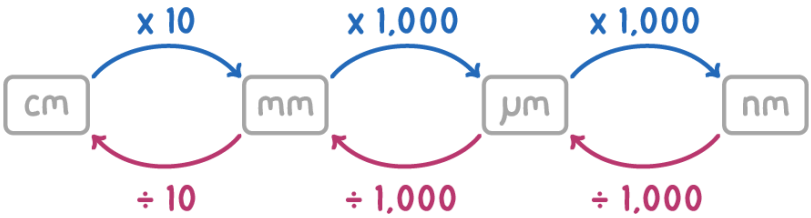
Cell Structure

Magnification

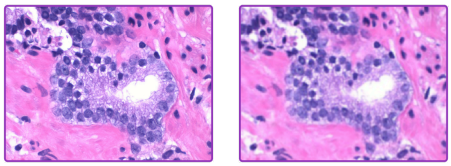
- How many times an image is larger than the object

$$\text{Magnification} = \frac{\text{Image Size}}{\text{Actual Size}}$$



Resolution

- Ability to distinguish between 2 separate points/structures and how detailed the image is



Light Microscope

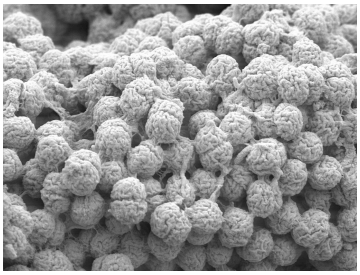
- To magnify cells and investigate structures
- Cells are stained to provide contrast between structures
    - Differential staining = more than 1 chemical stain
- Other methods for sample preparation include:
- Slide preparation = Sample must be thin
    - Dry mounts = The specimen placed directly onto the slide and covered with a cover slip
    - Squash slides = Cover slip pressed over a wet prepared mount squashing the cells
    - Smear slides = Edge of slide used to smear sample to create a thin, even coating on a separate slide
- Light (or Optical) Microscope
    - Resolution = 0.2 μm
    - Magnification = x 1,500
- Biological drawing = to record specimen observations
    - No shading, coloring, arrowheads for labels or overlapping lines
    - Must include a title, magnification or scale, smooth continuous lines drawn with sharp pencil with clean eraser to correct, labels in one side of the structure, structures being accurate ratio sizes

Electron Microscope

- Better resolution than light due to shorter wavelength of electrons
    - Transmission electron microscope (TEM)
        - Electromagnets used to transmit a beam of electrons through a specimen
        - Denser parts absorb more electrons, appearing darker in the image formed
        - Must be viewed through vacuum, restricting specimens to only thin sections of non-living or dead organisms
        - Resolution = 0.5 nm
        - Magnification = x 1,500,000



    - Scanning electron microscope (SEM)
        - Beam of electrons scan across the surface of the specimen by reflection of particles that form 3D image
        - Requires vacuum but can be used on thicker specimens
        - Resolution = 5 nm
        - Magnification = x 1,500,000

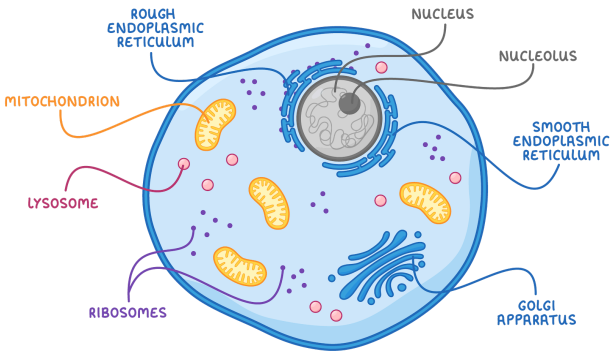


- Higher probability of artefact (air bubbles or fingerprints that aren't a part of the sample) creation due to complex preparation
- Expensive and only produces black and white images, which can be later digitally coloured

Microscope	Light	TEM	SEM
Magnification	× 1,500	× 1,500,000	× 1,500,000
Resolution	0.2 μm	0.5 nm	5 nm
Cost	Inexpensive	Expensive	Expensive
Sample prep	Simple	Complex	Complex
Image produced	2D, colour	2D, black and white	3D, black and white
Specimens used	Living or dead	Dead	Dead

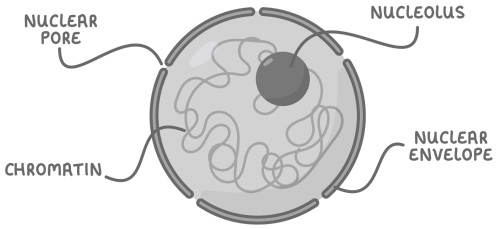
Eukaryotes and Prokaryotes

- Eukaryotes - Most multicellular organisms contain eukaryotic cells like animals, plants, fungi, and protists
    - Has membrane-bound organelles and contains DNA in the form of chromosome within a nucleus
- Prokaryotes - Single-celled organisms as made up of prokaryotic cells like bacteria

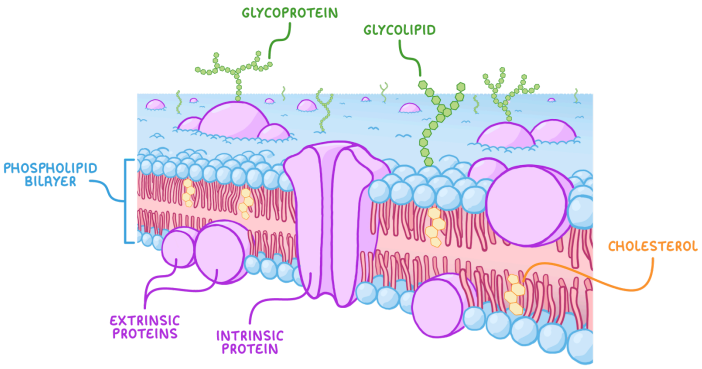


Animal Cells

- **Nucleus**
    - Largest organelle
    - Contains genetic information as chromosomes
        - DNA = Instructions to produce proteins
    - Contains nucleolus and is surrounded by a double-membrane nuclear envelope with pores
        - Nucleolus = Makes ribosomal RNA (rRNA) and is the site of ribosome synthesis, DNA replication and transcription (mRNA)
        - Nuclear pores = Controls transport of substance in and out of the nucleus

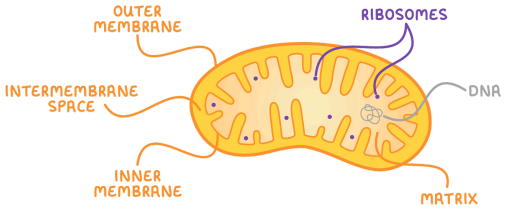


- **Cell-surface membrane**
    - Phospholipid bilayer with hydrophilic heads and hydrophobic tails
        - Controls movement of substances into and out of the cell
        - Large polar molecules require facilitation of proteins for transportation within and out of the cell



    - Contains receptors
        - Used for cell signaling to detect signals from other cells

- **Mitochondria**
  - Powerhouse of cell
    - Site of aerobic respiration - produced ATP
  - Contains matrix – enzyme-rich liquid
  - Double membrane with inner membrane folds forming cristae
  - Contains their own DNA, mtDNA, and ribosomes



- **Ribosome**
  - Present free in cytoplasm and attached to rough endoplasmic reticulum
  - Size measured in S units; eukaryotes = 80s; prokaryotes, mitochondria and chloroplast = 70s
  - Non-membrane-bound organelle made up of protein and ribosomal RNA (rRNA), consisting a large and a small subunit
    - Site of protein synthesis, handling the process of translation



- **Golgi apparatus**
  - Contains small vesicles and cisternae, fluid-filled, membrane-bound sacs
    - Vesicle = Storage and transport of lipids and proteins
    - Specialised vesicles = Synthesise lysosomes
      - Secretory vesicles pinched off of cristernae
    - Cisternae = Process and package of lipids and proteins
    - Combines carbohydrates and proteins to form glycoprotein
    - Pinched-off transport vesicles used or transportation



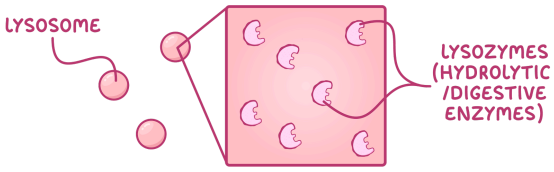
- **Rough endoplasmic reticulum (RER)**
  - Contains cisternae with its surface covered in ribosomes
    - Synthesis and transport of proteins



- **Smooth endoplasmic reticulum (SER)**
  - Contains cisternae without ribosomes
    - Synthesises, stores and transports lipids and carbohydrates such as cholesterol and steroid hormones



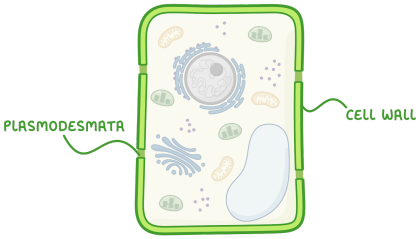
- **Lysosome**
  - Single membrane-bound organelle that contains hydrolytic digestive enzymes
    - Enzyme used to digest pathogens and break down waste materials such as old organelles and cells
      - Hydrolyse phagocytic cells, autolysis (breaks down) dead cells and exocytosis to release enzyme outside the cell destroy extracellular material while also digesting worn-out organelles to recycle useful materials



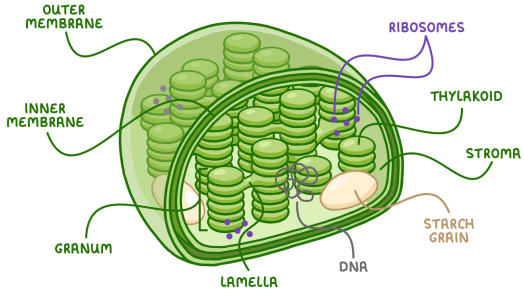
- **Cytoskeleton**
  - Present throughout the cytoplasm to provide support and structure to the cell
  - Consists of microfilaments, microtubules, and intermediate filaments
    - Microfilaments = Made of the protein actin, facilitating cell movement and locomotion (e.g. crawling, muscle contraction)
    - Microtubules = Made of the protein tubulin, forming a scaffold-like structured mitotic spindle, used for cell division and acting as tracks for intracellular transport of vesicles and organelles.
    - Intermediate filaments = Maintains position of organelles within and is responsible for mechanical strength of certain tissues (e.g. skin and hair)

Plant Cells

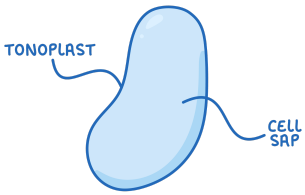
- **Cell wall**
  - Provides structure and is made up of cellulose
    - Withstands high osmotic pressure
  - Contains plasmodesmata/plasmodesma (pore-like channels)
    - Allows exchange of substances (connects neighbouring cells)



- **Chloroplast**
  - Double membrane-bound organelle enclosing stroma (fluid) and contains thylakoids (fluid sacs), stacked up to form grana
    - Site of photosynthesis (takes place in grana and stroma)
  - Contains their own DNA and ribosomes



- **Vacule**
  - Large, central, permanent
  - Contains cell sap (solution of salts, sugars and other substances) and is surrounded by tonoplast (partially permeable membrane)
    - Maintains pressure and rigidity within the cell to preventing wilting



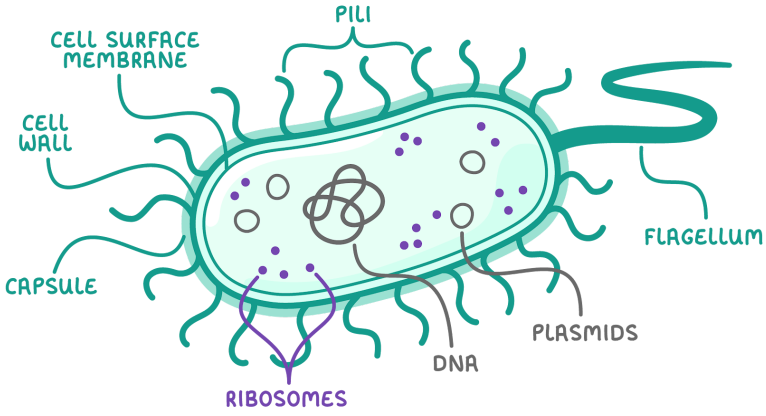
Algal and Fungal Cells

- **Algal cells**
  - Same organelles as plant cells
  - Differently shaped chloroplasts than those found in plant cells

- **Fungal cells**
  - Contain most of the organelles found in plant cells
  - No chloroplasts.
  - Cell walls made up of chitin

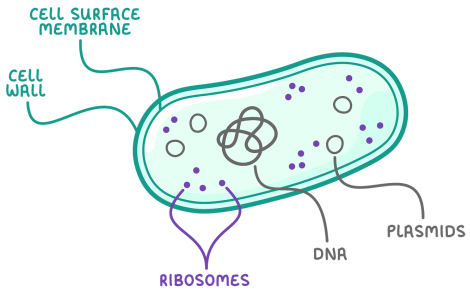
Other Eukaryotic Organelles

- **Capsule** - Cell wall made up of polysaccharides to protect the cells from attack by antibiotics or white blood cells.
- **Flagellum** - Rotates to push the cell through its environment aiding movement
- **Pili** - For attaching prokaryotic cells to other cells or surfaces



Prokaryotic Cells

- Single-celled (single prokaryotic cell)
- No nucleus and membrane-bound organelles
- Cell wall made of murein (peptidoglycan), 70S ribosomes, a large circular strand of DNA (circular chromosome/nucleoid), and plasmids (some extra genes for antibiotic resistance)



Feature	Eukaryotes	Prokaryotes
Cell type	Unicellular and multicellular	Unicellular
Size	10 to 100 µm	0.1 to 5 µm
DNA	Linear DNA contained in a nucleus	Circular DNA free in the cytoplasm
Ribosomes	80S ribosomes	70S ribosomes
Organelles	Contains both membrane-bound and non membrane-bound organelles	Contains a few non membrane-bound organelles
Cell wall	Made up of cellulose (plants) or chitin (fungi)	Made up of murein

Viruses

- Can only replicate inside a living host cell
- Acellular - Not made up of cells
- Always present
    - **Genetic material** - DNA or RNA, single- or double-stranded
    - **Capsid** - A layer of protein molecules that surrounds and protects the genetic material
- Sometimes present
    - **Envelope** - Phospholipid outer layer
    - **Glycoproteins (surface, attachment, or envelope proteins)** - Help viruses bind to host cells
    - **Enzymes** - eg. reverse transcriptase (to convert RNA into DNA)
- Replication relied entirely on the host cell's machinery
    - Glycoprotein used to bind to specific receptor on host cell
    - Injects it's viral DNA/RNA into the host cell
    - Uses host cell's machinery and resources (enzymes, ribosomes) to replicate viral particles
    - New viral particles released from the host cell

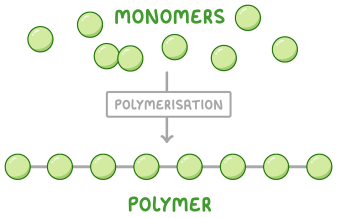
Biological Molecules

Types of Biological Molecules

- **Carbohydrates**
  - Carbon (C), hydrogen (H), and oxygen (O).
- **Lipids**
  - Carbon (C), hydrogen (H), and oxygen (O).
- **Proteins**
  - Carbon (C), hydrogen (H), oxygen (O), and nitrogen (N).
- **Nucleic acids**
  - Carbon (C), hydrogen (H), oxygen (O), nitrogen (N), and phosphorus (P).

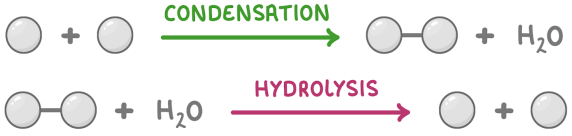
Monomers and Polymers

- **Monomer**
  - Smaller units that make up polymers (large molecules)
- **Polymer**
  - Large molecules made up of many repeating monomer units joined together by chemical bonds



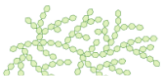
Biological molecule	Monomer	Polymer
Carbohydrates	Monosaccharides	Polysaccharides
Proteins	Amino acids	Polypeptides
Nucleic acids	Nucleotides	Polynucleotides

- **Condensation**
  - Removal of water to form chemical bond
- **Hydrolysis**
  - Addition of water to break chemical bond



Carbohydrates

- $C_x(H_2O)_y$
- Supplies and stores energy in complex forms such as starch and glycogen
- Acts as a structural component (cellulose and chitin)
- Glycoproteins help cells identify and communicate with each other for cellular recognition
- Building blocks of nucleic acid using deoxyribose and ribose

	Monosaccharide	Disaccharide	Polysaccharide
Subunits	One (monomer)	Two (dimer)	Many (polymer)
Examples	Glucose Fructose Galactose	Maltose Sucrose Lactose	Starch Glycogen Cellulose
Main Function	Energy source	Transport form	Storage form
Diagram			

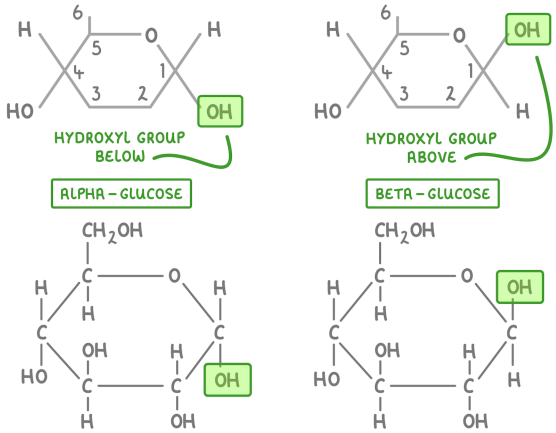
Monosaccharides and Disaccharides

- Mono = Simplest form; simple sugar
  - Soluble, sweet-tasting (fruits, vegetables, and grains)
  - $(CH_2O)_n$ where $3 \leq n \leq 7$
  - Hexose = 6 carbon
    - Glucose, fructose and galactose
  - Pentose = 5 carbon
    - Ribose and deoxyribose
- Di = 2 mono
  - Maltose (grains and cereals), sucrose (transport sugar) and lactose (milk)



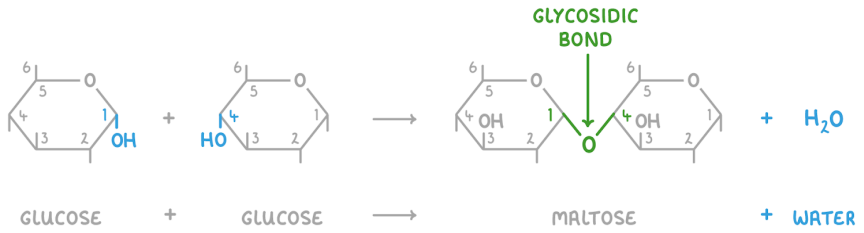
Glucose

- $C_6H_{12}O_6$
- Alpha (α) and beta (β)
- Soluble, as hydroxyl groups can form hydrogen bonds with water for transportation
- Energy released when bonds are broken

