ATP, NADPH, carbon dioxide and hydrogen are joined together to form glucose
        - This is also called carbon fixation
    - When this happens, ATP goes back to being ADP and NADPH goes back to being NADP+
    - ADP and NADP+ are recycled back into the light reaction

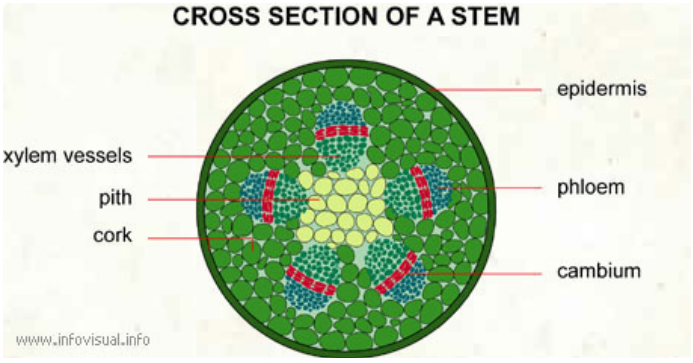
3.2. Transportation in Plants

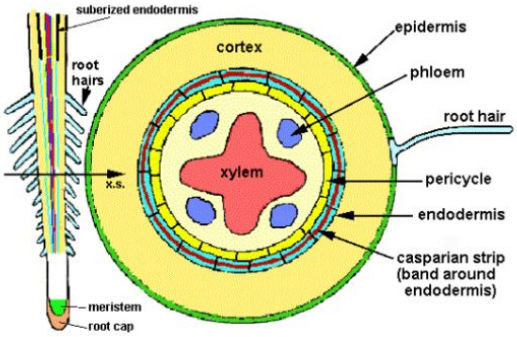
Vascular System

- Xylem - moves water and minerals obtained from the soil throughout the plant
    - No cell contents or nucleus
    - They are dead cells
    - Side walls are strengthened by lignin to prevent damage
- Movement of water
    - In the roots, cells are in contact with the soil and actively take up ions
    - This creates a concentration difference of ions between the water and the soil, so water from the soil moves into the root
    - From here, the water moves through the roots and into the xylem tube
        - The cells in the xylem lose their cell walls so that they can transport water more easily
        - The water moves up the xylem through osmosis
    - From here, water is distributed to the leaves who use it for photosynthesis
    - Some water goes to the stomata where it swells the stoma
- Transpiration
    - Plants need water for photosynthesis; also helps plants cool down
    - Water is absorbed in the roots and evaporated out of the leaves
    - Water is lost through the stomata
        - This water is replaced by the xylem vessels in the leaf, creating a suction which pulls water from xylem cells of the roots, causing the water to move upwards
        - Root pressure at night; transpiration during the day
    - Factors affecting transpiration
        - Light
        - Temperature
        - Humidity
        - Wind
    - Transpiration rate can be measured using a potometer
        - Changing the conditions around the potometer will change the rate of transpiration
        - It is a device used for measuring the rate of water uptake of a leafy plant shoot, mainly due to transpiration
- Guard cells
    - Water enters the guard cells
        - Becomes turgid
        - Thin outer wall stretches more than thich inner wall
        - Stoma opens
    - Water lost from guard cells
        - Guard cells become flaccid
        - Walls not stretched
        - Stoma closes
- Phloem - translocation takes place; movement of the products of photosynthesis, as well as amino acids
    - Translocation takes place in sieve tubes with the help of companion cells
        - Transfer of material like sucrose using ATP
        - Increases osmotic pressure of the tissue → water moves in
    - Columns of sieve tubes with sieve plates at either end
        - Sieve cells have thin walls; they lose their nucleus and organelles, but retain their plasma membrane
    - Companion cells sit next to the sieve tubes; they control the sieve tubes/cells

- They have a dense cytoplasm and a nucleus
- They are living cells







- Movement of sugar (sucrose) from source to sink
  - Food is synthesized in the green parts of the plant and deposited in the non-green
  - Pressure flow model - sugar is actively transported from the source cells to the sieve tubes
    - Increases concentration of solute → water flows into the sieve tubes via osmosis → sieve tube pressure near source cells increases → forces solution to move to regions of lower pressure
    - At regions of lower pressure, sink cells remove the sucrose by active transport → sink cells pull solute out of phloem → water leaves phloem by osmosis, passing to neighboring tissues with higher solute concentrations
    - Reduces pressure in this region of the sieve tubes → fluid continues to move from regions of higher pressure
  - Bidirectional flow - depending on stage of life and time of year, various parts of the plant can act as a source or a sink
    - In autumn, roots and stems act as sinks to store starch, but in spring they act as sources to supply the rest of the plant that is budding and flowering
    - When a plant is young, the leaves are sinks because they aren't completely developed yet, but in older plants, they are sources

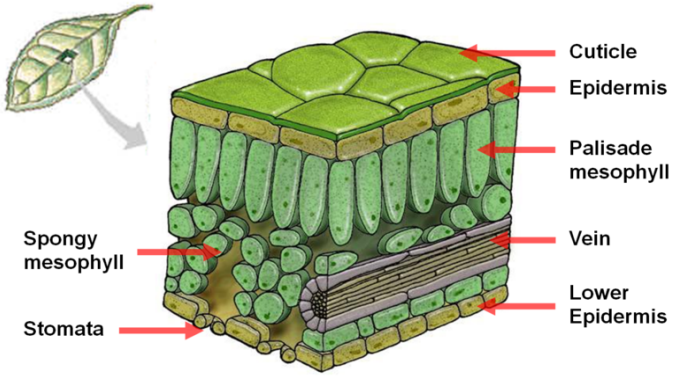
Ground Tissue System

- Parenchyma
  - Alive at maturity
  - Storage, photosynthesis
- Collenchyma - support the plant
  - Alive at maturity
  - Occur as vascular bundles
  - Thick walls
- Sclerenchyma - support the plant
  - Occur as bundle cap fibres
  - Thick secondary walls hardened with lignin

Dermal/Epithelial Tissue System

- Prevention of water loss and act as a barrier
- Guard cells - regulate the exchange of water vapor, oxygen and CO2
- Epidermis - contains stomata
- Periderm - nonliving + multilayered
  - Protects from pathogens and injury
- Trichome - hairs/fine outgrowths
  - Reflect radiation, lower plant temperature, and reduce water loss
  - They also provide defense against insects

Cross Section of a Leaf



- Cuticle - thin to allow light; waxy to prevent water loss by evaporation
- Upper epidermis - produces cuticle; transparent + thin to allow max light penetration

- Palisade mesophyll layer - contains chloroplasts; rod shaped
  - Close to surface → maximum absorption of light
  - Packed closely together to increase surface area
  - Chloroplasts found near the palisade surface reduce distance needed to travel by light, CO_2 and O_2
- Spongy mesophyll layer - smaller than palisade
  - Fewer chloroplasts
  - Lots of air space to allow for gas diffusion
- Vein - contains xylem and phloem
- Lower epidermis - protective layer; contains stomata; may be waxy in some species
- Stomata - pores surrounded by guard cells

Experiments

1. Transpiration
    1. Take some plants, water them until the soil becomes spongy and then weigh the plant
    2. Cover them with a plastic bag and leave them outside for a few hours
    3. Way them afterwards
    4. Broad leaf plants tend to lose more water than narrow leaf plants
2. Transport of Water
    1. Pour water into a glass and add food coloring and place them by water
    2. Place celery stalks in the colored water
    3. Wait for a few days
    4. Celery stalks will be dyed whatever color food dye you used
    5. Extension: split the stalk into three parts and stick each into a different color to create a "tie-dye" celery stalk

3.3. Coordination In Plants

Tropisms

- Tropism - a growth response of a plant to directional stimuli
  - Slow - involves cell division to see results
  - Positive → growth towards the stimulus
  - Negative → growth away from the stimulus
- Phototropism - stimuli is light
  - Growth towards light to maximize photosynthesis
  - Positive
- Geotropism - stimuli is gravity
  - Positive geotropism - roots grow in the direction of the force of gravity
    - Positive gravitropism
  - Negative geotropism - shoots grow against the force of gravity
    - Negative gravitropism
- Hydrotropism - stimuli is water
- Thigmotropism - stimuli is tough
  - Some plants like the touch me not are sensitive
    - Electrical-chemical means: no specialized tissue to communicate
    - Cell changes shape by changing the amount of water → swelling or shrinking
  - Tendrils - sensitive to touch
    - Part of the tendril is in contact with and part away from the object grow at different rates, causing the plant to grow around the object
- Receptor - the sensitive region, which is the tip of the shoot
  - Picks up the stimulus of light shining on it
- Effector - part of the shoot which responds to stimuli, which is just below the tip
- Effector and receptor communicate with each other by means of chemicals called plant hormones
- Phytohormones - plant hormones
  - Produced by the plant
  - Most important one is called auxin - help in growth of root and shoot tips
  - Gibberellins - help in vegetative growth
  - Cytokinins - promote cell division
  - Abscisic acid - inhibit growth and caused wilting of leaves
- Auxins - help in growth of root and shoot tips
  - Produced in the tip of the shoot and diffuses downwards
    - Diffuses to shady side of the shoot → shady side grows longer → plant appears to bend towards the light
  - It causes cell division and elongation
  - Response to high concentrations of auxins
    - Cells in stem
      - Grow more
      - Bend towards the light
      - When light comes from one direction, the auxins get transported to the shaded side
      - The shaded side elongates faster than the illuminated side and the shoot bends towards the light
    - Cells in root
      - Grow less
      - In a root, the shaded side contains more auxins and grow less, causing the root to bend away from the light
  - When the tips have been removed no auxin is produced and the stems don't grow longer
  - When no light reaches the tips, there is equal concentration of auxin on both sides and the stems grow longer evenly
  - When more light reaches on side of the tips, there is a greater concentration of the auxin on the shaded side and the cells on the darker side of the stem grow longer
- Gibberellins - growth of the stem
- Cytokinins - promote cell division
  - High concentration in fruits and seeds
- Abscisic acid - inhibits growth
  - Wilting of leaves

- Uses of plant hormones
  - Rooting powder contains growth hormones that make stem cuttings develop more quickly
  - Delaying ripening of fruit
  - Selective weedkillers kill some plants but not others
    - Can be useful for getting rid of dandelions in a lawn without killing the grass

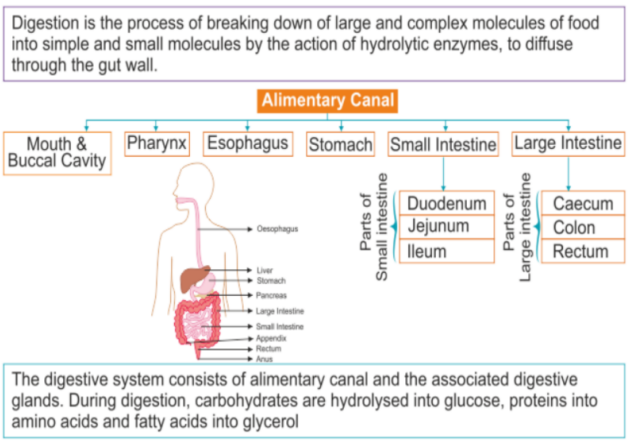
Darwin's Phototropism Experiment

- Take five shoots: control, tip removed, tip covered by opaque cap, tip covered by transparent cap, and base covered by an opaque shield

4. Human Physiology

4.1. The Digestive System

- Nutrition is the set of processes used by an organism to provide itself with food and convert the food molecules into a form that can be used by the organism
  - Aka processes where organism gets nutrition from food
- Balanced diet
  - Most animals need 7 types of nutrients in diet
    - Carbs
    - Proteins
    - Fats
    - Vitamins
    - Minerals
    - Fibre
    - Water
- Fat, obesity and health issues
  - Fat found in animal food is called saturated fat
    - Contains cholesterol, which can lead to coronary heart disease and heart attacks
    - People who take in more energy than needed gets increased amount of fat, which leads to obesity
    - People who take in less energy than needed can have malnutrition



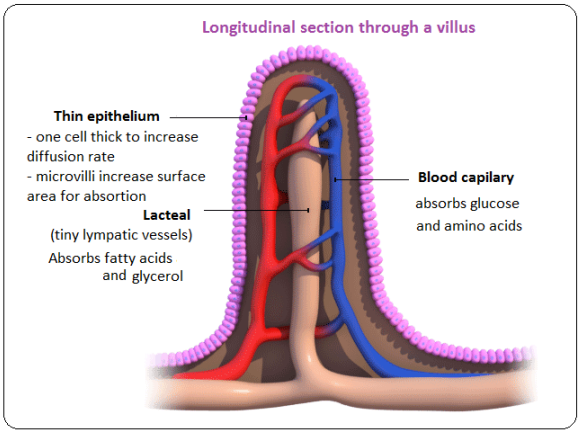
- What is digestion?
  - Complex series of organs and glands which break down insoluble food molecules into smaller water soluble molecules using a number of processes
- Phases include:
  - Ingestion
  - Movement
  - Mechanical and chemical digestion
  - Absorption
  - Elimination
- Mechanical digestion includes
  - Mastication (Chewing)
    - Chew
    - Tear
    - Grind
    - Mash
    - Mix
- Rolling action of the tongue and secretion of saliva creates bolus (chewed up food) which is swallowed and transported to stomach
- Chemical digestion includes
  - Enzymes change food into smaller particles
    - Helps in digestion of
      - Carbs
      - Proteins
      - lipids
  - Involves hydrolysis (Addition of water)
- Deficiency diseases
  - Protein - kwashiorkor
  - Anaemia
  - Goitre
  - Rickets
  - Night blindness
  - Scurvy
  - Early aging

Structures involved in digestive system

- Mouth - chewing/mastication
  - Salivary glands release saliva which contains salivary amylase which breaks down starch into simple sugars
  - Tongue + teeth → mixing and grinding
- Esophagus
  - Tube from mouth to stomach
  - Also known as the food pipe
  - 25cm long tube connecting the mouth and the stomach
  - Send the food down the pipe using a wave like motion called peristalsis
- Stomach
  - Has strong muscular walls which churn and mix food
  - Mixture is known as chyme
  - Secretes hydrochloric acid which kills bacteria and provides low pH level for the activation of pepsin (which acts on proteins and breaks peptide bonds)
    - acidic medium is created
  - Goblet cells
    - Give out the mucus that forms the mucus lining on the stomach to stop the acid from breaking down

the stomach walls
- Sphincter muscle controls the exit by releasing foods in small amounts
- Stomach stores food for a long time

- Small intestine
  - Divided into 2 parts: duodenum (close to stomach) and ileum (close to colon
    - Several enzymes which are made in pancreas are secreted in duodenum
  - Pancreatic juice and bile flow along small intestine
    - Contains sodium hydrogen carbonate which neutralizes acid
    - Trypsin acts on proteins
    - Lipase acts on fats
  - Bile digests fats via emulsification and neutralizes acid
    - Bile salts break down fat into small globules
  - Intestinal juice - contains enzymes which convert proteins into amino acids, carbohydrates into glucose and fats into fatty acids and glycerol
  - Digestion is completed in small intestine
    - Absorption: by now carbs, proteins, and lipids have been broken down into simple sugars, amino acids and glycerol respectively
    - These molecules are small enough to pass through the walls of small intestine and into the bloodstream
    - Lining of intestine walls have small finger-like projections called villi which increase surface area
      - The villi is then covered in microvilli for even more surface area
    - They have lots of blood vessels to absorb sugars and amino acids
    - lacteals absorb fatty acids and glycerol
    - The thin epithelium allows for a high diffusion rate



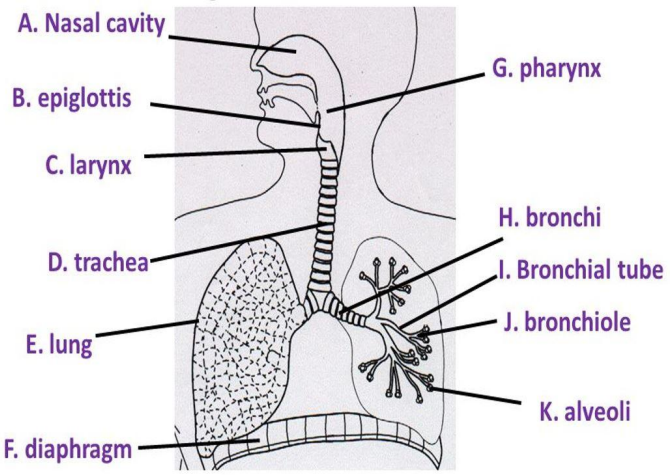
- Large intestine
  - Also called the colon
  - Accepts what small intestine does not absorb
  - Connects to rectim (short term storage which holds feces before it is expelled)
  - Function is to complete the absorption and production of vitamins as well as the formation and elimination of feces
    - Assimilation
      - After nutrients are absorbed into blood, it is taken to liver
      - Dissolved nutrients are then sent to other parts of body where they are assimilated as part of cell
    - Is responsible for the absorption of water
  - Rectum - temporarily stores feces
  - Anus - regulated by the anal sphincter
  - Accessory organs: not part of path of food, but play critical role
    - Liver
      - Directly affects digestion by producing bile which provides the alkaline medium for trypsin to act on the proteins
        - Bile helps emulsify fat
        - Also filters out toxins and wastes including drugs and alcohol
      - Important role in metabolism of glucose
      - Detoxifying of the food we eat
      - Breaking down of larger fat molecules into smaller ones which is easy for digestion
    - Gallbladder
      - Stores and concentrates bile from the liver and releases it into small intestine
      - Fatty diets can cause gallstones
    - Pancreas
      - Produces digestive enzymes to digest fats, carbs, and proteins
      - Regulates blood sugar levels by producing insulin
      - Secretes trypsin, a protease that works in a alkaline medium, which is used to neutralize the food that was made acidic by the HCl in the stomach
      - Also secretes other carbohydrases, proteases, lipases and nucleases
        - Carbohydrases - Act on carbohydrates
        - Lipases - Act on fats/lipids
        - Proteases - Act on proteins
        - Nucleases - Act on DNA
      - Also releases insulin
        - Insulin is a hormone that controls the levels of sugar in the blood. If there is not enough insulin, it can lead to diseases such as diabetes, which happen when the blood sugar levels go too high.
    - Appendix - true function is unknown
      - some think that it stores “good bacteria” to help reboot the digestive system after an illness
      - others believe that it is a useless remnement from our evolutionary past

4.2. The Circulatory System

- The body has its own transport system that carries substances around the body knows as the Circulatory System.
  - It is a network of tubes, blood vessels, blood and a pump (heart) that keeps blood flowing through the vessels.

- It is made of a special type of muscle called cardiac muscle. This muscle contracts and relaxes regularly.
- Types of blood
  - Oxygen rich
    - Travels to the body cells
    - High oxygen content
    - Low CO2 content
  - Oxygen poor blood
    - Travels away from the body cells
    - Low oxygen content
    - High CO2 content
  - Blood contains plasma which is the fluid medium in which cells are suspended
    - Transports food, CO2 and nitrogenous waste
- The inside of the heart is divided into two sections so that the two types of blood (oxygen-rich and oxygen-poor) are kept apart.
  - Right side of the heart = oxygen poor
  - Left side = oxygen rich
- Heart is divided into four chambers:
  - The two upper chambers are atriums and the two lower are ventricles.
    - Atria collect blood that enters the heart
    - Ventricles pump blood out of the heart; have thicker walls than atria because they need to supply blood to different organs
  - Left atrium - oxygen rich blood from lungs → relaxes while collecting
  - Left ventricle - pumps oxygen rich blood to the body; collects from the left atrium
  - Right atrium - expands to collects deoxygenated blood from the body
  - Right ventricle - pumps deoxygenated blood back to the lungs
  - The chambers are completely separated by a septum.
- Heart is a double pump, with right side pumping blood to the lungs and left side to all other organs.
- Journey
  - Left side of heart → body's cells → right side of heart → lungs → left side of heart
- During one complete circuit of the body, blood passes through the heart twice. The heart has two jobs to do and so the circulatory system involves a double circulation.
  - Pulmonary Circulation – blood flows from the heart to the lungs to get O2 supply.
  - Systemic Circulation – blood flows from the heart to the cells (distribute food and O2) and from the cells to the heart (carry wastes and to the heart CO2)
- One complete sequence of contraction and relaxation is called a heartbeat.
  - The opening and closing of valves in the heart is what creates the sound of a heartbeat
  - The valves between the atria and ventricles are connected to the inner walls of the heart by tough tendons.The tendons allow the valves to close and hold the valve flaps in place. They prevent the valves from flipping up and turning inside out
- Artery
  - Aorta – largest artery
  - Arterioles – smallest artery
  - Carry oxygenated blood away from the heart; the heart has high pressure
  - Elastic fibres allow the artery to stretch under pressure
  - Thick muscle and elastic fibres can contract to push the blood along
- Vein
  - Vena Cava – largest vein
  - Venules – smallest vein
  - Carry deoxygenated blood back to the heart
  - Have valves which act to stop the blood from going in the wrong direction and ensure unidirectional flow
  - Thin muscle and elastic fibre
  - Body muscles surround the veins so that when they contract to move the body, they also squeeze the veins and push the blood along the vessel.
- Capillary
  - They exchange materials between the blood and other body cells can only occur through capillaries
  - The wall of the capillary is one thick cell
- Platelet cells clot blood at points of injury
- Lymph - fluid
  - Some plasma, proteins and blood cells escape into intercellular spaces in tissues through pores in capillary walls
  - Colorless
  - Drains into lymphatic capillaries → lymph vessels → veins
  - Carries digested and absorbed fat from intestine and drains excess fluid from extracellular space back into the blood
- Flow of blood -
  - Superior and inferior vena cava → right atrium → tricuspid valve → pulmonary artery → lungs → pulmonary vein → left atrium → mitral valve → left ventricle → aortic valve → aorta → arteries → body systems
- Lungs - in humans, lungs are separated to keep blood from mixing; this allows for a highly efficient supply of oxygen to the body as humans have high energy needs
- Fish have 2 chambered hearts: blood is pumped to the gills → oxygenated → rest of body
- Amphibians and reptiles have 3 chambered hearts as they can tolerate some level of blood mixing
- Double circulation is a special feature of vertebrateS

4.3. The Respiratory System



- Lungs are part of breathing system adapted for two functions
  - Ventilation: movement of air in and out of lungs
  - Gas exchange: 'swapping' of gas between alveoli and blood
- Lungs are located in upper part of body known as thorax
  - Surrounded by rib cage and intercostal muscles which help lungs inhale and exhale
  - Beneath lungs in diaphragm
- Journey of air
  - You inhale, and air in warmed, moistened and filtered as it goes through mouth and/or naval passages
    - Nostrils have fine hairs and mucus to stop germs
  - The throat has a ring of cartilage to prevent the air passage from collapsing
  - Then goes through larynx, trachea and into one of the two bronchi and enters the lung
  - Then goes through one of the many bronchial tubes, bronchioles and into the alveoli, which has specialized surfaces for gas exchange
    - Alveoli are found in the alveolar sacs
    - Gas diffuses with the extensive network of blood vessels and capillaries
    - O2 from inhaled air enters the bloodstream and combined with the hemoglobin
      - Fun fact: low amounts of hemoglobin = low amount of oxygen
    - CO2 from bloodstream enters alveoli
    - There is a residual volume of air which allows for buffer time
  - Carbon dioxide leaves the body
- Haemoglobin transports oxygen
- CO2 is mostly transported through diffusion
- Diaphragm
  - Inhalation - diaphragm contracts and moves downwards; increases space in chest cavity → lungs expand → higher intake of air
    - Intercostal muscles between ribs also help enlarge the chest cavity
  - Exhalation - diaphragm expands and relaxes, moving upwards; decreases space in chest cavity → air is pushed out
    - Intercostal muscles are relax to reduce the space in the chest cavity
- Types of lung volumes
  - Tidal volume - the amount of air breather in with each normal breath (avg is 0.5 l)
  - Inspiratory reverse volume - max amount of additional air that can be taken into the lungs after a normal breath
  - Expiratory reverse volume - max amount of additional air that can be forced out of the lungs after a normal breath
  - Residual volume - amount of air left in lungs after a maximal out breath
    - Helps keep lungs partially inflated to protect microscopic structures from damage
- Measuring lung volume
  - Take a measuring cylinder and pour 250 cm3 of water into a plastic container/bottle
  - Mark the water level
  - Repeat this until the container is full
  - Half-fill a tub with water, put the lid on the container and turn the container upside down and put the neck under water; take the lid off
  - Hold one end of the tubing under the mouth of the container
  - Blow through the tube after a deep breath to measure lung capacity by taking water level readings before and after
- Respiratory disorders
  - Bronchitis
  - Pneumonia
  - Cold
  - Asthma
  - Cancer
- Annelids breathe through their skin
- Insects directly exchange gas with body cells
- Fish use gills - water moves in through mouth and then goes to the gills
  - The oxygen is diffused into the blood
  - Fish have a high breathing rate

Lung Problems

- Asthma - causes inflammation of the bronchioles → constriction makes it difficult for air to pass through
  - Excessive amounts of mucus secretion also blocks the bronchioles
  - Wheezing, coughing, shortness of breath, chest tightness
  - Exposure to dust, allergens, smoke, some foods, etc... can cause an attack
- Effects of smoking
  - Smoke irritates the bronchi, causing bronchitis
  - Build up of mucus and smoker's cough
  - Damages the walls of the alveoli → alveoli wall breaks down → join together → large air spaces
    - Reduces efficiency of gas exchange

- CO combines with haemoglobin → reduces oxygen carrying capacity → strain on circulatory system
  - Increased risk of coronary heart disease and stroke
- Carcinogens may lead to lung cancer

4.4. Cellular Respiration

- Respiration is series of oxidation reactions taking place in all living cells. It results in the release of energy from organic compounds such as glucose
- Gas exchange ≠ respiration
  - Gas exchange - oxygen into cell and carbon dioxide out of cell
- Why do living organisms need energy?
  - To drive metabolic reactions that take place inside your body such as:
    - Movement
    - Muscle contraction
    - Movement of chromosomes in cell division
  - Maintaining constant body temperature in mammals and birds
- Anabolic process
  - Process in which large complex molecules are built from smaller, simpler molecules
  - Involves input of energy
  - Ex: sugars from polysaccharides
  - Proteins from amino acids
- Catabolic process - complex molecules are broken down to form smaller, simpler molecules
- Aerobic respiration: consumes organic molecules and oxygen to yield ATP
- Anaerobic respiration: similar to aerobic but consumes other compounds instead of oxygen
  - Glucose = lactic acid + energy
  - Ex: alcohol fermentation
    - Pyruvate is converted into ethanol and CO_2
  - Anaerobic respiration is respiration in the absence of oxygen. Some organisms carry out aerobic respiration in the presence of oxygen, but are able to change to anaerobic respiration in its absence. Some bacteria can thrive only in the absence of oxygen.
  - In the absence of oxygen glycolysis can operate, as a result energy yield in anaerobic respiration is low and the pyruvate is converted into waste products.
  - Lactic Acid fermentation
    - Pyruvate is reduced to NADH
    - Forms lactate, no CO_2 produced
    - Human muscles do this when O_2 is scarce
    - Aka when u are running for so long, intake of O_2 is not enough
    - Buildup of lactic acid created the burning sensation in muscles
- Cellular respiration includes both but mostly refers to aerobic
  - Controlled by the breakdown of organic molecules
  - $C_6H_{12}O_6 + 6O_2 = 6CO_2 + H_2O + 38$ ATPs + Heat
- In cellular respiration, glucose and other organic molecules are broken down in a series of steps
- Electrons from organic compounds are usually first transferred to NAD+, a coenzyme
- As an electron acceptor, NAD+ functions as an oxidizing agent during cellular respiration
- Each NADH (the reduced form of NAD+) represents stored energy that is tapped to synthesize ATP
- NADH passes the electrons to the electron transport chain
- Unlike an uncontrolled reaction, the electron transport chain passes electrons in a series of steps instead of one explosive reaction
- O_2 pulls electrons down the chain in an energy-yielding tumble
- The energy yielded is used to regenerate ATP
- 1. Glycolysis: breaking up of glucose - divides it from c-c-c-c-c-c to c-c-c and c-c-c
  - Needs 2 ATPs to create 4 ATPs
  - Creates 2 molecules of Pyruvic acid
  - Anaerobic
- 2. Kreb's Cycle
  - The 2 c-c-c are converted into Acetyl CoA
  - Generates 2 ATPs
  - Aerobic
  - NAD+ turns into NADH (Each create 3 ATPS)
  - FAD turns into $FADH_2$
- 3. Electron Transport Chain
  - Creates 34 ATPs
  - Aerobic

Or in more simple terms...

