0. Overview

About these notes

- **Revise efficiently**
  - The textbook and school notes are too thick, which crowds out the important info. That's why I made a simple, condensed version of the content for my students, to help them cut through the clutter. The stuff in here is what you need to focus on for your syllabus, so use this to study efficiently.
  - The learning outcomes are not word for word compared to the textbook, because I've made them more concise/understandable. Rest assured, content is same as the syllabus.
- **Memory Hacks**
  - Along the way, you'll see headings like: ***[Memory Shortcut]*** / ***[Memory Hack]***. These are my own acronyms/mnemonics/memory hacks, so you can memorise content faster AND recall content easier in exams.
- **Know the commonly tested OEQs**
  - I've looked through many papers and assessment books to draw out the commonly asked questions. You'll find them under each topic's notes.
  - The secret to OEQs is that there are common OEQs that examiners always test you on. If you get good at these, you instantly score well for 80% of the paper. This is how you study smart. Enjoy OEQ success.
- **Disclaimer**
  - Just like yall, I'm always learning. That's why I constantly update these notes to make them better. You're currently reading v1.0.3. Check for the most updated version here: http://tinyurl.com/TBTnotes
- **If you're reading this on PDF**
  - Use the Ctrl + F search function to search for a note/content quickly
  - Viewing on computer might be better
- **If you're my current student reading this**
  - Please view these notes on Evernote! It's the most updated, and you guys get *bonus study smart pages* + *my suggested model answers* for the commonly asked questions.

Why I give these notes for FREE

- I get tons of messages requesting for notes, so this must be a big need in the community. A lot of you are needlessly struggling in this subject, and I don't want you to be one of them.

- If you are, maybe you're not getting the quality of teaching and materials you need. It shouldn't be this way, because bio is an easy subject, and you deserve to score well in it.
- I was in your position before, and I wished someone gave me notes like these to make my life easier. Now I get to make it a reality for you, and that brings me lots of joy.
- *Hold up. This sounds too good to be true. What's the catch?*
    - I do this because I'd like to earn your trust, by giving you results in advance.
    - I want you to know that this is the real deal. It's my hope that those of you who want bio tuition will choose me as your tutor :)
- With the right guidance, bio becomes a very easy subject. If you want my help, apply for my classes here: forms.gle/VgcQb75LgW6iLGoQ8
    - For more info: www.thatbiotutor.com

Can I share this with my friends?

- YES, share this with as many people as you want! They will thank you for it many times over.
- My aim is to get these in the hands of every O level pure bio student in Singapore, so more grades will be transformed.
- I want to empower you all to see that bio is a conquerable subject, which you can do very well in.
- If you like these notes and you believe in what I'm doing, why not leave a review here: https://tinyurl.com/tbtnotesreview

If you want more

- I wrote an eBook on **A1 Biology Study Hacks**, you can get it for free here: https://tinyurl.com/tbtebook

Acknowledgements

- These notes are the intellectual property of Keefe Fonseka and are not to be sold for profit.
- For more bio and study tips, check out *@thatbiotutor* on Instagram and TikTok.

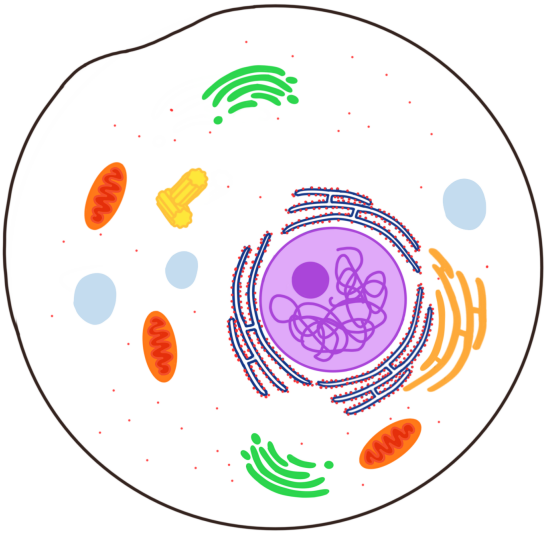
1. Cells

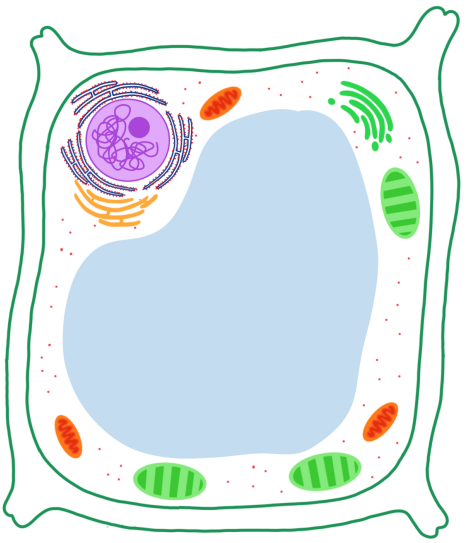
Learning Outcomes:

1. Identify and state the functions of plant and animal cell organelles
2. State the relationship between cell structure and function (w.r.t. RBC, xylem, root hair cell)
3. Compare structures of plant and animal cells
4. Differentiate between cell, tissue, organ, organ system

Keywords:

- Cell, tissue, organ, organ system





1. Identifying structures

Component	Function	Visible under Light Microscope?
Nucleus	• Contains **DNA** (in the form of chromatin) • Controls **cell activities**	Y
Nuclear envelope	• Is a **double membrane** • Separates nucleus from cytoplasm	Y
Nucleolus	• Aids in **protein synthesis**	N

Rough Endoplasmic Reticulum	• Studded with ribosomes • **Synthesises proteins** (for transport out of the cell)	N
Smooth Endoplasmic Reticulum	• Synthesises lipids, steroids • Carries out **detoxification**	N
Cytoplasm	• Place where most **cell activities** occur • Contains organelles • Site of **anaerobic respiration**	Y
Vacuole	Animals: • Several **small** and **temporary** vacuoles • Store food and water Plants: • 1 **large central** vacuole, its membrane is called **tonoplast** • Stores **cell sap** (food, water and mineral salts)	Y (plants) N (animals)
Golgi body/apparatus	• **M**odifies, **S**orts and **P**ackages substances into **vesicles** for secretion out of cell	N
Mitochondria	• Site of **aerobic respiration**, where glucose is **oxidised** to release energy	N
Chloroplast **(plants only)**	• Site of **photosynthesis**	Y