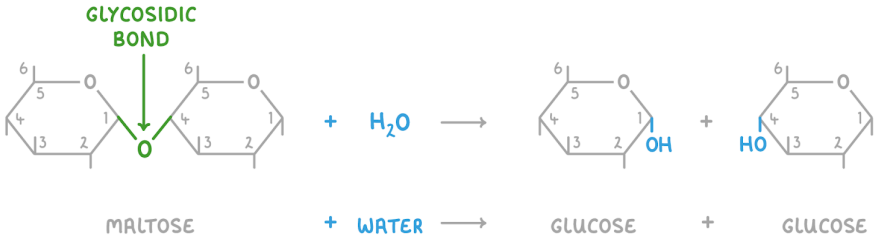


Condensation and Hydrolysis of Carbohydrates

- Condensation = Formation of disaccharide

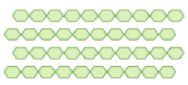
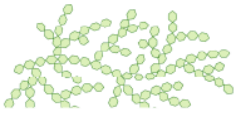


- Hydrolysis = Breakdown of disaccharide



Polysaccharides

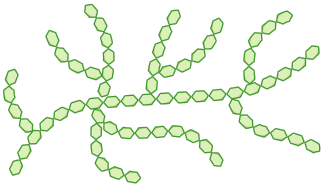
- Complex = Many monosaccharides joined via glycosidic bonds
- Starch, glycogen and cellulose

	Cellulose	Starch		Glycogen
		Amylose	Amylopectin	
Source	Plant	Plant	Plant	Animal
Monomer	β-glucose	α-glucose	α-glucose	α-glucose
Bonds	1-4	1-4	1-4 and 1-6	1-4 and 1-6
Branches	No	No	Yes	Yes
Shape				

Starch

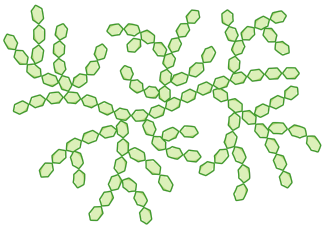
- Storage of extra glucose in plants
- Hydrolysed to glucose when energy is required
- Alpha glucose monomers
- Insoluble to prevent water from entering because it has no effect on the water potential and cannot dissolve out of cell due to large structure
- *Amylose*
    - 1-4 glycosidic bonds
    - Angles cause chain to coil into a compact helix structure to store large amounts of glucose
- *Amylopectin*
    - 1-4 and 1-6 glycosidic bonds
    - Branched structure allows enzymes to hydrolyse glucose easily





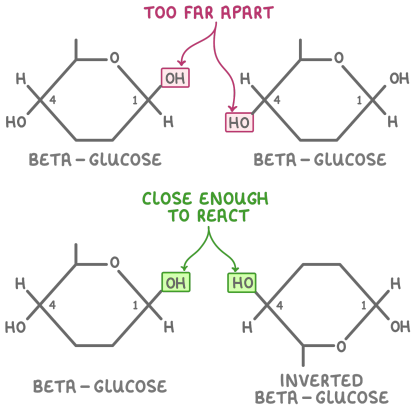
Glycogen

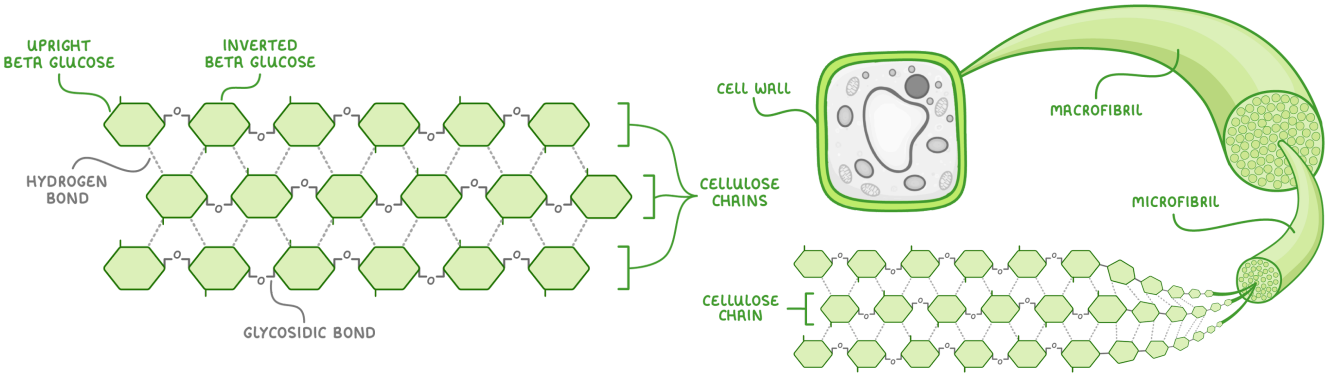
- Polysaccharide used by animals to store excess glucose
- Made up of alpha-glucose monomers joined via 1-4 and 1-6 glycosidic bonds to form highly branched chains
- Insoluble, large and compact to store lots of glucose in small space
- More highly branched than starch



Cellulose

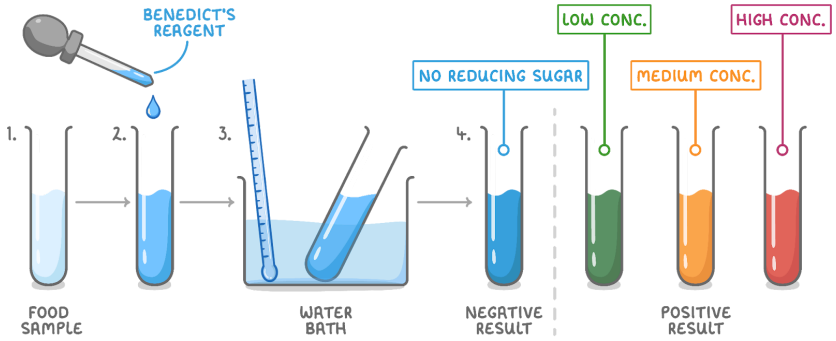
- Formed from glycosidic bonds of beta glucose monomers that are flipped upside down
    - 1-4 bonds too far apart to react when right side up, hence flipped 180°, bringing hydroxyl groups close enough to react
- Provides structural support for plant cells
- Long, straight, unbranched chains with bonds between individual chains due to inversion
- Despite week hydrogen bonds, huge number of such provides great strength
- Multiple cellulose chains tightly cross-link to form microfibril bundles using hydrogen bonds, which then join together to form macrofibrils, forming cell wall





Test for Sugar

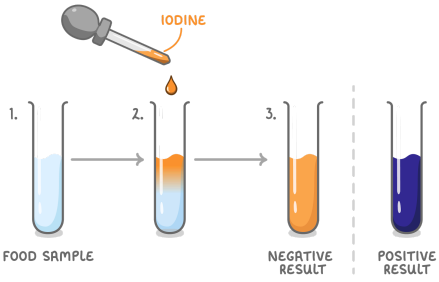
- Reducing sugar = All monosaccharides and some disaccharides, such as maltose and lactose
- Non-reducing sugar = Some disaccharides such as sucrose and polysaccharides
- Equal volume of sample and Benedict's reagent added to test tube, which is then heated in water bath of 80° C for 5 minutes
- Blue to red in the presence of reducing sugar (diff colour for diff conc.)
    - Blue = no
    - Green = low
    - Orange = medium
    - Red = high



- For non-reducing sugar, equal amounts of sample and dilute HCl in a test tube are kept in a water bath for the acid to hydrolyse disaccharides to monosaccharides. The solution is then neutralised using sodium hydrogencarbonate and test for sugar is carried out.

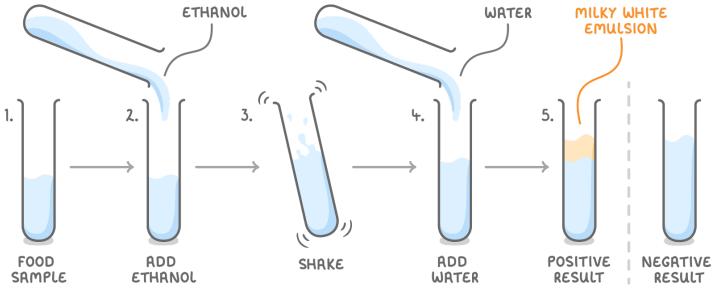
Test for Starch

- Iodine turns blue-black from orange in the presence of starch when a couple of drops is added to the sample



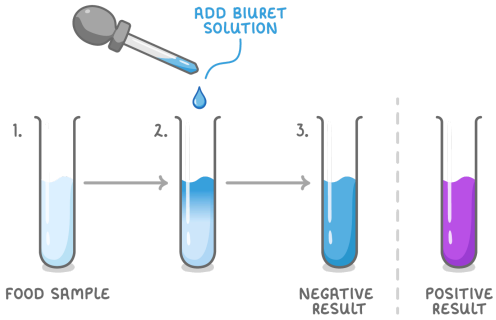
Test for Lipids

- Emulsion test carried out
- 2 cm^3 of ethanol is added to food sample in a test tube and is shaken. 2 cm^3 of distilled water is then added
- Milky white emulsion appears in the presence of lipids

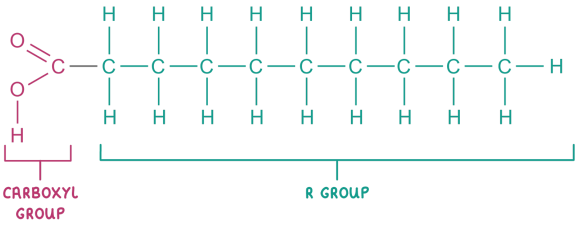


Test for Proteins

- Equal amounts of sample and Biuret solution (sodium hydroxide and copper sulphate) added to test tube
- Blue to purple in the presence of peptide bonds (protein)

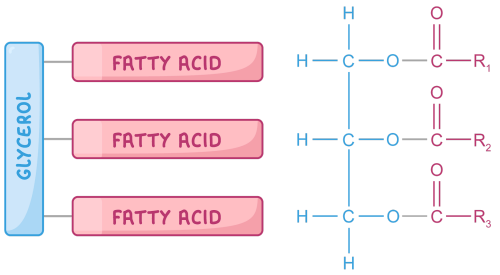


Lipids



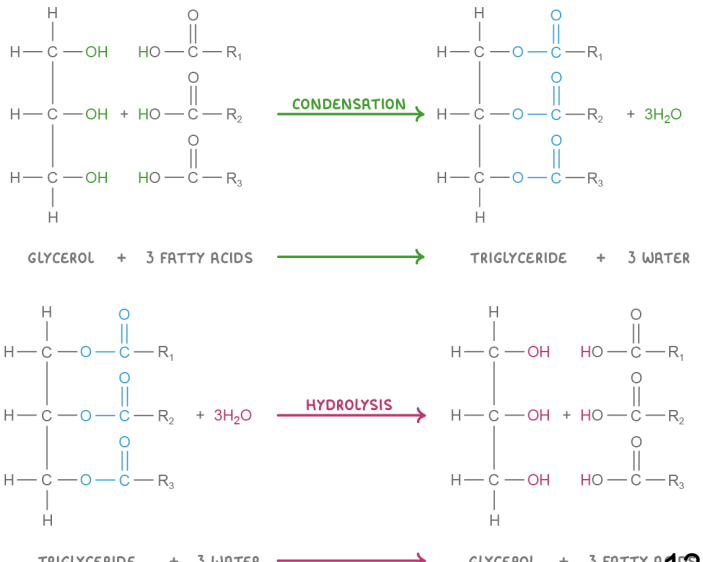
- Lower proportion of oxygen than hydrocarbons
  - Fatty acids + alcohol (usually glycerol)
  - Carboxyl group (-COOH) attached to hydrocarbon chain
- Not made up of chains of monomers, hence not considered a polymer
- Oxidises to provide energy to the cells
- Phospholipids are used in cell membrane
- Insoluble (waterproofing) and have insulation properties (retains heat and acts electrical insulators)
- Delicate organs are surrounded by a layer of fat for protection
- Saturated
  - All carbons are bonded to maximum number of hydrogen atoms with no C=C double bond
  - Usually solid at room temperature with higher melting point
- Unsaturated
  - Carbons are not bonded to maximum number of hydrogen atoms with at least one C=C double bond, causing chain to kink
  - Usually liquid (oil) at room temperature with lower melting point
  - Monounsaturated = One double bond
  - Polyunsaturated = Two or more double bonds

Triglycerides



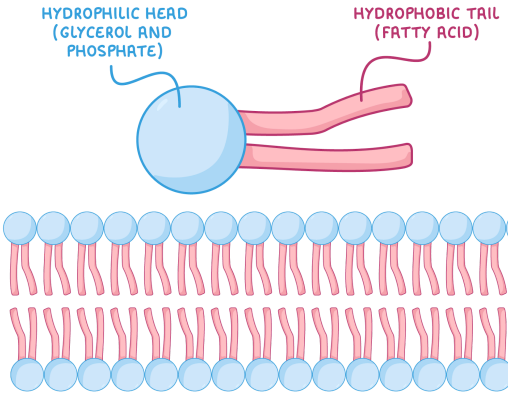
- Energy storage in animals, plants and some bacteria
- Glycerol backbone attached to 3 fatty acid tails containing varying length of hydrocarbon chains that may be saturated or unsaturated
- Lots of energy can be stored in a small volume
- Does not affect the water potential of the cell as large and non-polar (insoluble)
- Releases water when oxidised due to higher hydrogen-to-carbon ratio

Condensation and Hydrolysis of Lipids



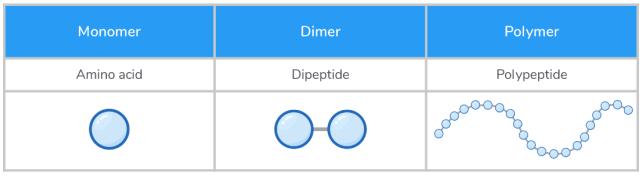
- Condensation
  - Hydroxyl group + 3 fatty acids = 3 ester bonds, releasing 3 water molecules
  - Hydrolysis = Breakdown of disaccharide
- Hydrolysis
  - Addition of 3 water molecules to break the ester bond, resulting in glycerol and fatty acids

Phospholipids

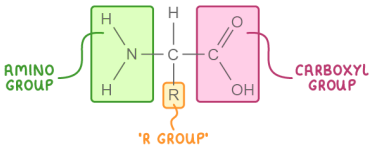


- Structural component of cell membrane
- 2 fatty acids + 1 glycerol + 1 phosphate group
  - 1 fatty acid from triglyceride replaced by phosphate group
- Polar due to hydrophilic (glycerol + phosphate) head and hydrophobic (fatty acid) tail
- Phospholipid bilayer = Hydrophilic heads out, creating hydrophobic centre preventing passing through of water-soluble substances

Proteins

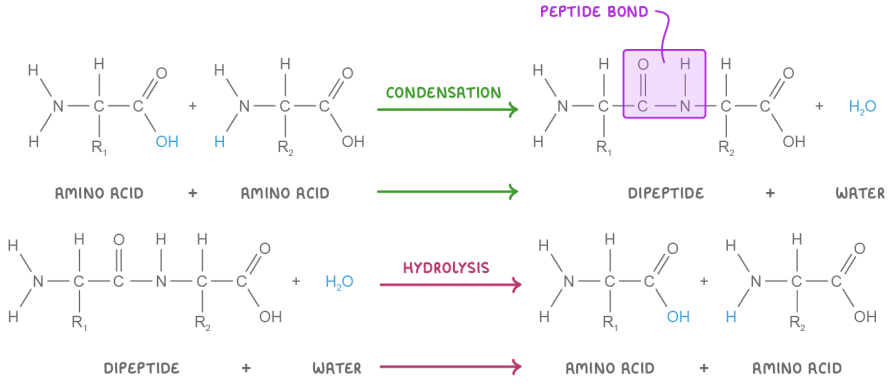


- Amino acid monomers joined together via peptide bonds to form dimers (dipeptides) and polymers (polypeptides)
- Enzymes are proteins used to break down and synthesise molecules
- Antibodies are proteins involved in immune response
- Transport proteins used for transportation of molecules and ions across membranes
- Keratin and collagen are structural component proteins that create strong fibres
- Some proteins are hormones, acting as chemical messengers
- Muscles are made up of proteins
- 20 different kinds of amino acids commonly found in living organisms
  - Central carbon, an amino group ($-NH_2$), a carboxyl group (-COOH), a hydrogen group (-H), an R group (variable)
  - R group determines the properties (cysteine could form disulphide bonds due to sulphur R group)



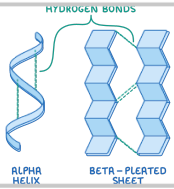
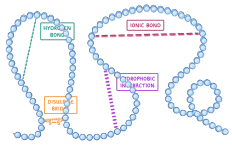
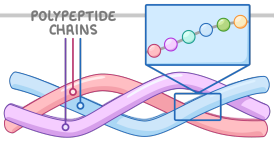
Condensation and Hydrolysis of Protein

- Condensation
  - Hydroxyl (OH) in the carboxyl group of one amino acid + hydrogen (H) in the amino group of another amino acid to form peptide bond between carbon of one amino acid and nitrogen of another, releasing water
- Hydrolysis
  - Addition of a water molecule breaks the peptide bond, resulting in 2 amino acids



Primary, Secondary, Tertiary and Quaternary Protein Structure

- Unique 3d structures to carry out specific functions

	Primary	Secondary	Tertiary	Quaternary
Description	Sequence of amino acids	Alpha helix or beta pleated sheet	Unique 3D shape	Multiple polypeptides or prosthetic groups
Bonds	Peptide	Hydrogen	Hydrogen Ionic Disulphide Hydophobic/Hydrophilic	Hydrogen Ionic Disulphide Hydophobic/Hydrophilic
Diagram				

Types of Proteins

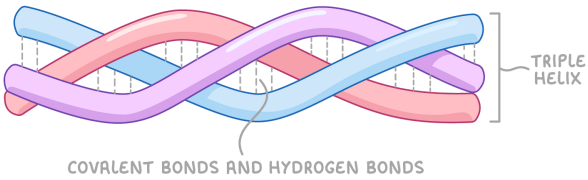


- Globular proteins
  - Compact, spherical, soluble
  - Enzymes, hormones and antibodies
- Fibrous proteins
  - Long, insoluble-in-water strands
  - Keratin, collagen and elastin (in connective tissues)



Collagen

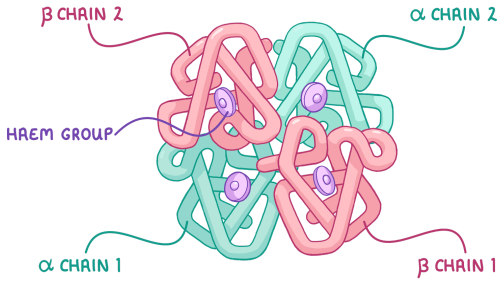
- Skin, tendons, cartilage, bones, teeth, walls of blood vessels; structural component
- 3 polypeptide chains twisted into helix shape wounded into triple helix structure (providing strength) held together by hydrogen and covalent bonds
- Almost every third amino acid is glycine (smallest amino acid), allowing strands to be be held closely together to form a tight coil



- Parallel collagen molecules form covalent "cross-link" bonds, forming fibrils which lay alongside each other to form strong bundles of fibres
- Ends of collagen molecules are staggered to prevent weak spots