- For all types of respiration - glucose (a 6 carbon molecule)is broken down into pyruvate (3 carbon molecule)
  - This takes place in the cytoplasm
- Fermentation - anaerobic respiration
  - Takes place in things like yeast
  - Pyruvate → ethanol + CO_2
- Aerobic respiration - presence of oxygen; takes place in the mitochondria
  - Pyruvate → $CO_2 + H_2O$
  - Lots of energy
- Lack of oxygen in muscle cells
  - Pyruvate → lactic acid

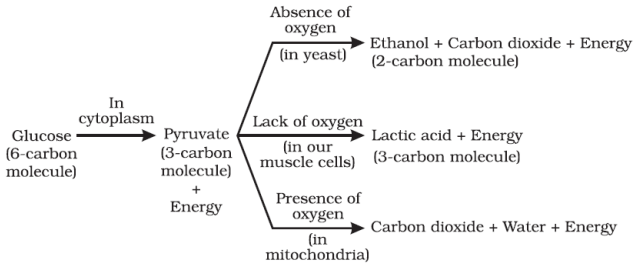


Figure 6.8 *Break-down of glucose by various pathways*

Experiments

1. Yeast in sugar
    1. Dissolve sugar in previously boiled water and add yeast
    2. Add a layer of vegetable oil (prevents air from entering while also allowing CO2 to escape
    3. Connect a delivery tube system to either a tube of lime water (Ca(OH)2), water setup or balloon to measure CO2 produced
    4. This can be used to either test the impacts of temperature or concentration of sugar
2. Measuring energy content (calories) in a seed
    1. Measure a mass of water and add it to a boiling tube clamped to a retort stand
    2. Record the starting temperature of the water
    3. Place a food sample on a mounted needle and ignite it using a bunsen burner
    4. Hold it under the boiling tube until it is completely burned
    5. Record the final temperature of the water
    6. Calculate results in table and repeat for accuracy → take average
        1. E = mass*4.2 (J/g*C)*change in temperature
    7. Not completely accurate as some energy is lost to surroundings, to heat the glass and the entire food sample may not be burned
    8. Controls: mass of food and water, starting temperature of the water, distance of flame from boiling tube
3. Effects of exercise on ventilation (breathing and respiration)
    1. Measure the person's resting heart rate by taking the pulse at their carotid artery
        1. Breaths per minute can be measured using a spirometer
        2. BLood oxygen saturation can be measured using a pulse oximeter
        3. Peak flow meter measures the rate of airflow that can be blown out of the lungs in litres per minute
    2. Perform exercise such as brisk walking for five minutes and take measurements again
    3. Run for 5 minutes and take measurements again
    4. Observe the differences in heart rate, breathing rate, peak flow and blood oxygen saturation in the three states
    5. Controls: age, sex, fitness level, body size/structure
    6. Caution: don't do this on people that are sick, or have lung problems; allow ample time between sessions to allow heart rate to return to normal

4.5. Homeostasis

- Homeostasis - the maintenance of a constant environment in the body

Body Temperature

- Thermoregulation
    - Cells in the region of the hypothalamus detect changes in core body temperature and effect different responses depending on whether the core body temperature is above or below the set point
- All mammals maintain a constant body temperature
- Human beings have a body temperature of about 37 degrees C
- Animals with a large surface area compared to their volume will lose heat faster than animals with a small surface area
    - The bigger the volume:surface area ratio, the faster heat will be lost
- Sweating
    - When your body is hot, sweat glands are stimulated to release sweat
    - The liquid swea turns into a gas if it evaporates
    - To do this, it needs heat
    - It gets heat from your skin
    - As your skin loses heat, it cools down
- Vasodilation
    - Your blood carries most of the heat energy around your body
    - There are capillaries underneath your skin that can be filled with blood if you get to hot
    - This brings the blood closer to the surface of the skin so more heat can be lost
    - This is why you look red when you are hot
- Vasoconstriction
    - Opposite of vasodilation
    - Capillaries underneath your skin get constricted
    - Ths takes blood away from the surface of the skin so less heat can be lost
- Piloerection
    - This is when the hairs on your skin stand up
        - AKA goosebumps or chicken skin
    - Hairs trap a layer of ai next to the skin which is then warmed by the body heat
    - The air becomes an insulating layer
- Too hot
    - Sweating

- Vasoconstriction
- Hairs relax
- Too cold
  - Hypothalamus receives information from the thermoreceptors in your skin and begins to activate warming mechanisms
  - Skin arterioles constrict so blood is diverted to deeper organs and tissues and less heat is lost by radiation
  - Stimulates skeletal muscles to start shivering → generation of body heat
  - Piloerection
  - Vasodilation
  - Fat

Glucose

- Your cells need an exact level of glucose in the blood
- Excess glucose gets turned into glycogen in the liver
- This is regulated by 2 hormones from the pancreas
  - Insulin
  - Glucagon
- High Blood Glucose
  - Islets of Langerhans in pancreas stimulated
  - Insulin is secreted by pancreas which is transported by blood to the liver and muscles
  - Liver cells lose some glucose in respiration. Some glucose is stored as glycogen
  - The blood glucose concentration falls
  - Normal level of blood glucose
  - Type B diabetes
- Low Blood Glucose
  - Islets of Langerhans in pancreas stimulated
  - Glucagon is secreted by pancreas which is transported by blood to the liver and muscles
  - The liver breaks down glycogen into glucose
  - Glucose is released from the liver into the blood and blood glucose concentration rises
  - Normal level of blood glucose
  - Type A diabetes

Controlling Water Levels

- Process is initiated when there is a high blood solute level, which signals the hypothalamus to release the ADH (antidiuretic hormone) hormone
  - ADH increases absorption of water from the urine
- Carried out by the kidneys
  - The kidneys clean the blood of waste products and control how much water is kept in the body
  - The waste products and water make up the urine which is excreted via the ureter
  - Dirty blood enters the kidney through the renal artery
- Closely linked to the excretion of urea
  - Ureas is a waste product made when the liver breaks down proteins that are not needed in the body
  - Contains the element nitrogen
- Process
  - Filtration
    - Blood enters the tubule area in a capillary vie renal artery → arterioles → Bowman's capsules
    - The capillary forms a small knot near the tubule
    - The blood is filtered so all the small particles go into the tubule
    - The capillary then carries on to run next to the tubule
    - The kidney tubule now contains lots of blood components including
      - Glucose
      - Ions
      - Water
      - Urea
  - Capillary cluster + tube = nephron
  - Reabsorb sugar
    - The body needs to have sugar in the blood for cells to use in respiration
    - All the sugar is reabsorbed into the capillary
  - Reabsorb water
    - Water and ions are the next to be absorbed
    - It depends on how much is needed by the body
    - If you have too little water in your blood, you will produce very concentrated urine
    - If you have too much water in your blood, you will produce very dilute urine
  - Excrete the waste
    - Everything that is left in the kidney tubule is waste
      - All the urea
      - Excess water
      - This waste is called urine
    - It is excreted via the ureter and is stored in the bladder
      - Pressure builds until there is urge to urinate
      - Nervous control
    - The clean blood leaves the kidney in the renal vein
- Or in more complex terms...
  - Osmoregulation
  - When the solute concentration of the blood is too high, the hypothalamus detects this and causes the pituitary gland to secrete the ADH hormone
  - This hormone causes the walls of the distal convoluted tubule and collecting duct to become much more permeable to water and most of the water in the filtrate is reabsorbed
  - This is helped by the solute concentration gradient of the medulla
  - As the filtrate passes down the collecting duct, it flows deep into the medulla, where the solute concentration of the intestinal fluid is high
  - Water continues to be reabsorbed along the whole of the collecting duct and the kidney produces a small amount of concentrated urine
  - The solute concentration of the water is reduced

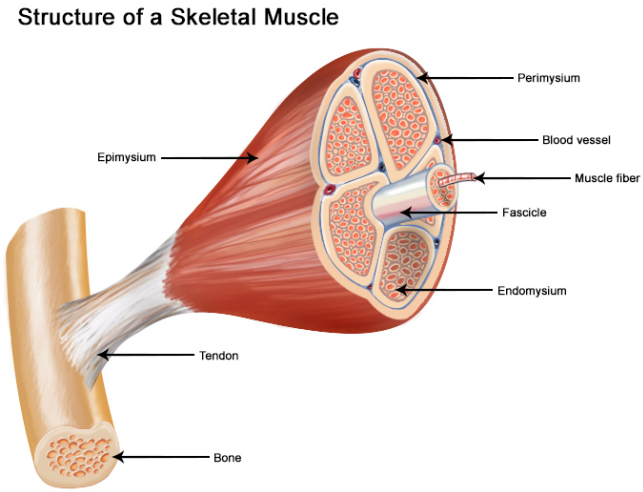
4.6. The Muscular System

- Responsible for the movement of the human body

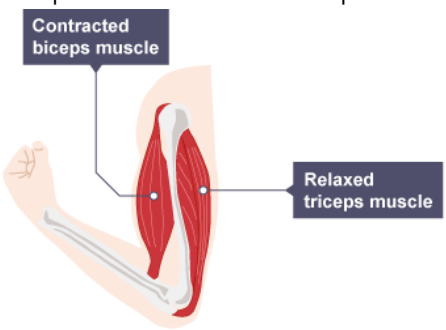
- Visceral muscles (smooth muscles) - found inside organs like the stomach
  - Weakest of all the muscles
  - Makes organs contract to move substances
  - Controlled unconsciously
  - Has a smooth uniform appearance under a microscope
- Cardiac muscles - found in the heart; responsible for pumping blood throughout the body
  - Involuntary muscle
  - Hormones from brain adjust rate of contraction
  - Cells appear to have light and dark stripes under a microscope
    - Caused by arrangement of protein fibers
  - X or Y cells are connected by junctions called intercalated disks
- Skeletal muscles -
  - Only voluntary muscles
  - Contract to move parts of the body closer to the bone that the muscle is attached to
    - Most are attached to two bones across a joint → muscle moves parts of those bones closer together
  - Progenitor cells lump together to form long, straight, multinucleated fibers
  - Tendons - tough bands of connective tissue
    - Strong collagen fibers firmly attach muscles to bones
    - Very strong and woven into the coverings of both muscles and bones

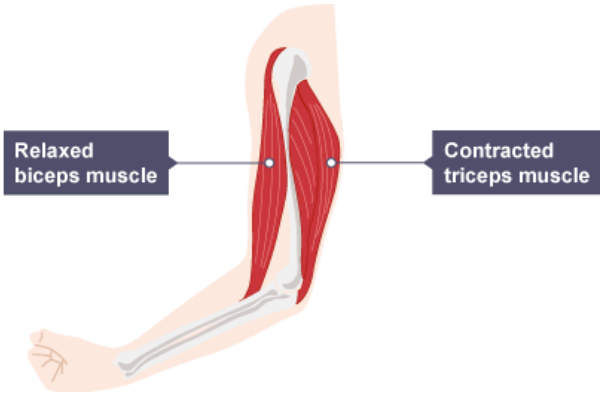
Structures of Various Muscles

- Skeletal muscles

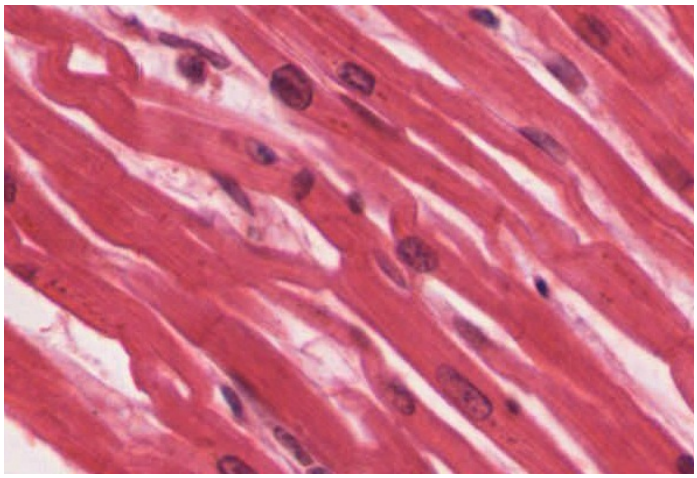


- Antagonistic muscles - one muscle of the pair contracts to move the body part, and the other muscle then contracts to return the body part back to the original position
  - As one muscle contracts, the other muscle relaxes or lengths
    - Contracting muscle = agonist
    - Relaxing muscle = antagonist
  - Ex: bicep curl - biceps contract while the triceps relax





- Fixators - supporting muscles
  - Synergist - a fixator muscle that assist the agonist
- Cardiac muscles
  - Is striated and has the same banding organization as skeletal muscles
  - Shorter than muscle fibre cells and usually only contain one nucleus which is located at the central region of the cell
  - Many mitochondria and myoglobin
  - Connected to each other at their ends by intercalated discs
    - Allows the cells to contract in a wave-like pattern so the heart can work as a pump



4.7. The Nervous System

- Change may occur around us or inside of our body

- Organisms can detect changes in the environment and respond to the changes in certain ways
- External environment - physical and chemical condition outside and organism
- Internal environment - physical and chemical conditions of the tissue fluid surrounding the tissues of an organism

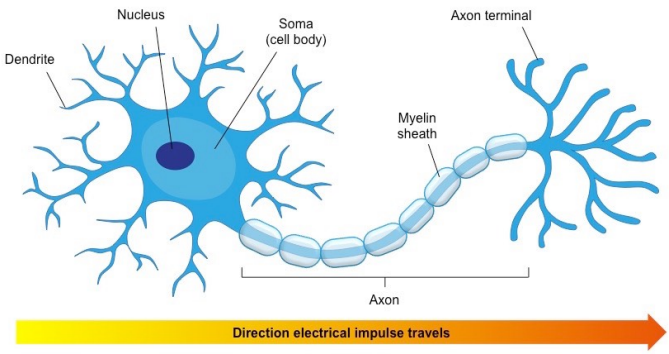
- To regulate internal environment
  - Obtain and use resources, grow, reproduce, and maintain stable internal conditions while living in a constantly changing external environment
- Response to stimuli
  - Stimulus - changes in the external and internal environment
  - Receptor - detect the stimulus
  - Afferent neuron - carries the nerve impulse to the integrating centre (CNS) in the brain
  - Efferent neuron - carries the nerve impulse to the effector
  - Effector - reacts to cause a response (muscles/glands)
  - Stimulus → receptor → CNS → response → effector

Internal stimuli are detected by receptors sensitive to changes within the body

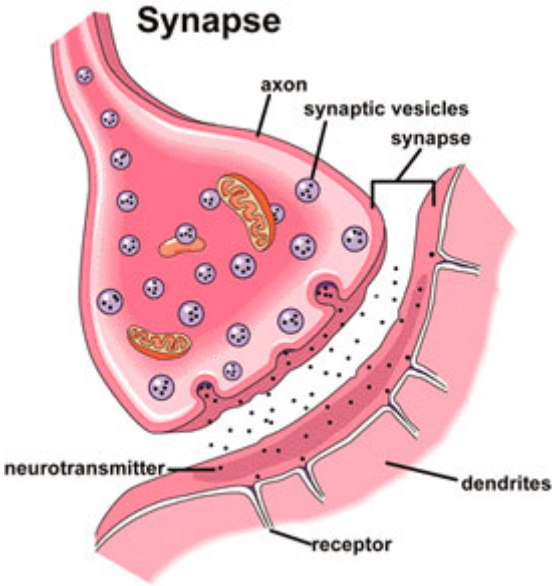
- The endocrine and nervous system control and coordinate functions in the body to maintain a constant internal environment through a negative feedback mechanism
- Eyes, ears, tongue, nose and skin are receptors

Neurons

- Neurons - nerve cells
  - Parts
    - Cell body/ soma - contains the nucleus
    - Dendrites - bushy branching extensions that receive messages and conduct impulses toward the cell body
    - Axon - the neuron extension that passes messages through its branches to other neurons, muscles, or glands
    - Myelin sheath - a fatty tissue layer segmentally encasing the axons of some neurons for greater transmission speed
  - Action potential - a neural impulse; a brief electrical charge that travels down an axon



- Types of neurons
  - Sensory neuron - carries impulses from the receptors to the spinal cord
    - These tell the rest of the brain about the external and internal environments by processing information taken from one of these five senses
    - They take information from the sense organ and pass it on to the brain/spinal cord
  - Relay neuron - carries impulses from the spinal cord and brain
    - Only found in the visual system, brain and spinal cord
    - Receive messages from sensory neurons and pass messages to other relay neurons or motor neurons
  - Motor neurons - carries impulses from the brain to the effector
    - SNS motor neurons connect skeletal muscles and involves voluntary actions
    - ANS motor neurons control glands and organs
- Synapses - a gap between axon of one cell and dendrite of next cell
  - Structure that permits a neuron to pass an electrical or chemical signal to another neuron or to the target cell



- Neurotransmitters - signals passed as chemicals
  - Diffuse across the synapse and bind to the proteins of the dendrite of the next neuron
  - Binding of neurotransmitters to the receptor triggers the generation of a new action potential/nerve impulse

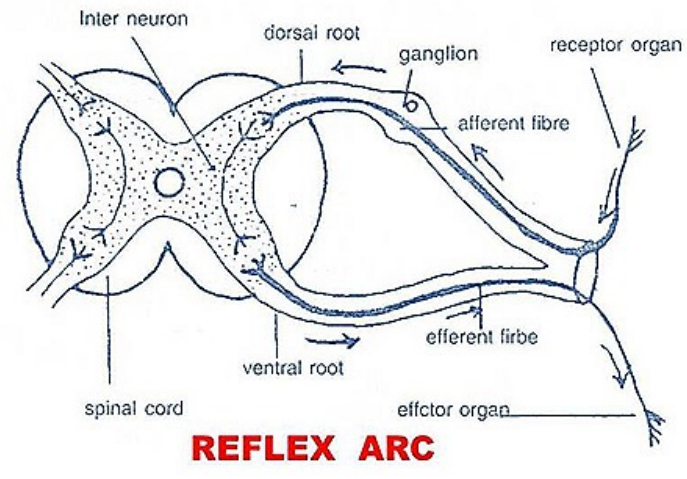
The Nervous System

- Nerves are bundles of axons
- Nervous System
  - Central Nervous System (CNS) - processes sensory information, makes decision and initiates response
    - Brain

    - Spinal cord
  - Peripheral Nervous System (PNS)
    - Afferent pathway - sensory nerves; brings information to CNS
    - Efferent pathways - motor nerves; sends information from CNS to other parts
      - Somatic pathway - convey messages to voluntary nerves
      - Autonomic Nervous System (ANS) - innervates involuntary effectors
        - Sympathetic - Stimulatory
        - Parasympathetic - Calming
- Role of the nervous system
  - Detect changes by receptors → process received sensory information and initiates responses
  - Helps us think and act consciously
  - Stores information and allows us to learn from past experiences
  - Adapts the body to changes in the environment
  - Controls and coordinates the activities of all other systems in the body

Reflex Arc

- It is a special nerve pathway for simple, automatic responses
- All nerve pathways involve the CNS, but reflex arc does not involve the brain
- When your body needs to react to something very quickly, it uses a reflex arc (spinal reflex)
- Receptor → spinal cord → effector
- Receptor → sensory neuron → relay neuron → motor neuron → effector
  - The sensory, motor and relay neurons constitute the reflex arc
- Reflex actions are useful because the messages get from the receptor the the effector as quickly as possible
- Reflex actions are examples of involuntary actions which are not under conscious control



- Muscle cells have special proteins that change their shape and arrangement in the cell in response to electrical impulses

- Experiment: voluntary response/reaction time can be measured by catching a dropping ruler
  - Materials: meter stick, volunteer, table, chair
  - Sit straight in the chair and place forearm on table so th that extends over the edge
  - Place index and thumb on either side of the ruler
    - 1 cm on bottom, 30 cm on top
  - Hold ruler 2 cm over the volunteers fingers, drop it without telling them and she will catch it as soon as she senses it dropping
    - Record the number over the thumb; lower number = faster reaction time
    - Repeat the trial several times
  - There may be slight improvements after each trial due to muscle memory
- Iris/Pupil reflex action
  - The way the iris adjusts the size of the pupil in response to bright or dim light, and thus the amount of light reaching the retina is also a reflex action

In Bright Light	In Dim Light
Radial muscles of the iris relaxCircular muscles of the iris contractLess light enters the eye through the contracted pupil	Radial muscles of the iris contractCircular muscles of the iris relaxMore light enters the eye through the dilated pupil

- It is advantageous since it prevents damage of the retina that could be caused by bright light

4.8. Sensory Receptors

- Baroreceptors - sensitive to pressure
- Chemoreceptors - taste
  - Sweet, sour, salty, bitter, umami
  - Taste protects us from danger
    - We won't end up eating bad tasting poisonous plants
    - Repeated ingestion of disliked foods can lead to the food tasting not as bad
  - Taste buds have receptor cells that have hairs that sense food molecules
    - Taste receptors reproduce every 1-2 weeks
    - No. of taste receptors decreases with age but sensitivity increases
      - This is why adults have a stronger sense of taste
  - Expectations influence taste
  - Sensory interaction - one sense may influence another
    - Smell influences taste
    - Can also influence hearing and seeing
  - Embodied cognition - the influence of bodily sensations on cognitive preferences
- Chemoreceptors - smell
  - Molecules of a substance reach receptor cells in the nasal cavity then the axon fibres alert the brain

        - These receptor cells come in different shapes for different odors
        - Receptors proteins are attached to the nasal cavity neurons
        - Odor molecules slip into these receptors
        - There isn't a receptor for each odor
            - Combinations of receptors are triggered in patterns that are interpreted by the olfactory cortex
    - Women have a better sense of smell than men
    - People with alzheimer's, parkinson's and alcohol dependence have a diminished sense of smell
    - Sense of smell peaks in early adulthood and gradually declines
    - We have our own chemical signatures that dogs and cats can sense
    - We prefer smells based on association
        - Smells that invoke pleasant memories are prefered
        - Hotline runs from area of the brain that receives information about smell and the limbic system
    - Smell is primitive and kept us safe
- Photoreceptors - look at eyes
- Mechanoreceptors
    - Touch is vital for social connections
    - 4 parts
        - Pressure
        - Warmth
        - Cold
        - Pain
            - Tells you that something has gone wrong
                - Without pain, we would be in great danger as we wouldn't know when we broke a bone or other serious injuries
            - Chronic pain - unable to stop the feeling of pain
            - Pain is a top- down process
            - Women are more sensitive to pain than men
            - Nociceptors - receptors that detect hurtful temperatures, pressures or chemicals
            - Gate control theory
                - Pain impulse → nociceptor → nerve cell → spinal cord → brain
                - Spinal cord contains a neurological gate
                - When you are injured, small fibres activate and open this gate
                - Large fiber activity closes the gate
            - Endorphins reduce pain
            - Phantom limb sensation
            - Brain only registers pain in memory at the peak moment, and end pain
                - Ex: if you feel sudden, sharp pain, and then less sharp pain, your overall experience of the pain will decrease
            - When we see other in pain, our perception of our own pain increases
            - Medication, acupuncture, hypnosis, etc... can reduce pain
            - Placebos can also reduce pain
                - They mimic drugs
                - As a result, the brain releases opiates
                - People also complain of the fake side effects of the placebo
- Osmoreceptors - a sensory receptor primarily found in the hypothalamus of most homeothermic organisms that detects changes in osmotic pressure
- Thermoreceptors - detect changes in temperature
- Advantages of having major sense organs in the head
    - Cephalization - evolutionary trend toward concentrating nervous tissue, the mouth and sense organs towards the front end of an animal
    - Fully cephalized animals have a head and brain
    - It allows for the development of a brain, complex neural system and intelligence
    - Clustering of sense to help and animal rapidly sense food and threats
    - Superior analysis of food sources - mouth is closer to the brain

Body Position and Movement

- kinesthesis - sense of position of body parts
    - light touch is important
    - also interacts with vision
    - without it, we would feel disembodied
- vestibular sense - sense of body movement
    - fluids in the semicircular canals and vestibular sacs, move when your head moves
    - movement stimulates hair like receptors which send messages to the cerebellum enabling you to sense movement of body

4.9. Vision

Stimulus: Light Energy

- Humans can see the visible light part of the electromagnetic spectrum

Physical properties wavelength determines hue which is the dimension of color intensity is determined by amplitude and affects brightness

The Eye cornea

- Allows light to enter and bends it to focus
- Pupil - Small opening
- Iris - controls how much light enters
- Lens - focuses light rays onto retina

Accommodation - the process by which the eye's lens changes shape to focus near or far objects on the retina

Retina

- The light sensitive inner surface of the eye containing rods and cones and layers of neurons that begin the processing of visual information
  - Rods - detect black and white
    - Share bipolar cells with other rods
  - Cones - detect bright colors
    - Each cone is connected to its own bipolar cell which transmits info to the visual cortex
- Steps:
  - Light entering the eye triggers photochemical reaction in rods and cones at back of retina
  - Chemical Reaction activates bipolar cells
  - Bipolar cells activate ganglion cells whose axons converge into the optic nerve
  - Optic nerve transmits information to the visual cortex
- Blind spot - the spot where the optic nerve leaves the eye; there are no receptor cells here

Fovea - central focal point in the retina around which the eye's cones cluster

Visual Information Processing

- Begins in retina
  - The layers help encode and analyze sensory information
  - Retinal cells are pressure sensitive
- Bipolar cells → ganglion cells → optic nerve → brain

Any given retinal area has a corresponding area in the visual cortex

Feature Detection

- Feature detectors - nerve cells in the brain that respond to specific features of the stimulus such as shape, angle or movement
  - Located in the occipital lobe
  - Receive info from individual ganglion cells
  - Pass info on to other cortical areas
- One temporal lobe area by right ear allows for facial recognition
  - Can know angle, posture, gaze, body movement, etc...