Cell surface/plasma membrane	• **Partially permeable/semi-permeable** • Controls movement of substances in and out of the cell	Y
Cell wall **(plants only)**	• Fully permeable • Gives cell its shape	Y
Ribosomes	• Synthesise proteins	N
Centrioles **(animals only)**	• Aid in **cell division**	N

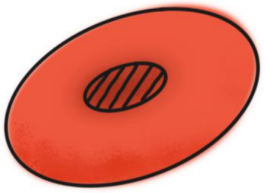
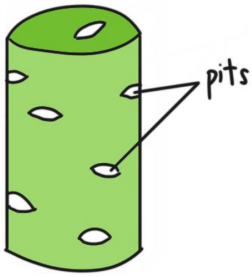
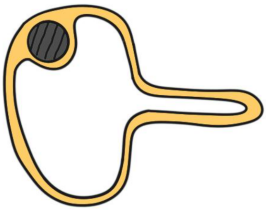
[Memory Hacks]

- Golgi Body:
  - When receiving vesicles from ER, says "**M**ajulah **S**inga**P**ura"
  - **M**odifies, **S**orts and **P**ackages substances into vesicles for secretion out of cell
- Rough ER:
  - Proteins --> Meat. When you bite into meat patty, has a **rough** texture
  - **Rough** ER synthesises proteins
- Smooth ER:
  - Lipids --> Oil. Oil is **smooth** and slippery.
  - **Smooth** ER synthesises lipids

2. Linking Structure to Function

**Pro Tip: These are repeated in their later respective topics.*

Cell structure	How it is adapted to its function

Red Blood Cell 	• **Biconcave**, increases **surface area to volume ratio**, so oxygen can **diffuse** in/out of it faster • Lacks a nucleus hence has **more space** for more **haemoglobin,** to transport more oxygen • **Flexible**, so it can squeeze through tiny **capillaries** • Can become **bell-shaped** in capillaries, further increasing **surface area to volume ratio**
Xylem vessels 	• No **end walls** to allow **unobstructed** flow of water • No protoplasm, to allow **unobstructed** flow of water • Walls are **lignified** to prevent collapse of xyelm vessels
Root hair cell 	• Has a **long, narrow** protrusion (root hair), that increases **surface area to volume ratio**, for faster absorption of water and mineral salts

3. Comparing Plant and Animal Cells

Comparison	Animal Cell	Plant cell
Chloroplasts	No	Yes
Cell wall	No	Yes
Vacuole	Small, temporary	Large, permanent

Centrioles	Yes	No
Size	Relatively smaller	Relatively bigger

4. Differentiate cell, tissue, organ, organ system

Cells < Tissue < Organ < Organ system < Organism
E.g. Epithelial cell < Epithelium < Small intestine < Digestive system < Human

- **Cell:** The most basic unit of life
- **Tissue**: A group of cells working together to perform a specific function
- **Organ**: Several types of tissues working together to perform a specific function
- **Organ system**: Several organs working together for a specific purpose

**Pro Tip: Blood is a tissue!*

1. Cells CAQs

Pathway Out Of Cell
Q: Describe how proteins made in the cell are released to the outside of the cell. [3]

Many Mitochondria
Q: Suggest why root hair cells [cell type] have many mitochondria. [2]

Cells With High SA:V
Q: What is the advantage of epithelial cells [cell type] having such a shape (having microvilli)? [2]

2. Movement of Substances

Learning Outcomes:

1. Define Diffusion, Osmosis and Active Transport
2. Movement of substances in nutrient uptake and gas exchange
3. Effects of osmosis on plant and animal tissues
4. Bonus: Factors affecting rate of diffusion.

Keywords:

- Diffusion, osmosis, active transport
- Water potential
- Concentration gradient
- Partially permeable/semi-permeable membrane
- Crenated, lysed/burst
- Plasmolysed, flaccid, turgid
- Turgor pressure

1. Definitions

1. **Diffusion:** The **net** movement of substances from a region of higher concentration to a region of lower concentration, **down a concentration gradient**.

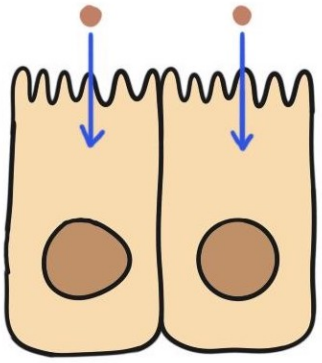
2. **Osmosis:** The **net** movement of **water molecules** from a region of higher **water potential** to a region of lower **water potential**, through a **semi-permeable** membrane.

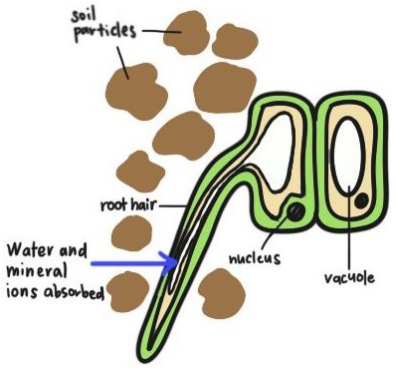
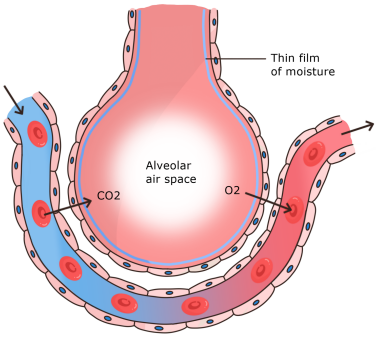
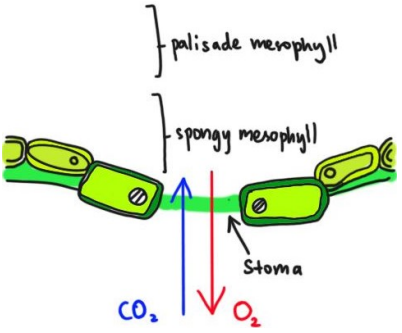
3. **Active Transport:** The movement of substances, using **energy**, from a region of lower concentration to a region of higher concentration, **against a concentration gradient**, through a **semi-permeable** membrane.