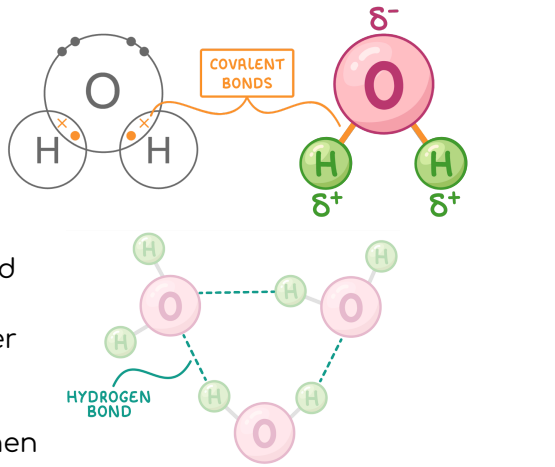
Haemoglobin

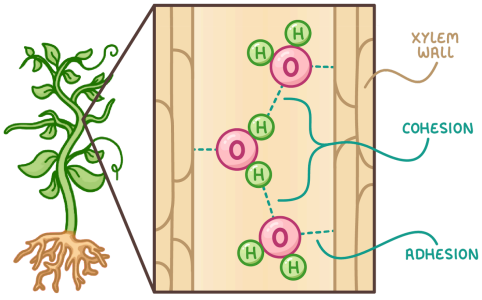
- Carries oxygen around the body in red blood cells
- Quaternary, compact, globular structure, made up of 4 polypeptide chains
    - 2 alpha (α) chains made from alpha-goblin and 2 beta (β) chains made from beta-goblin
- Each polypeptide chain contains a prosthetic haem group containing an iron ion that can reversibly bind with oxygen molecule (O_2)
    - 4 haem groups can carry 4 oxygen molecules
- Hydrophilic R groups make haemoglobin soluble and compact structure allows many haemoglobin to fit inside the RBCs



Water

- H_2O = 1 oxygen + 2 hydrogen; covalently bonded
- Dipolar molecule as shared electrons are pulled towards oxygen; oxygen = slightly negative (δ-) change and hydrogen = slightly positive (δ+) charge
- Hydrogen bonds formed due to dipolarity
- Solvent, used for temperature control, cooling mechanism and transport, acts as a metabolite and used and is a habitat for several species
- Ionic compounds are split apart as polarity of water causes causes attraction to respective ions
    - Biological reactions (in cytoplasm) and transportations (in blood plasma) occurs when dissolved
- The high specific heat capacity of water requires a lot of energy to raise the temperature of 1 gram of water by 1° C
    - Resistant to rapid change in temperature to remain at a fairly stable temperature (internal and external environments)
    - Evaporation of water by sweating cools body without losing much water
    - Floating ice insulates water preventing further freezing in water habitats
- Involved in hydrolysis, condensation and photosynthesis
- Cohesion = Sticking together via hydrogen bonds; surface tension
- Adhesion = Sticking to other materials

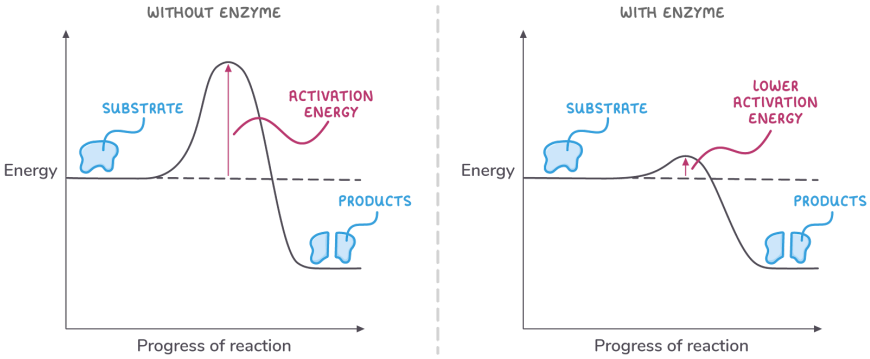


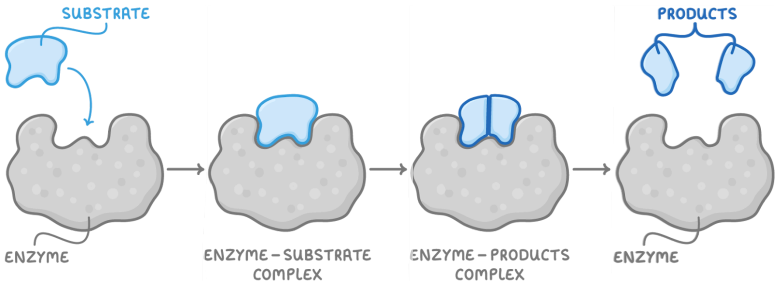


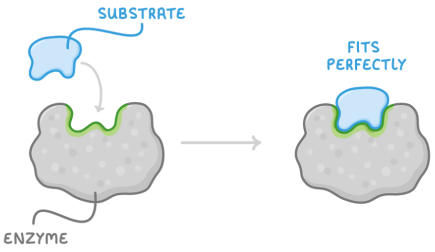
Enzymes

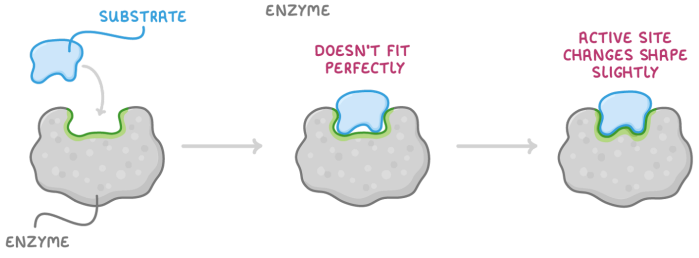
Biological Catalysts

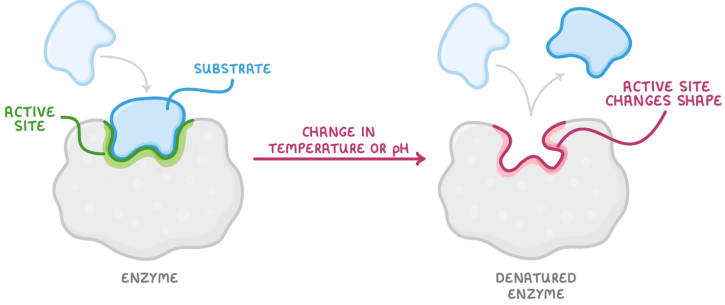
- Globular proteins complex and unique tertiary structures
- Increases the rate of reaction by providing alternate pathway with lower activation energy (mostly heat) without being used up in the reaction itself
- Intracellular = Act within cells that produce them
- Extracellular = Secreted and act outside of the cell that produce them
- Unique tertiary structures determine the shape of the active site in which substrate temporarily bonds (R groups within the active site and the substrate), breaking the substrate into products
- Lock and key model = Substrate fits into active site
- Induced fit model = Active site changes shape slightly to accommodate the substrate
    - Strain on substrate's bonds lowers activation energy
- Change in pH/temperature = Denaturing of enzyme
    - Change of active site's shape due to change in tertiary structure





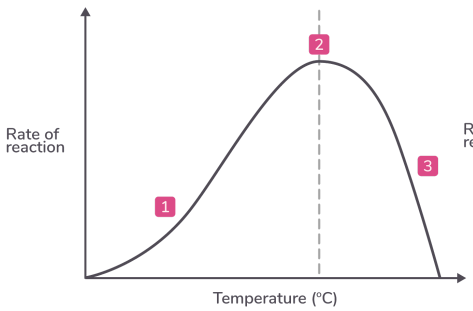


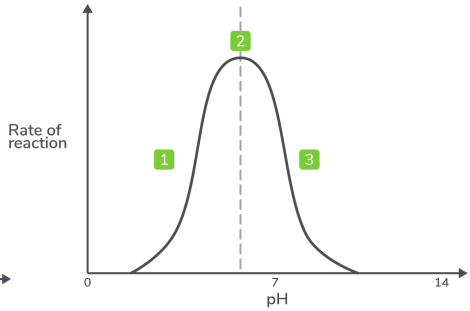




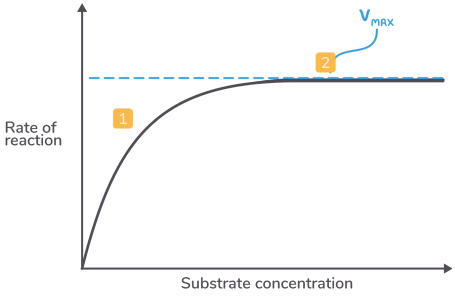
Effects on Enzymes

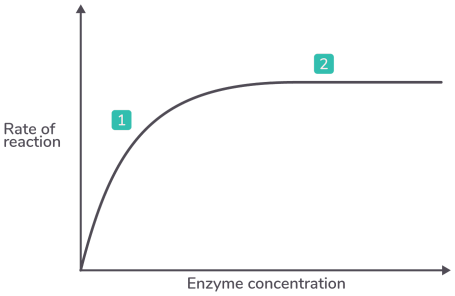
- As temperature increases, the rate of reaction increases as molecules have a higher collision rate due to more kinetic energy, but as temperature increases past the optimum, enzyme denatures and the rate of reaction decreases until the reaction stops





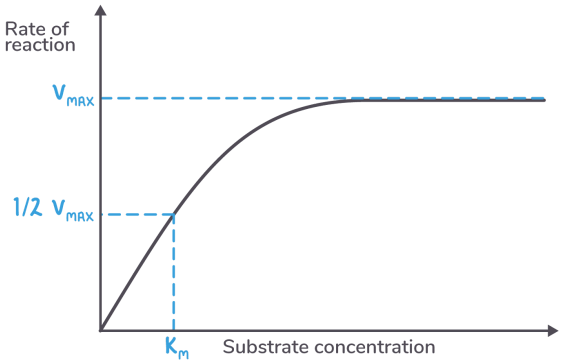
- In acidic conditions, H^+ ions break ionic/hydrogen bonds and denature enzymes. Enzymes work fastest at optimum pH. In alkaline conditions, OH^- ions break ionic bonds or hydrogen bonds and denature enzymes.
- High-concentration of substrate = A saturation point is reached when all active sites are occupied by a substrate; enzyme concentration = Limiting factor with max rate of reaction known as V_{max}
- High-concentration enzyme = When all available substrate molecules are being acted upon, substrate concentration becomes the limiting factor



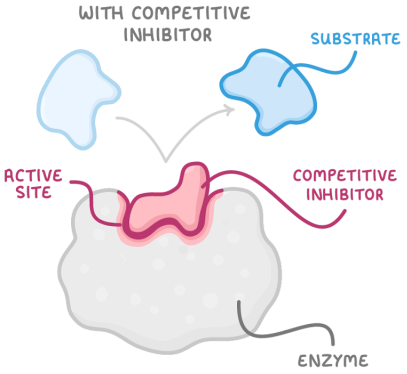


Enzymes Affinity

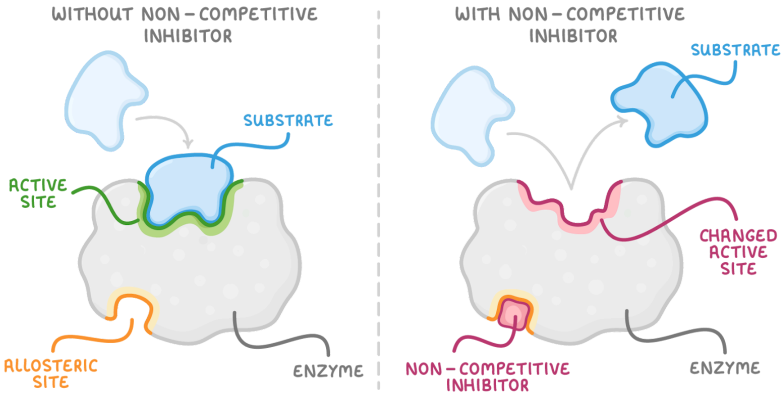
- High affinity = Stronger attraction to its substrates
- Low affinity = Weaker attraction to its substrates
- ½ of V_{max} = K_m to measure affinity
    - Higher affinity = Lower K_m as lower substrate concentration is required to reach ½V_{max}



Enzyme Inhibitors



- Molecules that bind to enzyme to reduce their activity
- Reversible inhibitors = Weak hydrogen/ionic bonds with enzymes
- Irreversible inhibitors = Strong covalent bonds with enzymes
- Competitive inhibitors = Bind to the active site
    - Similar shape to the substrate
    - Most are reversible
    - Can be overcome by increasing the substrate concentration
- Non-competitive inhibitors = Bind away from the active site
    - Changes the the tertiary structure of the enzyme, resulting in active site being no longer complementary to the substrate
    - Cannot be overcome by increasing substrate concentration, as it does not complete directly with the substrates



Enzyme Immobilisation

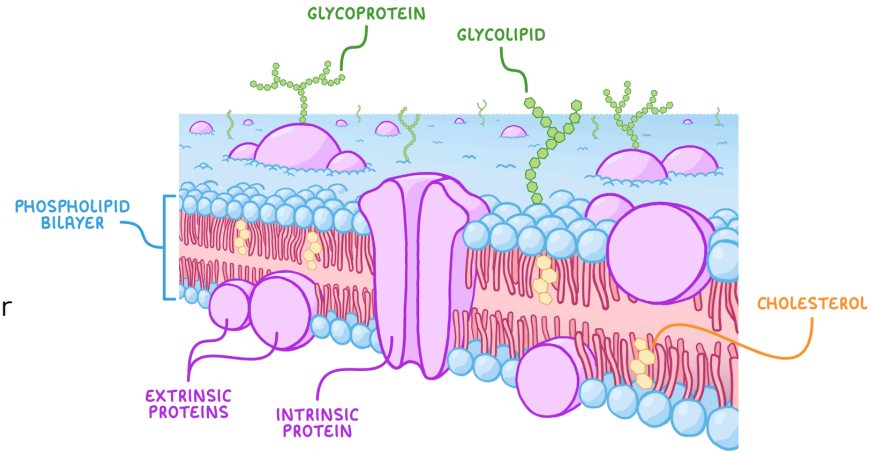
- To recycle and reuse enzymes as it's crucial for various industries such as medicine, food technology, and industrial processing
- Attaching or enclosing enzyme onto a solid support or matrix
    - Cost-effective, as it reduces the need for frequent new purchases
    - Avoids contamination of products producing pure, enzyme-free products
    - More tolerant to temperature and pH, increasing stability

Immobilising Lactase

- Imobilising lactase to break down lactose into glucose and galactose for lactose-free milk for lactose-intolerant individuals
    - Milk is allowed to flow through a column of lactase-containing alginate beads

Cell Membranes & Transport

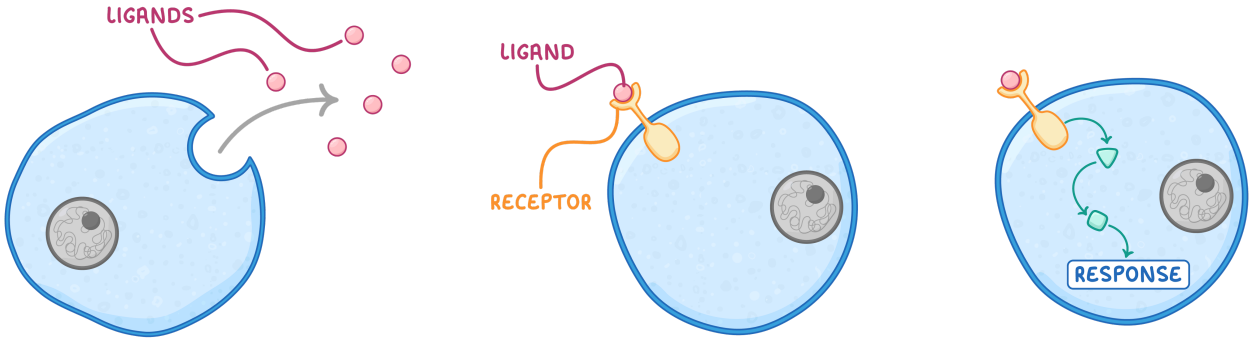
Cell Membrane



- Acts as a barrier between the cell and its environment, controlling movement of substances in and out of the cell.
- Surround organelles (e.g. mitochondria) to act as a barrier between the organelle and the cytoplasm, dividing the cell into different compartments (compartmentalisation)
- Fluid-Mosaic model = Proposed to describe the structure of cell membranes in 1972
    - Fluid = Constantly moving phospholipid bilayer
    - Mosaic = Proteins of different sizes and shapes embedded in the phospholipid bilayer
- *Phospholipid bilayer* - hydrophilic heads and hydrophobic tails
- *Cholesterol* - adds stability
    - Has hydrophobic and hydrophilic regions
    - Binds with phospholipid fatty acid tails, causing them to pack more closely together
- *Protein* - intrinsic and extrinsic proteins
    - Intrinsic (or integral) proteins = embedded through both sides of the phospholipid bilayer, which acts as channel and carrier proteins to transport large molecules and ions across the membrane
    - Extrinsic (or peripheral) proteins = present on only one side of the phospholipid bilayer, which provide support to the membrane or may be involved in cell signalling.
- *Glycoprotein* - protein attached to a carbohydrate
    - Attachment proteins bind cells together and enable recognition and communication between them.
- *Glycolipids* - lipids attached to a carbohydrate
    - Glycolipids bind cells together and enable recognition and communication between them

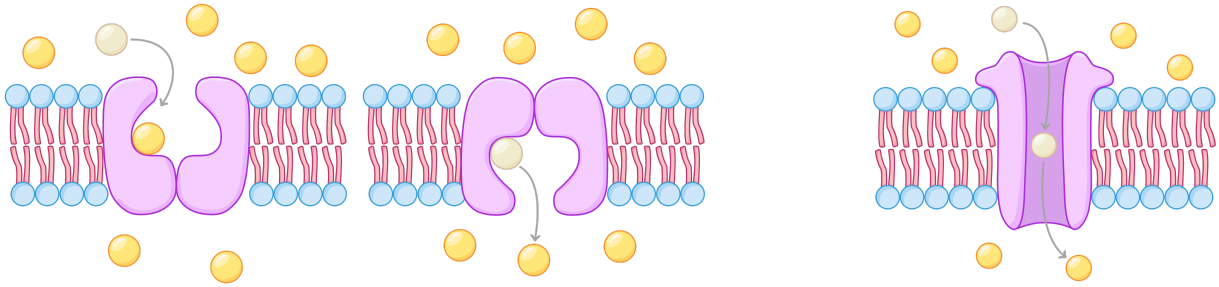
Cell Signaling

- Process by which cells communicate with one another
- Stimulus causes cells to secrete ligand, which travels to target cell and binds with the cell surface receptor with specific complementary shape, which changes shape post-binding, activating the other molecules (usually enzymes) inside the cell to transmit the message and bring about a response