    parallel processing - the processing of many aspects of a problem stimulus simultaneously

4.10. Hearing

The Stimulus Input: Sound Waves

- Ears detect brief pressure changes of air
- Physical characteristics of the wavs
  - Amplitude determines loudness
  - Frequency determines pitch
    - Short waves have a high frequency and pitch
    - Long wave have a low frequency and pitch
- Sound is measured in decibels
  - 0 decibels is the absolute threshold for hearing
  - Every 10 decibel intensity corresponds to a 10x increase in sound

The Ear

- Outer ear channels waves into the ear canal and then the eardrum
  - The eardrum is a tight membrane that vibrates
- Middle ear - chamber between eardrum and the cochlea containing three tiny bones called the hammer, anvil and stirrup, that concentrate the vibrations of the eardrum on the cochlea oval window
  - Picks up vibrations from eardrum and sends them to cochlea
  - Cochlea - snail shaped tube in the inner ear, filled with fluid
    - Sound waves travelling through the fluid trigger neural impulses
- Inner ear - the innermost part of the ear that contains the cochlea, semicircular canals and vestibular canals
- Motion in the fluid causes ripples on the basilar membrane, bending the hair cells lining the surface
  - Hair cells bending causes impulses to trigger in the adjacent nerve cells
    - Cilia - tiny tips at top of the hair cells
  - Axons of the cells converge to form the auditory nerve
- Neural message is sent to the auditory cortex via the thalamus
- Sensorineural hearing loss - hearing loss caused by damage to the cochlea's receptor cells or to the auditory nerves
  - Also called nerve deafness
  - Caused by aging, disease, hereditary, and prolonged exposure to loud noise
- Conduction hearing loss - hearing loss caused by damage to the mechanical system that conducts sound waves to the cochlea
- Listening to loud noise over an extended period of time, can cause damage to the hair cells
- Cochlear implant - a device for converting sounds into electrical signals and stimulating the auditory nerve through electrodes threaded into the cochlea
  - Can help restore hearing
  - Do not work if the person has always been deaf as the brain hasn't been trained to interpret sound

4.11. Pavlov's Experiment

- Ivan Pavlov's Experiments
  - Noticed that dog salivated at the sight of food
  - Paired the food with a neutral stimulus such as a bell
  - After several trials, the dog salivated at the sound of the bell
- Neutral stimulus (NS) - the stimulus which evokes no response before conditioning
- Unconditioned response (UR) - an unlearned, naturally occurring response

- Unconditioned stimulus (US) - the stimulus that evokes response before conditioning
- Conditioned response (CR) - a learned response to the previously neutral stimulus
- Conditioned stimulus (CS) - an originally irrelevant stimulus that after association with the US triggers the CR
- Steps:
  - Acquisition
    - The initial stage when one links the NS with the US in order to trigger the CR
    - US must follow the NS or nothing will happen
    - Through higher order conditioning, a new NS can become a new CS
  - Extinction and Spontaneous Recovery
    - Extinction - the diminishing of the CR
    - Spontaneous recovery - the reappearance of the CR after a short extinction
    - Extinction suppresses the CR, it doesn't get rid of it
  - Generalization
    - Once a response has been conditioned, it can be evoked with similar stimuli
      - Ex: a toddler scared of cars will also be scared of trucks and motorcycles
  - Discrimination
    - Ability to distinguish between a conditioned stimulus and other irrelevant stimuli
- Pavlov's legacy
  - Showed us that many other stimuli can be classically conditioned in other organisms
  - Showed us how a process such as learning can be objectively studied
- Applications
  - Helping recovering drug addicts
  - Medication

4.12. The Endocrine System

- Gland - an organ that secretes chemicals into the bloodstream
- Endocrine glands
  - Do not have ducts
  - Ducts are tube like structures that allow the secretions to move to the target location
  - In the endocrine system, chemical secretions are sent to the target site directly through the bloodstream
  - Exclusive endocrine glands - pituitary, thyroid, parathyroid, thymus, adrenals
  - Partially endocrine - pancreas, gastric and duodenal epithelium, gonads, placenta
- Hormones - secretions from specific cells or glands in the body that are carried by the blood
  - Effect is produced in one or more specific parts only
  - Secreted from the source directly to the blood
  - Regulate physiological processes
  - Produced in very small quantities and are biologically very active
  - Excess or deficiency can cause serious disorders
  - Chemically, hormones may be water soluble proteins, glycoproteins and amines or lipid-soluble steroids
  - Extra hormones are not stored in the body and are secreted out
- Target cells - chemicals are secreted into the blood and reach the target cell
  - Lock and key mechanism

1. Pituitary - the master gland; controls other glands
    1. Hangs from base of midbrain
        1. Connected to hypothalamus by pituitary stalk
        2. Hypothalamus
            1. Secretes the hormone somatostatin - inhibits secretion of growth hormone from anterior of pituitary
    2. Anterior of pituitary
        1. Growth hormone (GH)
            1. a.k.a. somatotropic hormone (STH)
                1. Promotes growth of whole body
                2. Under secretion → dwarfism
                3. Oversecretion → gigantism and acromegaly
        2. Trophic hormones - stimulates other endocrine glands
            1. Thyroid stimulating hormone (TSH)
        3. Gonadotropic Hormones
    3. Posterior Lobe of Pituitary
        1. Antidiuretic Hormone (ADH) or vasopressin
            1. Increase absorption of water from kidney tubes
            2. Deficiency causes diabetes insipidus
        2. Oxytocin
2. Thyroid -
    1. Located in the front of the neck
    2. Thyroxine
        1. Regulates basal metabolism
        2. Controls growth and development
        3. Under secretion (hypothyroidism) can lead to
            1. Simple Goitre
                1. Swelling of the neck is seen
                2. Iodine deficiency
                3. Dwarfism, mental retardation, general sluggishness
        4. Over secretion (hyperthyroidism) can lead to
            1. Exophthalmic goitre

1. Increase in the metabolic rate, rapid heartbeat, shortness of breath and the eyes protrude out together with goitre in the neck

3. Calcitonin
    1. Regulates calcium and phosphate levels in the blood
    2. High calcium → more calcitonin is secreted
        1. Calcium ions are moved from blood to the bones making them harder
        2. Reverse happens when the calcium level in the blood is low making the bones soft

3. Parathyroids
    1. Two small pairs of of glands embedded in the thyroid gland
    2. Secrete parathormone
        1. Raises calcium level by stimulating the release of calcium from bones

4. Thymus
    1. Base of neck
    2. Produces hormones involved in the maturation of T lymphocytes

5. Adrenals
    1. Situated like caps, one above each kidney
    2. Adrenal medulla
        1. Secretes adrenaline
            1. Fight or flight hormone
            2. Released in response to high stress conditions
            3. Increases heartbeat and blood pressure
            4. Increases blood supply to the visceral organs
            5. Releases more glucose into the blood and the liver
    3. Adrenal cortex
        1. Glucocorticoids
            1. Ex: cortisone
                1. Raises blood glucose through action of liver in response to stress
                    1. Deamination of amino acids
                2. Glucose is provided through this hormone during starvation
                3. Adapts body to extreme heat, cold, burns or infections
                4. Some act like sex hormones and overgrowth of adrenal cortex can lead to premature sexual development
        2. Cortisol
            1. Mental stimulation
            2. Breaks down fat and protein into glucose; anti-inflammation
            3. a.k.a stress hormone
                1. Involved in response to stress and anxiety
        2. Mineralocorticoids
            1. Ex: aldosterone
            2. Concerned with water retention
            3. Increases reabsorption of sodium and chloride ions in kidneys

6. Pancreas
    1. Endocrine and exocrine gland
    2. Islets of Langerhans - three kinds of cells
        1. Alpha cells → glucagon
        2. Beta cells → insulin
        3. Gamma cells → somatostatin
    3. Glucagon
        1. Stimulates breakdown of glycogen to glucose in the liver → rise in the blood sugar level
    4. Insulin
        1. Promotes glucose utilization by the body
        2. Stimulates deposition of extra glucose in the blood as glycogen in the liver
        3. Disorders
            1. Under secretion → diabetes mellitus (hyperglycemia)
                1. Higher than normal blood sugar
                2. Excretes lots of urine loaded with sugar → feels thirsty
                3. Weight loss/ becomes weak
                4. Patient may lose eyesight
            2. Over secretion → hypoglycaemia
                1. Low blood sugar levels
                2. Brain may enter state of come
    5. Somatostatin
        1. Growth inhibiting hormone
        2. Inhibits secretion of insulin as well as glucagon

7. Gonads
    1. Testes
        1. Germinal cells
            1. Produce sperm
        2. Interstitial cells
            1. Produce hormones

1. Androgen; ex: testosterone
2. Testosterone stimulates development of male characteristics
    1. Used as a steroid for athletes to improve athletic performance (this is very dangerous)

2. Ovaries
    1. Estrogen
        1. Secreted from follicles of the ovary
        2. Stimulates development of breasts and fat deposition
    2. Progesterone
        1. Prepares the wall wall if the uterus for having egg fertilized
        2. One of the components in birth control pills

8. Hormones secreted from the stomach and intestine
    1. Gastrin
        1. Secreted by the mucous membrane of the pyloric end of the stomach
        2. Stimulates gastric glands to secrete gastric juice
    2. Secretin
        1. Secreted by inner lining of the duodenum
        2. Stimulates the production of pancreatic juice
    3. Cholecystokinin
        1. Stimulates release of bile from gallbladder

- Negative feedback mechanism - when the gland secretes certain hormones into the bloodstream, the target cells detect the hormone and the function is done, then a message is sent to the gland to stop the secretion
- Disease is usually a positive feedback problem
    - When normal functions lose their negative feedback control, many times, disease is the result
    - If a gland doesn't get negative feedback, it keeps producing the hormone and as a result, there is excess of the hormone
- The hypothalamus links the nervous system to the endocrine system
- Uses of animal hormones
    - Bovine somatotropin (BST) - naturally produced in animals
        - Given specifically to produce more milk

Nervous System vs. Endocrine System

Nervous System	Endocrine System
Electrical impulsesVery fastShort lastingEx: moving muscle	Chemical messagesSlowerLonger lastingEx: insulin and blood sugar levels

5. Pathogens

- Pathogen - a disease causing organism
    - Human body is the perfect environment
        - Body temp - 36 to 37 degrees
        - Dissolved substances in body
        - Reproduce very quickly and circulate through the body along with the blood and other bodily fluids
- Transmissible disease - diseases that are caused by pathogens can usually be passed from one person to another
    - Water
    - Air
    - Direct contact
    - Food
- Vector - an organism that transmits a disease or parasite from one animal or plant to another
    - Ex: mosquito for malaria caused by plasmodium
    - Dogs for rabies
    - The vector is not affected by the disease or parasite
- Bacteria -
    - Microscopic organisms
    - Largest are 10 micrometers long
    - Living cells
    - Release poisonous toxins that make us feel sick once they are inside the body
        - Food poisoning, cholera, typhoid, whooping cough, gonorrhoea
    - Structure
        - Have a flexible cell wall
        - No nucleus
            - Chromosomal DNA carries most of the genetic info
            - Plasmid DNA forms small loops and carries extra information
        - Flagellum
        - Flagella
- Viruses
    - Smaller than bacteria
    - Only reproduce inside host cells
        - Damage a cell when they do this
        - Take over and make hundreds of thousands of copies of themselves
        - Virus fills whole host cell and busts it open
        - Then passed in the bloodstream, airways or other routes
    - Influenza, colds, measles, mumps, rubella, chicken pox, AIDS
    - Structure

- Consist of a fragment of genetic material inside a protein coat called a capsid
- Sometimes have a further membrane of lipid called an envelope surrounding the protein
- May have a tail section

- Transmission
  - Attachment - binds to a specific receptor on the host surface
  - Penetration - enters the cell
  - Synthesis of new components -
    - Takes over control of the cell metabolism stopping the cell's normal nucleic acid and protein synthesis
    - Replicated using nucleotides from the host cell
    - Protein coats are manufactured using the amino acids of the host cell.
  - Assembly - Whole virus particles are made when the nucleic acids are surrounded by the protein coats
  - Release - Many viral particles are released when the cell bursts open (lysis) or by slow leakage
- Parasites use the host as a source of nutrients and deprive the host of substances it needs for its own survival
  - Ectoparasites - surface of body
    - Ticks, fleas
    - Depend on host for food and shelter
    - Vectors for other parasites
  - Endoparasites - live inside the body
    - Protozoans - single celled
      - Ex: malaria
    - Helminths - worms
      - Flukes, roundworms, tapeworms
    - Major health concern
- Protozoa - single celled
  - Amoebic dysentery, malaria
- Fungi
  - Eukaryotic
  - Many important for food industry and antibiotics
  - Pathogenic fungi are responsible for the destruction of crops

5.2. Immune System

- Immune response - the way in which lymphocytes respond to pathogens, producing antibodies
- Active immunity - defence against a pathogen by antibody production to the body
  - Natural immunity - lymphocytes
  - Artificial immunity - vaccines
- Passive immunity - short-term defence against a pathogen by antibodies acquired from another individual such as from mother to infant
  - Natural - passed to fetus through a placenta
  - Artificial - medicine
- Vaccine - a vaccine contains weakened or dead viruses or bacteria that normally causes disease. These pathogens have the same antigens as the normal ones but they are not able to cause the disease
  - Herd immunity - not everyone needs to be immunized in order to stay healthy, but a majority of the population does
- Non specific defense
  - First line of defence - preventing entry
    - Skin
    - Internal surface mouth - saliva
      - Saliva contains lysozyme and stomach contains mucus, protein digesting enzyme and HCl
    - Nostrils - hairs
      - Hairs trap microbes along with other undesirables such as dust
      - Special cells in the respiratory tract produce lysozyme rich mucus to trap and destroy foreign bodies
      - Mucus membranes also lines with cilia tiny breathing hairs that sweep mucus up to throat where it is
    - Ears - wax
    - Eyes - tears
  - Second line of defense
    - Inflammation - a complex response involving protein and white blood cells

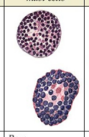
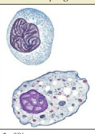
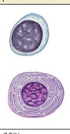
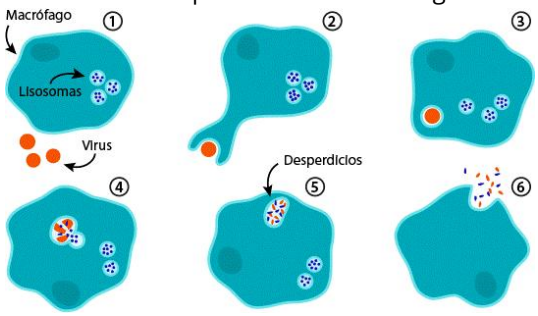
	Basophils and mast cells	*Neutrophils*	*Eosinophils*	*Monocytes and macrophages*	*Lymphocytes and plasma cells*	*Dendritic cells*
						
% of WBCs in blood	*Rare*	*50–70%*	*1–3%*	*1–6%*	*20–35%*	*NA*
Subtypes and nicknames		Called "polys" or "segs" Immature forms called "bands" or "stabs"		Called the mononuclear phagocyte system	B lymphocytes Plasma cells T lymphocytes Cytotoxic T cells Helper T cells Natural killer cells Memory cells	Also called Langerhans cells, veiled cells
Primary function(s)	Release chemicals that mediate inflammation and allergic responses	Ingest and destroy invaders	Destroy invaders, particularly antibody-coated parasites	Ingest and destroy invaders Antigen presentation	Specific responses to invaders, including antibody production	Recognize pathogens and activate other immune cells by antigen presentation

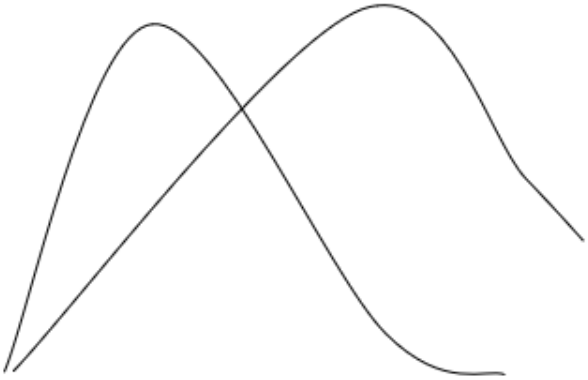
Fig. 24-4

    - Phagocytosis - the process by which a cell—often a phagocyte or a protist—engulfs a solid particle to form an internal compartment known as a phagosome
      - Often happens when cell is trying to destroy something like a virus or infected cell
      - Only happens when the cell is in physical contact with the particle it wants to engulf

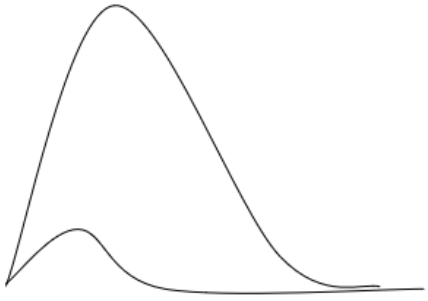


  - Third line of Defense: the adaptive immune system
    - Your body cells as well as all organisms and substances that may enter your body that are

covered with unique chemical markers known as antigens
- Specialized WBCs interpret these antigens and recognize whether they are own cells or invading materials or cells
- If a foreign invader is detected, the adaptive immune system can start to fight it
- Immune system can also detect whether this is a new pathogen or one that has been fought in the past
  - First infection - body starts producing antibodies and the antibodies multiply once the correct antibodies have been detected
    - It may take some time for the body to identify the correct antibody
    - Some antibodies remain as memory cells



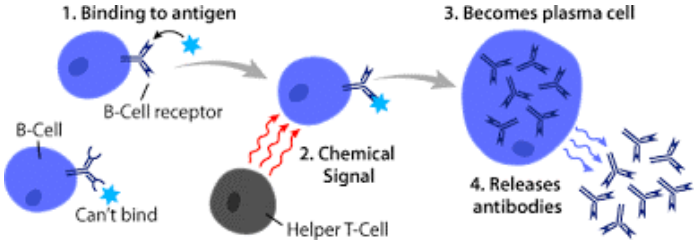
- First line is bacteria, second line is antibodies
- Second infection
  - Thanks to memory cells, the antibodies are produced very quickly
  - This is the concept of vaccination



  - Small curve is bacteria, large curve is antibodies
- When we are sick, the body tries to make itself unappealing to pathogens
  - Fever raises temp above 37 degrees
    - Chemicals from pathogens and immune cells get to hypothalamus
    - Hypothalamus detects signals
    - Turns up body heat
  - Mucus and phlegm trap pathogens before they can fully enter the body
    - Contain antibodies
    - When we cough or sneeze, the phlegm and mucus end up
  - Vomit
    - Digestive system becomes more acidic→ less pleasant for pathogens
    - Actively removing pathogens

5.3. Antibodies

- Antibodies - a protein molecule with a particular shape, rather like an enzyme molecule, this shape is just right to fit into another molecule. To destroy a particular pathogen, antibody molecules must be made which are just right shape to fit into molecules on the outside of the pathogen
- Antigen - pathogen molecules
- If a pathogen enters the body, it is likely to meet a large number of lymphocytes, one of these may recognize the pathogens as being something that its antibody can destroy. this lymphocyte well start to divide rapidly by mitosis, making clone of lymphocytes itself. These lymphocytes then secrete their antibody, destroying pathogens.



- Memory cells - Memory cells are a type of white blood cell that can respond quickly when it meets a microorganism for the second time. They produce the right antibody for the particular microorganism and destroy it before you feel unwell. This is described as being immune to a disease.
  - After the infection has passed most b cells die, and antibody numbers also fall off, but a small number become memory B cells. They are ready to respond to pathogens quickly if you meet it again
- T-lymphocytes (or t cells which mature in the thymus) ex: T killer cells which destroy bacteria that have become coated with antibodies and helper T cells which prompt B cells to start making antibodies
- B lymphocytes are produced in the bone marrow
  - Produce plasma cells that form antibodies
  - Also produce memory cells that stay in the body for a long time and can trigger the production of antibodies if infection occurs
- Antibiotics are substances that destroy, damage or kill certain types of cells
  - Many antibiotics are found in nature
    - Penicillin originates from mold
  - Not effective for viruses

5.4. Autoimmune Disease

- Lymphocytes normally respond only to foreign cells that enter the body
- They recognize our own cells as self cells and do not produce antibodies against them
- However, sometimes this system breaks down,lymphocytes behave as though some of our own cells are foreign and react to them as they would to an invasion of pathogens
- Diseases that result from this kind of malfunction of the immune system are called autoimmune diseases
- Ex: type 1 diabetes, multiple sclerosis, lung cancer
- Linked to people's lifestyle and behavior

Lifestyle and Mental Health Disorders

- Some diseases like type 2 diabetes and certain types of cancer can be linked to behavior
  - These lifestyle diseases can result from factors such as obesity (from excessive calorie intake,smoking and alcohol consumption)
  - Not entirely linked to behavior but indulgence in these behaviors can increase the chances of onset of these diseases
- Mental health disorders include depression, eating disorders, PTSD, and addictive disorders
  - Some are inheritable
  - Some result from traumatic experiences, brain damage from an accident, abuse, or stressful living conditions

5.5. Other Types of Diseases

- Ebola
  - Contagious and viral
  - Eating "bush meat", monkeys or apes seemed to be the source of infection in humans
    - These hosts caught it from the fruit bat
    - Monkeys are the intermediate hosts
- Influenza
  - One strain is called bird flu and is found in many migratory water birds
  - Sharing ponds or food with domestic fowl can lead to spread of the virus
  - Domestic birds like chickens are the source of bird flu in humans
  - Never passed from one human to another
  - Another strain is the Spanish flu, and another is swine flu
- Dengue fever
  - Mosquito borne
  - Mosquitos transmit the virus from one human to the next
  - Despite scientific advancement, there are 30x as many infections as there were in 1960
  - 4 types
    - Surviving one type means that you will suffer even more symptoms if you get another type later
- Polio
  - Hosted by human gut bacteria which are also capable of living wild in sewers
  - Can kill or cause paralysis
  - A few drops of attenuated virus are enough to protect a person for life

6. Reproduction

6.1. Life Cycles

- Life cycle - a series of developmental stages in a lifetime
  - Repeated every generation
  - Prereproductive vs. reproductive stage
  - Every species has its own stages
    - Time period of each stage varies
      - Ex: cicada spend 17 years as immature nymphs
    - Also depends on environment
  - Butterflies: egg → larva → pupa → adult
  - Locust: egg → nymph → adult
    - Not all live to adulthood
- Metamorphosis - change in form
  - Complete vs. incomplete
  - Incomplete
    - Moulting - shedding the exoskeleton
      - No. of times varies
    - Gradual/incomplete hemimetabolous - wings appear as protrusions on the thorax
  - Holometabolous/abrupt/complete
  - Immature nymphs are adults that can't reproduce
- Advantages of complete metamorphosis
  - Adults and larvae don't compete for the same food
  - Have different predators
  - Different habitats
  - Adaptable
  - Occurs in 85% of species
  - Higher survival rate

6.2. Asexual Reproduction

- Uniparent - one parent
- Uniform offsprings - genetically identical to parent
- Rare in multicellular organisms but common in prokaryotes
- No gametes involved
- Binary fission - cell division in prokaryotes that forms two genetically identical cells
  - DNA is copied
  - Cell grows longer pulling the two copies apart → cell membrane pinches inward → new uniform identical offspring
  - Unicellular organisms
  - Ex: Bacteria, Protozoa, Amoeba, Ecoli
- Budding - a new organism grows by mitosis and cell division on the body of its parent

- Bud can break off from the parent when it is large enough and live on its own
- Offspring may remain attached to form a colony
- Ex: Yeast, Hydra, Cactus

- Regeneration - occurs when an offspring grows from a piece of its parent
  - Ex:
    - a) New organisms: sea stars, sea urchins, sea cucumber, sponges and planarians
    - b) New body parts: gecko, newts, tadpoles, crabs, hydra, and zebrafish
- Vegetative propagation - uniform offspring grow from a part of the parent plant
  - Parent plants send out runners and when they touch the ground, roots can grow
  - A new plant is produced even if the runner is broken apart
  - Each plant is uniform and identical to the parent
  - Ex: strawberries, potatoes, ivy and crabgrass
- Advantages:
  - Rapid populating
  - No mates required
  - Useful in emergencies
  - No true investment
- Disadvantages:
  - No diversity
  - Prone to extinction
  - Cannot adapt
  - Dangerous mutations in DNA

6.3. Sexual Reproduction

- A type of reproduction in which the genetic materials from two different cells combine, producing an offspring
  - Sex cells - the cells that combine; egg and sperm; gametes
- Fertilization - the process in which an egg and a sperm fuse together
  - New cell formed = zygote

Plants

- Reproductive organs are found in the flowers
  - Most plants have male and female organs in their flowers
  - Carpel/pistil (female):
    - Stigma - surface for pollen to stick
    - Style - long tube which connects stigma and ovary
    - Ovary - contains the ovules; becomes the fruit
    - Ovules - contains the egg; become the seed
  - Stamen (male):
    - Anther - produces pollen enclosed by pollen grains by meiosis
    - Filament - holds up the anther
    - Pollen grain - male gametophyte which consist of male gametes
- Pollination
  - Self - transfer of pollen grains from anther to the stigma of the same flower
  - Cross - transfer of pollen grains from anther to the stigma of different flowers
  - Wind - different structure
    - Lots of small and light pollen grains
    - Anthers are exposed to allow the pollen to be blown away easily
    - Petals are small and green as there is no need to attract insects
    - No scent or nectary
    - Stigma are feathery to catch pollen carried on wind
    - Seeds have wing like feathery projections which increase surface area so that the seeds can float in air and be carried over long distances
    - Ex: sycamore, dandelion
  - Animals
    - Tomato
      - Fleshy, bright, and scented to attract animals
      - Tough seed coat to protect seeds from being digested in the animals' gut
    - Burr grass
      - Stiff, hooked spines which catch onto the animals' fur to be carried long distances before dropping off
- Fertilization
  - Transfer of pollen via wind or insects
  - Pollen grains land on stigma
  - Nucleus of pollen grain (sperm) travels through style to the ovule → egg and sperm fuse → zygote formed → grows into embryo through meiosis
- Germination - seed contains the future plant or embryo which develops into seedling under appropriate conditions and this is called germination
  - Factors
    - Water: allows the seed to swell and the embryo to start growing
    - Oxygen: needed for aerobic respiration
    - Warmth: increases growth rate and enzyme activity

6.4. Humans

- Growth - result of asexual cell divisions; body proportions and shape changes throughout life
- Puberty - physical changes in which the body of a girl or boy matures and becomes able to reproduce
  - Males: growth of facial and body hair, more muscle mass, deeper voices
  - Females: breasts, wider hips, growth of body hair
- Male reproductive system
  - Testis (testes)
    - Production of sperm and testosterone
    - Located in scrotum which is a sac like structure which maintains temperature
    - Contains seminiferous tubules