**Pro Tip: When explaining these processes in contexts of questions, replace' substances' with the molecule in the question, e.g. CO2*

Process	Diffusion	Osmosis	Active transport
Type of molecule	Any	Water	Any
Partially permeable membrane needed?	No	Yes	Yes
Energy needed? (ATP)	No	No	Yes
Direction w.r.t. Concentration gradient	Down (higher to lower)	Down (higher to lower)	Against (lower to higher)

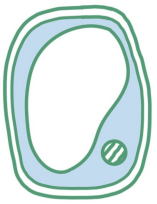
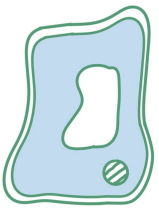
2. Movement of substances in nutrient uptake and gas exchange

Example	How substances are moving
	• Nutrients such as glucose, amino acids and triglycerides **diffuse** into epithelial cells of villi in the small intestine • After **diffusion** no longer occurs, these substances are pumped in via **active transport**

	• Mineral salts are pumped from the soil into root hair cells **via active transport**, to maintain a high concentration of mineral salts in their vacuoles • This creates a region of lower **water potential** than the surrounding soil, so that water flows in by **osmosis**
	• O_2 **dissolves** into the thin film of moisture lining the **alveolar air space**, then **diffuses** into the **blood plasma** • Conversely, CO_2 **diffuses** from the **blood plasma** into the **alveoli air space**
	• O_2 **diffuses** from the **intercellular air spaces** of the leaf to the surrounding air, through the **stomata** • CO_2 **diffuses** from the surrounding air into the **intercellular air spaces** of the leaf, through the **stomata**

3. Effects of osmosis on plant and animal tissues

Water potential of solution	High	Low	Very low

Effect on Animal cell	Bursts/lysed 	Crenated 	Crenated 
Effect on Plant cell	Turgid 	Flaccid 	Plasmolysed 

**Pro Tip: Turgidity in plant cells is important as it allows the plant to remain upright and reach for sunlight, especially if it has a non-woody stem.*

4. Bonus: Factors affecting rate of diffusion

- **Surface area to volume ratio:** The higher the SA:V, the higher the diffusion rate
- **Temperature:** Higher temperature, molecules have more **kinetic energy**, hence move faster and diffuse down the concentration gradient faster
- **Steepness of concentration gradient:** The steeper the gradient, the higher the diffusion rate
- **Distance:** The shorter the distance that molecules need to travel/diffusion distance, the higher the diffusion rate

2. Movement of Substances CAQs

Important Definitions

Q: Define the term diffusion.

Q: Define the term osmosis.

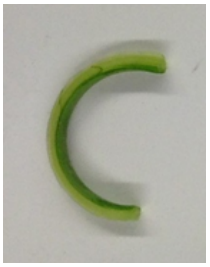
Q: Define the term active transport.

Applying Definitions

- Eg. Describe the movement of water into a root hair cell. [1]

Strip of Cut Stem Bending

Q: A leek stem was cut into small strips and placed into 0.1% salt solution. After 20 minutes, it looked like this:



Explain the bent appearance of the strip. [4]

3. Biomolecules

Learning Outcomes:

1. The roles of water in living organisms
2. Carbohydrates, fats, and proteins: Their chemical elements, and the smaller molecules that make them up
3. Food tests for starch, reducing sugars, fats and proteins

Keywords:

- Universal solvent, reagent
- Monosaccharide, disaccharide, polysaccharide, reducing sugar
- Condensation reaction, hydrolysis
- Amino acid, peptide, polypeptide
- Glycerol, fatty acid, triglyceride, emulsion
- Carbohydrate, starch, glycogen, cellulose

1. Roles of water in organisms

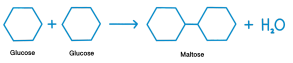
- **Main component** of organisms (70% of human mass is water), component of cell **cytoplasm**
- **Universal solvent** for reactions to occur, as well as a **reagent*** (e.g. photosynthesis) and a **product** in many chemical reactions (e.g. aerobic respiration)
- Allows **dissolved** substances to be easily transported (e.g. blood)
- Aids in **temperature regulation** (e.g. sweating, transpiration)
- **Maintains shape** of plant cells and plants

**Pro Tip: reagent = a reactant that participates in a chemical reaction*

2. Elements making up carbs, fats and proteins

Type of Nutrient	Carbohydrate	Fats	Protein

Atoms	C, H, O (1:2:1 ratio)	C, H, very few O	C, H, O, N, (S) *Pro Tip: Some proteins have S (the element Sulfur), but not all. If a question tells you the molecule has Sulfur, it is likely to be a protein.*
Basic unit	Monosaccharides • Glucose • Fructose • Galactose	Triglyceride (glycerol + 3 fatty acids)	Amino acid
Dimer (2 units)	Disaccharides • **Maltose** (Glucose + Glucose) • **Sucrose** (Glucose + Fructose) • **Lactose** (Glucose + Galactose) *Highlighted = reducing sugar	-	Dipeptide
Many units (several thousand)	Polysaccharides	-	Polypeptide

Functions (not exhaustive)	• Energy storage • Structural molecules, e.g. cellulose	• Energy storage • Thermal insulation • Protects vital organs • Forms cell membranes* • Solvent for fat-soluble vitamins • Secreted as oil on the skin to reduce water loss **Pro Tip: We intentionally do not say cell surface/plasma membrane here, as fats are part of membranes within cells too.*	• For the production of enzymes, antibodies and some hormones • Synthesis of new muscle fibres • Used to make new protoplasm
Condensation reaction*			

Pro Tip: The reverse of condensation reactions are **hydrolysis reactions.* ***[Memory Hack]***

- How to remember what the 3 disaccharides are made of?
  - The 3 disaccharides are all made of glucose + 1 of the 3 monosaccharides
  - **Lactose** = Glucose + Galactose (ga**lactose** has **lactose** in the name!)

- **Sucrose** = Glucose + Fructose (Fructose is found in Fruits, which are from plants. Plants also convert glucose into sucrose before transporting it in phloem. Therefore, associate sucrose with fructose as they are both linked to plants.)
- **Maltose** = Glucose + Glucose (once you know the other 2, glucose is the only blank option left for maltose)

**Pro Tip: There are 2'c's in -saccharides, be careful when spelling*

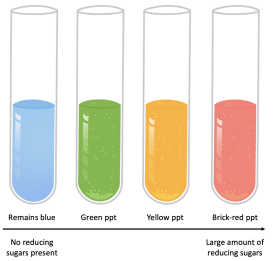
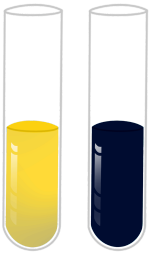
Reducing sugars

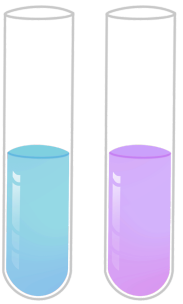
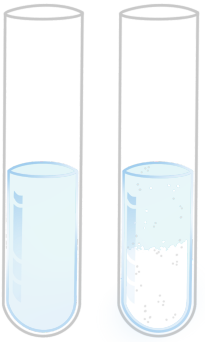
- All **monosaccharides** and **disaccharides** in our syllabus are **reducing sugars**, except sucrose.