Diffusion

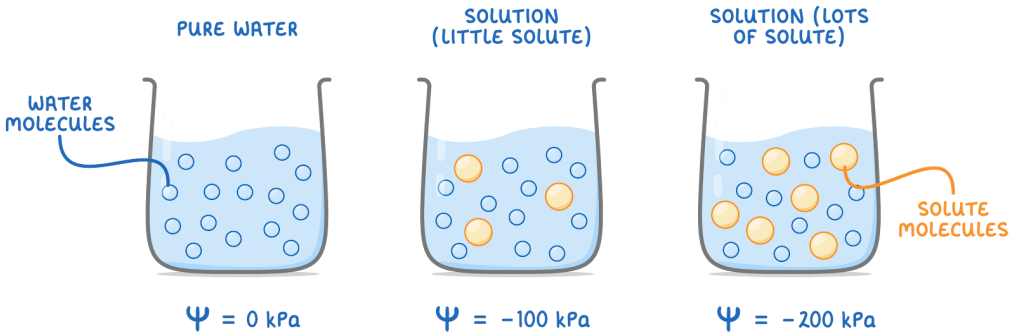
- Net movement of particles from an area of high concentration to an area of low concentration, down the concentration gradient, until equilibrium is reached (particles still moving but are evenly distributed)
- Passive, as no energy is required
- Simple diffusion = Small and non-polar molecules can directly diffuse across cell membrane
- Facilitated diffusion = Large and polar molecules need facilitation of carrier or channel proteins for diffusion
    - Carrier protein = Large molecules attaches to a carrier protein, which causes it to change shape, releasing molecule on the opposite side of the membrane
    - Channel protein = Ions travel through pores formed by channel protein



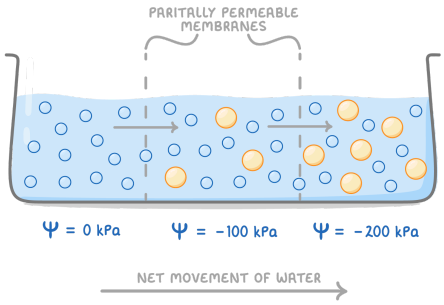
- The rate of diffusion is affected by:
    - Temperature = more kinetic energy in higher temperature results in faster diffusion
    - Concentration gradient = steeper concentration gradient results in faster rate of diffusion
    - Thickness of membrane, surface area and no. of carrier or channel proteins

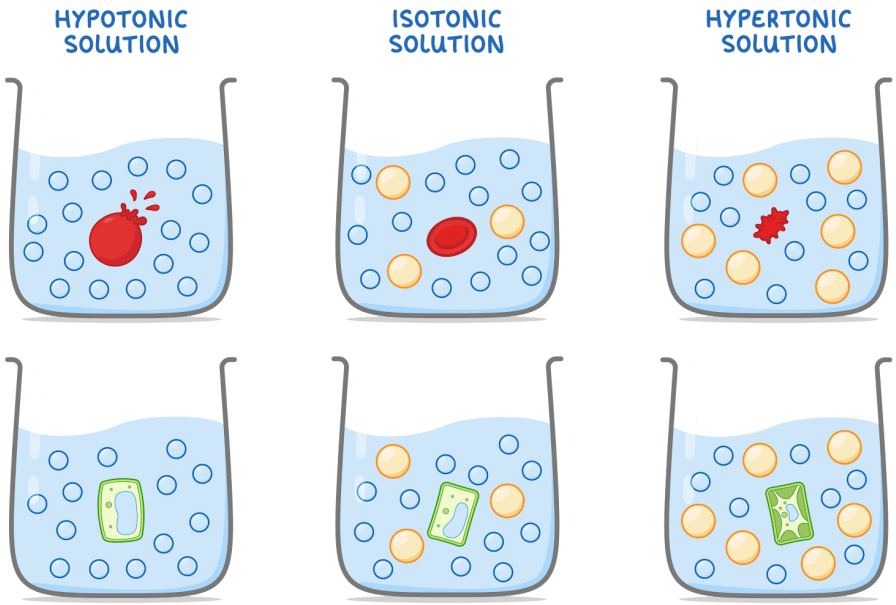
Osmosis

- Water potential (Ψ) = Pressure exerted by water molecules on the membrane/container surrounding a solution; measured in kiloPascals (kPa)
    - High water potential = Low-concentration solution with high water concentration (solvent > solute)
    - Low water potential = High-concentration solution with a low water concentration (solute > solvent)



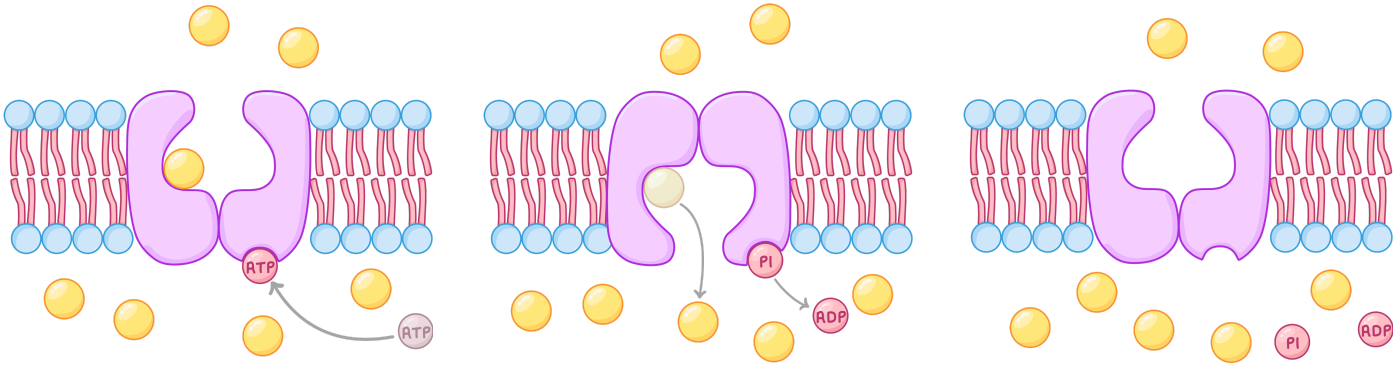
- Osmosis = diffusion of water molecules across a partially permeable membrane from an area of high water potential to an area of low water potential
- Hypotonic = Higher water potential than cell
    - Animal cel = blast; plant cell = turgid (swell)
- Isotonic = Same water potential as the cell
    - No effect
- Hypertonic = Lower water potential than the cell
    - Animal cell = shrinks; plant cell = plasmolysed and flaccid



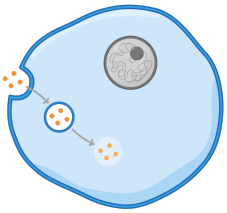


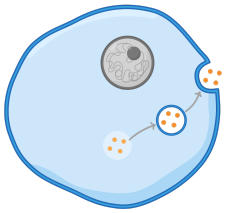
Active Transport

- Movement of particles from an area of low concentration to an area of high concentration with the help of ATP, as energy is required for particles to move up against the concentration gradient (active process
- The carrier protein facilitates active transport by hydrolysis of ATP to ADP and phosphate (Pi) once bound, causing change of shape and release of molecule to the other side along with release of Pi for the carrier protein to return to its original shape



- More kinetic energy due to higher temperatures and increased respiration speeds up active transport, while very high temperatures denatures carrier proteins
- An increased rate of respiration means more ATP available, increasing the rate of active transport
- Bulk transport = Movement of large molecules such as enzymes and hormones
    - Endocytosis = Transport of materials into cells
        - The cell surface membrane engulfs the materials to form a vesicle, which is then moved into the cytoplasm for the material to be processed
            - Phagocytosis = Uptake of solid materials
            - Pinocytosis = Uptake of liquid materials
    - Exocytosis = Transport of materials out of cells
        - Vesicles mostly formed by the Golgi apparatus love towards and fuse with the cell-surface membrane, where materials are released outside the cell

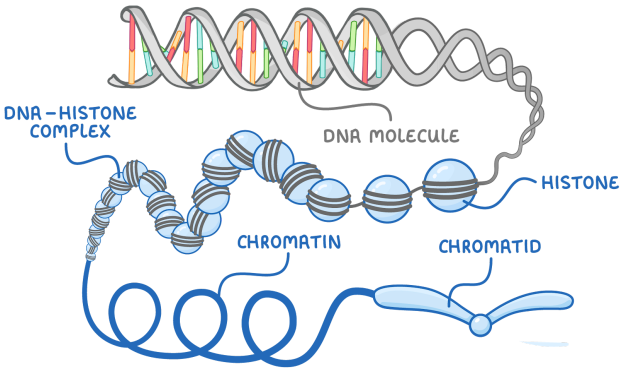


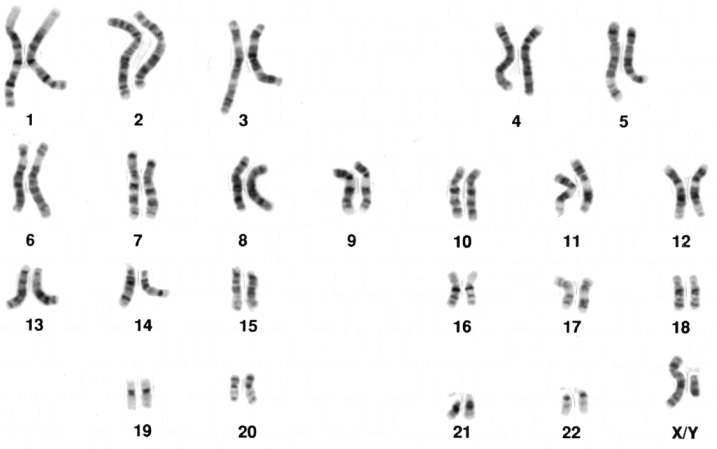


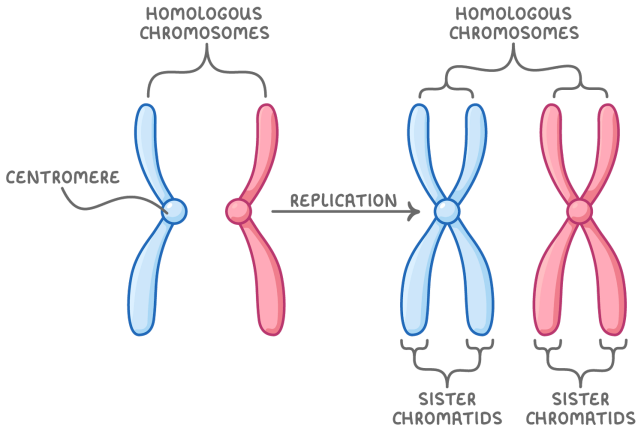
The Mitotic Cell Cycle

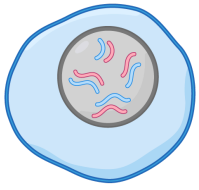
DNA and Chromosomes

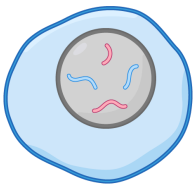
- DNA is stored as chromosomes
- Chromosomes = thread-like structures located inside the nucleus of animal and plant cells
    - Contain DNA tightly coiled around histone protiens
- Humans = 46 chromosomes/23 pairs
    - The first 22 pairs = autosomes (identical in both males and females)
    - 23rd pair = sex chromosomes; Females = XX and males = XY
- Homologous pairs = 2 homologous chromosomes
    - 1 paternal + 1 maternal
- May contain 1 or 2 chromatids depending on the stage in the cell cycle
    - Interphase (DNA replication) results in 2 chromatids
- Chromatids held together by centromeres
    - 2 chromatids are known as sister chromatids, as they are genetically identical
- Diploid = most cells
    - 2 copies of each chromosome from each parent cell
    - 2n; n = 23 for humans
- Haploid = sex cells/gametes
    - 1 copy of each chromosome
    - n; n = 23 for Humans



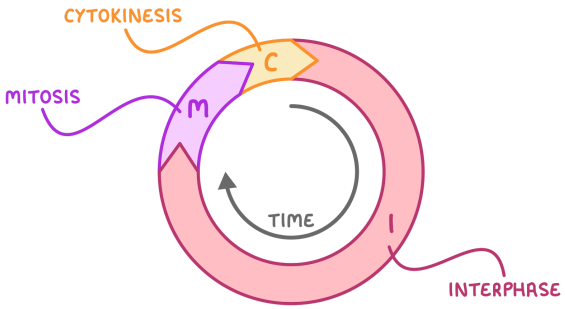





DIPLOID CELL 2n

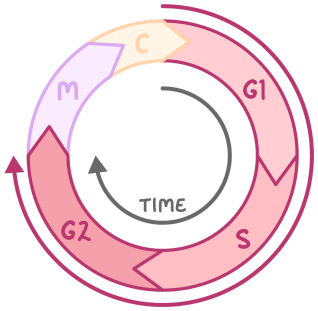

HAPLOID CELL n

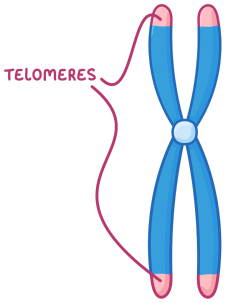
Cell Cycle



- New cells = Growth and repair
- Interphase = Preparation for cell division
- Mitosis = Division of nucleus into 2
- Cytokinesis = Division of whole and and cytoplasm into 2 to produce 2 identical cells

Interphase

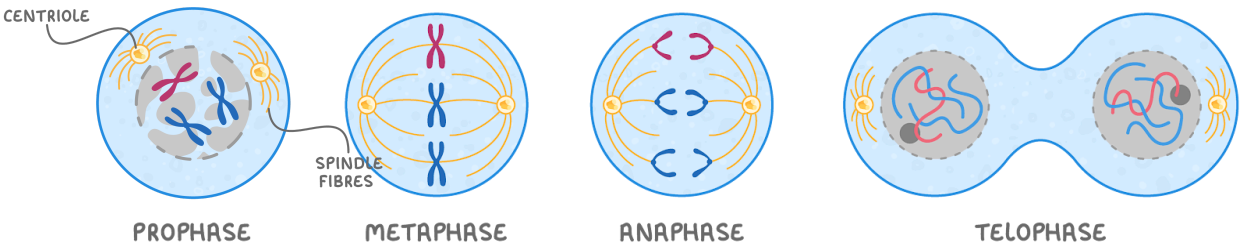




- Replication of DNA and organelles
  - **G_1 phase** = Cell grows and makes new proteins to replicate organelles
  - **S phase** = Replication of DNA
  - **G_2 phase** = Replicated DNA is checked for errors as cell continues to grow
- DNA polymerase cannot transcribe to the very end; hence, extra repeating bases are added to the ends, called telomeres, short sections of non-coding DNA (eg. CAG CAG CAG) to prevent the loss of genes during cell division and preventing shortening of chromosomes

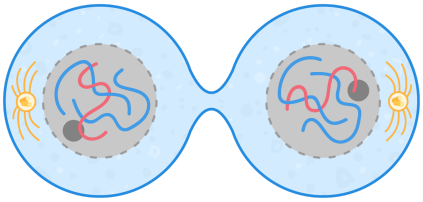
Mitosis

- Parent cell dividing to produce two genetically identical daughter cells containing the same DNA as the original parent cell
  - **Prophase** = Centrioles migrate to opposite poles of the cell, and each starts forming spindle fibres. Nucleolus disappears and nuclear envelope starts breaking down, leaving chromosomes free in cytoplasm
  - **Metaphase** = Chromosomes line up at the equator of the cell, where each chromosome is attached to the spindle by centromere
  - **Anaphase** = Centromeres divide to separate each pair of sister chromatids as the spindle fibres contracts and shorten to pull the chromatids to opposite poles of the cell
  - **Telophase** = chromatids uncoil to become long and thin chromosomes again as they reach opposite poles of the cell, on which a nuclear envelope formed around each set of chromosomes to form two nuclei, and the nucleolus starts to reform.



- Used for growth, replacement of damaged/dead tissues, asexual reproduction, development of body parts, and production of stem cells

Cytokinesis

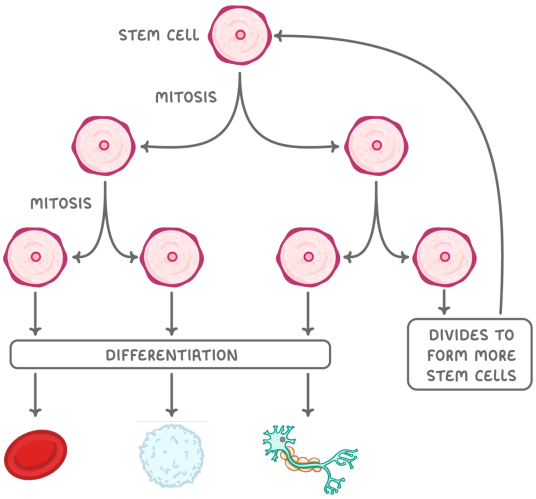


- Post mitosis, cytoplasm divides, producing 2 daughter cells that are genetically identical to one another

Cell Division and Cancer

- Cell cycle and mitosis are controlled by a number of genes
- Mutations in them can lead to uncontrolled cell division and growth, resulting in a group of abnormal cells known as a tumour
- Tumours turn cancerous when they start to invade neighbouring tissues
- Treatment = Disrupt cell division by targeting specific stages of cell cycle to prevent dividing and growth of cancerous cells
    - S phase = Some drugs can prevent DNA from replicating
    - Metaphase = Some drugs interfere with the formation of spindle fibres
- Treatments also disrupt the cell cycle of healthy cells; however, tumour cells divide at a faster rate than healthy cells, so they are more likely to be damaged by these drugs

Stem Cells

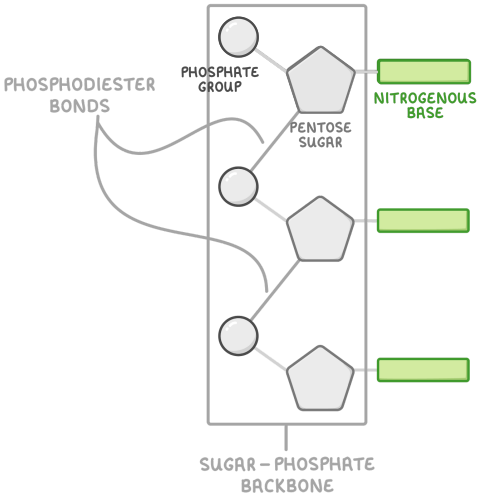


- Stem cells = Unspecialised cells
- Can develop into different types of cells; used for growth, development and tissue repair
    - Can divide by mitosis to produce more undifferentiated cells
- **Totipotent stem cells** = Can differentiate into any cell type to form whole organisms
- **Pluripotent stem cells** = Can differentiate into most cell types but cannot form whole organisms
- **Multipotent stem cells** = Can only differentiate into a few different cell types
- **Unipotent stem cells** = Can only differentiate into one type of cell
- **Embryonic stem cells** = Found in the early stages of embryo development, where they can differentiate into cells to form a foetus. For first few divisions of the embryo = the stem cells are totipotent and turn pluripotent after about 7 days
- **Adult stem cells** = Found in some adult tissues to replace faulty cells (multipotent or unipotent). Bone marrow stem cells replace worn-out erythrocytes (red blood cells) and neutrophils (white blood cells)
- **Plant stem cells** = Found in the meristematic tissue between vascular cambium (phloem + xylem) or meristems at the tips of the shoots and roots (pluripotent). Differentiates into cells of the xylem and phloem
- Transplanted stem cells could help to regenerate nerve cells and reduce symptoms of Parkinson's and Alzheimer's (neurological disorders = loss of nerve cell in the brain)
    - Drugs can be tested, organism dev. and causes of disorders can be studied