- Epididymis - site where sperm matures and develops the ability to be motile
  - Mature sperm is stored here until ejaculation
- Vas deferens - long tubes which conducts sperm from the testes to the prostate gland during ejaculation
- Seminal vesicle - secretes fluid containing fructose, mucus, and prostaglandin (triggers uterine contraction)
- Prostate gland - secretes an alkaline fluid to neutralise vaginal acids to maintain sperm viability
  - Mixture of sperm and fluid is semen
- Urethra
  - Conducts sperm from prostate gland out of the body via the penis
  - Only sperm or urine at a time not both
- Penis - copulatory organ in which there is erectile tissue through which blood enters
  - During sexual intercourse, penis is inserted into the vagina to transfer sperm

- Female reproductive system
  - Ovary - oocytes mature prior to ovulation and the secretion of estrogen and progesterone
  - Fimbria - fringe of tissue adjacent to an ovary that sweep an oocyte into the oviduct
  - Oviduct/fallopian tube - transports the oocyte to the uterus; also where fertilization occurs
  - Uterus - fertilized egg is implanted and develops into an embryo
  - Endometrium - the mucous membrane lining of the uterus
    - Thickens in preparation for implantation or is otherwise lost
    - Cervix: lower portion of the uterus
  - Vagina - passage leading to the uterus by which the penis can enter

Menstruation

- One egg per month s released by the ovaries
  - Inner lining of uterus becomes full of blood capillaries and becomes soft to receive the fertilized egg
- If fertilization doesn't take place, the egg dies and it's also accompanied by other changes
  - Uterus lining breaks down → menstruation
- Menstrual cycle
  - 4 hormones
    - Ovary: estrogen and progesterone
    - Pituitary gland: FSH (follicle stimulating hormone) and LH (luteinizing hormone)
  - Process:
    - Follicle stage: pituitary gland secretes FSH and LH → follicles develop → secrete estrogen → rebuilds the uterine lining (10-14 days)
    - Ovulation: pituitary increases FSH and LH (lots of LH) → LH causes the follicle and ovary to release an egg (ovulation) → fertilization is most likely to be successful (day 14)
    - Corpus Luteum Stage: LH and FSH drop → yellow cells occupy the place where the egg was → corpus luteum → produce and release progesterone → maintains uterine lining to ensure implantation
    - Menstruation: if the egg is not fertilized within about 24 hours of fertilization → corpus luteum breaks down and secretion of LH decreases → decrease in progesterone → lining breaks down → menstruation takes place
- Menopause - the permanent cessation of the menstrual cycle; occurs between 45-50 years of age

6.5. Fertilization

- Growth - increasing number of cells
- Differentiation - series of changes that transforms the unspecialized embryonic cells into specialized cells, tissues and organs
- Aging - complex series of developmental changes which occur with the passage of time caused by both heredity and environment
- Death - irreversible end of all brain functions
- When an egg is fertilized by a sperm, the egg will implant into the lining of the uterus and begin to develop
  - Zygote → embryo (0-8 weeks) → fetus (8 weeks to birth)
- Fertilization takes place in the fallopian tube
- Fertilization - fusion of sperm nucleus with egg nucleus
- Zygote divides into two identical cells by mitosis → 4 cells → 8 cells → 16 cells → solid ball of cells called morula
  - Zygote is a diploid cell
  - Morula - 30-50 cells (blastomeres)
    - Created is around 96 hours
    - No growth is seen → arise through cleavage
    - Each cell is half the size of the one it is derived from
- Blastula
  - 4th day after insemination → epithelial cellular layer forms → thicker outside
  - Blastopore
  - Blastocoel - fluid filled inside sphere
  - Vegetal plate - yolk filled end
  - Blastocyst
- Implantation - the embryo secretes enzymes that digest a path into the soft tissue; first phase of pregnancy
- Gastrula - one side of the blastula pushes inward forming a second, inner layer of cells called the endoderm
  - Endoderm → lining of digestive tract, lining of trachea, bronchi and lungs, liver and pancreas, thyroid, parathyroid, thymus, and urinary bladder
  - Outer cell layer = ectoderm
    - Becomes nervous system, epidermis, sweat glands, hair and nails, lining of mouth, nostrils and anus
  - Third layer called mesoderm forms between the endoderm and the ectoderm

        - Becomes bones and muscles, blood and blood vessels, heart, reproductive system, excretory system, inner layer of skin
    - Actual beginning of pregnancy (phase 2)
- Ectopic pregnancy - when an embryo implants somewhere other than the uterus
- Embryonic period
    - Primary organ differentiation
    - Ends at 8th week
    - Phase 3
- Fetal periods (last phase)
    - Rapid growth, changes in body parts and final prep for birth
    - End of week three - nervous and digestive systems begin to form
    - Chorion has grown into the uterine tissue to form the placenta
    - Placenta acts as a barrier for microorganisms
        - AIDS, German Measles, chicken pox and encephalitis can still pass through
- Gestation period of humans is 9 months
- Control of development
    - Nucleus → DNA contains hereditary information, controls cellular activity and encodes for the production of cellular proteins
    - Cytoplasm receives instructions from the DNA in the nucleus
- Development
    - External in water - nourishment →supplied by the yolk stored in egg; no parental care
    - External on land - production of egg and shell; some parental care
        - 4 extra membranes outside the embryo
            - chorion - outermost; aids in gas exchange
            - Allantois - exchange of O2 and CO2; stores waste until egg hatches
            - Amnion fluid sac that surrounds the embryo cushion; shock absorber
            - Yolk sac - surrounds the yolk; source of food for embryo
        - Shell prevents bacteria from entering, porous enough for O2 and CO2 exchange, slow rate of evaporation
    - Internal
        - Placental mammals - blood vessels of embryo are in close contact with mother's blood
        - Placenta - structure produced by the uterus of the mother which supplies nutrients to the embryo and removes waste from the embryo
            - Diffusion and active transport; no direct blood link between mother and fetus
        - Umbilical cord - attaches the embryo to the placenta of the mother in the uterus
    - Non placental mammals
        - Egg laying mammals/monotremes - duckbill platypus, spiny anteater
        - Marsupials - kangaroo, opossum
- For the first 6 weeks of development, male and female embryos are identical
    - 7th week - primary reproductive organs begin to develop
    - Testosterone in males and estrogen in females develop secondary characteristics
    - Progesterone prepares uterus for arrival of developing embryo
- Multiple births
    - Identical: 1 egg is fertilized and splits during the first division
    - Fraternal: 2 eggs are fertilized at the same time

6.6. Birth Control Methods and STDs

- Contraception - method of avoiding conception
    - Safe period - sexual intercourse is avoided during the period of ovulation as well as a few days before and after
    - Barrier method (condoms) - physical barrier is created between the sperms and the ovum
        - Also prevent STDs
        - No tears in condom, must not be expired, must be put on the penis correctly
    - Oral contraception (the pill) - manipulation of hormones → prevents ovulation
        - Cannot prevent STDs
        - Lots of side effects
    - Chemical contraception - creams and gels applied in the vagina
        - Melts into a viscous mass as a result of body heat → creates barrier
        - Acidic environment in unfavorable for sperms
- STDs
    - Also known as Sexually Transmitted Infections
    - Chlamydia - caused by bacteria
        - Causes a burning pain when urinating and forms a thick yellow or green discharge from an infected penis or vagina
        - Can cause bleeding in between periods or swollen testicles in men
        - Can result in infertility
        - Treated with antibiotics
    - HIV - human immunodeficiency virus
        - Transmitted through sexual intercourse as well as unsterilized needles or cuts
        - Mild flu-like symptoms
        - Many people don't even know that they are affected
    - AIDS - acquired immune deficiency syndrome
        - Months or years after HIV, the virus may attack the immune system at which point HIV results in AIDS
        - Antiviral drugs can slow the development of AIDS and HIV even though there is no cure
    - Gonorrhoea - caused by the bacteria called Neisseria gonorrhoeae or gonococcus
        - Yellow/green discharge

- Pain while urinating, bleeding between periods
- Anal itching and discharge
- Reduced fertility
- Antibiotic injection and tablet is a simple cure

- Herpes -
  - Cold sores in reproductive regions
  - Aching, gland swelling, tiredness, and flu symptoms
  - No treatment
- Syphilis - bacteria called treponema pallidum
  - Small sores
  - Blotchy red skin rashes
  - White patches in mouth
  - Headache, fever, swelling, hair-loss, etc...
  - Brain, joint, bone, eye, heart and nerve damage
  - Can be treated with antibiotics**

6.7. Sexual vs. Asexual Reproduction

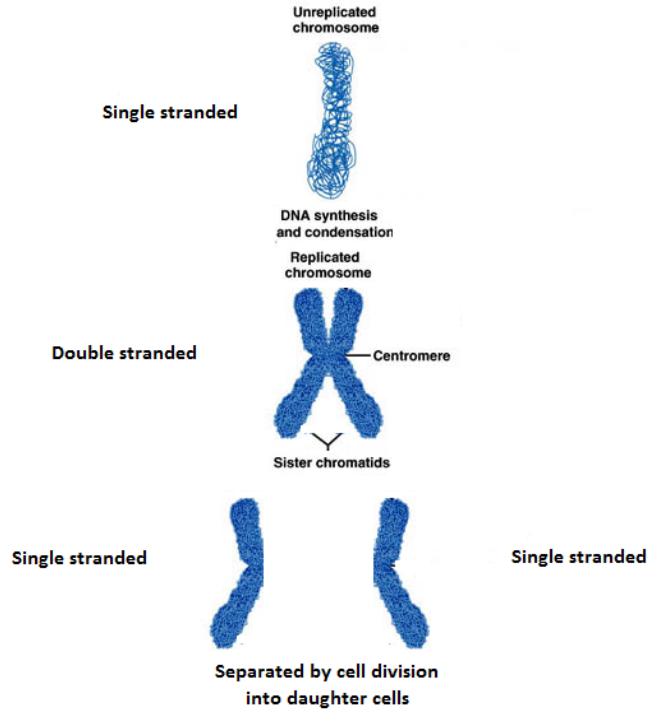
Sexual Reproduction	Asexual Reproduction
ADVANTAGES	ADVANTAGES
Diverse offspring/genetic variation:	**No waste of time or energy**
Slight differences amongst individuals	No true investment
Resistance to disease	**No mate required**
Traits can develop to resist harsh environments that allows an organism +to survive	**Rapidly reproduce a large number of uniform offspring**
Selective breeding:	**In case of emergency**
Develop organisms with desirable traits	DISADVANTAGES
Agriculture	**No genetic variation**
Pets	Chances of survival decrease

Sexual Reproduction	Asexual Reproduction
DISADVANTAGES	DISADVANTAGES
Time and energy:	Whole species can be wiped out from a disease
Have to grow and develop until they are old enough to produce sex cells	Prone to extinction
Finding a mate exposes the organism to threats (predators, disease, environment)	**Dangerous mutations are always passed on**
Fertilization can't take place during pregnancy	**Cannot adapt**

7. Cell Division

7.1. Introduction

- Chromatin - a network of DNA
  - Turns into chromosomes when cell division is about to take place
  - DNA has to duplicate
- Chromosomes - condensed chromatin
- Chromatids and centromeres
  - Sister chromatids

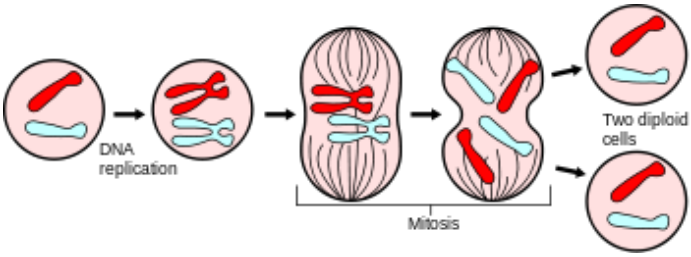


- Cell division - when a single cell divides into two identical cells
- Cell cycle
  - 1. Interphase - rest phase
    - G1 = growth
    - S = growth and DNA synthesis
    - G2 = growth and final preparation for division
  - 2. Mitotic Phase - division takes place; PMAT; aka Karyokinesis
    - Prophase, Metaphase, Anaphase, Telophase
      - cell doesn't change shape during mitosis
    - → Cytokinesis
    - 2 daughter cells
    - Back to interphase

7.2. Mitosis (equational division)

- Asexual
- Phase in which the nucleus divides to form two nuclei, each containing a complete set of the cell's chromosomes
  - Prophase - chromosomes become visible and spindles form; nuclear envelope breaks
  - Metaphase - chromosomes line up along the equator and spindles connect to the centromere

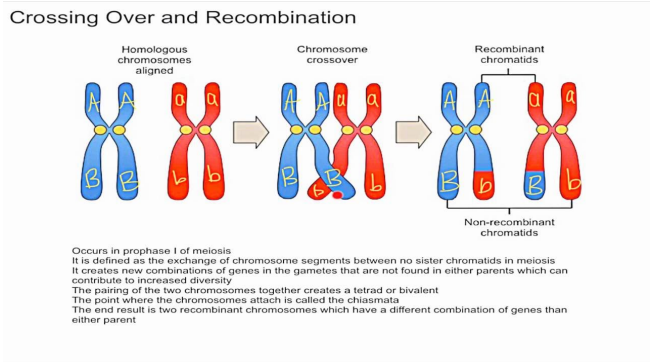
- Anaphase - sister chromatids separate at the centromere and are pulled to opposite poles; microtubules contract
  - Mitotic spindles
- Telophase - nuclear envelope forms, chromosomes uncoil and spindles dissolved



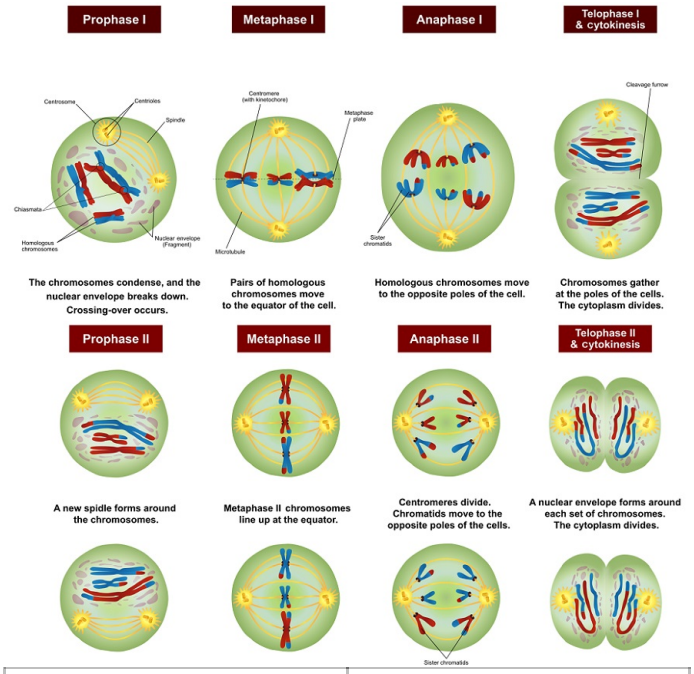
- Cytokinesis - process where the cytoplasm divides into two
- One original cell and one exact copy
- Plant cell - cell plate appears in center
- In animal cells, it starts at the periphery and ends at the center
- In plant cells, it starts at the center and moves to the periphery

7.3. Meiosis (reductional division)

- Meiosis I - PI, MI, AI, TI
- Meiosis II - PII, MII, AII, TII
- homologous - a pair of chromosomes
  - similar shapes, size and arrangement of genes
  - maternal and paternal chromosomes
- crossing over - mutual exchange of genes takes place
  - genetic variation occurs



  - occurs in prophase I of meiosis
  - chiasmata - point where the chromosomes attach
  - recombinant chromosomes
- haploid cells cannot undergo meiosis but diploid cell can
- both haploid and diploid can undergo mitosis



Mitosis	Interphase
Embryonic developmentGrowthTissue repairAsexual reproduction	Cell growthDNA synthesisResting but activeOrganelles duplicate

7.4. History and Discovery of the Structure and Role of DNA

- 1869 - Friedrich Miescher was a Swiss chemist and the first to identify DNA as a unique molecule
- 1914 - Robert Feulgen (German chemist); staining technique
  - More DNA = more staining
  - All cells in an organism have the same amount of DNA except gametes
- Fred Griffith - demonstrated that bacteria could be transformed from one strain to another by transferring genetic factor from one organism to another
  - Living S (smooth) cells = mouse is dead(strain is protected by a capsule from the mouse's defenses)
  - Living R cells = alive
  - Heat killed S cells = alive
  - Heat killed S cells + Living R cells = dead
  - conclusion was that the bacteria had incorporated heredity factor from a source and in doing so expressed a new smooth trait
- Avery, MacLeod and McCarty examined various molecules found in S-strain Pneumococcus cells to prove that DNA was responsible for the transformation of the bacterial cells
  - When various isolated chemical components of the S-strain pneumococcus cells were mixed with the R-strain pneumococcus cells, it was shown that the DNA from the S-strain cells that caused transformation
- Alfred Hershey and Martha Chase
  - Demonstrated that genetic material is DNA by using viruses that infect bacteria

- Phage used in experiment = DNA molecule surrounded by a protein coat
- Part 1
  - Phages grown with sulfur (S 35) labeled amino acids → radioactive protein coat
  - No radioactive DNA
  - Phages infected bacteria
    - Phages produced in these cells contained no radioactivity
    - Separate phages outside the bacteria from the cells using a blender
  - Centrifuge the mixture so bacteria form a pellet at the bottom of the test tube
- Part 2
  - Phages grown with phosphorus (P 32) radioactive deoxyribonucleotides → radioactive DNA
  - Radioactive DNA present in bacteria
- This demonstrated that the DNA not protein carries the genetic information

- Chargaff's rule
  - Found the percentage of various nucleotides in genome
  - Rules
    - A+G = C+T = 50%
    - Percentages of nucleotide vary for different species
- Rosalind Franklin - used x-ray crystallography to determine that DNA was double stranded, a helix, phosphates were on the outside and three distances (2 nm, 0.34 nm and 3.4 nm) showed up in a pattern over and over again in the diffraction pattern
- James Watson and Francis Crick
  - Determined that the sugar and phosphates were on the outside
  - Determined that the nitrogenous bases were forming the rungs of the ladder
  - Two purines are too wide to overlap and two pyrimidines are too far apart to form the hydrogen bonds
  - A purine and a pyrimidine is just right

7.5. Structure of DNA

- Double helix - two chains of atoms twisted around each other
  - Atoms are held together with covalent bonds
  - Two strands in the spiral are held together with hydrogen bonds
    - Hydrogen bonds are weaker → important when unzipping
- DNA is a polynucleotide
  - Each nucleotide is made of a nitrogen base, a sugar and a phosphate group
    - Sugar = deoxyribose
  - Base pairs - A+T or G+C
    - Held together with hydrogen bonds

The Power of DNA

- DNA-DNA hybridization
  - The closer the two species are, the fewer mispairings there are in hybridization
- Human Genome Project - only 5% of DNA is actually useful
- Lynn Margulis - extracted and compared DNA from organelles and confirm its similarity to the DNA in groups of wild, free-living bacteria and cyanobacteria
  - Ideas of eukaryotic cells gained acceptance as a result of DNA analysis

7.6. DNA Replication

- Helicase - enzyme that breaks hydrogen bonds
  - Replication fork - where replication begins
    - Leading strand - continuous synthesis
    - Lagging strand - not continuous; okazaki fragments
  - 5′ → 3′
- SSBP - single stranded binding protein; binds to both strands to keep them apart
- RNA primase - synthesizes primer for replication to start
- DNA polymerase - adds nucleotides to the parent DNA strand
  - A-T and G-C
    - Complementary base pairings
  - Strands are antiparallel
- DNA ligase - joins the two DNA strands together by forming a phosphodiester bond

7.7. Protein Synthesis

- Essential amino acids - our body can't synthesize them
  - Non essential = can synthesize
  - 20 amino acids build up proteins
- Transcription - happens in the nucleus
  - Transcription unit - length of DNA to be copied
  - Transcribe DNA
  - Only one strand is formed at a time from a template to avoid complication
    - Copied strand = antisense strand
    - Not copied strand = sense strand
  - If both strands are used, various proteins will form at the same time (hypothetically)
  - RNA polymerase - binds to DNA at the TATA box to unzip the double helix
    - Read the DNA bases and helps the RNA versions find a match
    - RNA polymerase adds on in the 3′ → 5′ to create a strand that is 5′ → 3′
  - mRNA - messenger RNA
    - Leaves nucleus through nuclear pores and moves to the cytoplasm and attaches to a ribosome
    - Uracil instead of Thymine
- rRNA is the ribosome
- Translation - happens in the cytoplasm/ribosome
  - Codon - thee template bases on mRNA

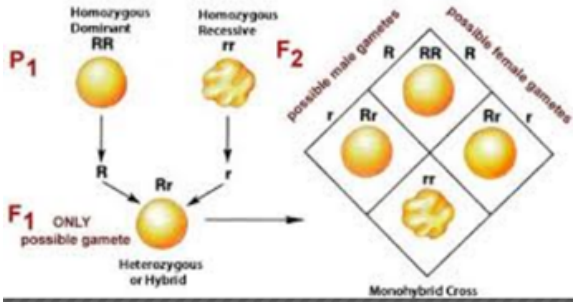
- Anticodon - three template bases on tRNA
- tRNA decodes and brings the amino acids from the cytoplasm and sequences them according to the mRNA codons
  - Polypeptide chain forms → protein
  - tRNA leaves

7.8. Mutations

- Mutation - a change in the DNA base sequence
  - Substitution - one replaced by another
  - Insertion - addition of an extra base
  - Deletion - removal
  - Inversion - change in sequence
  - Duplication - one segment is repeated
- When a mutation occurs, the type of protein formed changes
- Point mutation - change occurs for one base pair only
  - Substitution
- Frameshift mutation - protein changes from the point of insertion, deletion, duplication or inversion
  - Entire frame shifts from that point
- Silent mutations - changes in the bases that don't cause mutation in phenotype/mutation/amino acid
  - This happens when there are multiple ways to code the same amino acid ** \n **

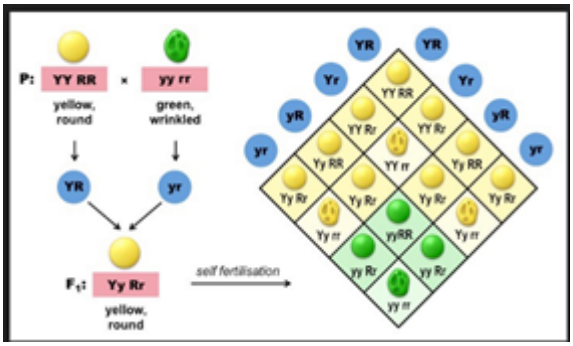
7.9. Mendel's Laws

- Somatic cells - non-reproductive cells
  - Diploids - 2 sets of chromosomes
  - Reproductive cells are haploids
- Gregor Johann Mendel - first to explain inheritance patterns
- Pea plant (pisum sativum) complete dominance experiments
  - Identified 7 different visible characteristics that are of contrasting strains
  - Self and cross pollinated the plants
    - Plant is bisexual so both self and cross pollination can take place
    - This can occur in a short period of time
  - Parental (P) and filial (F1 and F2) generations
  - Self pollinate plants for a few generations to ensure purity of plants
  - Cross pollinate a tall plant and a short plant
    - Remove the anthers from the plant to be pollinated
    - Tall x Dwarf \n TT x tt \n Tt → F1 generation = tall
  - Self pollinate F1 generation
    - Tt x Tt
    - Punnett Square → TT, Tt, Tt, tt
    - Phenotype and genotype ratios
  - Monohybrid Cross:
    - In this case, we are taking the alleles for the seed shape of the pea plant, where R (round) is the dominant allele and r (wrinkled) is the recessive gene.
    - Breeding experiment between P generation (parent generation).
    - P generation parent are homozygous with different alleles for the same trait.
    - The possible gametes for the first parental generation are R and r (homozygous dominant parent will have R, R and homozygous recessive parent will have r, r).
    - The first filial generation or F1 will all be daughters that will be Heterozygous Dominant with gametes R, r.
    - After this, the first generation are all self-pollinated. Here the possible gametes are (R. r) (R, r). To find the exact ratios we use the Punnett Square. From the Punnett Square we can see that the Phenotypic Ratio is 3: 1. While the genotypic ratio is 1:2:1.



    - Test cross is the crossing of an individual with a recessive individual in order to build the genotype of the dominant individual.
    - In a heterozygous individual the dominance is called Complete Dominance as recessive allele is completely suppressed by the dominant allele.
    - Incomplete dominance is when two homozygous plant with two dominant genes are crossed and a new allele is formed that is a mix of the two dominant.
    - All F2 generations of incomplete dominance have genotypic and phenotypic ratio.
    - Mendel could only explain complete dominance and not incomplete dominance.
    - Co-dominance is two homozygous individuals with dominant alleles have an offspring with alleles being equally dominant without interference.
- Di-hybrid cross:
  - It is a cross with two different traits.
  - In this example, we are taking the seed colour and seed shape. That is either yellow/round and either green/wrinkled. In this Round and Yellow are the dominant alleles.
  - Again, both the parents in the parent generation are either homozygous dominant or homozygous recessive. That is YY RR and yy rr.
  - The possible gametes for the first parent in the first generation are (Y R) and (r y)

- Thus, the first generation filial offspring are all R r y Y.
- We then self-pollinate the F1 generation.
- Here the possible gametes for one of the parents- RY, Ry, rY, ry.
- And the same for the second parent.
- We make a Punnett Square grid again and the following are the ratios- phenotypic ratio is 9:3:3:1 :: Round Yellow: Round Green: Wrinkled Yellow: Wrinkled Green.
- Recombinants that are formed after the crossing like Round Green and Wrinkled Yellow.

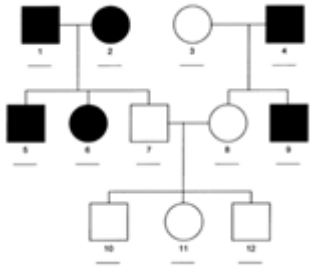


- Chromosomes are either autosomes or allosomes
- Allosomes are the sex chromosomes.
- There are 22 pairs of autosomes and one pair of allosomes.
- Genes of autosomes are autosomal genes and genes of allosomes are sex-linked genes.
- Genes of Y-chromosome are Y-linked genes
- Y-linked are inherited from male to male only.
- In females, the 23rd pair of the sex-linked pair is XX and in males it is XY.
- Therefore, the sex determining is the Y chromosome and whether the males pass it on.