Polysaccharides

Polysaccharide	Structure	Function	Found in
Cellulose	Thousands of glucose bonded together (FYI: straight chained)	Structural support	Plant cell walls
Starch	Thousands of glucose bonded together, bonds are different from those in cellulose (FYI: Branched)	Energy storage (plants)	Leaves/storage organs
Glycogen	More branched than starch	Energy storage (animals)	Liver/muscle cells

3. Food Tests

Test	Procedure	Results
Benedict's test [Reducing sugars]	**Liquid sample:** 1. Add $2cm^3$ of **Benedict's reagent** to an equal volume of the sample in a test tube and shake. 2. Heat water in a beaker until it starts **boiling** (bubbles vigorously). **Pro Tip: The water level in the beaker should be higher than that of the test tube.* 3. Place the test tube into a beaker of **already boiling water.** 4. Observe for colour change. **Solid sample:** 1. Add $2cm^3$ of **Benedict's reagent** to a finely cut sample in a test tube and shake. 2. (Remaining steps are the same as if sample were liquid.)	 (-) Solution remains blue (+) A brick-red/orange/green ppt is formed
Iodine test [Starch]	**Liquid sample:** 1. Place a few drops of the sample on a white tile. 2. Add a few drops of **iodine** to a sample, observe for colour change. **Solid sample:** 1. Add a few drops of **iodine** to a sample, observe for colour change.	 (-) Solution remains yellow-brown (+) Yellow-brown solution turns blue-black

Biuret test [Proteins]	**Liquid sample:** 1. Add $2cm^3$ of **sodium hydroxide** solution to an equal volume of sample and shake. 2. Add **1% copper (II) sulfate solution**, drop by drop (just a few drops), shaking after each drop. 3. Allow the mixture to stand for 5 minutes and observe for the colour change. **Solid sample:** 1. Add $2cm^3$ of **sodium hydroxide** solution to a finely cut sample and shake. 2. (Remaining steps are the same as if sample were liquid.) **Pro Tip: Biuret reagent/solution is an already prepared solution. Adding protein to it turns it violet.*	 (-) Remains blue (+) Turns violet/purple
Ethanol Emulsion test [Fats]	**Liquid sample:** 1. Add $2cm^3$ of **ethanol** to equal volume of sample and shake. 2. Add $2cm^3$ of **water** to the mixture, shake. **Solid sample:** 1. Add $2cm^3$ of **ethanol** to finely cut sample, shake and allow solids to settle. 2. Decant the ethanol into another test tube containing $2cm^3$ of **water**, shake.	 (-) Solution remains clear (+) Cloudy white emulsion formed

3. Biomolecules CAQs

Roles of Water

Q: Explain why water is important in living organisms. [5]

Functions of Biomolecules

Q: State the functions of carbohydrates in living organisms. [3]

Q: State the functions of fats in living organisms. [6]

Q: State the functions of proteins in living organisms. [4]

4. Enzymes

Learning Outcomes:

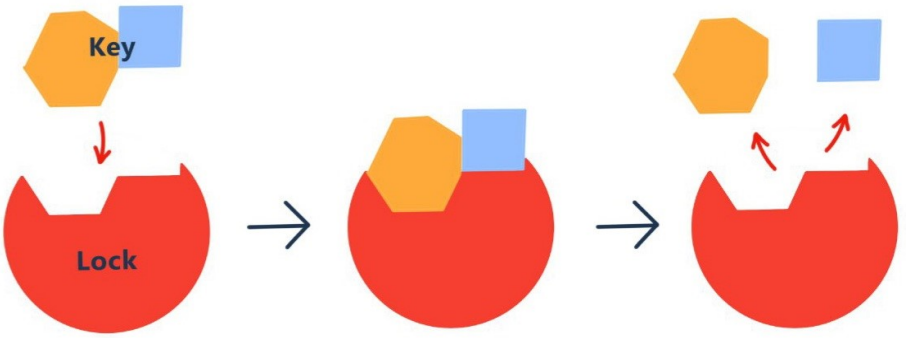
1. Explain the mode of action of enzymes using 'lock and key' hypothesis, including active site, activation energy, enzyme specificity
2. Effect of pH and temperature on enzyme-catalysed reaction
3. Bonus: Benefits of using enzymes
4. Bonus: Enzymes of the digestive system

Keywords:

- Biological catalysts, alternative pathway, activation energy, chemically unchanged
- Substrates, active site, specific three-dimensional structure, complementary
- Lock and key hypothesis, enzyme-substrate complex, optimum temperature/pH
- Kinetic energy, chance of collision
- Weak bonds, denature

1. Mode of action

- **Enzymes:** Biological **catalysts** that speed up chemical reactions by providing an **alternative pathway** of **lower activation energy**, and remain **chemically unchanged** after the reaction.
- **Activation energy:** The energy needed to start a chemical reaction.



Lock and Key hypothesis (Mode of Action)

- According to the **lock and key** hypothesis,

- a **specific** substrate (key) is **complementary** to and binds to the **active site** of the enzyme (lock), and bind,
- forming an **enzyme-substrate complex**.
- The enzyme then **catalyses** the reaction (by breaking/forming the bond in context)*
- After reaction, products are **no longer complementary** to the **active site**, hence they leave the **active site**.
- The enzyme remains **chemically unchanged** and can accept a new substrate.