Nucleic Acids & Protein Synthesis

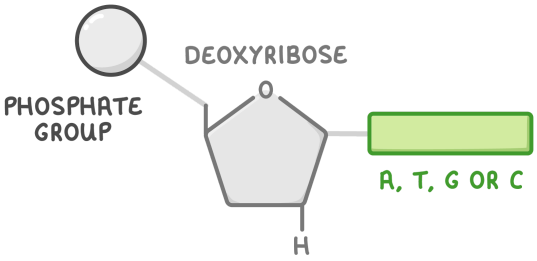
Nucleotide Structure

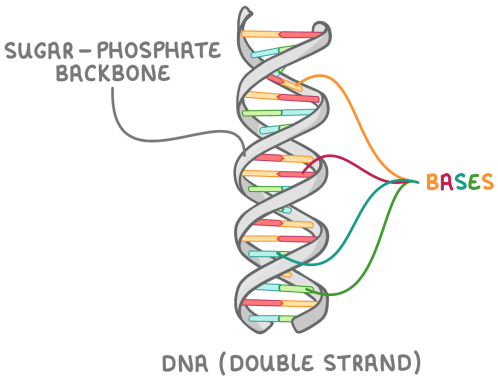
- Building blocks of DNA and RNA
- Nucleotides monomers join together to form dimers (dinucleotides) and polymers (polynucleotides)
    - Pentose sugar = 5 carbon atoms
    - Nitrogenous base = carbon and nitrogen
    - Phosphate group - = phosphate
- Nucleic acid = functional molecule made up of one or more polynucleotide chain
    - Nucleotides joined together via condensation = polynucleic chain
    - Phosphate of one nucleotide + sugar of another = phosphodiester bond; covalent bond
    - Sugar-phosphate backbone



DNA

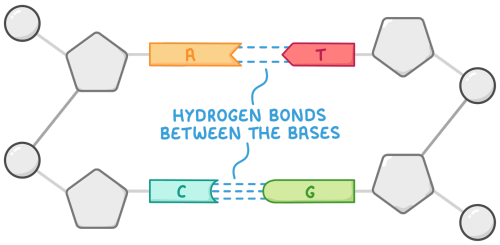
- Deoxyribonucleic acid (DNA) = nucleic acid containing instructions needed to make proteins
- Phosphate group + Deoxyribose (pentose sugar) + A, T, G, or C base (adenine, thymine, guanine, or cytosine)
- James Watson and Francis Crick (1953) = credited with working out the structure of DNA; Rosalind Franklin = DNA made up of two polynucleotide strands wounded around each other to form a double helix
- Sugar-phosphate backbone = Protects coding bases on the inside of the helix
- Double-stranded = allows strands to act as templates in DNA replication
- Complementary base pairing = Allows accurate DNA replication.
- Weak hydrogen bonds = Allows strands to separate in DNA replication.
- Large molecule stores lots of information, while double helix structure make the molecule compact

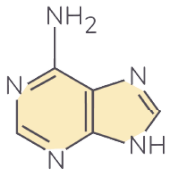
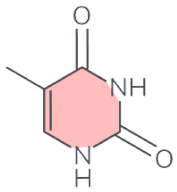
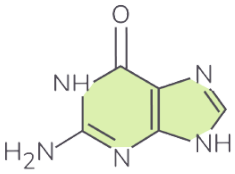
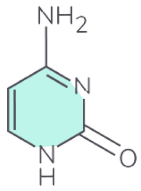




Bases

- Purine = larger with 2 rings; Pyrimidines = smaller with 1 ring
- Purine + Pyrimidine = Complementary base pairs (to maintain distance between 2 sugar-phosphate backbones)
    - Adenine pairs with thymine via 2 hydrogen bonds
    - Cytosine pairs with guanine via 3 hydrogen bonds

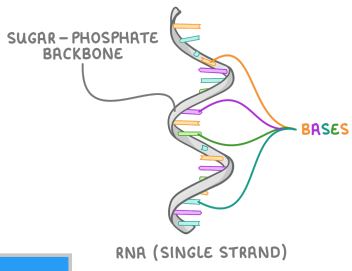


Purines	Pyrimidines
2 rings	1 ring
 Adenine	 Thymine
 Guanine	 Cytosine

- Antiparallel DNA strands = run in opposite directions
    - One strand 5' to 3' and the other 3' to 5' (5' end = carbon 5 to phosphate; 3' end = carbon 3 of the deoxyribose exposed)

RNA

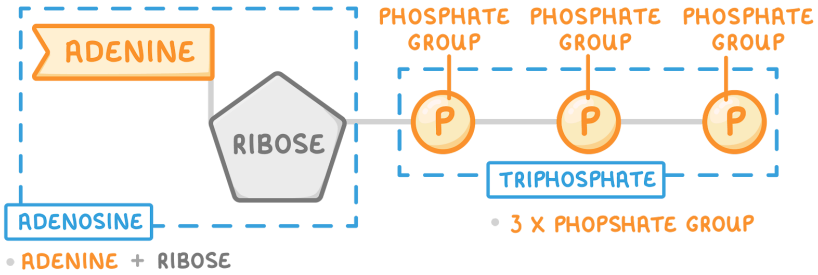
- Ribonucleic acid = Uses information from DNA to synthesise proteins; single-strand made up of one polynucleotide strand (much shorter than DNA)
- Phosphate group + Ribose (pentose sugar) + A, U, G, or C base (adenine, uracil, guanine, or cytosine)



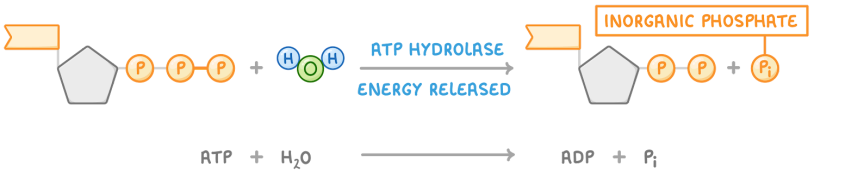
	DNA	RNA
Pentose sugar	Deoxyribose	Ribose
Bases	A, T, G, C	A, U, G, C
Size	Long	Relatively short
Number of strands	2	1
Diagram		

ATP

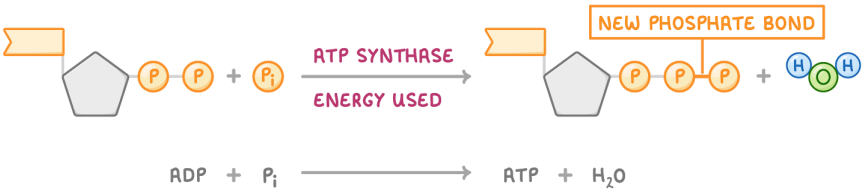
- Adenosine triphosphate
- Involved in energy transfer within cell; energy currency
- Adenine (nitrogenous base) + Ribose (5-carbon sugar) + Phosphates (3 phosphate groups)



- Used for movement (muscle contraction, for sperm cells to swim, e.g.), active transport, synthesis of large molecules (DNA and proteins) and secretion of substances from cells (hormones from glands)
- Phosphorylating = Activating molecules by addition of phosphate post-hydrolysis to make them more reactive
- Hydrolysis to release energy = ATP breaking down into ADP and Pi when reacted with water
  - Catalysed by ATP hydrolase



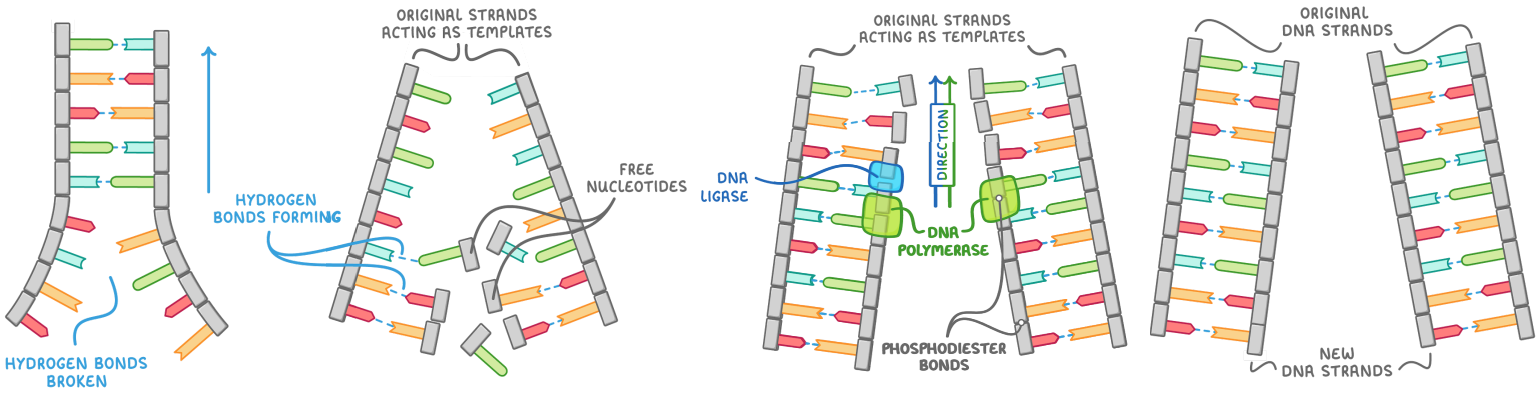
- Condensation to reform ATP = ADP and Pi join, releasing water
  - Catalysed by ATP synthase



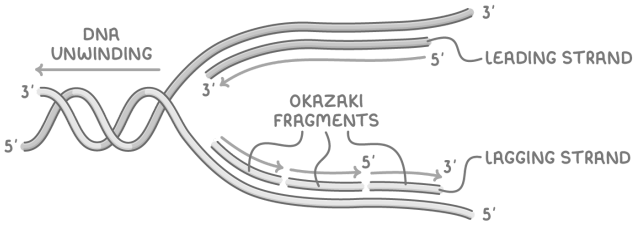
- Energy release is quick as hydrolysis is a single step and needs to be rapidly re-synthesised for ready availability
- Phosphate group bonds = unstable; low activation energy and easily broken
- ATP = Soluble

DNA Replication

- Copied via semi-conservative replication
- One original strand and one newly synthesised strand
- Hydrogen bonds broken → Activated nucleotides attach complementary pairs → DNA polymerase joins new nucleotides via phosphodiester bonds (5' to 3') forming sugar-phosphate backbone; DNA ligase used to join Okazaki fragments



Leading and Lagging Strands



- DNA polymerase can only build new DNA strands in the 5' to 3' direction, which affects the process
- Leading strand = synthesised in the same direction as unwinding of double helix with continuity
- Lagging strand = synthesised in the opposite direction of the unwinding; hence, short section of DNA will be synthesised, then polymerase goes backwards to synthesise next section
    - Series of copied DNA = Okazaki fragments → Joined by DNA ligase

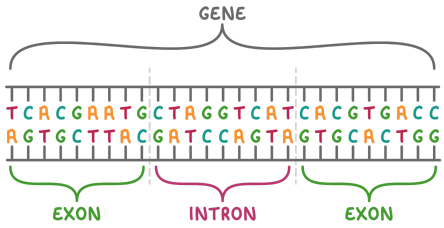
The Meselson-Stahl Experiment

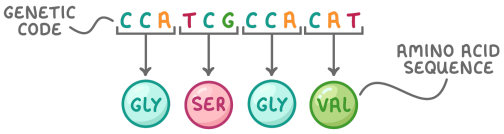
- Proposed theories to explain DNA replication
    - Conservative replication
        - The original DNA molecule stays intact while a completely new copy is built, and after a single replication, one molecule has two original strands, and the other has two new strands
    - Semi-conservative replication
        - The original DNA splits, and each strand acts as a template for a new strand, and after a single replication, each molecule has one original strand and one new strand
- Bacteria were first grown N-15 (heavy nitrogen); their DNA became heavy, then they were moved to a medium with N-14 (light nitrogen) for one round of DNA replication (bacteria use nitrogen from their surroundings to build new DNA molecules)
- New DNA strands made during this round used the lighter nitrogen.
- DNA was extracted and centrifuged to see how heavy or light it was.
- Steps 2–4 were repeated for a second round of replication
- DNA bands were analysed: heavy bands sink to the bottom, intermediate bands (one heavy + one light strand) stay in the middle, and light bands (two light strands) stay higher in the tube
- Each DNA molecule had 1 original heavy strand (N-15) and 1 new light strand (N-14) forming the intermediate bands (middle of the tube), supporting semi-conservative replication
- After the 2nd replication. each of the 4 strands (2 old + 2 new) acted as templates and new strands were all light
- 50% of final DNA molecules had 1 heavy + 1 light strand (intermediate bands) and 50% had 2 light strands (light bands), confirming semi-conservative model

	Conservative prediction	Semi-conservative prediction	Actual results
Parent generation	All heavy.	All heavy.	All heavy (DNA only had ^{15}N). ^{15}N
First generation	½ heavy, ½ light.	All intermediate.	All intermediate (each DNA molecule had ^{14}N and ^{15}N). $^{14}N + {}^{15}N$
Second generation	¼ heavy, ¾ light.	½ intermediate, ½ light.	½ intermediate, ½ light (each DNA molecule had ^{14}N and ^{15}N, or had ^{14}N only). ^{14}N $^{14}N + {}^{15}N$

Genes

- Short section of DNA that codes for a polypeptide (protein)
    - Exons = Sections of DNA that do code for amino acids
    - Introns = Sections of DNA that do not code for amino acids (interfering)
- Each gene is located at a specific position of chromosome known as a locus
- Complete set of genes = Genome
- Full range of protein that a cell is capable of producing = Proteome
- Genetic code = Sequence of base that codes for amino acids; sequence of 3 DNA bases (triplet)
    - Universal = Each DNA triplet codes for the same amino acid in all organisms (with a few minor exceptions)
    - Non-overlapping = Each base in the DNA sequence is only read once (e.g. CGTATC is read as CGT and ATC)
    - Degenerate = Most amino acids are coded for by more than one triplet (e.g. ACA and ACG both code for cysteine).
- Codon table; shows mRNA, hence uracil (U) instead of thymine (T)

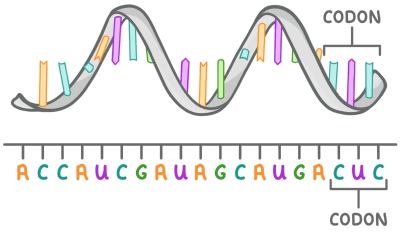




First base	Second base				Third base
	U	C	A	G	
U	Phe	Ser	Tyr	Cys	U
					C
	Leu		Stop	Stop	A
				Trp	G
C	Leu	Pro	His	Arg	U
					C
			Gln		A
					G
A	Ile	Thr	Asn	Ser	U
					C
	Met		Lys	Arg	A
					G
G	Val	Ala	Asp	Gly	U
					C
			Glu		A
					G

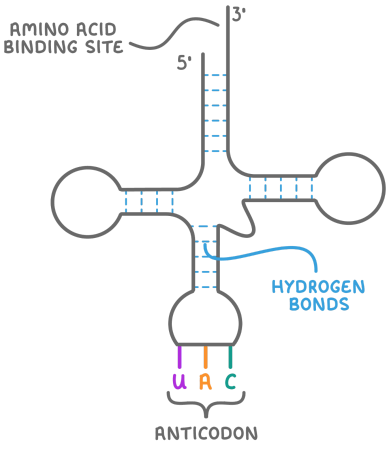
mRNA

- Messenger RNA (mRNA) = synthesised during transcription
- Carry genetic information from DNA to ribosome (site of protein synthesis)
- Single-stranded, linear molecule that contains sequence complimentary to DNA sequence and codons; small enough to leave nucleus

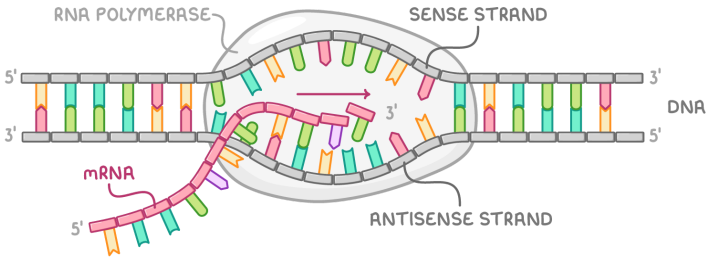


tRNA

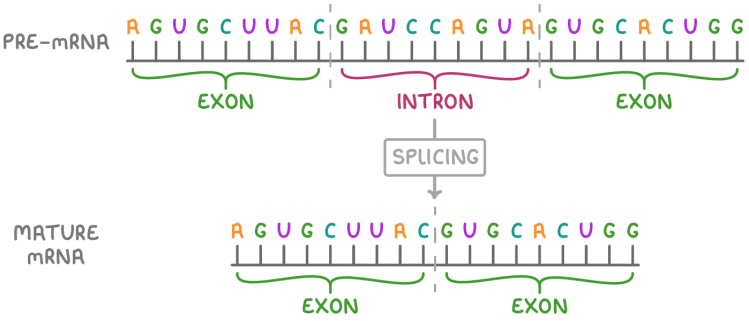
- Transfer RNA (tRNA) = used in the translation process
- Transports amino acids to ribosomes to build a polypeptide chain
- Single-stranded molecule folded into a cloverleaf shape (hydrogen bonds between complementary base pairs to holds the shape)
- Contains a specific sequence of three bases at one end = Anticodon; Amino acid binding site at the opposite end



Transcription

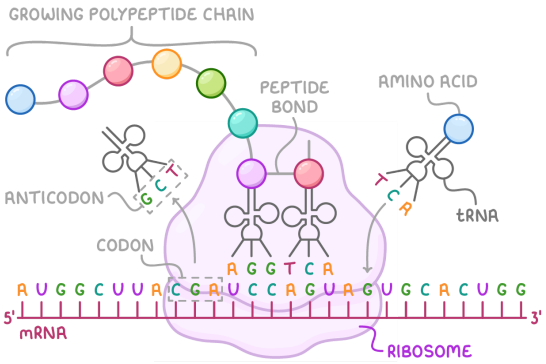


- Initial step in synthesis of proteins; occurs within nucleus then exits into cytoplasm for translation
- Creates mRNA copy of a gene from DNA template
- RNA polymerase enzyme binds to DNA → hydrogen bonds between the DNA bases break → separation of double helix → antisense strand acts as the template for mRNA synthesis → free RNA nucleotides align with the DNA template through complementary base pairing → RNA polymerase catalyses the formation of phosphodiester bonds between adjacent RNA nucleotides → complementary mRNA strand is formed (same base sequence as the DNA sense strand) → process ends when RNA polymerase reaches a stop codon (detaches from DNA and terminates transcription) → mRNA is released, detaches from DNA, and DNA rewinds into its double helix structure
- No splicing required for mRNA production in prokaryotes; however, pre-mRNA is spliced after transcription to remove introns before transportation to cytoplasm in eukaryotes
    - In eukaryotic cells, both introns (non-coding regions) and exons (coding regions) of DNA are transcribed into the initial mRNA transcript (pre-mRNA), which undergoes RNA splicing to remove introns and join together exons, producing mature mRNA consisting of only exon sequences