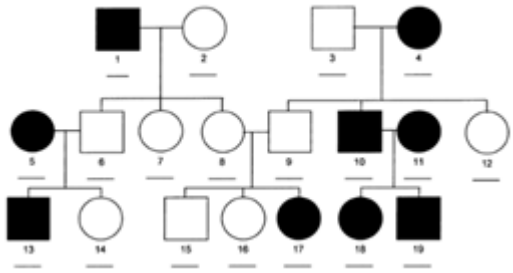
- Key terms:
  - Allele - different versions of a gene
  - Gene - a segment of DNA which defines a certain trait
  - Homozygotes - same alleles for the same trait
  - Heterozygotes - different alleles (identical
  - Dominant - whichever trait is more possible/expressive
    - Represented by the capital letter of the trait
  - Recessive - whichever trait is less likely to occur
    - Represented by the lower case letter of the trait
  - Phenotype - external/visible characteristics
  - Genotype - genetic constitution/composition
    - Possibilities/gene combinations
- Law of dominance - the phenotype is that of the dominant gene/allele
- If a plant self-pollinates and you get the same traits, it is homozygous
- If a plant self-pollinates and you get varying traits, it is heterozygous
- Test cross - cross tall plants with dwarf plants to see the nature of the offsprings; it is used to find out whether the parent if homozygous or heterozygous
  - Determine the genotype of the dominant parent
  - If all offsprings are found to be of one type, then the dominant parent is homozygous
  - If the offspring produced are both types in 1:1 ratio, the the dominant parent is heterozygous
  - If some are dwarf, then the parent plant is heterozygous
- Back cross - individual is crossed with either of the parents
- Incomplete dominance
  - Ex: Andalusian fowl
    - Black and white chickens exist
    - If a white chicken breeds with a black chicken, you get a gray chicken
    - WW + BB → WB = gray
  - Ex: Mirabilis Jalapa (4 o'clock plant)
    - Red flower and white flower = pink flower
    - RR + WW → RW = pink
- Codominance - both are equally dominant
  - Ex: blood groups
    - A is dominant over O → IaIa or IaIo
    - B is dominant over O → IbIb or IbIo
    - A and B are equally dominant → IaIb
      - Ex: IaIa + IbIb → IaIb (codominance)
    - O → IoIo
- Sex-linked inheritance - gene is linked to the 23rd chromosome
  - More likely to affect maleS

7.10. Pedigree Charts

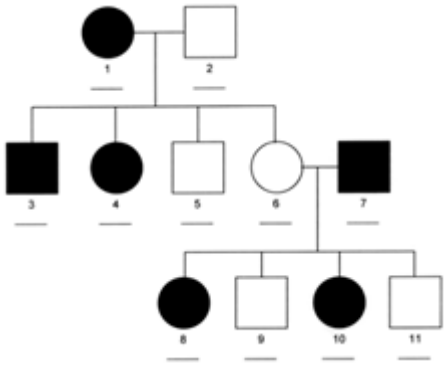
- A pedigree chart is a flow chart that shows the relationship within a family over several generations.
- Offspring are shown in order of birth from left to right.
- Generations are labelled with Roman Numerals
- A person that is not affected but passes it onto their offspring are called carriers only applicable in recessive disorders.
- Autosomal Dominant - there is an altered autosomal gene on one of the 22 autosomes and someone who carriers this gene is affected by the disorder
  - If the person has offspring there is a ½ chance that they pass on the disorder even if they are female or male.
  - If both parents are affected but the offspring is unaffected, the trait must be dominant
  - You will be affected if you have a A allele.
  - Those that are affected can be homozygous or heterozygous.



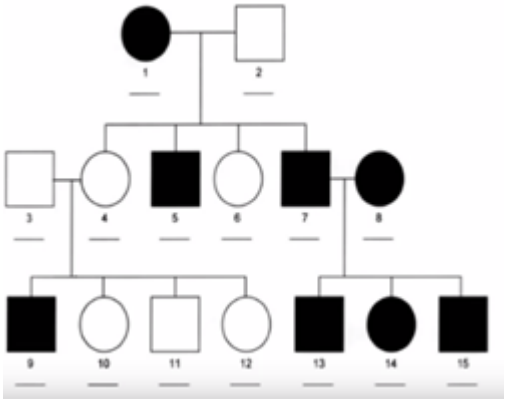
- Autosomal Recessive
  - In this the person is darkened if he/she is recessive gene.
  - They have to be homozygous or AA



- X-linked Dominant
  - Affected female- XAXA or XAXa
  - Unaffected female- XaXa
  - Affected Male- XAY
  - Unaffected Male- XaY.,
  - An affected father will have all affected daughters.
  - To find the genotype of the mother look at the sons.



- X-linked Recessive
  - Affected mother all sons should be affected. '
  - Affected female- XaXa
  - Unaffected female- XAXA or XAXa , in the latter case the female is a carrier
  - Affected Male- XaY
  - Unaffected Male- XAY
  - To find the genotype of father look at the females and to find mother look at the males



7.11. Genetic Disorders

- Caused by the passing down and inheritance of defective genes
- Mutation - a change in the sequence of bases in DNA
- Cystic fibrosis
  - Excess secretion of mucus
  - Protein channels are dysfunctional and don't allow substances to pass through
  - CFTR gene codes for a protein which balances the salt levels in either side of cells in lungs
  - If a defective variation of the gene is present → blockages in some parts of the body
    - Trouble in breathing
    - Blockage in parts of digestive food that can't be absorbed
    - Blockage in vas deferens → infertility
  - Life expectancy = 30-40 years
- Huntington's disease
  - Progressive brain disorder
  - Causes uncontrolled movements, emotional problems and loss of cognition
    - Involuntary jerking, muscle problems, slow eye movement, impaired gait, difficulty with speech production
    - Difficulty organizing, lack of impulse controls, lack of awareness, slow processing, difficulty learning new information
    - Sadness and irritability, insomnia, fatigue, and frequent thoughts of death
  - Usually develops between the ages of 30 and 50
  - Caused by the huntingtin gene which is attached to the 4th chromosome
    - Produces an important brain protein called huntingtin which is needed by neurons in the brain and for the body's development before birth
    - When faulty → repeats genetic sequences too many times → damages neurons in certain areas of the brain
- Haemophilia (bleeder's disease)
  - Inherited bleeding disorders where blood doesn't clot properly
  - Very rare in females
  - Bleeding episodes may occur spontaneously
    - Lots of internal bleeding
    - Nosebleeds take long time to stop, bleeding gums, skin bruises easily, pain and stiffness around joints
  - Haemophilia A - reduced clotting factor VIII
  - Haemophilia B - reduced clotting factor IX
  - X-linked recessive pattern
  - Mutations of the F8 or F9 gene lead to the production of an abnormal amount of coagulation factor VIII or IX or reduce the amount of one of these proteins
    - The altered or missing protein cannot effectively participate in the blood clotting process → proper blood clots cannot form
- Down Syndrome
  - Individual has an extra copy of the 21st chromosome (3 copies instead of 2)

    - Extra genetic material → alters course of development
  - Low muscle tone, small stature, upward slant to the eyes, single deep crease across the palm
  - Types
    - Trisomy 21 (nondisjunction) - results in an embryo with three copies of chromosome 21 instead of the usual two
      - Accounts for 95% of cases
      - Extra chromosome is replicated in every cell of the body
    - Translocation
      - 4% of cases
      - Total number of chromosomes is still 46
      - An additional full or partial copy of chromosome 21 attaches to another chromosome, usually chromosome 14
    - Mosaicism
      - 1% of cases
      - Mixture of two types of cells - some containing 46 chromosomes and some containing 47
        - Ones with 47 contain one extra chromosome 21
- Sickle Cell Anemia
  - An inherited form of anemia
  - Red blood cells become rigid and stockey and are shaped like crescent moons
    - Irregularly shaped cells get stuck in blood vessels
    - Slow blood and oxygen flow throughout body
  - Sickle cells usually die in 10 to 20 days rather than the usual 120 days
    - Leads to shortage of RBCs → fatigue due to lack of oxygen
  - Block of blood flow and lead to body pains
    - Painful swelling of hands and feet
  - Sickle cells can damage an organ that fights infection and leave the person more vulnerable to infection
  - Delayed growth due to lack of oxygen and nutrient supply
  - Vision problems if the blood vessels that supply the eyes are plugged with sickle cells → retina damage
  - Caused by mutations in the HBB gene
    - Abnormal haemoglobin called haemoglobin S
    - Causes rigid, non-liquid protein strands to form within the red blood cell
    - Distorts RBCs into a sickle shape
  - Autosomal recessive
- Alkaptonuria
  - HGD (homogentisic dioxygenase) gene provides instructions for making an enzyme called homogentisate oxidase
    - Breaks down homogentisic acid
    - Faulty HGD gene → body can't produce enough of homogentisate oxidase → build up of homogentisic acid
  - Build up causes bones and cartilage to become discolored and brittle → osteoarthritis
    - Urine turns dark brown or black when exposed to air
    - Black earwax
    - Dark sweats stains
    - Blue speckled discoloration of skin particularly around sweat glands
    - Arthritis
  - Autosomal recessive
- Color blindness
  - X-linked recessive

8. Evolution

- It is the change in the characteristics of a species over several generations and relies on the process of natural selection.
- The theory of evolution is based on the idea that all species are related and gradually change over time.
- Evolution relies on genetic variation in a population which affects the physical characteristics (phenotype) of an organism.
- Some of these individuals may have characteristic advantage over other individuals which they can pass on to their offspring.

8.2. Theories of Evolution

- Thales - water origin theory - all life originated in the sea and arose out of the sea
  - Greek philosopher
  - 640-546 BC
- Aristotle - there has been a natural progression from plants to plant-animals to animals to humans
  - Greek philosopher
  - Classified animals based on anatomy
  - Purpose: to achieve "The Divine"
  - Ladder of life
- Carl Linnaeus - organisms can be grouped together according to their degree of similarity
  - Swedish botanist
  - Developed a system for classifying all living things in "Systema Naturae"
  - Based on physical appearance and method of reproduction
- Georges Louis Leclerc and Comte de Buffon - similar organisms may have a common ancestor, and living things do change over time
- James Hutton - the natural forces that currently shape the Earth's surface were operating in the past in much the same way as they do today
  - Theory of uniformitarianism
- Jean-Baptiste Lamarck - for a species to survive it must be able to adapt to changing environmental conditions
  - Evolutionary changes as a result of this
  - Acquired adaptation can be passed from one generation to the next so species are not static

- First to fully state a theory that involved descent by modification
- He was an early proponent of evolution and the fact that it proceeded in accordance to natural laws.
- Lamarckism is the idea that an organism can pass on characteristics that it acquired during its lifetime to its offspring.
- This is also known as the heritability of acquired characteristics or soft inheritance.
- His theory is called the Theory of inheritance of acquired characters.
- The use and disuse of organs: The organs of the body that are used more and more get well developed while the organs that are not used, get weakened, smaller and gradually disappear.
- Inheritance of acquired characteristics- the characters acquired during the life time of an individual are transmitted to the next generation.
- Disproved by the rat experiment. They cut off tails for 20 generations and it still appeared

- Dr.Erasmus Darwin - all warm blooded animals have a common origin
- Charles Darwin - species evolve and change by a process of natural selection
  - More offspring are produced than can survive
  - Survival of the fittest
- Alfred Wallace - independently proposed a theory of natural selection at the same time as Darwin
  - Darwin-Wallace theory of natural selection
- Gregor Mendel - research into genetic inheritance provides an insight into the patterns in which heritable traits are passed from one generation to the next, including the mixing of maternal and paternal trait

8.3. Darwin: Theory of natural selection

- There is a struggle for existence because since every organism can reproduce then there is over-population and there is a limited quantity for food, thus there is a struggle for basic necessities and therefore a struggle to exist.
- Variations exist within population- The offspring from same parents also differ and show variation.
  - One species can split into two if the two populations are living in different places
- Survival of the fittest and Natural selection- of the offspring that are produced as a result of the struggle for existence the offspring with the favourable variations will survive, this is called selection and since this occurs naturally it is called Natural selection.
  - Evolution occurs by natural selection acting on chance variations present in each population
  - over many generation the species become more and more different
    - Physiology and behavior
  - Eventually become two different species
- He also proved Adaptive Radiation- this is when a certain species evolves into many different species due to the adaptation to the local environment and available food that is stimulated by the environment.

8.4. Industrial Melanism: The Peppered Moth

- The Peppered moth was commonly a pale whitish colour with black spots.
- The colouring enabled them to hide from the potential predators on trees with pale coloured barks
- The rarer dark coloured peppered moths were easily seen against the pale bark of trees more easily by predators
- Due to industrial evolution, air became full of soot. This stained trees and the buildings darker
  - The lichen died
- Due to this, the lighter moths were seen easily by predators.
- The darker were able to camouflage.
- As the lighter moths would keep getting eaten the darker moths grew in population.
- In the end, the darker moths were more common.

8.5. Adaptive Radiation:

- It is also known as the Darwin-Wallace of Natural Selection.
- Proposed that populations living in different places could evolve to different species over time.
- For example, the birds on the Galapagos Islands developed different shapes of beaks due to the different prey.
- For example, there is environmental isolation, this isolation leads to two different gene pools of the two populations so they can never interbreed and exchange genes so they become reproductively isolated. Over time, the gene pools become so different structurally even if they meet they can't reproduce, thus a new species was born.
- This is also called Speciation.
- Homologous Organs: Similar origin and structure but different function. It explains divergent evolution. This means common ancestor but different species.
- Analogous Organs: Different origin but same function. Explains convergent evolution. This means different ancestors but form similar species with similar functions.
- Vestigial Organs- Organs which had a use but not anymore.
- Embryological evidence
  - Early stages: common characteristics
  - Later stages: more differences

8.6. Speciation

- the formation of new and distinct species in the course of evolution

- It involves reproductive isolation.
- It is of two types- Allopatric and Sympatric
- Allopatric is when two groups that have different lands/environment.
- Sympatric is when two groups have the same land/environment.
- In Allopatric is when you have barrier that is formed, for example, on an iceberg there are a species living, if the iceberg cracks along the middle and the two species are separated and become reproductively isolated and then when the iceberg joins again they can't interbreed and two new species are formed.
- Sympatric is when there is a mutation in the same area and the new organism can't interbreed and the new species is formed.
  - reproductive isolation
  - polyploidy is the most common - Where a normal individual has two copies of each chromosome (diploidy), these offspring may have four copies (tetraploidy). A tetraploid individual cannot mate with a diploid individual, creating reproductive isolation
- Parapatric - populations are separated by an extreme change in habitat
  - populations may develop very distinct characteristics/lifestyles
  - ex; plants that live on boundaries between very distinct climates may flower at different times in response to their different environments, making them unable to interbreed
- Peripatric - similar to allopatric but smaller population size and genetic drift acts more quickly in small populations
- Prezygotic Barriers: Temporal, Behaviour and Mechanical.
  - Temporal: They can live in the same spring but the breeding takes place in different times. So even if two groups have the ability to interbreed, they can't.
  - Mechanical: They live in the same area and they are very similar but can't interbreed but because their sexual parts are in the wrong orientation.
  - behaviour: There are two gene pools that were separated for a very long time but then are brought back together, however their mating behaviours have changed so they can't mate.
- Post-Zygote: Zygote mortality, Hybrid Sterility.
  - Zygote Mortality is when even though interbreed happens the offspring can't survive for long time, it will die in infancy
  - Hybrid Sterility- When the offspring of the interbreed is sterile.
- Species can be impacted by more than one type of isolation
- Isolation itself is not a mechanism for change over time just reduces gene flow
  - Genetic drift or natural selection are mechanisms
- Due to mutations, Polyploidy- when the 4n can't interbreed with 2n thus new species.
- Factors
  - Geographical isolation
  - Natural selection
  - Genetic drift - drastic change in the frequency of particular genes and prevention of gene flow between populations
    - Mutations
  - Reproductive isolation - incompatible for reproduction

8.7. Extinction

- Extinction - when a species stops existing
- Sometimes individuals of a species show a range of variations
  - Species that are better suited to the environment reproduce a lot
  - Others that aren't as well suited die
  - If an entire species fails to adapt to the environment, if it can't compete with other species, or if it has a low birth rate lower than the death rate, it will become extinct
- Most species become extinct after 10,000,000 years
- Living fossils - when a species remains genetically unchanged for millions of years
- Mass extinction
  - Devastating change in the number of species alive
  - [K-T] extinction event - 65 million years ago
    - Dinosaurs
  - [P-Tr] - 251 million years ago
    - Eradicated 96% of all known species
    - Comet or asteroid impact

8.8. Antibiotic Resistance

During a bacterial infection, the bacteria disrupts the host cell to multiply → bacterial colony is formed

- Antibiotics inhibit growth and kills bacteria/microbes
  - Bactericidal = kills bacteria
  - Bacteriostatic = inhibits growth of bacteria
- Antibiotic resistance
  - Gene mutation
  - Occurs when the bacteria are no longer affected by the antibiotics
    - Flourish
    - May confer resistance to plasmids
    - Horizontal gene transfer
      - Competence - taking up extracellular DNA from its environment
      - Transduction - phage contains DNA that can be incorporated into bacteria
        - Virus latches onto the bacteria and transfers DNA
        - If the virus was antibiotic resistant, the bacteria also becomes antibiotic resistant
      - Conjugation
        - Two bacteria have make contact
        - Plasmid DNA is transferred from one to the other → becomes a template to form a

double stranded DNA
- Both cells have double stranded plasmids
- If these strands are antibiotic resistant, both cells are antibiotic resistant

- Indiscriminate usage of antibiotics can lead to antibiotic resistance
- This is an example of natural selection and survival of the fittest

8.9. Evidences for the Theories of Evolution

- Sedimentary rocks
  - Horizontal layers called beds
    - Sediments are created by weathering and erosion and are layered on top of each other
  - Sedimentary basin forms
  - Oldest rock is at the bottom of the pile of sediments
  - If you dig through the strata (layers) you can see a timeline of the past
- Fossils
  - Any preserved remains of an organism or trace of an organism and its activity
  - Dead organisms must be covered quickly and must remain relatively undisturbed
  - Paleontologists - scientists who study fossils
  - Can be found in sedimentary rocks, peat bogs, amber, permanently frozen or tar pits
  - Fossil record - a comprehensive catalogue of all the fossils that have been discovered
    - 250,000 species
    - Microfossils such as those of pollen grains are most common
- Dating fossils and rocks
  - Carbon-14 can be used to find the age of relatively young fossils
    - Depends on the concentration of C-14 left
    - When an organism is alive, the C-12 to C-14 ratio is the same in both its body and the environment
    - When it dies, the carbon-14 decays
  - However C-14 is only useful up to 50,000 years
  - To get around this problem
    - Potassium-argon: half life = 100,000 years
    - Uranium-lead: half life = 1,000,000-4,500,000 million years

8.10. Wegener's Ideas

- 1915 - Alfred Wegener
  - Theory: over time, continents have drifted apart creating the continents we have today
  - Pangaea = supercontinent
  - Continental drift - the slow movement of continents
- Wegener's Evidence -
  - Continents looked like pieces of a jigsaw puzzle that could fit together
    - South America and Africa
  - Fossils of similar plants and animals and mountains with similar rocks were found in South America and Africa
  - Mid-atlantic ridge patterns
    - Convection currents in the mantle of the Earth could be responsible for the movement of continents
    - Submarine mountain ridge with volcanoes runs down the center of the Atlantic ocean
      - Similar patterns of humps and ridges on either side
      - Found that every half million years, the Earth's magnetic field flips
  - Seafloor spreading - when two adjacent plates are being pulled in opposite directions, magma keeps oozing up through the gaps between them causing the plates to move further apart
    - Magma adds to the size of the plate
    - Spreading center
    - Mid-Atlantic ridge - pushing Africa and Europe away from the Americas
  - Subduction - plates being pushed beneath one another
    - As one plate sinks and is reabsorbed, the other is pushed up → mountain ranges
  - Convection currents → cause semi molten magma to move → drag plates along with it

8.11. How Old is the Earth

- Lord William Kelvin - used the fact of molten rock beneath the surface the calculate the age of the earth to be 15-20 million years
  - Now we have evidence that the Earth is around 4.5 billion years old
- Nuclear reactor in core
  - Radioactive isotopes in Earth's core
  - Half lives are billions of years long
  - Used to be kept hot by the radioactive decay of isotopes with shorter half lives
- Faults - evidence that rocks aren't strong enough to withstand all forces
  - Massive blocks of rock pushed together → lots of friction → high pressure → rocks snap apart
  - Energy release causes solid rock to vibrate → earthquake
    - Vibrations = seismic waves → transmitted rapidly through rocks
    - Shockwave travels in all directions from the focus
    - Max disturbance at epicenter
- Tectonic plates - earth's crust is broken up into plates
  - Over 90% of earthquakes occur at these boundaries
  - Float on the mantle which consists of magma
  - Convection currents cause the plates to move
- Tsunami - violent push of water
  - Caused when huge block of seafloor is thrust upwards near or around subduction zones
  - Lighter plate is pushed up by heavier plate

- Huge forces
  - Brittle rocks fracture
  - Pliable, ductile rocks fold
  - When brittle and ductile rocks occur in the same area, the ductile rocks may bend or fold over the fault
    - Anticlines = upwards fold
    - Synclines = downwards folds
    - Monoclines = broad step like folds

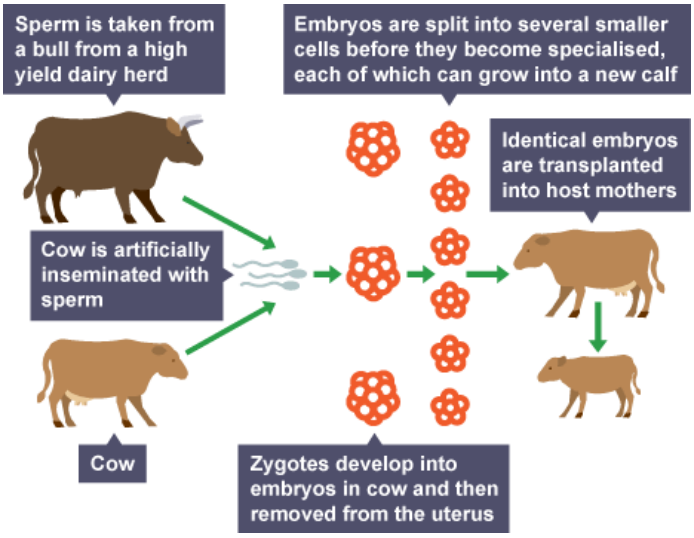
9. Biotechnology

9.1. Definition

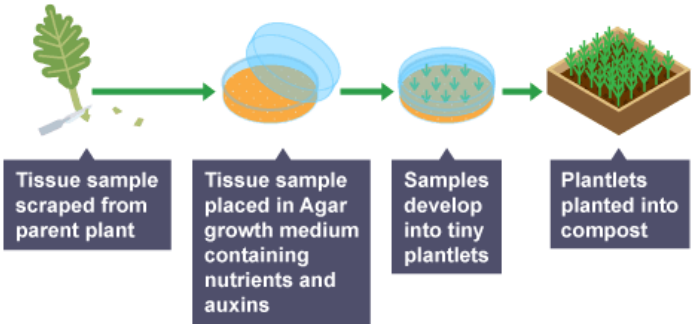
- Use of living systems and organisms to develop/make useful products Any technological application that uses biological systems, living organisms, or derivatives thereof to make/modify products or processes for specific use

9.2. Cloning

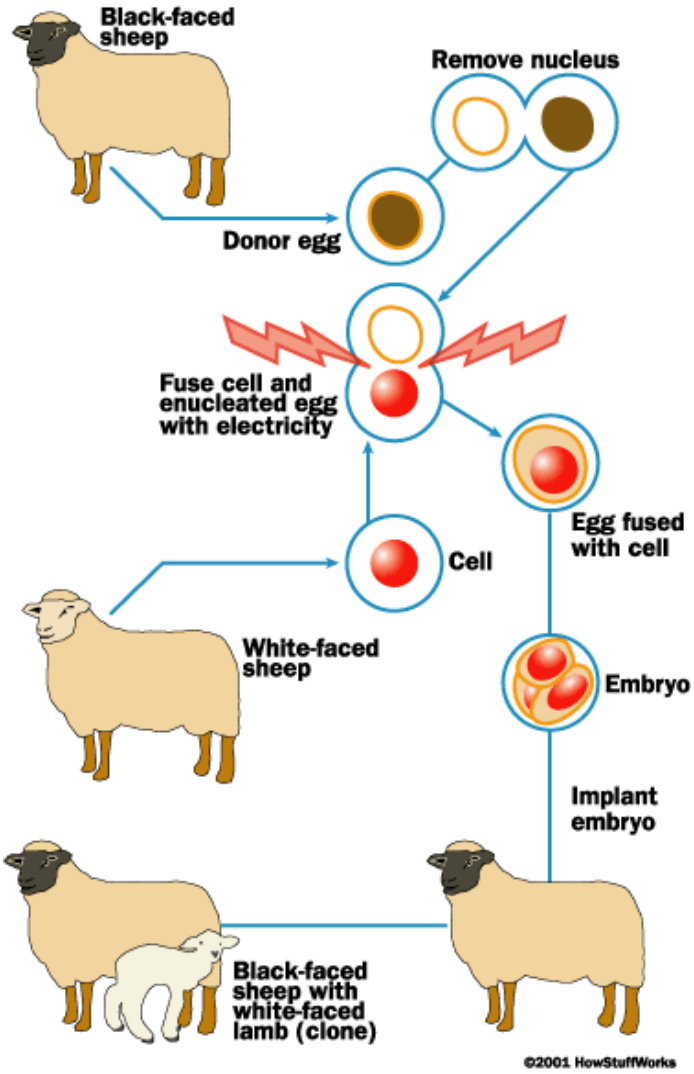
- Cloning - the DNA of one organism is copied exactly into another organism
  - Genes are copied within the same species
- Types of cloning
  - Embryo cloning/embryo splitting - splitting cells apart from a developing embryo, before they become specialized to produce several embryos
    - Identical twins are natural clones



- Nuclear transfer - transferring a body cell into an egg and then stimulating cell division to produce an embryo
- Cuttings - taking a small piece of stem or leaf and growing it in the right conditions to produce anew plant
  - Cut a branch off and plant it in damp compost
  - Plant hormones are often used to encourage new roots to develop
  - Cutting is covered in a clear plastic bag to keep it moist and warm
- Tissue cloning - getting a few cells from a desirable plant to make a big mass of identical cells, each of which can produce a tiny identical plant
  - Grown in vitro (in glass tubes/petri dishes) using sterile agar jelly that contains plant hormones and nutrients
  - More expensive than cuttings
  - Used to preserve rare plant species or grow commercially larger nurseries



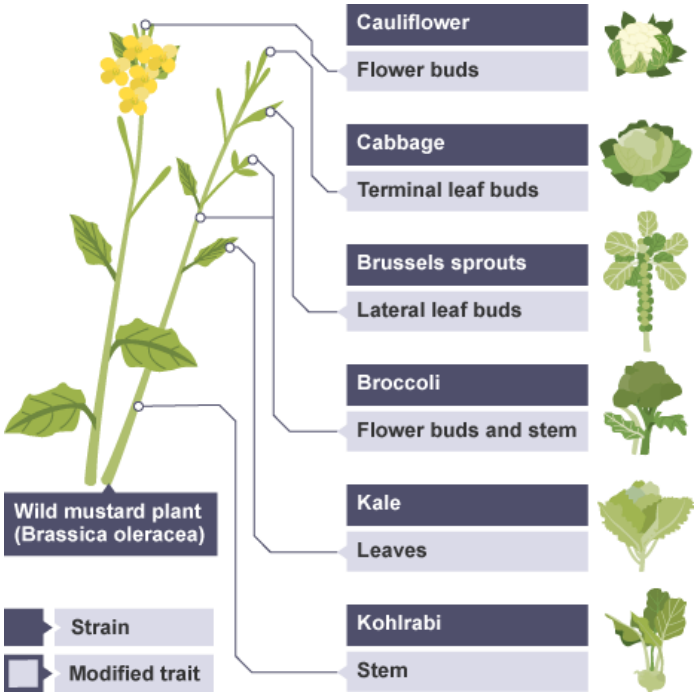
- Clones are also naturally produce via asexual reproduction
- Dolly the Sheep
  - 1996
  - Cell nucleus was removed from an egg cell from a Scottish Blackface ewe
  - Adult cell from the udder of a 6-year old Finn Dorset was cultured and was injected into the egg cell
  - Spark of electricity fused the udder cell with the egg cytoplasm and stimulated the egg to grow into an embryo in the womb of a surrogate sheep