**Pro Tip: If the question was on 'explain the mode of action of sucrase', state here that sucrase catalyses the reaction by breaking the bond between glucose and fructose*

[Memory Shortcut]

- Mode of action of enzymes [Be Careful Red Light Unchanged]
  - **B:** enzyme and substrate **B**inds
  - **C:** forming an enzyme-substrate **C**omplex
  - **R:** **R**eaction is catalysed
  - **L:** products **L**eave active site
  - **U:** enzyme remains chemically **U**nchanged

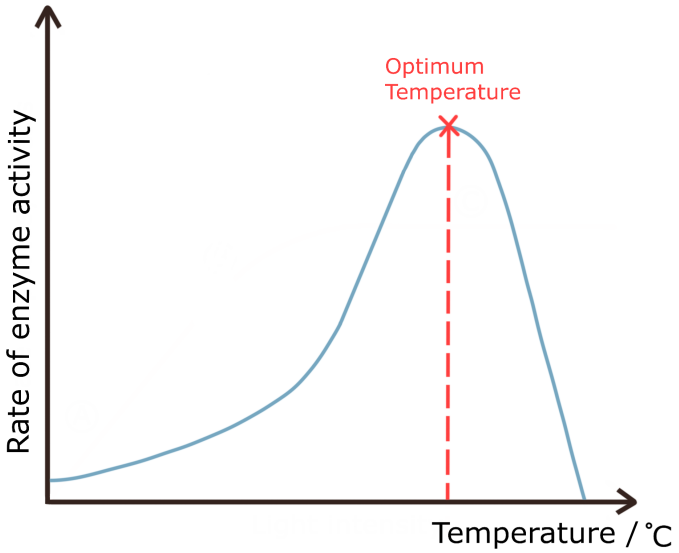
Characteristics of Enzymes

- **Protein** in nature
- Have a **specific three-dimensional (3D) structure**, only catalyse one type of reaction
- Has an **active site** that the substrate is complementary to
- Has an **optimum temperature** and **optimum pH** where rate of activity is highest

**Pro Tip: Each enzyme has its own preferred optimum temperature and pH, depending on its function.*

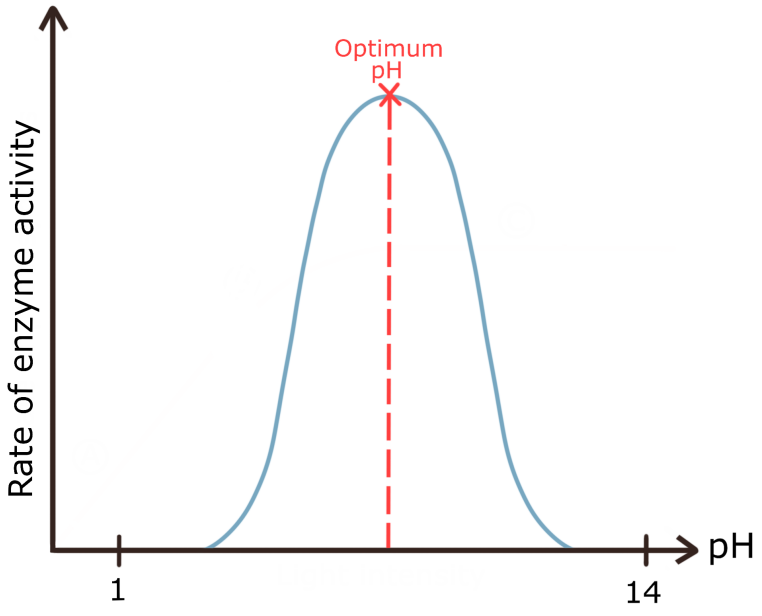
2. Effect of Temperature and pH

Effect of increasing temperature on enzyme activity



- As temperature increases from low until the **optimum temperature**, **kinetic energy** of enzyme and substrate molecules increases, increasing their **chances of collision**.
- **Enzyme-substrate complexes** form faster, and rate of reaction increases until the **optimum temperature**, where rate is highest.
- As temperature increases beyond **optimum temperature**, **weak bonds** within enzymes are broken, causing the enzyme to lose the shape of its **active site** and become **denatured**.
- The substrate can **no longer fit** into the **active site**, hence rate of reaction decreases sharply to 0.

Effect of pH on enzyme activity



- At pH 7, reaction rate is maximum as this is the enzyme's **optimum pH**.
- As pH moves further from pH 7, reaction rate decreases sharply. When pH moves too far from 7, weak bonds within the enzyme are broken,
- the enzyme loses the shape of its **active site** and becomes **denatured**.
- The substrate can **no longer fit** into the **active site**, hence rate decreases sharply until 0.

3. Bonus: Benefits of using enzymes

- As **catalysts**, they speed up reactions that would otherwise take a long time (saves time)
- Since enzymes remain **chemically unchanged** after reaction, only a small amount of them is needed (saves money/resources)
- Enzymes can **catalyse** reactions at lower temperatures than if they were to be done without enzymes (saves energy)
- Enzymes are **specific**, hence only the intended reaction will occur

**Pro Tip: Each of these are actually linking a characteristic of enzymes to a benefit*

4. Bonus: Enzymes of the digestive system

Enzyme	Produced by	Digests	Found in	pH of Location
Amylase (salivary)	Salivary glands	Starch --> Maltose	Saliva (Mouth)	7
Pepsin	Gastric glands	Proteins --> Short Polypeptides*	Stomach	2
Lipase (pancreatic)	Pancreas	Triglycerides --> Glycerol + Fatty acids	Small intestine	7-9
Amylase (pancreatic)		Starch --> Maltose		

Trypsin	Proteins --> Short Polypeptides*			
Sucrase	Epithelial cells	Sucrose --> Glucose + Fructose	Small intestine	7-9
Maltase		Maltose --> Glucose + Glucose		
Peptidases (**A**mino acids are products)		Short Polypeptides* --> Amino acids		
Lactase		Lactose --> Glucose + Galactose		
Lipase (Intestinal)		Triglycerides --> Glycerol + Fatty acids		

**Pro Tip: Short polypeptides is more accurate than just 'polypeptides', since it distinguishes between the length of the polypeptide (undigested proteins are folded polypeptides, giving this even more ambiguity). An even more specific term to use would be 'short peptides'.*

4. Enzymes CAQs

Important Definitions
Q: Define the term enzyme.

Q: Define the term activation energy.