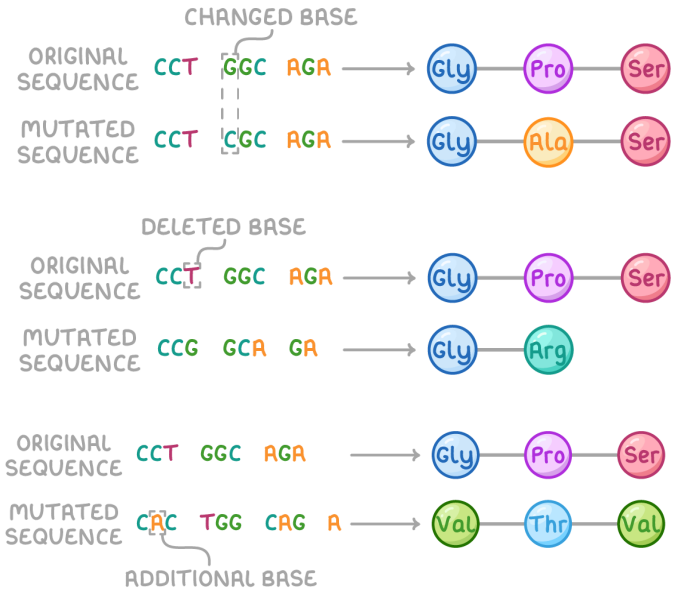
Translation

- Decoding information in mRNA to synthesise polypeptide chain with the help of tRNA; Occurs in cytoplasm, specifically on the ribosome (for both eukaryotic and prokaryotic)
- A ribosome attaches to the mRNA strand at a start codon (AUG) → A tRNA molecule carries a specific amino acid and has a complementary anticodon (UAC) to the start codon that binds to the mRNA → Second tRNA molecule with an anticodon complementary to the next mRNA codon, and also carrying a specific amino acid, attaches to mRNA → Amino acids carried by the first two tRNA molecules are linked together via a peptide bond using ATP → First tRNA molecule detaches from mRNA and is free to collect another amino acid for future use → Ribosome moves along mRNA, allowing another tRNA molecule, which carries the next amino acid, to bind to the next codon on mRNA → process is repeated to elongate the polypeptide chain until the ribosome reaches a stop codon on mRNA → Completed polypeptide chain detaches from the ribosome



Gene Mutations

- Change in DNA base sequence, leading to a different polypeptide and potentially a different tertiary structure (changes shape of active site if protein is an enzyme)
- Occurs spontaneously if DNA is misread during replication
    - Substitution = One base is replaced by another
        - Not all results in change of amino acid sequence, as several triplets code for the same amino acid
    - Deletion = One base is removed from the sequence
        - When a frameshift occurs, the entire sequence moves one base to the left following the removal
    - Insertion = One base is added into the sequence
        - When a frameshift occurs, the entire sequence moves one base to the right following the insertion



- Mutagens = Increase the rate of mutation = UV, ionising radiations, chemicals, viruses

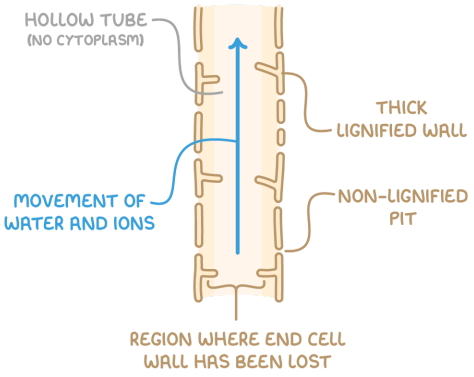
Transport in Plants

Transport System

- Required, as plants are multicellular with low surface area to volume ratio and substances need to be moved long distances, resulting in extremely slow diffusion that does not meet their metabolic needs
- To facilitate transportation, plants have two main transport tissues: xylem and phloem located throughout the plant, connected in a vascular bundle/system

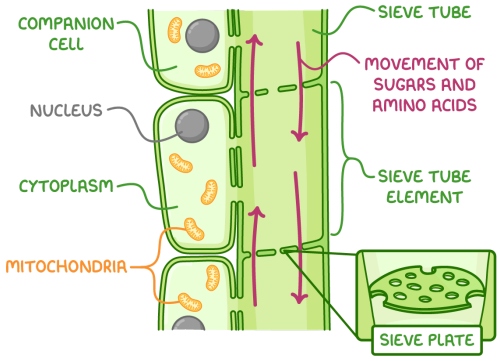
Xylem

- Transports water and mineral ions
- Provides structural support and is mostly made up of xylem vessels
- Elongated hollow tubes without end walls or organelles
- Walls are thickened with lignin for support and have non-lignified pits that allow movement of water and ions into and out of vessels



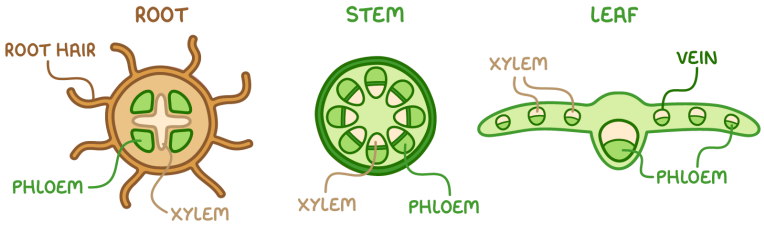
Phloem

- Transports sugars and amino acids (assimilates)
- Mostly made up of sieve tube elements with sieve plates with pores at the ends to allow flow, connected end-to-end to form sieve tubes, and companion cells
    - Companion cells connect to sieve tube elements through plasmodesmata pores and have large nucleus, many mitochondria (to release energy for active transport of substances through the sieve tube elements) and ribosomes (for protein synthesis)
- Lack most organelles and nuclei; however, contains a thing layer of cytoplasm

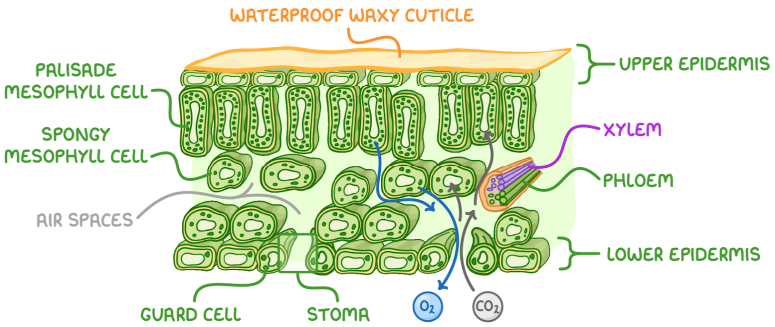


Distribution of Xylem and Phloem Tissues in Herbaceous Dicotyledonous Plants

- Roots = central cylinder surrounded by phloem providing support as the root grows through soil
- Stem = in outer region form scaffolding to resist bending
- Leaf = network of veins (thin leaves)



Structure of a Typical Leaf



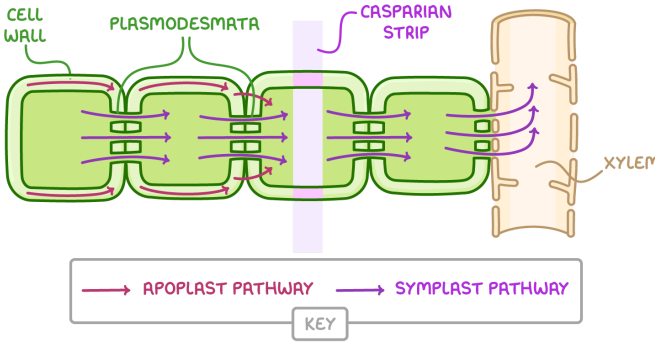
- Upper epidermis with waxy cuticle = Reduces water loss from the leaf surface
- Air spaces = Interconnecting spaces that run throughout the mesophyll layer for gases to diffuse in and out
- Palisade mesophyll cells = Located beneath the upper epidermis to carry out photosynthesis
- Spongy mesophyll cells = Dispersed cells located beneath the palisade mesophyll layer to carry out photosynthesis
- Stomata = Small pores surrounded by guard cells on the underside of leaves that can open when conditions are suitable for photosynthesis for inward diffusion of carbon dioxide and outward diffusion of oxygen, and close to prevent water loss
- Lower epidermis = Bottom layer of cells in a leaf that contains the stomata and guard cells
- Vascular tissue (xylem and phloem) = This transports water and nutrients

Xerophytes

- Plants adapted to live in dry environments with limited water availability
- Thick waxy cuticle = Reduces water loss through evaporation
- Rolling or folding of leaves = Encloses the stomata on the lower surface to reduce air flow and the evaporation of water
- Hairs on leaves = Trap moist air against the leaf surface to reduce the diffusion gradient of water vapour
- Sunken stomata in pits = Reduce air flow and the evaporation of water
- Small, needle-like leaves = Reduce the surface area across which water can be lost
- Water storage organs = Conserve water for when it is in low supply

Movement of Water

- Water enters a plant's root hair cells via osmosis and moves through the cytoplasm or cell walls towards the xylem
- Xylem transports water from the roots up to the leaves
- Some evaporate from leaf cells by transpiration and diffuse out of the plant
- The apoplast pathway:
    - Water moves through spaces in the cell walls and between cells due to the cohesive and adhesive properties of water
- The symplast pathway:
    - Water moves from cell to cell through the cytoplasm and plasmodesmata due to water potential gradients

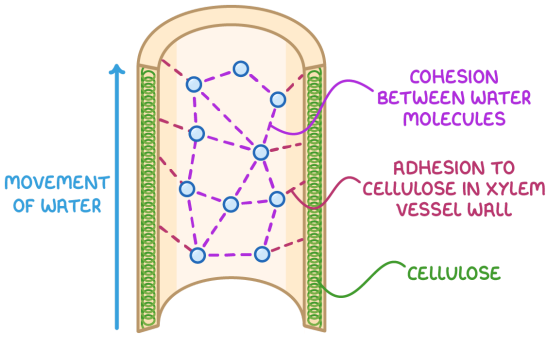


The Casparian strip

- Band of a waterproof substance called suberin that surrounds the endodermis cells causing blockage in apoplast pathway at the root endodermis by the Casparian strip
- Forces water out of apoplast pathway and into the symplast pathway

Cohesion-Tension Theory

- Cohesion = Hydrogen bonding causes water molecules to stick together and move as one continuous column
- Adhesion = Hydrogen bonding between polar water molecules and non-polar cellulose in xylem vessel walls pulls water upwards through the xylem
- Transpiration pull = Evaporation of water at leaves creates the transpiration pull, and this tension is transmitted down the whole water column due to cohesion

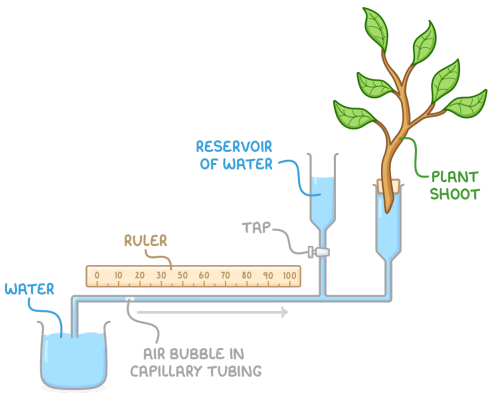


Transpiration and Gas Exchange

- Water evaporates (changes from liquid water into gaseous water vapour) from the moist surfaces of mesophyll cells → Stomata open so they can absorb carbon dioxide for photosynthesis → This provides a pathway for water vapour loss through the open stomata → Water vapour moves down a water potential gradient from the air spaces in the leaf into the atmosphere
- High light intensities = Stomata opens for maximum CO_2 absorption for photosynthesis = Increased the transpiration rate
- High temperatures = Evaporation of water molecules is faster = Increased the transpiration rate
- Low humidity = Increased water vapour gradient between the leaf and atmosphere = Increased the transpiration rate
- High wind speed = increased water vapour gradient between the leaf and atmosphere = Increased the transpiration rate

Potometer

- Used to measure the rate of transpiration
- Cut the shoot underwater at a slant to increase the surface area for water uptake → Assemble the potometer with the shoot submerged in water → Keep the capillary tube end of the potometer submerged throughout the experiment (check that apparatus is airtight) → Dry the leaves, and give the shoot time to acclimatise → Shut the tap, form an air bubble and record its position → Measure the distance the air bubble moves and the time taken → Change one variable at a time and keep everything else constant

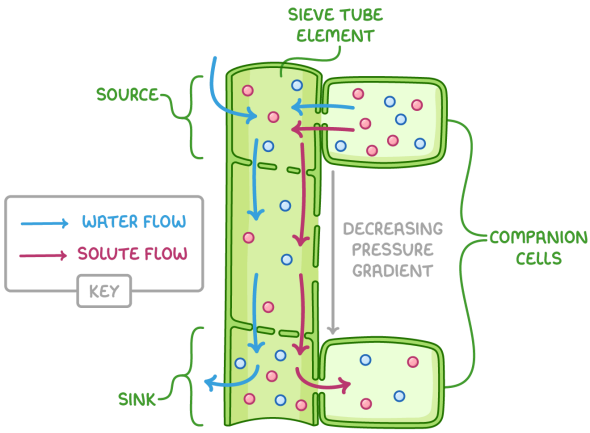


Calculating Rate of Transpiration

- Calculate the cross-sectional area of the capillary tube = πr^2
- Calculate volume of uptake = πr^2 x distance the air bubble travelled
- Rate of transpiration = Volume of Water Uptake / Time Taken

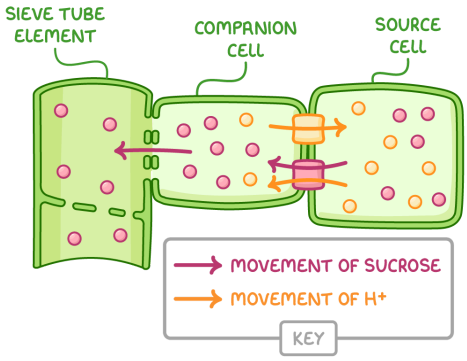
Mass Flow Hypothesis

- Proposes that translocation occurs due to pressure gradients
    - At the source, solutes like sucrose are actively loaded into sieve tube elements from companion cells, which decreases the water potential in sieve tube elements
    - Water enters the sieve tube elements from the xylem and companion cells by osmosis, which increases hydrostatic pressure in the sieve tube elements at the source
    - At the sink, solutes are actively removed from the sieve tube elements, which increases the water potential in sieve tube elements at the sink
    - Water leaves the phloem by osmosis, decreasing the hydrostatic pressure at the sink which creates a pressure gradient, pushing solutes from the source to areas of lower pressure at the sink



Active Loading

- Assimilates like sucrose are actively loaded into the phloem to set up a pressure gradient from source to sink
    - Hydrogen ions (H^+) are actively transported out of companion cells into surrounding source cells, where they are co-transported along their concentration gradient back into companion cells with sucrose
    - Sucrose can then diffuse along its concentration gradient through plasmodesmata from companion cells to sieve tube elements



Active Loading

- Mass flow of assimilates from one part of a plant, the source, to another part of the same plant, the sink
    - Assimilates = substances that have been manufactured/modified in the plant (sucrose and amino acids) that are transported in the phloem sieve tubes during translocation
- Requires energy and substances are transported dissolved in the phloem
- Concentration gradient using enzymes

Transport in Mammals

Transport System

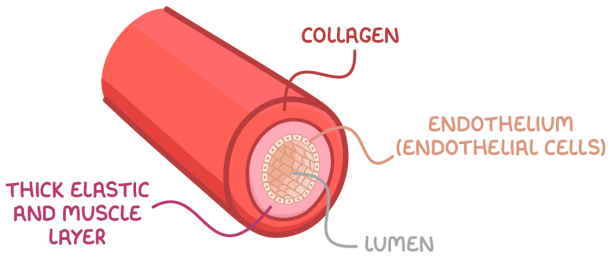
- Multicellular organisms = larger (large diffusion distance across), have higher metabolic rate and need to supply nutrients and oxygen rapidly to a larger number of active cells
- Mammals = closed, double circulatory system
    - Closed system = Blood is contained in blood vessels
    - Double system - Blood passes through heart twice per circuit
- Systemic circulatory system
    - Oxygenated blood is pumped out of the heart via the aorta and other branched blood vessels to most body tissues
    - Veins collect deoxygenated blood from these organs and return to the heart via the vena cava
- Pulmonary circulatory system
    - Deoxygenated blood is pumped out of the heart via the pulmonary artery to the lungs
    - Oxygenated blood is returned to the heart via the pulmonary vein from the lungs

Blood Vessels

- Arteries = Carry blood away from the heart
- Arterioles = Carry blood from arteries into capillaries
- Capillaries = Site of diffusion between blood and body tissues
- Venules = Carry blood from capillaries into veins
- Veins = Return blood to the heart

Arteries and arterioles

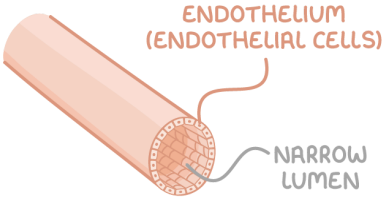
- Adapted to carry blood at high pressure away from the heart
    - Collagen = Provides strength to prevent the vessel from bursting and to maintain vessel shape
    - Elastic fibres = Contain elastin that lets them stretch and recoil to minimise changes in pressure
    - Thick smooth muscle layer = Contracts/relaxes to constrict/dilate the lumen and control blood flow



- Arterioles are smaller than arteries, but with a comparatively larger lumen with more smooth muscle and less elastin (no pressure)
- Vasoconstriction = SM contracts, constricting the blood vessel and ↓ blood flow
- Vasodilation - Smooth muscles relaxes, dilating the blood vessel and ↑ blood flow

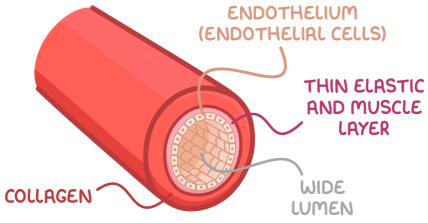
Capillaries

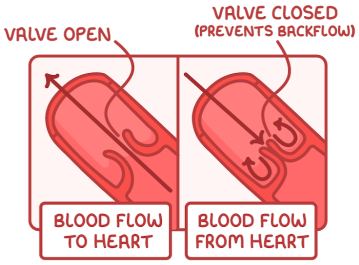
- Extensive networks between arterioles and venules
    - Narrow lumen = red blood cells close to body cells
    - Thin walls = Shorter substances exchange distance for diffusion
    - Highly branched = This provides a large surface area for diffusion



Veins and Venules

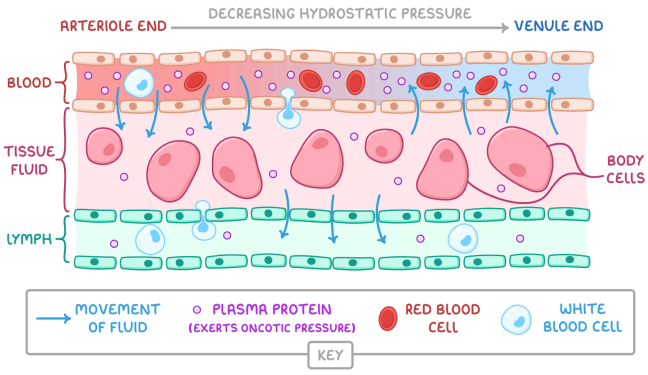
- Adapted to carry blood towards the heart at low pressure
    - Collagen = Provides strength to prevent the vessel from bursting and maintain vessel shape
    - Little smooth muscle and elastic fibre = Not much is needed due to low blood pressure, and thinner walls allow veins to be easily compressed, aiding the flow of blood
    - Valves = Pocket valves shut to prevent the backflow of blood when veins are squeezed by surrounding skeletal muscle
        - Pocket valves = Only type of valve controlled by skeletal muscle