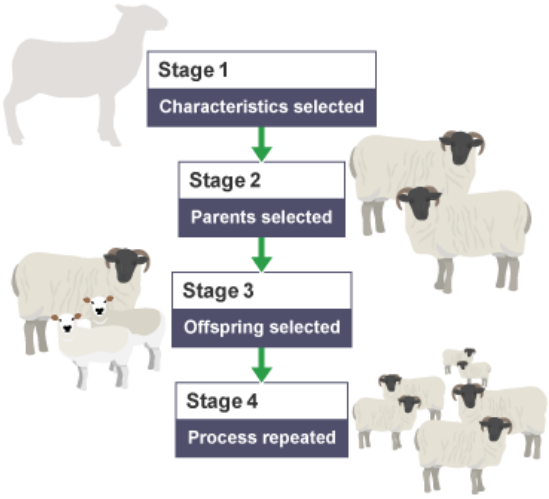
- Pros of cloning
  - Producing new babies for infertile couples
  - Organ transplants won't be rejected
  - Ensure survival of endangered species and bringing back extinct animals
  - Producing useful proteins in milk to treat diseases
  - Producing medically useful animals
  - Producing prize agricultural animals
  - Pet cloning
- Cons of cloning
  - Many embryos miscarried before Dolly
  - High embryo wastage
  - Religious/ethical beliefs that it is wrong to interfere with nature
  - Wrong to destroy/tamper with embryos
  - Reduce genetic variation

Selective Breeding

- Selective breeding - modifying gene pools by selecting favorable characteristics, providing us with improved crops and livestock
  - Ex: disease resistance or improved milk yield
- Humans have created hundreds of varieties of different species, generally used for food, by selecting desirable characteristics in organisms and then cross-breeding them with similar individuals



- Desirable characteristics: disease resistant food crops, wheat plants that produce a lot of grain, large or unusual flowers
- New varieties may be economically beneficial, provide more or better quality food, and allow farmers to feed more people
- Takes many generations
- Steps
  - Decide which characteristics to select
  - Choose parents that show these characteristics and breed together
  - Choose best offspring with desired characteristics to produce the next generation
  - Repeat the process over many generations



- Desirable traits: animals that produce a lot of milk or meat, chickens that lay large eggs, domestic dogs that have a gentle nature
- Pros

- Economically beneficial and higher quality food
- Animals can be bred to cause no harm; ex: cattle without horns

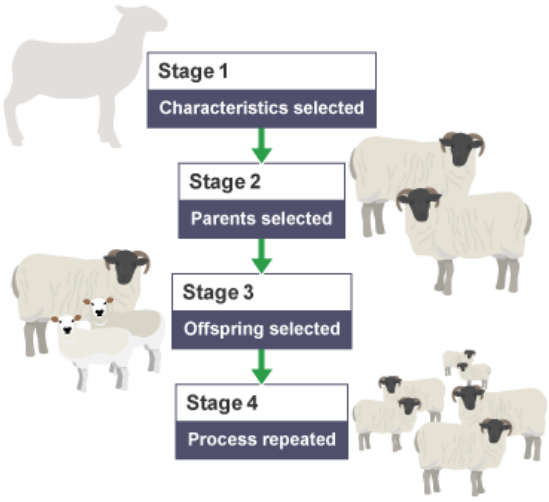
- Cons
  - Reduced genetic variation → attack of disease/insect → extreme destruction
  - Rare disease genes may be selected as a part of a desired trait → problems with specific organisms
  - May create physical problems in specific organisms; ex: overbred dogs

9.3. Genetic Engineering

- Genetic engineering/genetic modification - DNA is modified so a unique set of genes is produced
  - Genes can be swapped across species
- Direct manipulation/modification of DNA so that unique set of genes is produce
- Faster way to modify species by directly transplanting genes for a desired trait into an organism
- Now, we can genetically modify many organisms such as bacteria or even cows
- Major part of Genetic engineering includes moving a piece of DNA from one genome to the other
- To chance the DNA of an organism, the desirable gene must be located, isolated, copied, and introduced to the new genome
- Big different between genetic engineering and selective breeding is that with genetic engineering scientists can introduce genes from a completely different species into the genome of an organism
  - These organisms are called transgenics

Recombinant DNA Technology

- Tool kit
  - Restriction enzyme - found in bacteria and used to destroy viruses; cut DNA at a particular sequences leaving "sticky ends"
    - Sticky ends - when a staggered cut is made in DNA by a restriction enzyme, the exposed unpaired bases can pair with complementary bases on another strand of DNA which has been cut with the same restriction enzyme
    - Exposed ends = sticky ends
  - DNA ligase - connects pieces of DNA together; can be used to "stick" a gene into a vector such as a plasmid
  - Plasmid - independently replicating circle of DNA containing a few genes
    - Found in bacteria and can be used to carry genes into a suitable host bacterium
  - Vector - something which can carry DNA from one organism to another
  - Host bacterium - a bacterium which can be modified by adding genes using a vector
    - Allowed to multiply to produce multiple copies
- Steps
  - Restriction enzymes are used to isolate the required gene leaving it with sticky ends. Sticky ends are a short section of unpaired bases
  - A vector, which is usually a bacterial plasmid or a virus, is cut by the same restriction enzyme leaving it with corresponding sticky ends
  - The vector and the isolated gene are joined together by ligase enzyme
  - The vector inserts the gene into required cells
  - The genes are transferred to animal, plant or microorganism cells, during early development, which allows them to develop with the desired characteristics



* reproduction occurs in an incubated fermenter

- Benefits
  - Agriculture - see GMOs
  - Create insulin which can be used to treat diabetes
  - Sterile insects could be created, such as mosquitoes. They would breed with fertile mosquitos, but be unable to reproduce. This would reduce the number of offspring and may help with spread of diseases, such as malaria, dengue fever and the Zika virus.
- Risks
  - A gene that benefits one organism may harm another
  - Not ethical
  - Genetically engineered crop seeds are usually more expensive so people in developing countries can't afford them

Genetically Modified Foods

- GMO - genetically modified organisms
- In some countries, vitamin deficiencies are common
  - Insert genes that add nutrients into plants such as rice so that they have vitamin A, iron, etc...
    - Golden rice - gene produced beta carotene (needed in humans to make vitamin A)
  - Can help reduce the occurrence of deficiency diseases
- Include those that are resistant to insect attack or are herbicide resistant → increased yields
  - Herbicide resistant crops can tolerate herbicide, but the weeds can't so they're killed

- Ethics
  - Health risks
    - May contain substances which cause allergic reaction in some people
    - Higher levels of toxins may be found in the food
    - Long term effects are not known
  - Some think it is ethically wrong to create new life forms or to move genes between different species
  - Pollen produced by the plants could be toxic and harm insects that transfer it between plants
  - However, it may help reduce hunger around the world by increasing crop yields
    - It's also faster than selective breeding
- Transgenic plants
  - Crops are added with herbicide/pesticide resistant gene
  - 98% of soybeans in Argentina are genetically modified

9.4. Stem Cell Research

- Stem cells are the cells of the early embryo from which all the cells in the adult body will develop (ESCs)
  - They are totipotent (Can differentiate into any specific cell type)
  - Other types of stem cells in body: bone marrow/certain blood cells (ASCs)
  - Used to replace worn out or faulty cells
  - These are pluripotent and can only differentiate into only one type of specialized cell
- Bone marrow transplants - have been in use for over 20 years
  - Patient's bone marrow cells are replaced with those from a health, matching donor
  - If successful, cells migrate into the patient's bone marrow and produce nex, healthy blood cells to replace the old faulty cells
- Applications
  - Replacing damaged tissue
  - Screening toxins
  - Development of treatment that allows people paralyzed because of spinal injuries to walk again
  - Possibility of growing replacement organs that are matched to the patient
  - Genetic disorders to be studied and new drugs to treat them can be tested
- EMCs are highly controversial
  - People think it is unethical to use embryonic stem cells since they can turn into baby
    - They think it's "meddling with nature"
  - Others say its unethical to ignore EMCs since research can help save lives - remove paralysis, regrow amputated limb, etc
    - Heart disease: Adult bone marrow stem cells can be injected into heart arteries and may improve cardiac function in victims of heart failure/heart attack
    - Type I diabetes: pancreatic cells do not produce insulin, so stem cells may be able to reproduce healthy pancreatic cells which can secrete insulin

9.5. Organ Printing

- Process where artificial organ can be created using 3d printer/bio printer by utilizing stem cells
- Use ink jet needles to deliver cells
  - Sticky polymer to form support structure
  - Pressurized air
- Small electric field is applied that converts the mixture into superfine threads with cells trapped inside
- Challenges
  - Selection of correct cells
  - Materials to project these onto
  - Use of factors that help stem cells grow and differentiate in the correct way
  - Technical challenges related to sensitivities of living cells
  - Proper construction of tissue
- Method usually utilizes the layer-by-layer method to create tissue like structures that are later used in medical and tissue engineering fields
- Steps
  - Stem cells from the patient are put in a growth medium so that they can multiply
    - When enough cells are available, they are put into bioprinter cartridges
  - Stem cells form "bioink" which, once loaded into cartridges, can be used in the bioprinting process
    - Cartridge is made from a chamber attached to a long extrusion nozzle fitted with a syringe
  - Bioprinter is driven by software that lays down the stem cells in precise patterns
    - Cells can be put down in layers, interspersed with a water-based material called hydrogel, which forms a temporary mould around the cells
    - Sticky polymers can also be used to scaffold the cells
      - Scaffolding material is laid down by separate nozzles on the bioprinter
      - These sticky polymers are printed through fine inkjet nozzles
  - Printed tissue is left to grow
  - Printed tissue can be used in transplants or in medical research
  - View Hodder pg. 293 for diagram
- Lab-grown tissues and organs can be made by creating artificial scaffolds in the shape of the desired organ and then by adding living cells to the scaffold
- Problem in creating tissue: vascular system - needed to provide cells with oxygen and nutrients
- Recent situations
  - First patent related to this technology was filed in '03 and granted in '06
  - '06- world's first artificial bladder was built and transplantation done on 7 patients
  - '09- artificial liver was made
  - '11 world's first artificial trachea

    - '11 In situ skin bioprinting for burn wound was done
    - '15 partnership between organovo and l'oreal for commercial production of artificial skin by using bioprinting technology
- Why don't the organs work?
    - Difficult to create blood vessels between tissue layers
    - Organs have many specialized functions difficult to replicate
- Advantages
    - Artificial organ personalized using patient's own cells
    - No DNA rejection
    - Eliminate need for immunosuppressant drugs after a regular organ transplant
    - Eliminate organ donation
    - No waiting period
- Disadvantages
    - Printers cost hundreds of thousands of dollars
    - Possibly more expensive than regular organ transplant
    - Use of stem cells is still controversial
    - Cost of using stem cells
    - No success yet

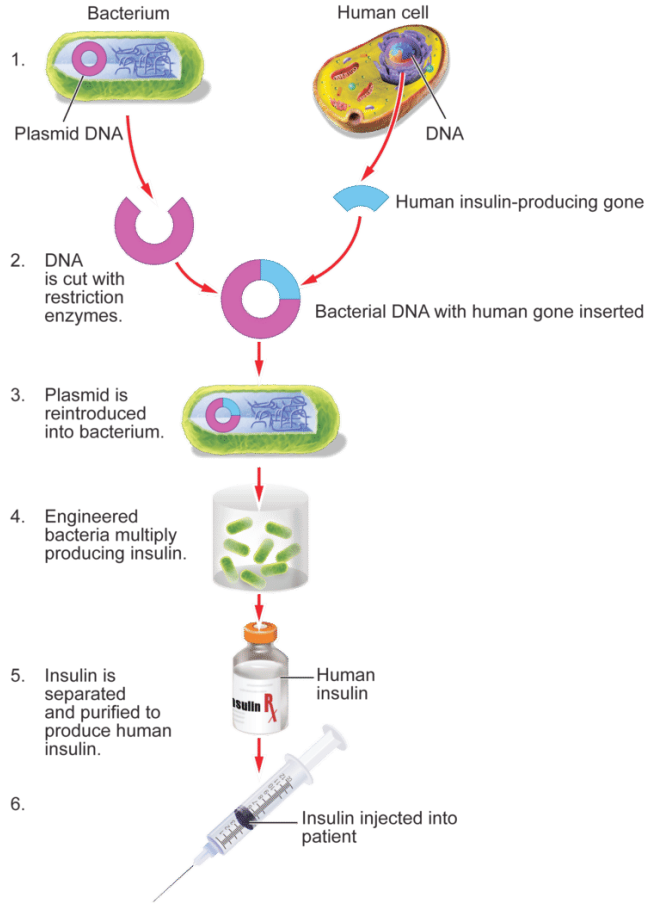
9.6. Genome Mapping

- Genome - the entire genetic material of an organism
    - Each diploid cell has one copy of your entire genome
- Finding exact location of specific gene on a chromosome
- Human Genome Project: mapped out entire sequence of human dna
    - Began in 1990 and completed in 2003
    - 13 year effort coordinated by
        - Department of Energy (DOE)
        - National Institute of Health (NIH)
    - Human genome consists of 24 chromosomes
    - Human genome contains over 3 billion nucleotide pairs
    - Average gene consists of 3000 bases
    - Sizes of genes vary greatly, with largest known human gene encoding dystrophic containing 2.5 million base pairs
    - 3% of genome encodes amino acid sequences and the rest of the genome is junk
    - Functions are unknown for over 50% of the discovered genes
        - Opened up ways which genetic disease can be identified
        - Ex- CF is on chromosome 7
- Importance
    - Enables us to search for genes linked to different types of disease
    - Opened up new ways in which genetic diseases could be identified and treated
    - Understand inherited disorders and their treatment
    - Trace human migration patterns from the past
    - Ex: Two examples of these are genes that can contribute to breast cancer, which are known as BRCA1 and BRCA2
        - Mutations in these genes account for approximately 10% of all inherited breast cancer cases detected
        - Scientists detected BRCA1 and BRCA2 genes by studying families where breast cancer was known to have been inherited between individuals
        - They were able to create a pedigree analysis that showed the close relationship of those affected and unaffected within the family
            - Illustrates the inheritance pattern of the disease to be determined
        - This enabled scientists to test DNA from the affected and unaffected individuals to identify differences
        - Now possible to detect the presence of the genes by having a simple blood test

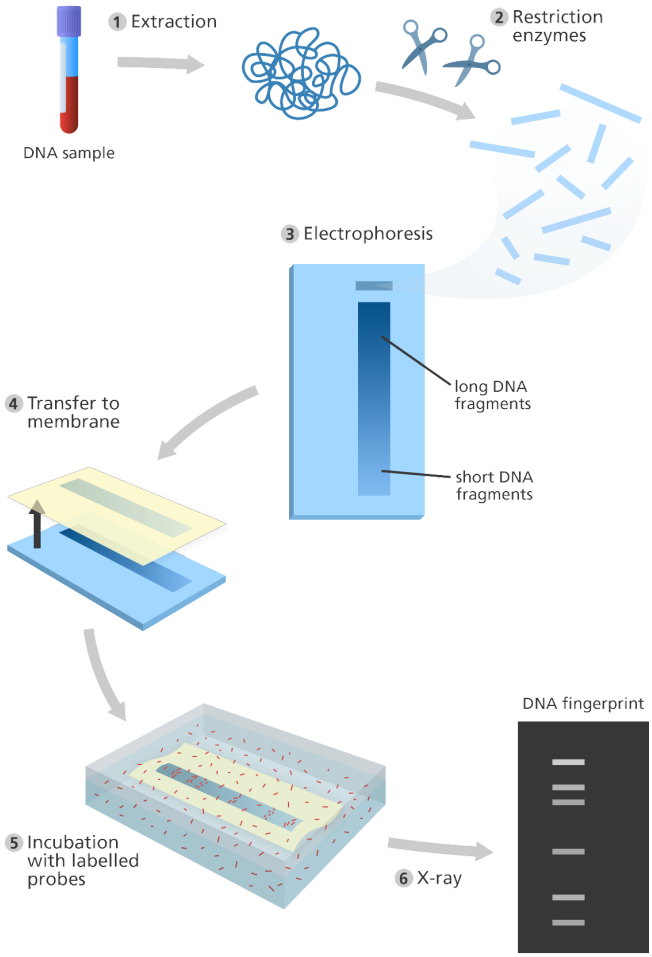
DNA Fingerprinting

- Developed by Alec jeffreys in 1984
- Method that identifies and individual based on patterns formed from variations in genetic coded
- Also known as dna profiling, genetic fingerprinting, dna typing
- Minisatellites are short sequences (10-60 base pairs long) of repetitive DNA that show greater variation from one person to the next than other parts of the genome. This variation is exhibited in the number of repeated units or 'stutters' in the minisatellite sequence.
    - Humans share about 99.9% of DNA
    - Remaining percentage contains around 3 million base pairs
        - These differences can be compared and used to help distinguish you from someone else
- Procedure
    - Extract DNA from a sample of human material, usually blood
    - Restriction enzymes used to cut the DNA → thousands of pieces of DNA of varying lengths
    - Separated according to size by gel electrophoresis
        - DNA was loaded into wells at one end of a porous gel, which acted a bit like a sieve
        - Electric current was applied which pulled the negatively-charged DNA through the gel
            - Shorter pieces move easier and faster; longer pieces travel slower
        - Electric current is switched off → DNA pieces are separated according to size
            - Smallest DNA molecules were farthest away from where the original sample was loaded onto the gel
    - DNA were transferred or 'blotted' out of the fragile gel on to a robust piece of nylon membrane and then 'unzipped' to produce single strands of DNA
    - Nylon membrane was incubated with radioactive probes
        - Probes are small fragments of minisatellite DNA tagged with radioactive phosphorus

    - Probes only attach to the pieces of DNA that they are complementary to – in this case they attach to the minisatellites in the genome
- Minisatellites that the probes have attached to were then visualised by exposing the nylon membrane to X-ray film
    - When exposed to radioactivity a pattern of more than 30 dark bands appeared on the film where the labelled DNA was
    - This was the DNA fingerprint
- To compare two or more different DNA fingerprints the different DNA samples were run side-by-side on the same electrophoresis gel



- Uses
    - Way of telling individuals of same species apart
    - DNA sequences are variable and can be used as identifying characteristics
    - DNA fingerprinting has advantages over other sources of evidence such as fingerprints, blood type, etc
    - Much more accurate
    - Good for paternity testing: In the example, first male is father since the offspring shares half the genes with him



- Criminal cases: eliminating suspects
- Identifying corpse
- Food testing (champagne, horse meat, etc)
- Genetics matching for organ or bone marrow donation

10. Habitat Alteration

A HIPPO - Agriculture, Habitat Loss, Invasive Species, Pollution, Human Population, Overhunting/Over-exploitation

- Usually human-induced
    - With human population on the rise, natural resources are being put on pressure
    - More humans= more needs = more destruction for these items such as wood/water/etc
- If large amount of habitat is destroyed, species may go extinct
- Case study: Southeast Asian Rainforests
    - Indonesian and Malaysian rainforests are being cleared to create palm oil plantations and harvest wood resources
    - Threatens native animals such as orangutan, tiger, and Asian elephant
- European wetlands: over 60% destroyed before 1990, but still continuing
    - Ethical issue: since most threatened animals which are from these wetlands are reptiles/amphibians

which aren't 'cuddly' or 'cute,' they do not get as much support
    - Smaller amount of people are inclined to protect them
    - These wetlands have been converted by being drained for farming, or reclaimed by private owners
- Success story: Giant Panda
    - Giant Pandas have always been threatened by habitat loss, almost to extinction at one point
    - China took initiative and bought every single Giant Panda in the world in efforts to help restore their numbers
    - Recovered habitats and helped species come from endangered classification to vulnerable

10.2. Biodiversity

- The variety of species found in an ecosystem
- Extinction - when a group of organisms fail to adapt to the environment and therefore cannot survive
    - Usually a natural process
    - The destruction of natural habitats by humans is causing the current rate of species extinction to be much higher than the natural rate
- Measuring biodiversity
    - Genetic biodiversity - relates to the genetic variation of the number and frequency of alleles in a specific gene
        - If one population of a species dies out, then the species may lose some genetic diversity
    - Species diversity - number of different species in an ecosystem and the proportion of each species in the ecosystem
        - Richness and abundance of species
    - Ecosystem diversity - number of distinct ecosystems in a defined area
- Threats to biodiversity
    - Overexploitation
        - Overfishing
        - Overharvesting
    - Bottleneck effect - population has been almost wiped out by a natural disaster
        - Surviving population is very small and has lost lots of genetic info
    - Habitat fragmentation - habitat is broken up into smaller sections
        - Can lead to habitat loss, and increased competition in species as fragments become smaller
    - Invasive species

10.3. Habitat Change and Destruction

- Population growth → need for more resources → habitat loss
    - Deforestation, mining, land clearance for housing and infrastructure
    - Conversion of land to agricultural land has led to further loss of habitat
        - 40% of Earth's land surface is used for agriculture
    - Deforestation - cutting down of trees for either land clearance or plant based products leads to a loss of habitat
    - Pollution - can damage ecosystems; landfills, ocean pollution, air pollution, etc...
    - Additionally, overhunting can reduce the size of a species' population
        - Animals are hunted for food, medicines, souvenirs, fashion, etc...
        - Exotic pet trade has become rampant cause rich people can't seem to have basic common sense
        - Over hunting of North Atlantic cod in the 60s and 70s led to a collapse in fish numbers

10.4. Invasive/ Introduced Species

- Invasive species is any alien species introduced to a new area (usually because of humans),
    - Adapted to grow rapidly and take resources from native species
        - Often leads to a reduction of the population of the endemic species
- Usually threatens resources and causes damage
- Effects can be drastic
- Native plants and animal population decreases
- Other species may flourish to extremely high population levels thanks to the new species (new species can become prey, etc)
- All these things disrupt the whole entire food chain
- Case study- dogs
    - Introduced to minimize number of rats
    - Now have taken over the world and have started world domination are now in excess everywhere
- Zebra mussel
    - Introduced accidentally through ballast water of ocean-going ships
    - Now invasive in:
        - N. America
        - Great Britain
        - Italy
    - Attach themselves to pipes and clog them
    - Females reproduce merely 6 weeks after settling
        - Produce nearly 30k eggs
    - This means each female produces 1 million eggs every year
- Grey squirrel - introduced into the UK from North America
    - Competes with native red squirrels
    - Has led to such a reduction in red squirrel numbers that the native red squirrel is now rare

10.5. Pollution

- Introduction of contaminants into a natural environment that causes:
  - Instability
  - Disorder
  - Harm
  - Discomfort to the ecosystem
- Takes the form of:
  - Chemical substances
  - Noise
  - Heat
  - Light
- 3 actors determine the severity of a pollutant
  - Its chemical nature
  - Concentration
  - Persistence
- Water pollution
  - The presence of pollutants in water
    - Sewage
    - Dissolved metals
    - Waste from farms/factories
    - Crude oil spilled from shipwrecked tankers
  - 3 main substances that pollute water are
    - Nitrites from fertilizers
    - Sewage
    - Detergents
  - Pollution causes harm to biotic factors such as plants and animals, and in turn- humans
    - Can cause health issues such as cancer
  - Main sources of water pollution is from:
    - Sewage
    - Farms
    - Factories
  - 100k marine animals and 2 million seabirds die every year after ingesting or getting trapped by plastic debris
  - Case Study: Laysan Island
    - Large bird rookery and guano mining
    - In 1857, reported 800k birds
    - Thanks to pollution, plastic and other debris is everywhere, threatening native wildlife, especially seabirds
- Air pollution
  - Harmful gases and tiny particles (like carbon monoxide, nitrogen dioxide, and Sulphur dioxide) pollute the air, causing its quality to decrease and become harmful, especially to humans
    - Causes funny cough, asthma, and burning eyes
  - Big 6 Air Pollutants
    - Carbon dioxide
    - Carbon monoxide
    - Sulfur oxide
    - Hydrocarbons (benzene, terpene, etc)
    - Particulates
- Noise Pollution
  - Harmful- often human caused- noise in environment, directly affecting animals and sometimes older humans
  - Ex. fireworks can be extremely traumatizing for dogs

Greenhouse Effect

- Process by which atmosphere gases absorb heat energy from the sun and prevent heat from leaving our atmosphere
- Greenhouse gases trap heat energy and keep it close to earth
- 3 main greenhouse gases
  - CO2
  - Methane
  - Water vapor
- Process
  - Sun's heat energy passes through atmosphere
  - 26% is reflected/scattered
  - 19% is absorbed by clouds/gases/ particles
  - 4% reflected to space
  - 51% reaches surface
- Possible Causes
  - Deforestation/agriculture
    - Trees play an important role in maintaining CO2 levels on earth, and without them CO2 levels rise
    - Deforestation means earth is losing trees= more CO2
    - Agricultural growth of farm animals (mostly cows) means more methane on Earth
  - Burning of fossil fuels/gasoline/oils
    - Releases greenhouse gases into the air
  - CFCs
    - CFCs are used for our plastic bags and other plastic materials which we produce in millions every day
    - When we throw them away we burn these plastics, releasing CFCs into the air
  - Population growth
    - More population = more needs = more deforestation/burning of fossil fuels/ more agriculture
- Greenhouse effect is good, as it keeps Earth at a good temperature for us to survive, but in excess, it is leading to global warming and thus, climate change

Global Warming

- Increase in average global temperatures
- Caused by increase in amount of greenhouse gases in atmosphere
- Consequences
  - Melting ice caps: losing glaciers and ice caps- meaning loss of habitat for native species such as polar bears/penguins
  - Many species adapted to a certain temperature are unable to survive in new, warmer temperature
  - On the other hand some species are flourishing in the new temperature, disrupting the food chain as there is now an excess of one species

Glacial/Interglacial Cycles

- Large continental ice sheets in the Northern Hemisphere have grown and retreated many times in the past
- Times with large ice sheets = glacial periods (ice ages)
- Times without large ice sheets = interglacial periods
- Most recent glacial period occurred between about 120k and 11k years ago
- Since then, Earth has been in an interglacial period knows an Holocene
- Glacial periods are colder, dustier, and generally drier than interglacial periods
- These glacial/interglacial cycles are apparent in many marine and terrestrial paleoclimate records from around the world
- The ultimate pacing of these glacial cycles is statistically linked to cyclic changes in the orbital parameters of Earth, which characteristic frequencies of roughly 100, 41, and 23 thousand years