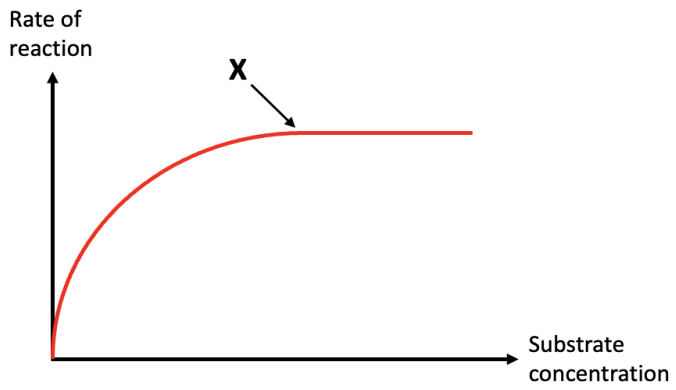
Enzyme Mode of Action
Q: Using the lock and key hypothesis, explain the mode of action of an enzyme. [5]

- **Related Questions:**
  - Q: Explain the mode of action of sucrase. [5]

Enzyme Activity and Temperature
Q: Explain how the rate of an enzyme-catalysed reaction may be affected by increasing temperature. [4]

- **Related Questions:**
  - Q: The temperature of the water bath for an enzyme-catalysed reaction was maintained carefully at 40°C. Explain why (assuming the enzyme is a human enzyme). [3]

Enzyme Activity and pH
Q: Explain how the rate of an enzyme-catalysed reaction may be affected by changes in pH (assuming the optimum pH of the enzyme in question is 7). [4]
Limiting Factor Questions



Q: Explain why the rate of reaction does not increase after point X, despite the substrate concentration increasing. [2]

Biological Washing Powders

Q: Biological washing powders (detergents) contain one or more enzymes. Suggest the advantages of using biological washing powders compared to those without enzymes. [4]

5. Nutrition in Humans

Learning Outcomes:

1. Main parts of the alimentary canal, related processes and enzymes involved (see topic 4 notes for enzymes)
2. Peristalsis
3. Structure and function of villi
4. Liver functions and its associated blood vessels
5. Effects of excessive alcohol consumption

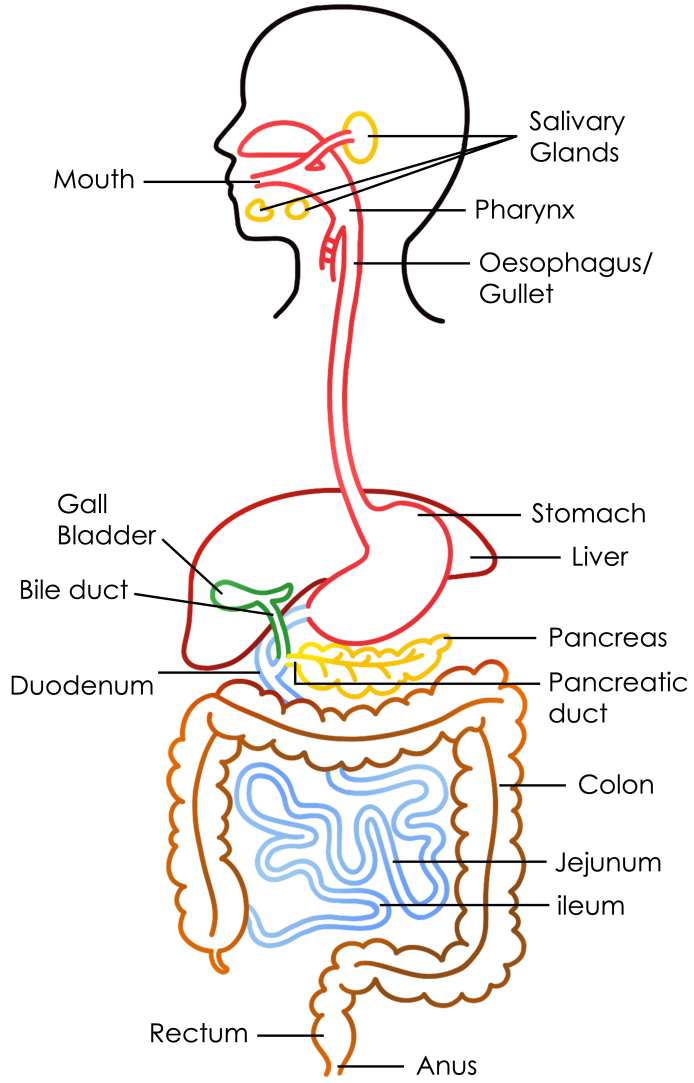
Keywords:

- Ingestion, digestion, absorption, assimilation, egestion
- Peristalsis, antagonistic
- Bile salts, emulsify, fat globules
- Protoplasm, digested food substances
- Deamination, detoxification, blood glucose concentration
- Addictive, depressant, reaction time, cirrhosis, haemorrhage, social responsibilities

1. Main parts of the alimentary canal and enzymes involved

Definitions of processes

1. **Ingestion:** The intake of food through the mouth.
2. **Digestion:** The physical or chemical breakdown of larger food molecules into smaller and soluble molecules that can be absorbed by body cells.
3. **Absorption:** The uptake of digested food substances into body cells.
4. **Assimilation:** Digested food substances are converted to new protoplasm or used for energy.
5. **Egestion:** The removal of undigested food waste from the body.



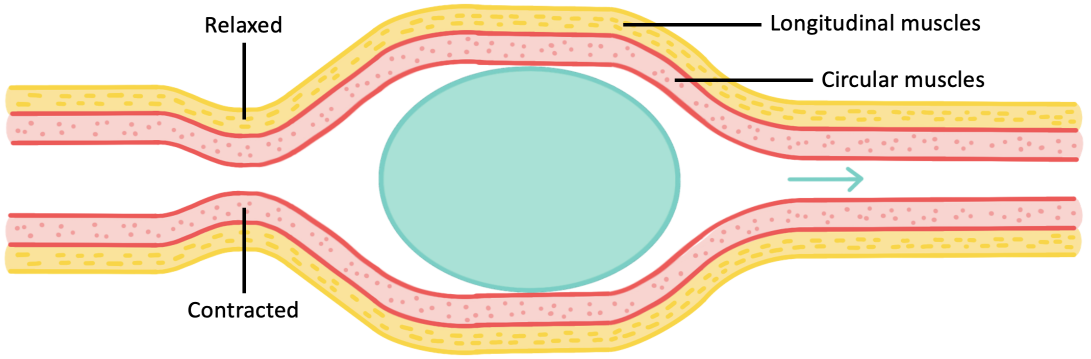
Part (Processes)	**Function**	**pH**	**Digestive enzymes**