Composition of Tissue Fluid

- Tissue fluid = Interstitial fluid fills spaces between cells = interstitial space
- Site of diffusion between blood and body cells, providing nutrients and oxygen while removing waste products, and helps fight infection as it forms part of the immune response
- Tissue fluid = same composition as plasma, except no red blood cells, fewer proteins and fewer white blood cells
- Formed from the blood flowing through capillaries
    - A high hydrostatic pressure, exerted by the force of the heart pumping, forces fluid out of capillaries at the arteriole end of capillaries
    - The hydrostatic pressure is lower at the venule end of capillaries, so proteins in blood exert a high oncotic pressure (osmotic pressure) in capillaries, and lower water potential in capillaries than in tissue fluid results to fluid loss, and some tissue fluid moves back into capillaries by osmosis



Composition of Lymph

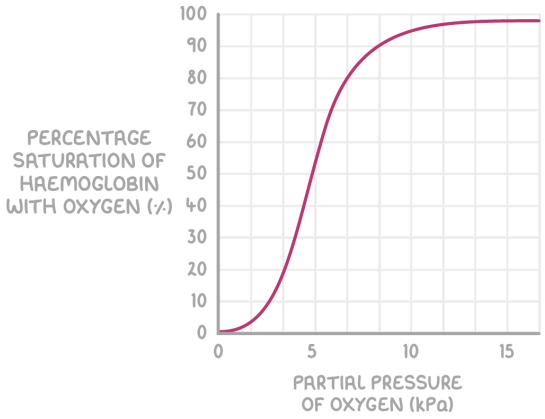
- Fluid that flows around the lymphatic system via lymph vessels; formed from tissue fluid
    - Some tissue fluid doesn't re-enter capillaries from tissue fluid which drains into lymph vessels (lymph capillaries), forming lymph that is transported through lymph vessels by muscle contractions
    - Lymph is passed through lymph nodes to filter pathogens and eventually returned to the blood
- Lymph fluid = similar composition to tissue fluid, except less oxygen and nutrients and more fatty acids and white blood cells (lymphocytes)

Composition and Functions of Blood

- Plasma = Mostly water, transports substances in solution
- Red blood cells = Carry oxygen effectively due to their flexible, biconcave shape and lack of organelles, allowing more space for haemoglobin
- White blood cells = Immune cells, including phagocytes (e.g. neutrophils with lobed nucleus and monocytes that develop into macrophages) and lymphocytes (which have a large round nucleus and very little cytoplasm)
- Platelets = Involved in clotting
- Transports oxygen and carbon dioxide, nutrients from digestion, waste for excretion, hormones, food from storage and clotting factors

Factors Affecting Haemoglobin Saturation

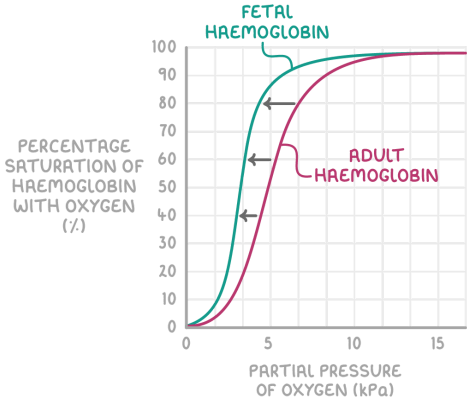
- Haemoglobin saturation with oxygen depends on the oxygen concentration, or partial pressure of oxygen (pO_2)
    - Units of partial pressure are kilopascals (kPa)
    - Can be represented in oxygen dissociation curve
- Higher pO_2 = Haemoglobin has a high affinity for oxygen and binds with it (e.g. in the lungs)
- Lower pO_2 = Haemoglobin has a low affinity for oxygen and releases it (e.g. at respiring body cells)



- When haemoglobin binds with one oxygen, it changes shape so it becomes easier to bind another oxygen and
- when haemoglobin is mostly saturated with oxygen, it is harder for more oxygen to bind

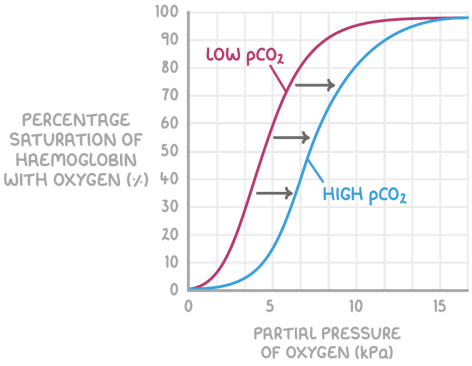
Fetal and Adult Haemoglobin

- The foetus needs to obtain oxygen from the mother's blood and therefore has a higher oxygen affinity than the adult haemoglobin found in the mother's blood, allowing the oxygen to dissociate from the mother's haemoglobin and bind with haemoglobin in the foetal blood, ensuring that the foetus gets enough oxygen to survive while it develops



Bohr Effect

- Haemoglobin has lower affinity for oxygen at higher partial pressures of carbon dioxide (pCO_2)
- Higher pCO_2 at respiring tissues causes haemoglobin to release oxygen due to the Bohr effect, meaning oxygen saturation of haemoglobin is lower for a given pO_2 when pCO_2 is higher

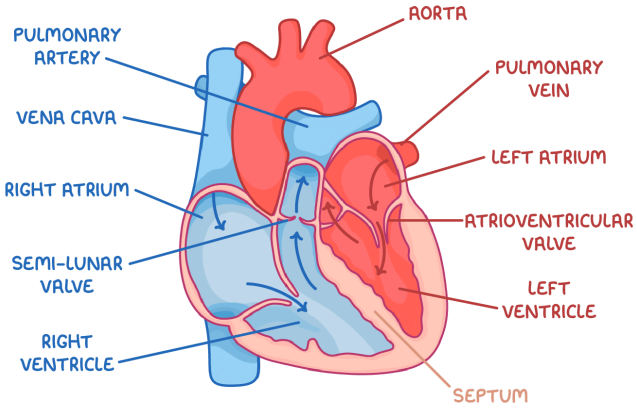


Transport of Carbon Dioxide in the Bloodstream

- To maintains a steep diffusion gradient between respiring tissues, which is needed to get rid of CO_2, CO_2 is converted into another form
    - A small percentage of CO_2 is transported dissolved in plasma.
    - Some CO_2 enters red blood cells and is transported bound to haemoglobin as carbaminohaemoglobin
    - Most CO_2 enters red blood cells and undergoes a reaction in the cytoplasm to form hydrogen carbonate ions
        - High pCO_2
            - CO_2 reacts with water to form carbonic acid (H_2CO_3), catalysed by the enzyme carbonic anhydrase.
            - H_2CO_3 dissociates to H^+ and HCO_3^-, and H^+ binds to haemoglobin, forming haemoglobinic acid, causing haemoglobin to release oxygen, which prevents the blood from becoming too acidic (H^+ ions reduce pH)
            - Also causes the Bohr effect: at high pCO_2, haemoglobin releases oxygen so it can diffuse into respiring tissues; HCO_3^- ions leave red blood cells and are transported via plasma, while chloride ions (Cl^-) enter red blood cells in a process called the chloride shift, and it maintains the charge balance by preventing excessive positive charge in red blood cells
        - High pCO_2
            - The low pCO_2 causes HCO_3^- and H^+ to reform CO_2 that diffuses out of the body during expiration

Heart Structure

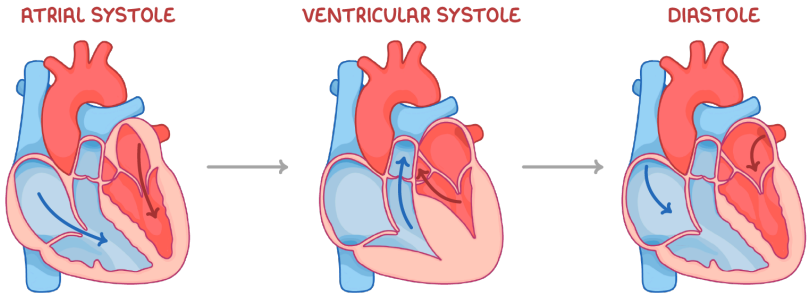
- 4 chambers = left and right atria, and the left and right ventricles
    - Atria = Top chambers in the heart that collect blood from veins
    - Ventricles = Bottom chambers in the heart that pump blood into arteries
- Left = oxygenated; right = deoxygenated
- 2 separate pumping mechanisms, as two pumps increase the pressure before the blood circulates which drops in lungs as it flows through capillaries
- The atrioventricular valves = Prevents backflow of blood into atria when the ventricles contract
    - The tricuspid valve = Located between the right atrium and the right ventricle
    - The bicuspid (mitral) valve = Located between the left atrium and the left ventricle
- The semi-lunar valves = Prevent the backflow of blood into the ventricles when they relax
    - Located between the ventricles and the pulmonary artery and the aorta
- The pulmonary vein = Moves oxygenated blood into the left atrium from the lungs



- The aorta = Moves oxygenated blood from the left ventricle to the body
- The vena cava = Moves deoxygenated blood into the right atrium from the body
- The pulmonary artery = Moves deoxygenated blood from the right ventricle to the lungs
- Ventricles = Thick walls with more muscles than atria with left thicker than right
    - Lot of pressure to pump blood from heart to organs while it's a short-distance pump for atria
    - Right = Only to lungs; Left = Distant organs

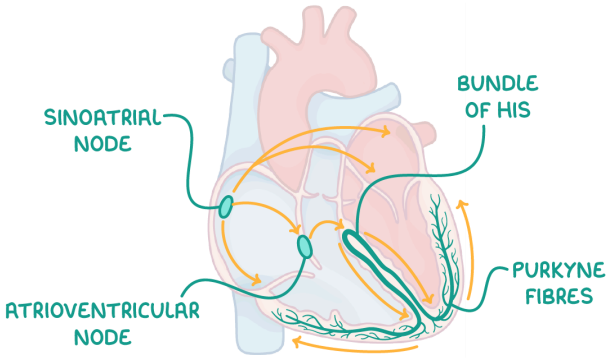
Cardiac Cycle

- Stage 1 = Atrial systole
    - The ventricles relax, and the atria contract which increases the atrial pressure, resulting in opening of atrioventricular valves and, allowing flow of blood into the ventricles
- Stage 2 = Ventricular systole
    - The ventricles contract, and the atria relax, which increases the ventricular pressure increase, resulting in opening of semi-lunar valves, and closing of atrioventricular valves, allowing flow of blood into the arteries
- Stage 3 = Diastole
    - The ventricles and atria relax, semilunar valves close and blood flows passively into the atria



Heartbeat

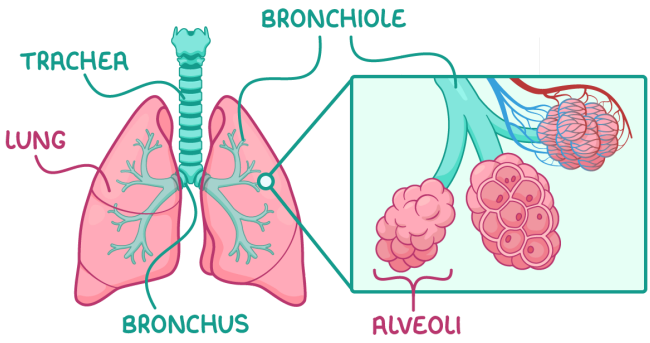
- Cardiac muscle = Myogenic
    - Contraction of cardiac muscle initiates within the heart itself and the basic rhythm of the heart is maintained by a wave of electrical excitation
- Sinoatrial node (SAN) = Initiates the heartbeat by stimulating the atria to contract
- A layer of collagen fibres = Prevents direct electrical flow from atria to ventricles
- Atrioventricular node (AVN) = Picks up the electrical activity from the SAN and imposes a slight delay
- Bundle of His = Receives electrical activity from the AVN and conducts the wave of excitation to the apex (base) of the heart
- Purkyne fibres = These branch off the bundle of His, causing the right and left ventricles to contract from the bottom upwards



Gas Exchange

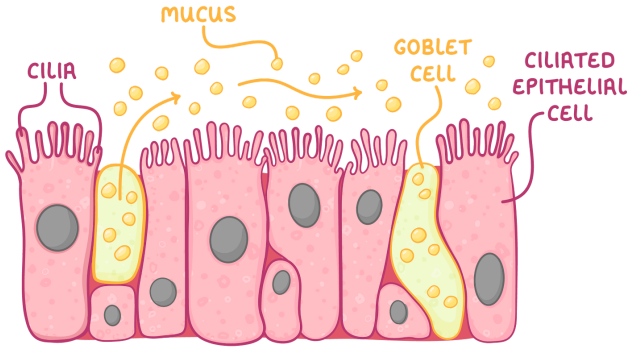
Exchange System

- Lungs = Located inside the chest in the thoracic cavity (thorax) and protected by the ribcage
- Present inside the body, as it is not dense enough to support and protect these delicate structures and the body would otherwise lose water and dry out
- Air first enters the trachea, then travels into the two bronchi, with one bronchus going to each lung, into smaller airways called bronchioles and finally into clusters of air sacs called alveoli at the end of the bronchioles



Ciliated Epithelium

- Tissue located throughout most of the airways
  - Goblet cells = Produces and secrete mucus that traps dust and microbes
  - Cilia on ciliated epithelial cells = Wafts the mucus upward to the mouth so it can be swallowed
  - Macrophages = Patrols the surfaces of the airways, engulfing and destroying debris and microbes



Trachea

- Rings of cartilage keep the airway open
- Smooth muscle contracts or relaxes to constrict or dilate the airway and change airflow
- Elastic tissue contains elastic fibres with elastin that allows stretching and recoiling
- Lined with ciliated epithelial cells and goblet cells

Bronchi

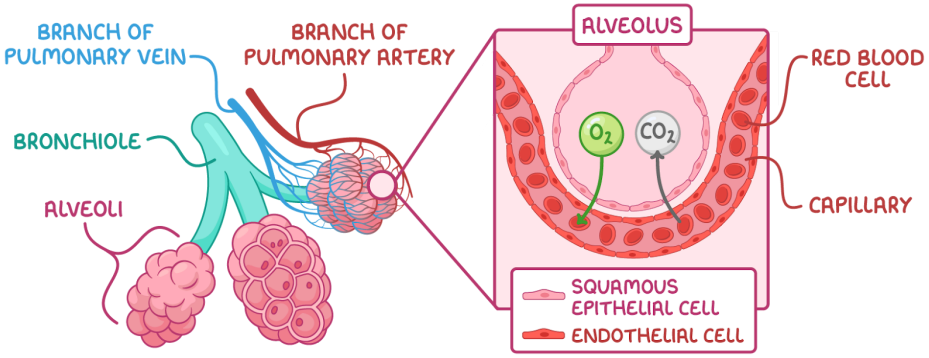
- Reinforced with cartilage to keep the airway open
- Smooth muscle can contract or relax to constrict or dilate the airway and change airflow
- Elastic tissue contains elastic fibres with elastin that allows stretching and recoiling
- Lined with ciliated epithelial cells and goblet cells

Bronchioles

- No cartilage, can change shape
- Smooth muscle can contract or relax to constrict or dilate the airway and change airflow
- Elastic tissue contains elastic fibres with elastin that allows stretching and recoiling
- Simple squamous epithelium (only larger bronchioles have a ciliated epithelium)

Alveoli and blood vessels

- Alveoli = Tiny air sacs clustered at the ends of the bronchioles surrounded by a network of capillaries so gases can be exchanged between the air in the alveoli and the blood
    - Oxygen diffuses from the alveoli into the pulmonary capillaries, where it binds to haemoglobin in red blood cells
    - Carbon dioxide dissociates from haemoglobin and diffuses from the blood into the alveoli
- Adaptations of the alveoli for gas exchange:
    - Wall consists of one layer of squamous epithelial cells = allows rapid diffusion.
    - Large surface area = Increases rate of gas exchange
    - Partially permeable = Only certain gases can move across the wall
    - Surrounded by dense network of capillaries = Brings blood close to air for gas exchange
    - Ventilation of air = Maintains steep diffusion gradient
    - Elastic fibres = Allow stretching and recoiling
    - Collagen fibres - Contains strong collagen that prevents alveoli from bursting and limits overstretching
    - Moist inner surface = Allows gases to dissolve, and lung surfactant helps alveoli remain inflated



Infectious Disease

Pathogens

- Communicable (or infectious) diseases are those that can be passed from one organism to another which are caused by pathogens
    - Bacteria = Produce toxins that damage body cells
    - Viruses = Use host cells to replicate before bursting out and destroying cells
    - Protoctists (protists) = Take over cells and break them open
    - Fungi = Digest living cells to destroy them, and some also produce toxins
- Direct transmission = Pathogens transferred directly from one organism to another
    - Direct contact = Skin-to skin contact, kissing, or sexual intercourse.
    - Airborne droplets = Coughing or sneezing tiny droplets of mucus or saliva onto someone.
- Indirect transmission = Passed from one organism to another using an intermediate (e.g. water or another organism)
    - Food and drinking water = Ingestion of contaminated food or water
    - Vectors = Transmission from one host to another (e.g. mosquitoes transmit malaria)
    - Contaminated objects = Pathogens from infected individuals can live on objects for a short time and infect others
- Overcrowded areas increase the risk of direct transmission
- Warmer temperatures allow mosquitoes to breed and transmit malaria
- Lack of health education and healthcare systems increases the risk of communicable disease

Cholera

- Infection of the small intestine, causing severe diarrhoea that usually occurs in areas where people do not have access to a clean water supply or uncontaminated food
- Cause = Bacteria - Vibrio cholerae
- Transmission = Water that has been contaminated with faeces or contaminated food which has been handled by infected individuals
- Treatment = Rehydration therapy; Usage of salt and glucose solutions to rehydrate the body
- Prevention and control = Provision of clean water that has been chlorinated to kill bacteria and using vaccination programmes where cholera is common

Malaria

- Life-threatening disease caused by parasites transmitted to humans via infected mosquitoes
- Cause = One of four possible protoctist species - Plasmodium falciparum, Plasmodium vivax, Plasmodium ovale, or Plasmodium malariae
- Transmission = Vectors (female Anopheles mosquitoes), blood transfusions or re-use of unsterile needles and across the placenta from mother to fetus
- Treatment = Anti-malarial drugs such as quinine and chloroquine
- Prevention and control = Reducing the number of mosquitoes in an area by using insecticide and the chance of being bitten by using mosquito nets and insect repellents and using prophylactic (preventative) drugs to prevent infection in pregnant women and young children