Carbon Footprint

- Defined as total set of greenhouse gases (GHG) emissions caused by an organization, event, product, or person
- Extremely powerful tool to understand the impact of personal behavior on global warming
- Main effects
  - Climate change: effect of large carbon footprint- from 1990-2004, carbon emissions increased by 31%; by 2008, emissions had contributed to a 35% increase in radiative warming (or a shift in Earth's energy balance towards warming)
  - Depletion of resources: Large carbon footprints deplete resource on large and small scales, from a country's deforestation activities to one's home's increased use of air conditioning

10.6. Causes of Climate Change

- Human causes
  - The greenhouse effect
    - Greenhouses gases are produced naturally and trap heat in the atmosphere like a blanket
      - Water vapor accounts for 98% of the natural greenhouse effect
    - Enhanced greenhouse effect → global warming
      - CO_2, methane, fluorocarbons
      - Burning of fossil fuels (industry, cars, homes)
    - Nitrous oxide - produced by soil cultivation practices like commercial and organic fertilizers, fossil fuel combustion, nitric acid production and biomass burning
    - Methane - decomposition of waste in landfills, agriculture, manure, livestock
    - More solar radiation is absorbed by the greenhouse gases → heat is trapped
  - Chlorofluorocarbons (CFCs)
    - Found in aerosols, hairspray, fridges and foam plastics
    - Ozone layer keeps harmful UV rays out
      - Destroy ozone molecules → depletion of the ozone layer
        - Ozone holes let harmful UV radiation in → add to the problems of the greenhouse effect and global warming
  - CO_2 → rising temperatures
  - Deforestation → fewer trees to absorb carbon dioxide
    - Forests and bushland act as carbon sinks
    - Clearing vegetation for farming, urban development, infrastructure, timber and tree products, etc...
    - When vegetation is burnt, the stored carbon in released back into the atmosphere
  - Atom bomb testing
- Natural
  - Solar irradiance
    - Little ice age between 1650 and 1850 - Greenland was largely cut off by ice from 1410 to the 1720s and glaciers advanced in the Alps
    - However, there is limited evidence because it has been seen that the upper layers of the atmosphere are actually cooling while the lower layers are warming
  - Volcanic eruptions
    - Gas and dust particles during eruptions
      - These particles can block sunlight and cool parts of the earth
    - Sulphur dioxide - haze of tiny droplets → reflects incoming solar radiation → cooling of surface
    - Greenhouse gases - water vapor and CO_2
      - When there was intense volcanism in history, the amount of CO_2 was enough to cause significant global warming
  - Milankovitch Cycles - variations in the earth's eccentricity, axial tilt, and precession
    - Create alterations in seasonality of solar radiation reaching the Earth's surface
      - Directly influence climate system → impact the advance and retreat of Earth's glaciers
    - Eccentricity - the shape of the Earth's orbit around the Sun
      - Ranges more or less elliptically (0-5%) every 100,000 years
      - Changes the distance of short wave radiation from the Sun
      - Prominent changes in the Earth's climate and glacial regimes
- Axial tilt - inclination of Earth's axis in relation to its plane of orbit around the Sun
  - Periodicity of 41,000 years from 21.5 to 24.5 degrees
- Precession - Earth's slow wobble as it spins on its axis
  - Wobbles from pointing at Polaris to Vega
  - Periodicity of 23,000 years
  - Significant alterations → seasonal contrasts
- El Nino Southern Oscillation Cycle (ENSO)
  - a climate cycle in the Pacific Ocean with a global impact on weather patterns

    - ocean temperatures and rainfall from storms veer to the east
    - La Nina - waters of the tropical eastern pacific are colder than normal and trade winds blow more strongly than usual
    - During an El Nino → trade winds weaken → oceans warm → warm waters release a lot of energy into atmosphere → weather changes all over the planet
- Melting permafrost → releasing large quantities of methane

10.7. Impacts of Climate Change

- Global Warming
    - The Greenhouse Effect
    - Greenhouse gases absorb more solar radiation that is reflected back from the surface, keeping heat trapped in the atmosphere
- More frequent and severe weather conditions and changes in weather patterns
    - High temp → disasters
        - Storms, heat waves, floods, droughts, etc...
        - 2015 - 10 climatic disasters in the US that caused $1 billion in losses
            - Average annually for 1980 to 2015 was $5.2 billion for all disasters combined in the US
    - Jeopardize access to clean drinking water, out of control wildfires, and result in dust storms, extreme heat and flash flood, hazardous material spills, property damage
    - More warmth + wetness → more waterborne illnesses
- Higher death rates and health risks due to diseases
    - Heat exhaustion, waterborne illness, heat stroke, cardiovascular disease, etc...
    - Extreme heat in areas where people aren't used to it
- Polluted, dirtier air
    - Warm temp → more ground level ozone
        - Created when pollution from cars and factories reacts with sunlight and heat
        - More airborne pollen → more allergies and hayfever
- Loss of habitat and more wildlife extinction
    - Land, freshwater, and ocean species are shifting to cooler climates or higher altitudes in attempt to escape global warming
    - Still face increased extinction risk
    - Vertebrae species are disappearing 114 times faster than they should be
- More acidic oceans
    - Absorption of excess emissions
    - Threat to aquatic life → $CaCO_3$ shells or skeletons like mollusks, crabs and corals
        - Impact on shellfisheries → economic risks
- Higher sea levels
    - Glaciers and ice sheets
    - Threatening coastal systems and low lying areas
    - NYC, LA, Miami, Mumbai, Sydney and Rio
- Changes in precipitation patterns
    - Crops such as oranges, grapes and peaches can be grown in the UK
- Food insecurity
    - Changes in rainfall patterns → impact on global water supplies
    - → Impact of food production → food insecurity
    - Random weather events and disasters wipe out crops
    - Unsuitable climate
    - Unpredictable climate
    - Cropping seasons
- Migration
    - Areas suffering drought
    - In 2015, 19 million people were internally displaced because of natural disaster
    - Bangladesh
        - 35 million live in the coastal region
        - Prone to natural disasters
        - A sea level rise of 1 m could endanger the mangroves in the region
            - 15 million would lose homes and be forced to migrate
        - Flooding from sea → increase salinity of soil and groundwater
        - Spring 2016: Cyclone Roanu
            - Entire villages were destroyed and people left without access to food or water
        - August and September 2014: flooding of the Brahmaputra
            - Displaced 325,000
            - Rice harvest was destroyed
            - Agricultural employment declined
            - Food insecurity
            - Migration to urban areas due to struggle to maintain livelihood
    - East Coast US
        - Sea levels on the east coast are rising more than world average
        - Flood hazards
        - 0.9 meter rise by 2100 could expose 4.2 million people to flooding and 1.8 meters could affect 13.1 million
        - More flooding in general
        - People are moving towards the inland to avoid hurricanes, flooding and general unfavorable climatic conditions
    - Deficit in workforce

10.8. Controlling Climate Change

- Sustainability - avoidance of the depletion of natural resources in order to maintain ecological balance
    - Meeting present needs without compromising the ability of future generations to meet their needs
- Mitigation - reducing climate change
- Adaptation - adapting to life in a changing climate
- Management
    - International agreements, carbon tax and trading, alternative energy

    - Change lifestyle: food, clothing, energy...
- Mitigation
    - Carbon tax - pay a fee for every ton of greenhouse gases emitted
    - Carbon credits and trading
    - London Congestion Charge
    - Cap and trade - permits to pollute above certain level are sold on the free market, any organization that is under allocation can make profit by selling the extra permits
    - Individual lifestyle changes
- Geoengineering and reducing emissions
    - CO_2 reduction by extracting GHGs from the atmosphere
    - Carbon capture - removal of CO_2 from waste gases from power stations and storing it in old oil and gas fields or coal mines underground
    - Reduced intensive livestock farming
    - Reduce chemical fertilizer use
- Adaptation
    - Improved air circulation methods and building design
        - Reduce use of fuels for the heating of homes to minimum levels by economical designs of housing and reduce use of fuels in more efficient transport systems
    - Monitoring control and spread of disease
    - Improved sea defenses or managed retreat from low lying coastal areas
- Protecting carbon sinks and fuel-stocks
- Using biomass and other alternative sources of energy such as nuclear power
    - Wave energy, wind power
- Afforestation and stopping deforestation

10.9. FACE - Free-air Carbon dioxide Enrichment - Trials

- A FACE plot is circular and surrounded by a ring of pipes that release carbon dioxide enriched air, at vertical intervals just above the ground to just above the top of the plant canopy.
- Wind direction, velocity and CO_2 are measured at the center of each plot
- This information is used by computer-controlled system to adjust CO_2 flow rate and maintain the target amount of CO_2
- Only pipes on upwind side release CO_2, unless wind velocity is very low, at that time CO_2 is released alternately from adjacent release points
- For vegetation of low stature only 1 or 2 vertical release points are necessary, whereas for tall vegetation several vertical release points are needed to enrich the whole canopy
- FACE was developed as a means to grow plants in the field at controlled elevation of CO_2 under fully open air conditions, as opposed to greenhouses where the atmosphere is completely controlled
- Results from these FACE experiments provide best estimate about how plants and ecosystems will respond in a future high CO_2 world
- Duke Forest FACE Experiment - 8 years; examine the response of a temperate coniferous forest to high, future level of atmospheric CO_2
    - Photosynthetic rates by canopy foliage increased up to 50% over controls
    - Biomass increment increased by 27% over that in control plots
    - Higher growth and respiration of roots
    - Increase of forest floor accumulation and literfall

El Nino

- Means little boy/ Christ Child in Spanish
- Originally recognized by fisherman off the coast of South America in the 1600s, with appearance of unusually warm water in Pacific Ocean
- Name was chosen based on time of year (around December) during which these warm waters events tended to occur
- El Nino refers to the large scale ocean atmosphere climate interaction linked to a periodic warming in sea surface temperatures across the central and east central Equatorial Pacific
- El Nino Southern Oscillation Cycle (ENSO)
    - A climate cycle in the Pacific Ocean with a global impact on weather patterns
    - Ocean temperatures and rainfall from storms veer to the east
    - La Nina - waters of the tropical eastern pacific are colder than normal and trade winds blow more strongly than usual
    - During an El Nino → trade winds weaken → oceans warm → warm waters release a lot of energy into atmosphere → weather changes all over the planet
- El Nino presents process of upwelling -movement of cold-nutrient rich water to the surface- off the coast of Peru, Ecuador, and Chile
    - Forces fish that normal thrive in that region to relocate somewhere to find food
    - Birds that feed on these fish die off
    - Can have devastating impact on local economies
- Can also cause far-reaching weather events as well
    - Drought and heat waves across Australia, Indonesia, and Philippines
    - Reduction in annual monsoons in India
    - Torrential rainfall in central/south America
    - Heavy winter snows and floods in southern USA
    - All of these affect water resources and food supply
- Occurs every 3 - 8 years and usually lasts around a year
- Scientists do not know why the pressure changes causing winds to shift
- Warm water arrives at south America around Christmas-hence the name El Nino

10.10. Overexploitation

- Extreme use of some important areas like wetlands/forests for resources in damaging manner
- Forests
  - Deforestation
    - Depletion of habitat
    - Global warming
    - Industries that benefit: mining, lumber/timber, agriculture
      - Loud noises also scare away species
    - Rainforests were once 14% of land surface; now 6%
  - Overexploitation
    - Clearing land/trees
    - Poaching and hunting
    - Mining of oil, gold and iron
  - Have allowed for the discover of many medicines
- Case study: Wetlands
  - Most people destroy them for drinking water
- Resource gets destructed, and can lead to a species diminishing
- Ex.
  - Wild medicinal plants
  - Grazing pastures
  - Fish stocks
  - Forests
  - Water aquifers
- Causes
  - Rich countries over consuming
  - Lack of incentives to conserve such as environmental taxes
  - Economic growth causes environmental degradation,
    - However, lowering economic growth in rich countries will lower it in poor countries
  - Increase in human population number
- Case study: Passenger Pigeon
  - Flocking bird found in N. America
  - Estimates suggest that there was at least 3 billion individuals
  - Birds roosted together making them easy target
  - Hunters came up with several ingenious ways to killing the birds
    - Suffocation by burning grass
    - Fed alcohol soaked grain
    - Beaten down with long sticks
    - Netted and trapped using decoy
  - Last one was seen in 1900 in Ohio
- Case Study: Fishing industry
  - Commercial fishing fleets exceed the ecological limit
  - Caused by greed, lack of data on actual fish stocks, and lack of concern about the environment
  - Out of the 21k species of fish only 9k are actual used by humans
  - 22 species are harvested in excess of 100k tons per year
  - In the Great Lakes in N. America there has been a decline in fish numbers and the lake trout and Atlantic Salmon are extinct in Lake Ontario

Apo Islands - Philippines

- One of the most important fisheries in the world
- Fishers used dynamite and cyanide fishing methods
  - These methods had massive consequences on the ecosystem
  - Killed local populations
  - Soon there was very little diversity and very few fish to capture
  - This was damaging to local economy
- Local fishers started to take action against the deterioration of the marine life
- Local volunteers formed a marine guard to enforce rules against modern fishing methods
  - Muro-ami method: rocks are pounded against corals to scare fishes and "herd" them in a certain direction in order to trap them
  - Dynamite fishing: illegal, but nobody enforced these rules so fishers illegally used left over WWII dynamite to capture the fish
  - Nylon mesh nets: if left behind in the water, many animals get trapped and starve in it (basically litter inside the ocean)
- Fishers had to use traditional fishing methods instead, which were much less harsh on the ecosystem
  - Small paddle canoes
  - Gill nets
  - Hook and lines
  - Conventional bamboo fish traps
- Made the islands into a marine sanctuary, and opened it for tourism
  - Used money generated from tourism to help preserve the island
- Within 10 years, immense diversity and growth returned to the island
  - Now around 650 species of fish thrive there (and it is surprising, as the region is very small and shallow)
  - 400 coral species originated in this time period within the sanctuary

10.11. Eutrophication

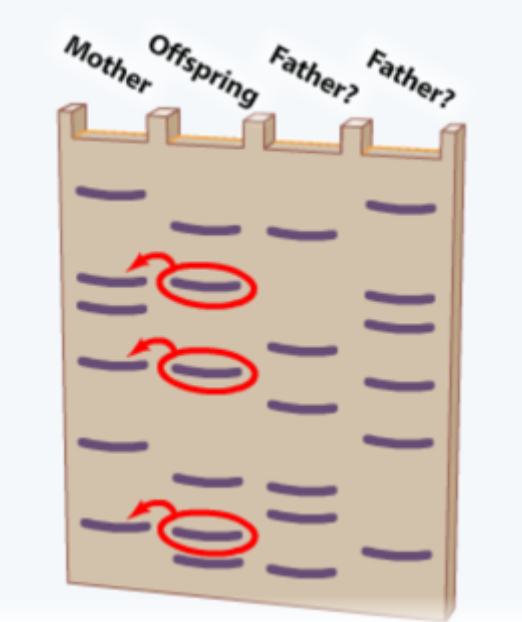
- Pollutants coming from land is the usual cause for eutrophication, the process where water bodies receive excess amounts of nutrients which results in excessive plant growth and algal bloom
- Causes
  - Overuse of fertilizers can pollute freshwater resources
  - Nitrate and phosphate fertilizers from surrounding farmland can be washed into the water bodies
- Increased nitrogen and phosphorus in the water bodies leads to increased algal growth (algal bloom) - nitrogen is used by the algae to make protein, and phosphorous is needed to make cell membrane, DNA and other molecules of life
- Algal Bloom
  - Can block sunlight and prevent underwater photosynthesis and causes them to die

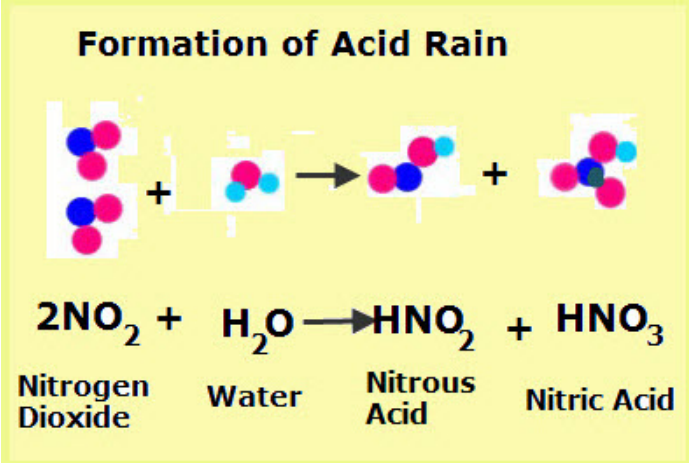
- Algae also die - build up of dead organic matter on the bottom of the lake
- Bacteria builds up to feed on dead matter - they need oxygen to respire and so oxygen levels in the lake decrease
- Shellfish may feed on harmful algae, and once we ingest the shellfish we also can get illness and possibly death
- lack of oxygen means that animals in the lake die

- Red Tides (Harmful algal blooms)
  - Harmful algal bloods can be colorful (red, green, brown, orange, or sometimes colorless)
    - can discolor coastal waters
    - may deplete oxygen
    - may release toxins that may cause illness in humans and other animals
  - Have no relation to actual ocean tides
  - Many different species and organisms can cause this (not only caused by human-induced eutrophication
    - factors: warm ocean surface temps, low salinity, high nutrient content, calm seas, and rain followed by sunny days during the summer months
  - tracking and monitoring efforts are helping scientists better understand red tides
- Global warming is allowing more species of algae to create algae blooms
- Changes in local ecosystems may allow exotic species to thrive if introduced
- Most common HAB- cyanobacteria (blue-green algae)
- Human harm
  - Ingesting shellfish which have ingested HABs can cause Paralytic shellfish poisoning
  - Neurotoxic shellfish poisoning
  - Ciguatera fish poisoning

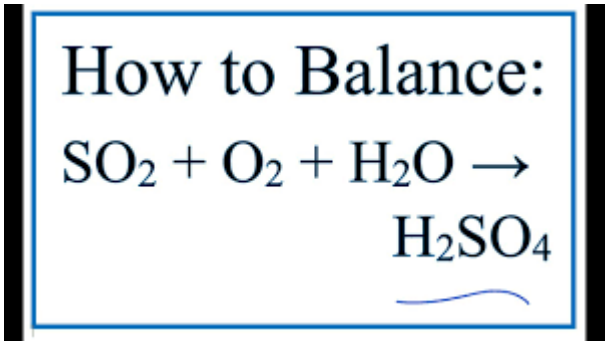
Acid Rain

- Rainfall made by acidic atmospheric pollution causes environmental harm
- It possesses elevated levels of hydrogen ions (low pH)
- Can have harmful effect on plants, aquatic animals, and infrastructure
- Caused by emissions of sulfur dioxide and nitrogen oxides which react with water molecules in the atmosphere to produce acid





- Nitrogen oxides can also be produced naturally by lightning strike/ sulphur dioxide by volcanic eruptions
- Impact
  - Contribute to heart/lung problems such as asthma and bronchitis
  - Can lead to loss of fish in acid sensitive lakes/streams
  - Eliminates insect life and some fish species (brook trout and creeks)
  - pH lower than 5 kills most fish eggs and even lower can kill adult fish
  - Chronic acidification can reduce important nutrient levels such as calcium which can weaken other fish and plants
  - May remove soil nutrients such as calcium and magnesium from soils in high elevation forests
- Oceans
  - Oceans absorb ¼ of the CO2 that is released into the atmosphere every year
    - Helps reduce the impacts of global warming, but also leads to ocean acidification



- Carbonic acid is formed and hydrogen ions are released → decrease in pH → more acidic oceans
- Hydrogen ions combine with carbonate ions → bicarbonate
  - This lowers the carbonate ion concentration
  - This is a problem for marine calcifiers (corals, crustaceans, and mollusks) who need carbonate ions to build their shells and skeletons
- If ocean acidification persists, some organisms may no longer be able to produce and maintain their shells
- Pollutants from acidic fertilizers and industries also contribute to this problem
- Prevention
  - Vehicle emission can be controlled
  - Fluidized bed combustion also reduces about of sulfur emitted by power reduction
  - Wet scrubber is a reaction tower equipped with a fan that extracts hot smoke stack gases from a power plant into the tower

Salmon Farming and the Infectious Salmon Anaemia (ISA) Virus

- Discovered in Norway in 1984
- Lead to the destruction of many salmon farms
- Has been reported in freshwater farms, but generally occurs in hatcheries which use part sea water
  - Mostly in sea water
  - Detected in wild fish
  - Cases of clinical disease only in farm fish
- Control
  - Compulsory slaughter and disinfection of infected farms
  - Strict movement controls on suspect farms
  - Placing farms in the vicinity of an outbreak under surveillance
- Cause - orthomyxovirus
- Effects - severe anaemia, hemorrhaging and necrosis
  - Pale gilles, distended abdomen

Combating Pollution

- Altering human activity through education, incentives and penalties
  - Development of alternative technologies
  - Adoption of alternative lifestyles ex: zero waste lifestyle
  - 3 Rs
- Regulating and reducing pollutants
  - Setting and imposing standards
  - Introducing measures for extracting the pollutant from waste emissions
- Cleaning up pollutants and restoring ecosystems
  - Extracting and removing pollutants from the ecosystem
  - Replanting and restocking with animal populations

10.12. Sustainable Development

- Maintenance of the delicate balance between the human need to improve lifestyles and feeling of well-being on one hand, and preserving natural resources and ecosystems, which we depend on
- Aim
  - Define viable schemes combining economic, social, and environmental aspects of human activity
  - Constant tussle between the planet, people, and profit
- Importance
  - Provides basic human needs
    - Rising population will also make use of the bare essentials of life such as food, water, and shelter
  - Agricultural necessity
    - Agriculture must catch up with growing population
  - Accommodate city development (urbanization)
    - As population rises, cities need to become larger
  - Control climate change
    - Through sustainable development, global warming can be partially remedied
    - Would mandate lower usage of fossil fuels, an unsustainable energy source
  - Provide financial stability
    - Can produce more financially sustainable economies worldwide
  - Sustain biodiversity

10.13. Conservation

- "Striving to save what we have"
  - Slows down rate of extinction caused by unsustainable exploitation of natural resources
  - Aims to maintain interaction between various species
  - Protect/preserve ecosystems
- Intergovernmental organizations (IGOs): international agreements- UNEP
- Nongovernmental organizations (NGOs): not run/influenced by government- Greenpeace, World Wide Fund for Nature (WWF)
- Role of organizations
  - work together to preserve and restore ecosystems and biodiversity
  - ensure that human activities are run on a more sustainable basis
- International Conventions

- UN conference on the human environment- discussed global environment and development
- Earth summit in Rio De Janeiro- sustainable development of Earth's resource
  - Agenda 21 - blueprint for action to achieve sustainable development worldwide, to be implemented at a local level
  - Aims
    - Collecting information about conservation areas
    - Persuading politicians to implement sustainable development
    - Raising environmental awareness through publications, local activities, education, TV and radio
    - Working with other NGOs
    - Sharing information, and best practices; creating networks; sharing resources
- UN convention on Biological Diversity (UNCBD)

Kyoto Protocol to the United Nations Framework Convention on Climate Change

- Adopted in Kyoto Japan on December 11, 1997
- Entered force on February 16, 2005
- International treaty aimed to reduce the emission of gases that contribute to global warming such as CO2, CH4, N20 (nitrous oxide), perfluorocarbons. hydrofluorocarbons and sulfur hexafluoride
- Commits its parties by setting internationally binding emission reduction targets
- 150 years of industrial activity → developed countries are primarily responsible for GHG emissions → heavier burden on developed nations under the "common but differentiated responsibilities"
- Marrakesh Accords: Conference of the Parties 7 - Marrakesh, Morocco, 2001
  - Rules for implementation of the Protocol
  - First commitment period was 2008 to 2012
    - 27 industrialized countries and the European Community committed to reduce GHG emissions to an average of 5% against 1990 levels
  - Second commitment period (2013-2020) - committed to reduce GHG emissions to an average of 18% below 1990 levels
- Kyoto Mechanisms
  - Clean Development Mechanism - allows a country with an emission reduction/limitation commitment to implement an emission reduction project in developing countries
  - Joint implementation - allows a country with an emission reduction or limitation commitment to earn emission reduction units from an emission reduction or removal project in another party each equivalent to one tonne of CO2
  - Emissions trading - allows countries that have emission units to spare, to sell this excess capacity to countries that are over their targets
- Monitoring emission targets
  - Registry systems and an international transaction log verify that transactions are consistent with the rules of the Protocol
  - Reporting annual emission inventories and national reports at regular intervals
  - Compliance system ensures that parties are meeting their commitments and assists if needed
  - Assists countries in adapting to the adverse effects of climate change → technology
    - Adaptation fund

Paris Agreement

- Conference of the Parties 21; Paris, December 12, 2015
- Entered force on November 4, 2016
- Aim: to strengthen the global response to the threat of climate change by keeping a global temperature rise below 2 degrees C above pre-industrial levels and to limit the temperature increase even further to 1.5 degrees C
  - Increase ability of countries to deal with climate change
- Appropriate mobilization of financial resources and technology frameworks; enhanced transparency
- Nationally determined contributions
- Global stocktake every 5 years to track progress
  - Countries will have to disclose an inventory of their emissions
  - Developed countries are need to give information about the finance they are mobilizing
- Key features
  - Long term temperature goal
  - Global peaking of GHGs
  - Conserved sinks and reservoirs of GHGs
  - Voluntary cooperation
  - Adaptation
  - Minimizing loss and damage due to the negative effects of climate change
  - Climate change education
  - Transparency
  - Global stocktake
- Developed nations will help developing nations with the costs of going green and coping with the effects of climate change
  - Obliged to mobilise $100 billion per year

In-situ Conservation

- The conservation of species in their natural habitat
- Endangered species are conserved in their natural habitat
- The animals are not the only things being protected, but also the habitat and ecosystem
- Works within the boundaries of conservation areas/nature reserves
- Pros
  - Can conserve whole ecosystems
  - Allow research and education
  - Preserve many habitats and other species

- Prevent hunting and other human disturbance
- Cons
  - Can be extremely expensive
  - Difficult to manage
  - Subject to outside forces that are difficult to control
  - Difficult to establish in the first place due to political issues/vested interests

Ex-situ Conservation

- Preservation of species outside of their habitats
- Usually takes place in zoos which carry out captive breeding and reintroduction programs
- Botanic gardens also come under Ex-situ conservation where both living collections and seed banks are used to store genetic diversity
- Pros
  - Allow controlled breeding and maintenance of genetic diversity
  - Allows research
  - Allows chance to educate others
  - Effective for protection for individuals/species
  - More useful for extremely endangered species which have populations in the 100s
- Cons
  - Have historically preferred popular animals, many of them which aren't even at risk
  - Reintroduction to wild can be very tough
  - Ex-situ conservation does not preserve natural habitat \n