Mouth (Ingestion, Digestion)	**Teeth:** • Chews food **(mechanical digestion)** • Breaks food into smaller pieces, increasing **SA:V** for enzymes to digest it faster **Salivary glands:** • Secrete **saliva** containing **salivary amylase**, breaks down **starch** into **maltose** **Tongue:** • Rolls food into a **bolus** to be swallowed • Mixes **saliva** with food	7	Salivary amylase
Oesophagus /Gullet	• Pushes food from mouth into the stomach	7	-
Stomach (Digestion)	• **Gastric glands** secrete **gastric juice** containing **hydrochloric acid** and **pepsin** • **Pepsin** breaks down **protein** into short **polypeptides** • Stomach **churns** food, breaking up food **(mechanical digestion)** and mixing it with gastric juice **Pro Tip: Gastric glands actually release pepsinogen, which is then activated by H+ ions in the acidic environment into pepsin. For simplicity, we just say gastric glands secrete pepsin.*	2	Pepsin

Small Intestine (Digestion, Absorption,
 	
Assimilation)
	Small intestine
	• Is **very long**, giving **more time** for digested food substances to be absorbed
	• Has many **folds**, increasing **SA:V**
	• Parts of the small intestine **[DJI]**
	  ◦ **D**uodenum: Mainly digestion, some absorption
	  ◦ **J**ejunum: Some digestion, some absorption
	  ◦ **I**leum: Some digestion, mainly absorption
	
	• **Epithelial cells** of the small intestine secrete **SMaLL** enzymes
	  ◦ **S**ucrase: **sucrose** -> glucose + fructose
	  ◦ **M**altase: **maltose** -> glucose + glucose
	  ◦ Peptidases:short **polypeptides** -> **a**mino acids
	  ◦ **L**actase: **lactose** -> glucose + galactose
	  ◦ Intestinal/epithelial **L**ipase: **fats/triglycerides** -> glycerol + fatty acids
		7-9	(Epithelial, **SMaLL**): Sucrase,
			
			Maltase, Peptidases Intestinal Lipase, Lactase

Small Intestine	**Gall bladder** • Stores **bile** (an alkaline yellow-green liquid) • Bile is secreted into the **duodenum** via the **bile duct** during digestion • **Bile salts** in bile **emulsify** large fat droplets into smaller ones, increasing **SA:V** for **lipase** to digest **triglycerides** into **glycerol** and **fatty acids** **Pancreas** • **Pancreas** secretes **pancreatic juice** (alkaline) containing **LAT** enzymes into duodenum ◦ Pancreatic **L**ipase: **fats/triglycerides** -> glycerol + fatty acids ◦ Pancreatic **A**mylase:starch -> maltose ◦ **T**rypsin: **proteins** -> short polypeptides **Pro Tip: Pancreatic juice actually contains trypsinogen. Once in the small intestine, enterokinase produced by epithelial cells activates trypsinogen to trypsin. For simplicity, we just say pancreatic juice contains trypsin.*	7-9	(Pancreas, **LAT**): Pancreatic Lipase, Pancreatic Amylase, Trypsin
Large Intestine/Colon (Absorption)	• Has many **folds**, increasing **SA:V** • Large intestine absorbs **water** and **mineral salts** • **Undigested** food (**faeces**) are temporarily stored in the **rectum**	7	-
Anus (Egestion)	• **Faeces** is expelled	7	-

2. Peristalsis



Definition (in digestion): Rhythmic, wave-like muscular contractions in the wall of the alimentary canal that moves food forward

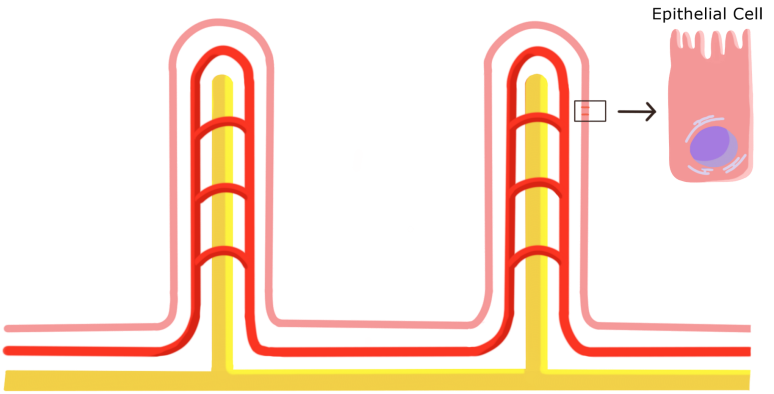
- Peristalsis propels food forward ensuring it moves in the right direction,
- also mixes food with digestive juices

How it works:

- At the region before the food mass, **circular muscles** contract while **longitudinal muscles** relax, narrowing the **lumen** and pushing food forward
- At the food mass, **circular muscles** relax while **longitudinal muscles** contract, widening the **lumen**, allowing food to pass through easily
- The above also applies for the region just in front of the food mass
- **Circular muscles** and **longitudinal muscles** are **antagonistic** (i.e. when one contracts, the other relaxes)

**Pro Tip: Peristalsis occurs throughout the alimentary canal, not just in the oesophagus*

3. Structure and function of villi



Where digested substances are absorbed:

- **Glucose** and **amino acids** diffuse into **blood capillaries** of **villi** to be transported to the **liver**.
- **Glycerol** and **fatty acids** diffuse into the **epithelial cells** of **villi**, where they **reform** into **triglycerides**, then enter the **lacteal** as **fat globules**.

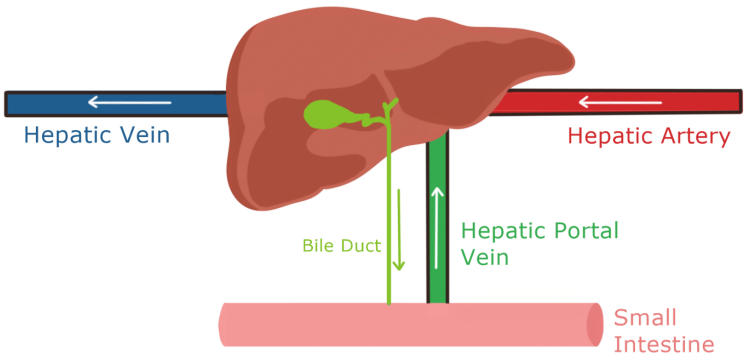
**Pro Tip: Villus is singular, villi is plural.*

Adaptations for fast absorption:

- **Villi** are **finger-like projections** in the small intestine, increasing **SA:V**
- Are lined with a **one-cell-thick** layer of **epithelial cells**, minimising **distance** digested food substances have to travel
- **Epithelial cells** have **microvilli**, further increasing **SA:V**
- Absorbed substances that enter the **lacteal** and **blood capillaries** are constantly transported away, maintaining a steep **concentration gradient** between the **lumen** and **villi** to maximise **diffusion** rate of digested substances into villi.