HIV/AIDS

- Human immunodeficiency virus (HIV) is a virus that damages the immune system and can lead to acquired immunodeficiency syndrome (AIDS)
- Cause = Human immunodeficiency virus (HIV)
- Transmission = Exchange of bodily fluids via sexual intercourse, blood donation, or sharing of needles and across the placenta from mother to fetus.
- Treatment = No cure, but antiretroviral drug therapy can slow down the onset of AIDS by stopping the virus replicating in the body
- Prevention and control = Blood donations can be screened for HIV and heat-treated to kill viruses; HIV-positive pregnant women can be treated to prevent infection of the foetus; barrier methods of contraception, such as condoms, reduce the risk during intercourse; educational programmes to encourage the public to protect themselves and others

Tuberculosis (TB)

- Bacterial infection of the lungs but can also spread to the glands, bones or brain
- Cause = One of two possible bacteria - Mycobacterium tuberculosis or Mycobacterium bovis
- Transmission = Unaffected individuals inhale airborne droplets containing the bacteria and can be spread from cattle to humans in meat and milk
- Treatment = Antibiotics for 3 to 6 months.
- Prevention and control = Contact tracing in which individuals who have been in contact with an infected person are screened and tested for TB; vaccination using the BCG vaccine; routine testing of cattle and destroying those that test positive; milk pasteurisation to kill any TB-causing bacteria

Antibiotics

- Drugs that kill or inhibit the growth of bacteria by targetting the bacterial enzymes and ribosomes used in metabolic reactions, meaning they do not damage human cells (as they contain different enzymes and ribosomes)
    - Prevents the synthesis of bacterial cell walls, disrupts protein activity in the cell membrane, disrupting enzyme action, prevents DNA synthesis and/or prevents protein synthesis.
- Do not work against viruses due to their lack of cell structures (relying on host cells to carry out metabolic reactions)

Penicillin

- One of the first antibiotics to be discovered; Alexander Fleming; the mould Penicillium chrysogenum, growing on his bacterial cultures
- Inhibits growth of bacteria by preventing formation of bacterial cell walls, inhibiting enzyme autolysins, which are responsible for building cross-links between peptidoglycan polymers by making tiny holes in the cell wall

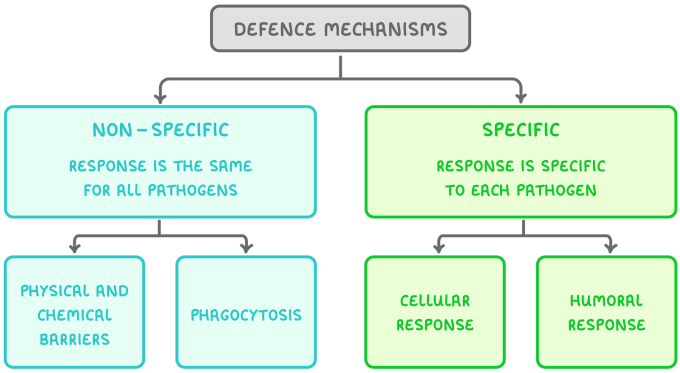
Antibiotic Resistance

- Antibiotics that were once effective against these bacteria no longer work, making it much more difficult to treat bacterial infections
    - Genetic mutations (often occur on plasmid) = Makes some bacteria resistant to an antibiotic
    - Resistant bacteria are able to survive infection treatment
    - Resistant bacteria reproduce, passing on the allele for antibiotic resistance to their offspring, or through conjugation
- Choosing appropriate antibiotics for treatment tested against bacterium strains to make sure they are effective in treating the disease
- Using antibiotics only when needed
- Avoiding the use of wide-spectrum antibiotics as use of narrow-spectrum antibiotics (antibiotics specific for the infection) is less likely to lead to antibiotic resistance
- Ensuring that patients complete courses of antibiotic treatment to ensures all bacteria are killed and so does not give them the chance to develop resistance.
- Avoiding the use of antibiotics in farming which reduces the chance of bacteria becoming resistant to antibiotics

Immunity

Non-Specific and Specific Defence Mechanisms

- Non-specific defences = Act quickly to defend the body but respond in the same way for all pathogens
- Specific defences = Slower to defend the body but produce a specific response for each pathogen

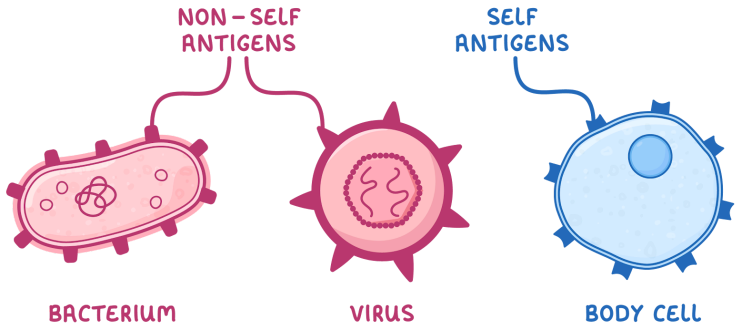


Physical and Chemical Barrier

- Skin
  - Blocks pathogens from entering the body as a physical barrier
  - Producing sebum, an oily, antimicrobial substance that lowers pH to inhibit the growth of pathogens as a chemical barrier
- Mucous membranes
  - Parts of the ears, nose, throat, and digestive tract are lined by mucous membranes that secrete mucus to trap pathogens and use lysozymes to destroy them
- Expulsive reflexes
  - Coughing and sneezing are methods for expelling foreign objects (or pathogens) from the gas exchange system, and vomiting and diarrhoea expel the contents of the gut along with any pathogens present
- Blood clotting and wound repair
  - Blood clots act quickly to seal any wounds that might be a possible entry for pathogens as clot dries out to form a scab that blocks entry to the body. After a scab has formed, the skin is capable of repairing itself to reform its physical barrier
  - Epidermal cells underneath the scab divide while damaged blood vessels regrow and collagen fibres are used to provide strength to the new tissue and once the epidermis is the required thickness, the scab breaks off and the wound is healed
- Inflammation
  - Swelling, heat, redness, and pain at the site of infections or wounds
  - Blood vessels dilate which increases blood flow to the area, making it hotter to prevent pathogens from reproducing, and blood vessel walls become more permeable so that they start to leak tissue fluid, causing swelling and isolating any pathogens in the damaged tissue

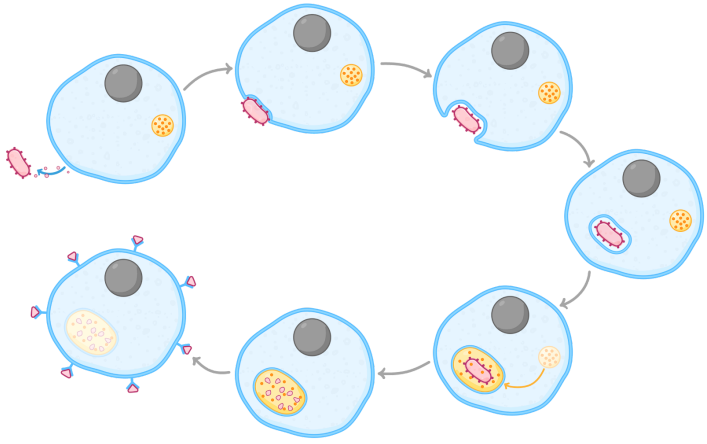
Antigens

- Unique molecules (usually proteins) that can be found on the surface of cells
- Allows the immune system to distinguish between the body's own cells (self) and foreign cells (non-self) so any foreign cells can then be destroyed whilst leaving the body's own cells unaffected
    - Pathogens (foreign antigens)
    - Abnormal body cells (cancerous or infected cells display abnormal antigens that trigger an immune response)
    - Toxins (antigen molecules themselves, not cells, and can be recognised by the immune system)
    - Cells from other organisms of the same species (different antigens from the body's own cells and so are identified as being foreign)



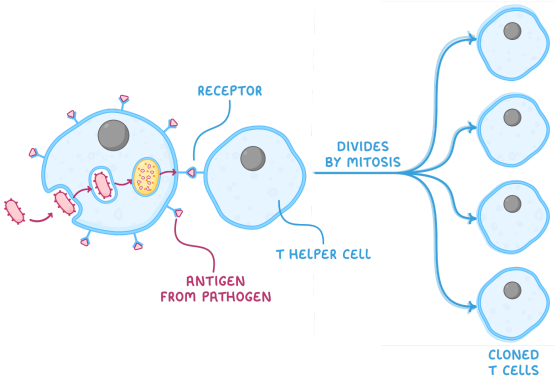
Phagocytes

- Engulf and destroy pathogens by phagoctytosis
    - Neutrophils = Rapidly engulf and destroy pathogens at the site of infection
    - Macrophages - Engulf and digest pathogens but also present the pathogen's antigens on their cell surface to activate other cells in the immune system
- The pathogen releases chemicals that attract a phagocyte, which recognises the pathogen's antigen as foreign and engulfs it, and is contained within a vesicle called a phagosome. Lysosome's hydrolytic enzyme, lysozyme, fuses with the pathogen to form a phagolysosome for lysozyme to digest and destroy the pathogen
- Phagocyte presents the pathogen's antigens on its surface to activate other cells in the immune system; this phagocyte is then referred to as an antigen-presenting cell (APC)



Lymphocytes

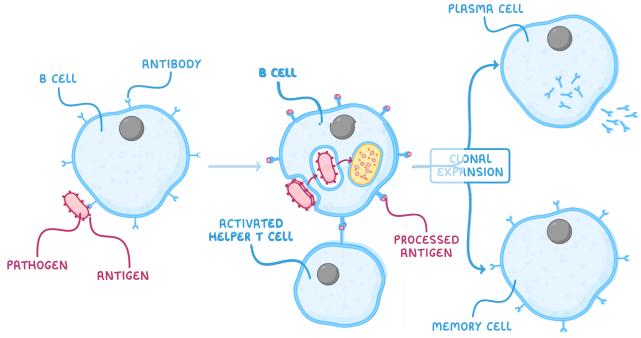
- T lymphocytes/T cells = Mature in the thymus gland and are involved in the cellular response where they respond to antigens presented on body cells
    - T-helper cells = Have receptors on their cell surface that bind to complementary antigens on antigen-presenting cells to produce interleukins (a type of signalling molecule called a cytokine), which stimulates B cells or phagocytes; T-helper cells can also form memory cells or T-killer cells.
    - T-killer cells = Kill abnormal and foreign cells by producing a protein known as perforin which makes holes in the cell-surface membrane, causing it to become freely permeable and causing cell death
    - T-memory cells = Provide long-term immunity against specific pathogens with rapid response if the body is re-infected by the same pathogen

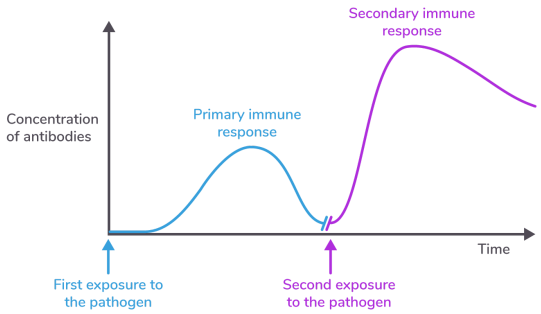


- B lymphocytes/B cells = Mature in the bone marrow and are involved in the humoral response, where they produce antibodies found in body fluids (or 'humours')

Humoral Response

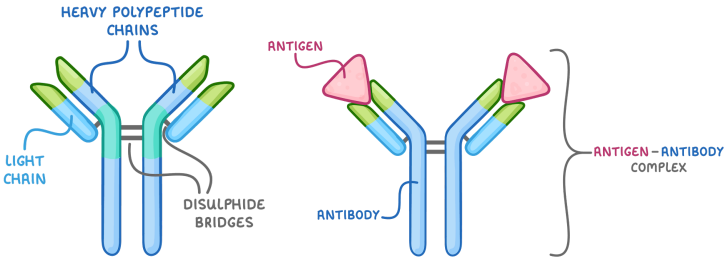
- B cells = Antibodies on their cell-surface membrane that bind to complementary antigens; on doing so, they engulf the antigens and display them on their cell surface to become antigen-presenting cells and once activated, B cells can divide into plasma cells and memory cells
- Plasma cells = Types of B cell that can produce and secrete antibodies against a specific antigen with a short lifespan of only a few days
- Memory cells = Types of B cells that provide long-term immunity against specific pathogens with a much longer lifespan than plasma cells and rapidly divide into plasma cells if the body is re-infected by the same pathogen
- Helper T cells = Bind to antigen-presenting cells to activate the division of B cells



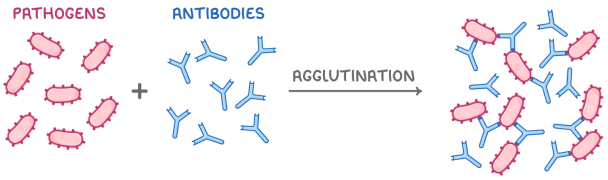


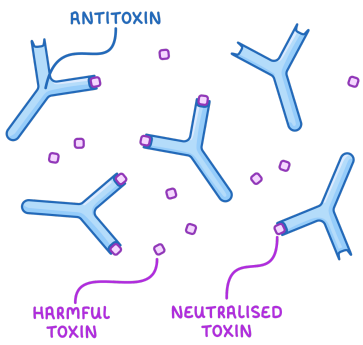
	Primary immune response	Secondary immune response
Exposure to pathogen	First exposure	Second or subsequent exposure
Speed of response	Slow	Fast
Symptoms experienced	Yes	No
Cells activated	B and T cells	Memory B and T cells
Rate of antibody production	Low	High
Number of antibodies produced	Only a few antibodies	Large numbers of antibodies
Time between pathogen exposure and antibody production	Long (4 - 7 days)	Short (1 - 3 days)

Antibody



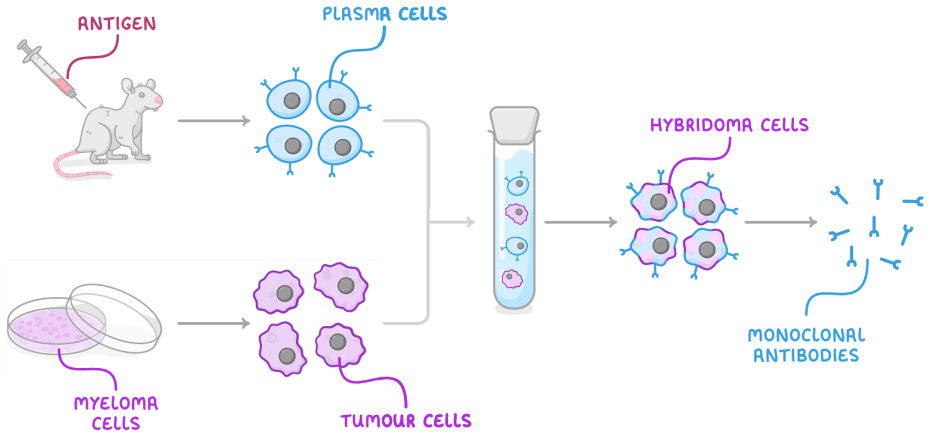
- Y-shaped glycoproteins made up of four polypeptide chains, two heavy chains, and two light chains
  - Constant region = Same for all antibodies and binds to receptors on cells such as B cells
  - Variable region = Different for each antibody, as its shape is complementary to a specific antigen, the part of the antibody that binds to antigens
  - Hinge region = Allows the antibody to be flexible so it can bind to multiple antigens at once
- Bind to specific antigens on a pathogen's surface
  - Unique binding site (in the variable region) that fits onto a specific antigen; antigen-antibody complex
    - Agglutination of pathogens = Clumping pathogens together to enable easier phagocytosis
    - Neutralisation of toxins = Antibodies bind to toxins to inactivate them
    - Preventing pathogens from binding = Antibodies bind to pathogens to stop them from infecting body cells



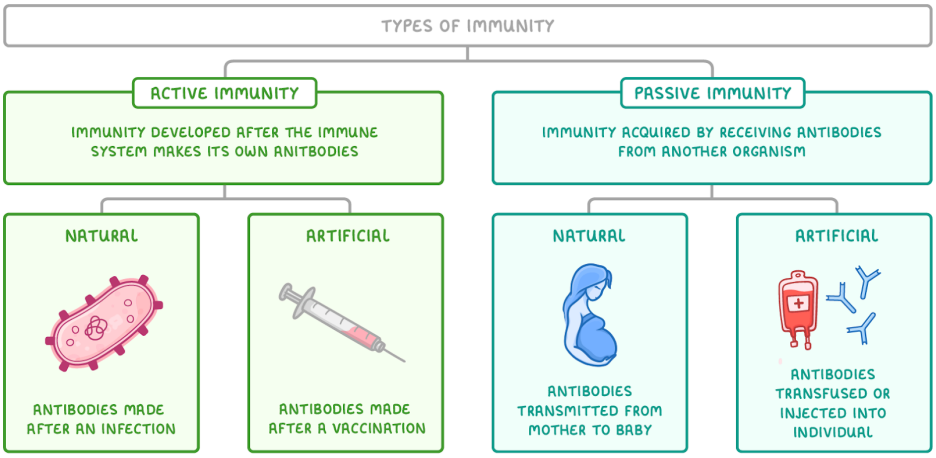


Monoclonal Antibodies

- 'Mono' = single; 'Clonal' = clone; produced from a single clone of plasma cell
- Identical to one another
    - Diagnosis of disease = Bind to specific cell types to identify infected cells
    - Treatment of disease = Bind to specific cells, bringing therapeutic drugs with them
    - Pregnancy testing = Bind to a pregnancy hormone in home pregnancy testing kits
    - Detecting certain cancers = Bind to prostate-specific antigens (PSA) to identify prostate cancer in men (example)
- A mouse is injected with a specific antigen which stimulates plasma cells to produce antibodies against this antigen. These plasma cells are extracted from the mouse's spleen. At the same time, myeloma cells (cancer cells) are cultured and tumour cells are extracted. The plasma and tumour cells are mixed together in suspension as some plasma cells fuse with tumour cells to form hybrid cells known as hybridomas, which can be screened to check whether they produce the desired antibody and hybridoma cells are isolated and cultured to produce large number of monoclonal antibodies



Immunity



Vaccination

- 'accination involves the introduction of a pathogen's antigens into the body, usually via injection which stimulates the body to produce an immune response to the pathogen and, in doing so, allows the body to develop artificial active immunity
    - Dead or inactivated pathogens
    - Attenuated (weakened) pathogen strains
    - A harmless version of a toxin
    - Isolated antigens from a pathogen
    - Genetically engineered antigens
- The vaccine, containing antigens, is injected into the blood, which stimulates the primary immune response to produce antibodies against the pathogen. Memory cells, capable of recognising these antigens, are produced and on second exposure to this pathogen, memory cells rapidly divide into plasma cells which rapidly produce antibodies against the pathogen, which destroys pathogens before any symptoms are experienced
- Successfulness of vaccine
    - Availability
    - Minimal side effects
    - Infrastructure
    - Administration
    - Herd immunity (immunity to those that receive them, but also provide some protection to those not vaccinated)
- Completely eliminating a disease can still pose a significant challenge
    - Individual immunity failures.
    - Pre-immunity infection
    - Pathogen mutation and antigenic variability
    - Pathogen variety
    - Pathogen hiding
    - Vaccine objections