11. Interactions Between Organisms and the Environment

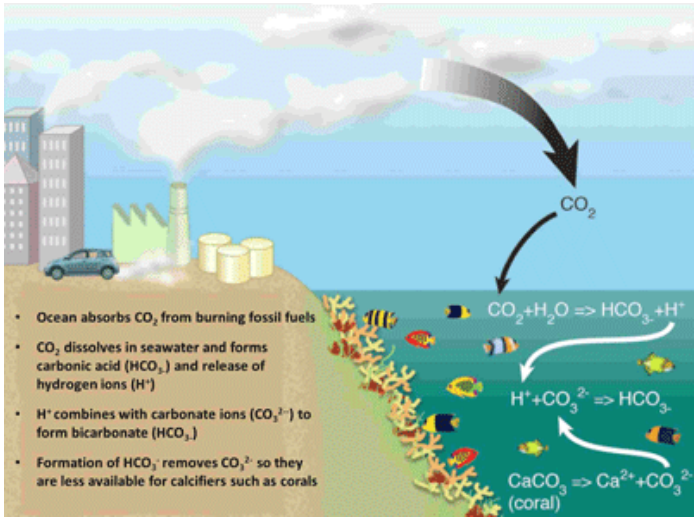
11.1. Energy Transfer

Vocabulary

- Species - a group of closely related organisms that are very similar to each other and are usually capable of interbreeding and producing fertile offspring
- Habitat - a place where an organism or a community of organisms lives, including all living and nonliving factors or conditions of the surrounding environment
- Ecosystem - a system that includes all living organisms (biotic factors) in an area as well as its physical environment (abiotic factors) functioning together as a unit
- Interdependence - the mutual dependence between entities

Trophic Levels

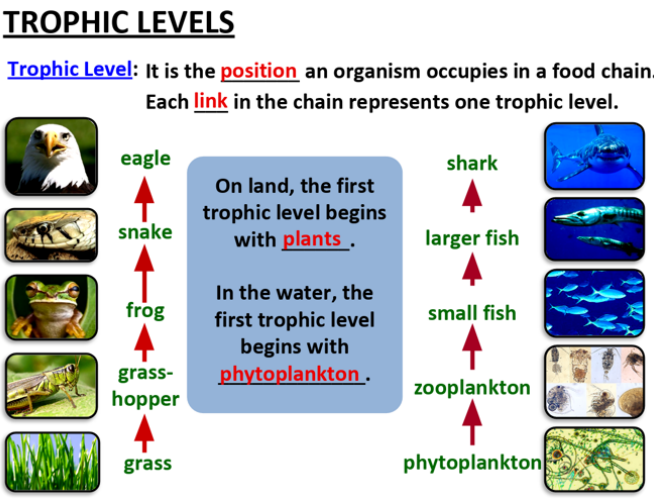
- Heterotrophs - dependent for food (secondary/tertiary/quaternary consumers)
  - Note that quaternary consumer is considered apex predator
- Producers/Autotrophs - produce own food by harnessing energy from surroundings
- Saprotrophs - feeds on decaying matter (decomposer/scavengers/detritivores/me)
- Producers and prey provide a source of food and energy, whereas predators keep population size in balance
  - This interaction makes up a food chain or a food web



Food Chains

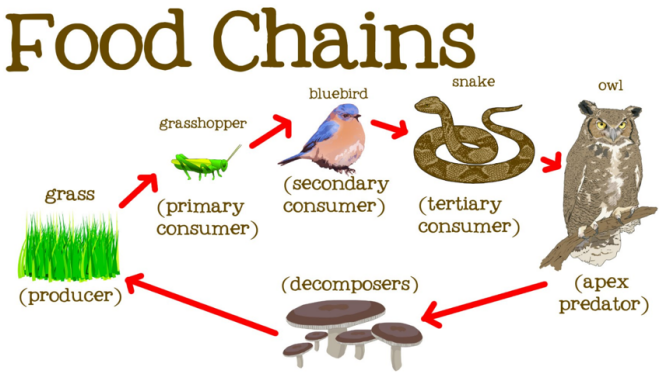
- Chemosynthesis - chemosynthetic microbes convert inorganic molecules and heat energy from geothermal vents that consumers cannot use into forms of energy that consumers can use
  - Happens deep below the surface of the ocean where photosynthesis cannot take place
- Who eats what
- Usually around 4 levels
- Biological magnification - humans are at the top level of the food chain, hence the maximum concentration of chemicals get accumulated in out bodies
- Producers - produce food and are the start of the web
- Primary consumers - animals that eat the plants
  - Control population size of producers
    - Ensures that producers have sufficient access to sunlight, water, space and other resources
    - Ensures that all producers can survive, not just the ones that can grow very tall
  - Allows for a variety of food options for primary consumers
- Secondary consumers - animals that eat the primary consumers
- Tertiary consumers - animals that eat the secondary consumers
- Quaternary consumers - animals that eat the tertiary consumers
- All levels of consumers keep the level below them in check to maintain balance and a diverse ecosystem

- When the ecosystem is not diverse, it can lead to one species dominating and wiping out the other species
- Herbivores, omnivores, carnivores
- Trophic levels
  - Plants are trophic level 1
  - Trophic level 2 can be herbivores or omnivores
  - Trophic level 3 and higher can be carnivores or omnivores
- Decomposers - keep the number of dead plants and animals under control by breaking down dead organisms
  - Saprotrophs - fungi and bacteria; cannot be seen
    - Break down dead plant and animal tissue through the process of chemical digestion
    - Do not "eat" but do use the products of chemical digestion as nutrients to perform life functions
    - Turn organic wastes into organic materials such as nutrient-rich soil
  - Detritivores - worms, maggots; eat dead plants and animals that died or natural causes or that were hunted by predators
  - Scavengers - vultures and hyenas; eat dead plants and animals that died or natural causes or that were hunted by predators



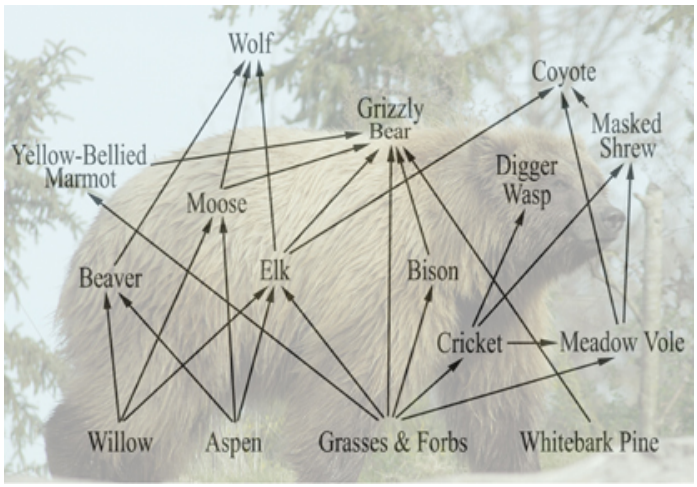
11.2. Yellowstone National Park Food Web

- Mountains, grasslands and forests
- Fauna: deer, mice, wolves, grizzly bears, elk and bison; birds, reptiles, amphibians and insects
- Flora: pine trees, aspen trees, sagebrush and a variety of grasses and wildflowers

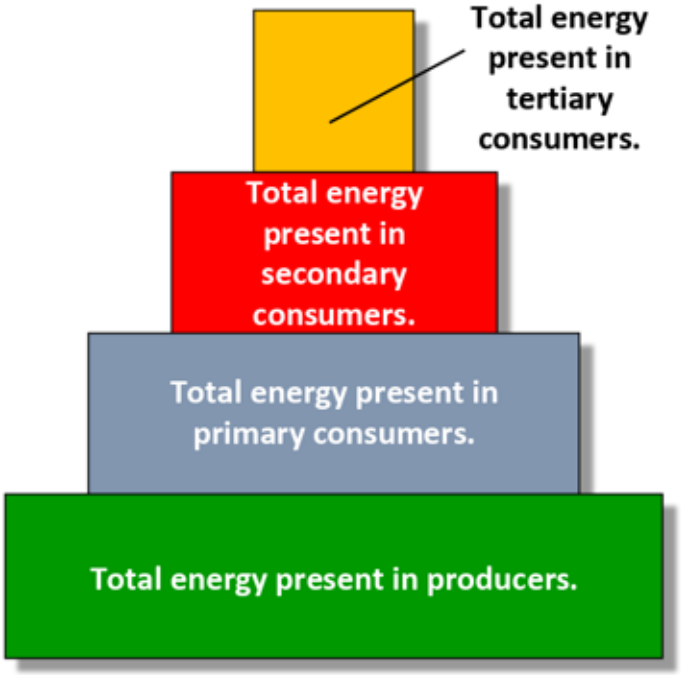


Ecological Pyramids

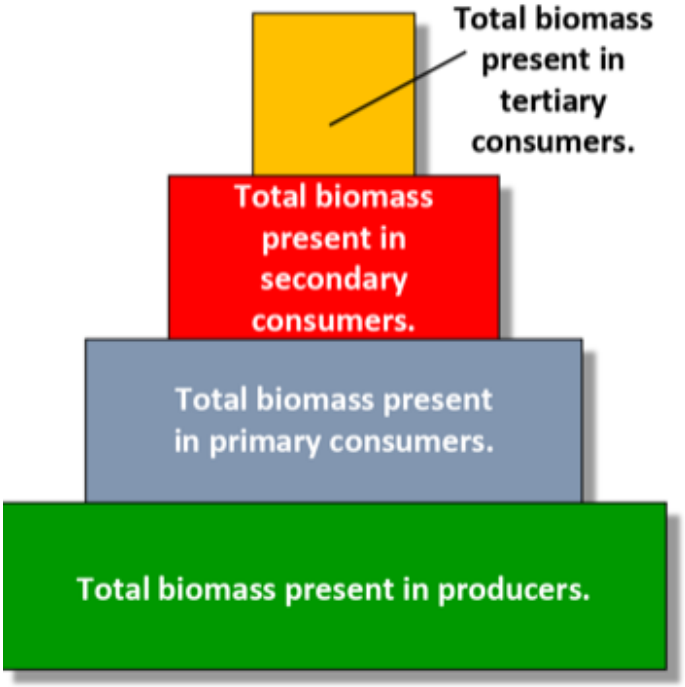
- 3 types
  - Energy
  - Biomass
  - Population
- Energy: indicates how much energy is present in each trophic level
  - Always decreases as you go up the levels because energy is lost as metabolic heat



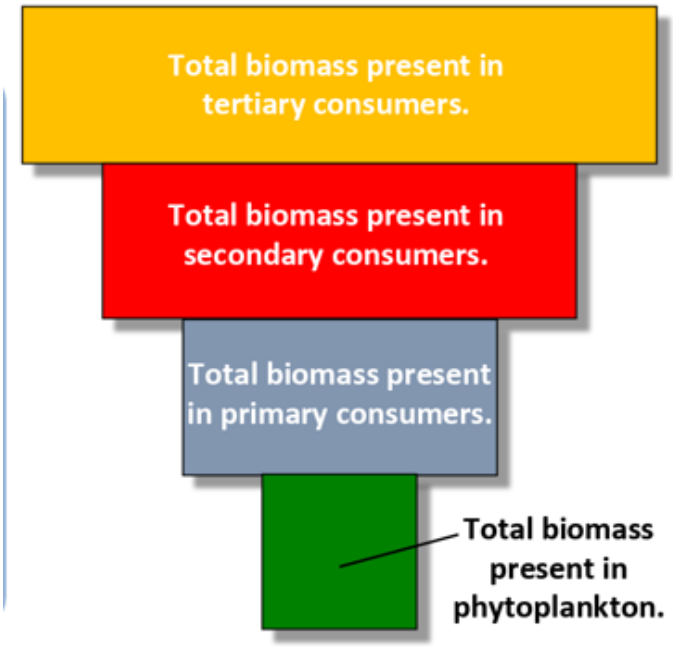
- Biomass: amount of dry matter present in each level
  - Always decreases as you go up as only energy stored as tissue is transferred



- Opposite is true for some underwater ecosystems
  - Amount of biomass increases as you move up the levels (inverted pyramid



- Population pyramid
  - Decreases as you go up



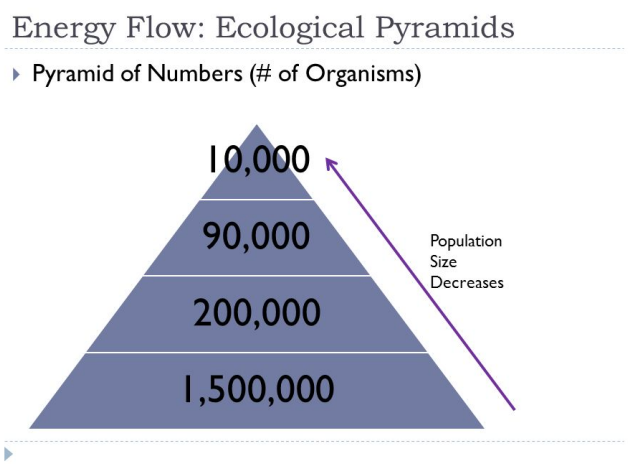
11.3. Cycles

Water Cycle

- Evaporation:
  - Water from oceans and other water bodies evaporates
  - Changes to a gaseous state as part of the atmosphere
- Condensation
  - The water vapor within the atmosphere condenses into clouds under the right conditions
- Precipitation
  - The clouds gather more and more water molecules until it finally falls down to the earth
  - Either the liquid or solid state (rain, snow, or hail)
- Transpiration
  - The water gets absorbed by the soil and taken in by plants
  - They release water vapor through transpiration

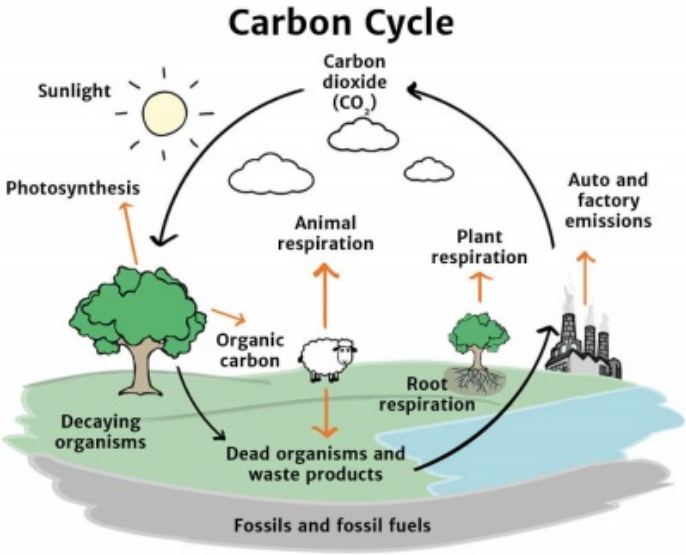
Carbon Cycle

- Plants absorb carbon dioxide from the air for photosynthesis
- The carbon becomes a part of the plant
- once the plant dies, the carbon becomes a part of the soil
- Through respiration, both plants and animals release carbon dioxide back into the air



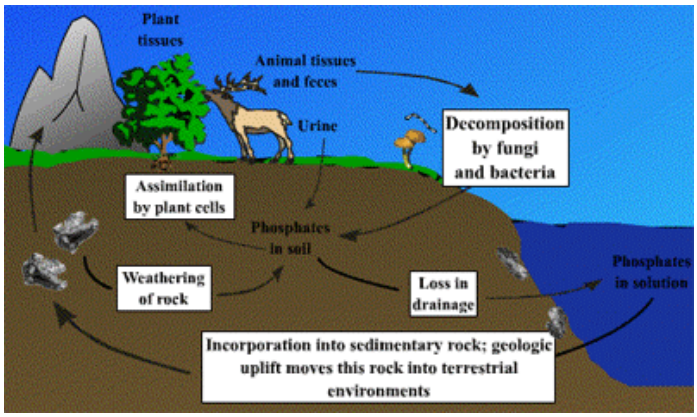
Phosphorus Cycle

- Weathering
  - Phosphorus found in rocks is extracted through weathering by air or water
  - Eventually becomes a part of the soil
- Absorption
  - Plants, fungi, and microorganisms absorb phosphorus from the soil
  - Animals also absorb the phosphorus by eating these plants
- Decomposition
  - All organisms which have absorbed phosphorus die
  - Through decomposition return back to the soil



Nitrogen Cycle

- Nitrogen fixation
  - Atmospheric N2 is taken into the soil by precipitation
  - After it is in soil/ surface water, it changes into NH4 thanks to microorganisms such as anaerobic bacteria and algae (rhizobian)
- Nitrification
  - Bacteria converts NH4 into NO2 and then NO3
- Assimilation
  - Plants absorb these various forms of nitrogen from the soil
  - Used for creation of plant/ animal proteins
- Ammonification
  - When the organism dies/ emits wastes, the nitrogen re enters the soil
  - Is broken down by more microorganisms (decomposers), and produce ammonia
- Denitrification
  - Nitrogen returns to the atmosphere where NO3 is converted to N2
  - occurs mostly in wet soils where the water makes it tough for organisms to get oxygen
  - Denitrifying bacteria will convert the NO3 to N2 to get bacteria



11.4. Keystone Species/ Paine Experiment

- Species which is necessary for food chain - the health, balance, and diversity of an ecosystem depend on the keystone species
  - they are not always top predators
  - ex: beavers in wetlands, prairie dogs in grasslands, grey wolves in Yellowstone
- Chain would self destruct without it
- Case study: Pisaster Ochraceus (a type of starfish) in rocky shoreline water ecosystem
  - When pisaster is gone, its prey snails, mussels, and barnacles increase in population
    - in the area of the shoreline next to the removal site, he left the ecosystem in its original state as a control group, with the Piaster still present
    - kept the shoreline Piaster free for 10 years
  - Now these prey feed on more phytoplankton algae
  - The phytoplankton and algae are unable to grow and are eliminated from ecosystem
  - Now mussels, snails and barnacles have no food and they die too
- Paine did all this to understand the role of different species within a food chain, and like that, discovered the concept of keystone species
  - Showed that the removal of a top predator can lead to the imbalance and destruction of an ecosystem

- Predator/prey relationship
  - Predators hunt or feed on other animals
  - The animals that are eaten by the predators are called prey

11.5. Competition

- Among same species is intraspecific competition
- Between different species in interspecific competition
- Ex:
  - Predation - predators eating prey
  - Herbivory - animals eating plants
  - Symbiosis - when two species live together/interact closely
    - Parasitism
    - Mutualism
    - Commensalism
- Interspecific interaction can affect survival/reproduction of species, so effects are either +, - , or 0

Interspecific Competition

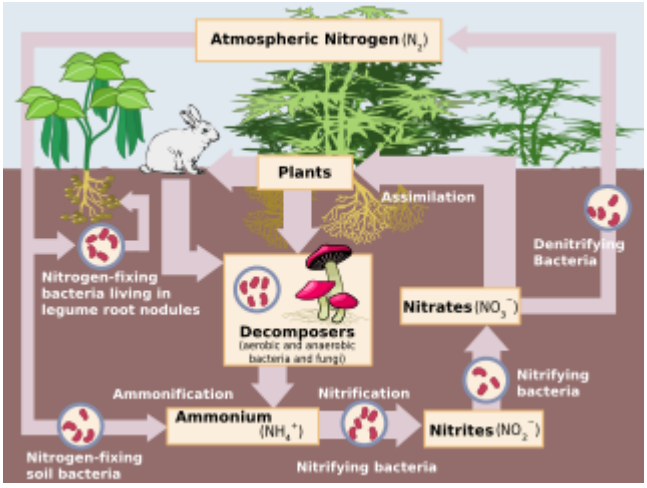
- Competition (-,-)
  - Two or more species compete for a resource that is short in supply
  - Competitive exclusion principle states that two species cannot coexist in same community if their niches (ecological role) is identical
- Predation (+,-)
  - One species (predator) kills and eats prey
  - Predator is benefitted
  - Prey is at disadvantage
  - This relationship led to more diversity in adaptation (mimicry, camouflage, etc)
- Herbivory (+,-)
  - Same as predation
  - Allows for plants to have adaptations against being eaten
  - Herbivores have adaptations to eat plants
- Symbiosis: individuals of 2 or more species live in close contact with each other - 3 main types:
  - Parasitism (+,-)
    - Parasite derives its nourishment from host species, which is harmed, weakened and sometimes killed
    - Parasites usually don't kill host
    - Parasites are also usually much smaller than host
    - Lice, hookworms, etc
    - Some good parasites - Case Study: Worm therapy
      - Worm like parasites (Helminths) are injected into body and they suck blood
      - Supposedly helps with autoimmune ailments, inflammatory bowel disease, and hay fever
      - In the future, people will probably use genetic engineering to get molecules/genes from these worms instead of injecting themselves with live worms
  - Mutualism (+,+)
    - Both species benefit; cannot live without each other cause they're dramatic and clingy
    - Birds eating excess food on crocodile teeth
    - Crocodile gets teeth cleaning
    - Bird gets food
  - Commensalism (+,0)
    - One species benefits while the other in completely unaffected
    - Creepers growing on larger tree
    - Larger tree is unaffected
    - Creeper get a way to grow

Predation vs Parasitism

Predation	Parasitism
May have several types of preyLacks metabolic dependence on the preyUsually larger and stronger than the preyActive effort requiredImmediately kills preyLife cycles of predator and prey are independent of each otherEx: lion and zebra, bear and fish	Very specific relationshipMetabolically depends on the host organismSmaller than hostGenerally passive in progressionDoesn't immediately kill hostRequires host to complete life cycleEx: lice on humans, tapeworms in cows

Relationships Within a Species

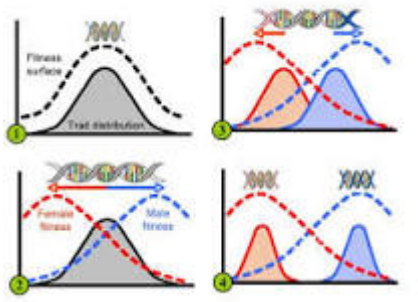
- Territoriality - the methods by which an animal or group of animals protects its territory from incursions by other of its species
  - Boundaries may be marked by sounds such as bird song, or by scents such as pheromones secreted by the skin glands of animals
  - Ex: wolf packs maintain territories in which they hunt and live
- Group defence - living in groups for safety and to defend against predators
  - Have collective senses - many eyes, ears, noses, etc...
  - Group of animals feeling from a predator can create confusion → harder to catch
    - Ex: herd of zebras running - you can't tell where one zebra ends and where another begins
- Sexual conflict - conflict that exists as a result of the divergent evolutionary interests of males and females
  - Genes may be expressed in both males and females that may be beneficial to only one sex → sex-limited gene expression



- Individuals of either sex may also attempt to shift the balance of conflict in their favor by coercion or manipulation
- Monogamy - a mating system of one male and one female forming an exclusive social pair bond
  - Pattern of social organization
  - Share a territory and live in cohabitation
  - Both individuals take care of progeny in some way
  - Ex: beavers
- Parental care - any behaviors on the part of either or both parents that help their offspring survive
  - Ex: nest building and feeding young
  - Teaching important skills
  - Ex: meerkat adults teach their pups how to eat scorpions
- Infanticide - when a parent kills its own offspring
  - Can be evolved as a reproductive strategy in males and sometimes in females
    - Often harms females that dedicate time and energy
  - Counter strategies by females
    - Promiscuity - the more promiscuous the female, the more sperm the male needs to ensure mating success
    - Kill the kids of other females
    - Have kids the same day as dominant female so dominant female can't kill them
- Predation - the process of killing and eating an individual of the same species

11.6. Population Growth

- Development of settled agriculture represents one of the most significant changes in human history, and enabled human populations to start growing
- Industrial revolution - further fuelled growth
- 20th century - growth became exponential
- Factors that contributed to an increase in human population
  - Better healthcare
  - More nutritious food
  - Cleaner water
  - Better sanitation
- More growth in LEDCs
  - Less chance of survival → women have more children
  - Agricultural families → more kids = more labor
  - Lack of contraception, education, and medical services also leads to increased birth rates
- More population = more pressure on resources
  - MEDCs use more resources than LEDCs even though they have less population growth
- Population growth limits
  - Low food supply
  - Lack of space
  - Light
  - Water
  - Nutrients/minerals
  - Disease/parasites
  - When population increases, pressure is put on resources → supply of resources decrease → some individuals die since they don't have access to resources → population can't reproduce at same rate → birth rate drops



11.7. Speciation

- Development of a new species through a variety of vectors
- Rate of speciation depends on generation time, environmental conditions, etc
- Can be caused by change in just 1 gene or a set of genes causing some sort of isolation
- 3 main types
  - Allopatric
    - Gene flow is interrupted when a population is divided into geographically isolated subpopulations
    - Berlin blockade for animals
  - Parapatric
    - Part of population enters a new habitat bordering the range of the parent species
    - Some gene flow may occur between populations which live in border zone
  - Sympatric
    - Occurs in populations that live in same geographic area
    - Less common than allopatric speciation
    - Happens when gene flow is diminished by:
      - Polyploidy
      - Habitat differentiation

- Sexual selection

11.8. Classification

Five Kingdom System

1. Monera: prokaryote, unicellular, some perform photosynthesis
    1. Bacteria
    2. Cyanobacteria
2. Protista: prokaryotes, simple multicellular
    1. Algae
    2. Protozoans
    3. Fungi-like protists
3. Fungi: eukaryotes, multicellular, autotrophs (some decomposer types are heterotrophs)
    1. Molds
    2. Yeast
    3. Mushroom
    4. Lichen
4. Plantae: eukaryotes, multicellular, autotrophs
    1. Thallophyta:
        1. Undifferentiated (no stems, roots leaves, etc)
        2. No embryo formation or vascular system
        3. Mainly multicellular algae
        4. Mainly aquatic
        5. Multicellular form is ribbon-like
    2. Bryophyta
        1. Mosses, liverworts
        2. Small multicellular
        3. Do not have true leaves and roots but have root-like and leaf-like structures
        4. No xylem and phloem
        5. Usually grow in damp-shady places
        6. Non-vascular land plants
    3. Pteridophyta
        1. Pointed needle-like leaves
        2. Found in cool places
        3. Contain vascular systems and reproduce via spores
        4. Has differentiated body w/ stems, leaves, and roots
        5. Has well developed tissue for conduction (xylem and phloem)
        6. Ex. ferns
    4. Angiosperms
        1. Dicots- 2 embryos
        2. Monocots- 1 embryo
        3. Flowering plant which carries reproductive organs
    5. Gymnosperms
        1. Coniferous
        2. Seeds on the outside
5. Animalia: Eukaryotes, Complex multicellular, heterotrophs
    1. Invertebrates - 7 types
        1. Profera- multicellular, lack true tissue, sponges
        2. Cnidaria-radial symmetry, only one mouth/anus, sea anemone, jellyfish
        3. Platyhelminthes- unsegmented flatworms (flukes)
        4. Annelids - segmented worms (Earthworms and leeches)
        5. Arthropoda - segmented body and chitinous exoskeleton (scorpion, cockroaches, spider)
        6. Mollusca- unsegmented muscular (snail, octopus, clam)
        7. Echinoderm- marine, spiny skinned (sea urchin, star fish)
    2. Vertebrates - 5 types
        1. Fish- have scales, fin, and gills
        2. Amphibians- smooth moist skin, metamorphosis
        3. Reptiles- scales, lungs, lay eggs with leathery shell
        4. Aves- feathers, beak, lay eggs with hard shell
        5. Mammals- fur mammary glands

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Biology