**Pro Tip: After diffusion has reached equilibrium, active transport is needed to further absorb digested substances*

4. The Liver



What happens to absorbed digested food substances:

- **Hepatic portal vein** transports **glucose** and **amino acids** from small intestine to the **liver**
- **Glucose** is converted to **glycogen** and stored in the **liver** and **muscles**, or transported around the body for cells to uptake and use for energy
- **Amino acids** are transported around the body and taken up by cells during **assimilation**, to build new cell parts/**protoplasm**
    - **Deamination:** The process where **amino groups** are removed from **excess amino acids** and converted into **urea**, in the liver.
- **Fats** are transported around the body to be stored/used for energy

Functions of liver	Description
Bile production	The liver **produces bile**, which is stored in the **gall bladder**.
Iron storage	**Haemoglobin** from old RBCs are broken down, the **iron** from which is stored in liver, to be used for making new red blood cells.
Blood Glucose regulation	When **blood glucose concentration** is too high, liver converts **glucose** to **glycogen** in response to **insulin**. When **blood glucose concentration** is too low, liver converts **glycogen** to **glucose** in response to **glucagon**.
Toxins (Detoxification)	**Detoxification** is the process where **harmful substances** (e.g. hydrogen peroxide, alcohol) are converted into **harmless** ones

Amino acids (Deamination)	The process where **amino groups** are removed from **excess amino acids** and converted into **urea**, in the liver.
Protein synthesis	The liver produces blood proteins such as **prothrombin** and **fibrinogen**

[Memory Shortcut]

- **BIG TAP** for functions of the liver
  - **B**ile production
  - **I**ron storage
  - **G**lucose regulation
  - De**T**oxification
  - **A**mino acids --> Urea (Deamination)
  - **P**rotein synthesis

5. Effects of excessive alcohol consumption

Short term effects:

- Alcohol is a **depressant**, meaning it slows **brain functions**, increases **reaction time**
- Reduces **self-control**, increasing tendency to make irrational decisions

Long term effects:

- **Addictive**, leading to neglect of **social responsibilities**
- Stimulates acid secretion in stomach, increasing risk of **stomach ulcers**
- Liver is overworked, cells start dying, which can lead to liver **cirrhosis** (formation of fibrous tissue), **haemorrhage** (liver bleeding), liver **failure**

5. Nutrition in Humans CAQs

Important Definitions
Q: Define the term ingestion.
Q: Define the term digestion.
Q: Define the term absorption.
Q: Define the term assimilation.
Q: Define the term egestion.

Q: Define peristalsis. (in the context of digestion)
Q: Define deamination.
Q: Define detoxification.
Digestion of Various Biomolecules
Q: Describe the digestion of protein in the body. [2]
Q: Describe the digestion of carbohydrates in the body. [4]
Q: Describe the digestion of fats in the body. [3]

- **Related Questions:**
  - Q: Describe how bile aids in fat digestion. [2]
  - Q: Describe the roles of enzymes in human digestion. Give examples in your answer. [5]

Adaptations of Villi
Q: Villi are found in the digestive system. Describe the structure and function of a villus. [6]

- **Related Questions:**
  - Q: Describe how villi are adapted to absorb digested food. [4]
  - Q: Describe how the small intestine is adapted for absorption of digested food substances. [4]

Functions of Liver
Q: Describe the functions of the liver. [6]
Effects of Alcohol
Q: State the short term and long term effects of excessive alcohol consumption. [4]
Q: Alcohol is a depressant. Explain why it is dangerous to drive under the influence of alcohol. [3]

6. Transport in Humans

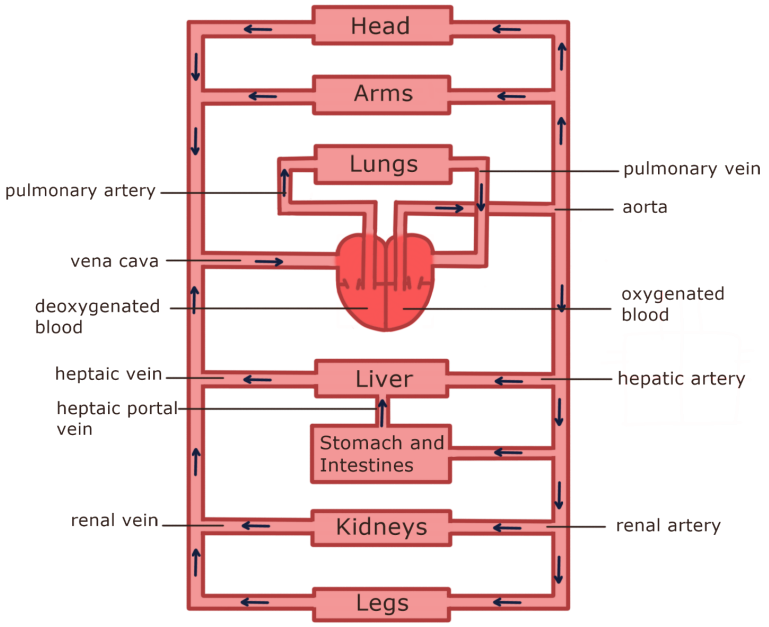
Learning Outcomes:

1. Main blood vessels in the body
2. The role of blood (transport, defence) and its components
3. Blood groups and their compatibilities
4. Structure and function of arteries, capillaries and veins
5. Transfer of materials between capillaries, tissue fluid and cells
6. Structure and function of heart + types of circulation
7. Cardiac cycle
8. Coronary heart disease

Keywords:

- Oxygenated, deoxygenated
- Insoluble, coagulation, clot, universal donor, universal recipient
- Tissue rejection, antibody, neutralises, antigen, agglutination
- Biconcave, bell-shaped
- Arteries, arterioles, capillaries, venules, veins
- Tissue fluid, one-cell-thick, endothelium
- Systemic, pulmonary circulation, repressurised, gas exchange tissues
- Blood pressure, backflow, semi-lunar valves, systole, diastole
- Coronary, atherosclerosis, fatty deposit, lumen, thrombosis

1. Main blood vessels in the body



2. The role of blood (transport, defence) and its components

Component	Structure/Appearance	Function
Plasma (55%)	Made of 95% water	Carries **dissolved** substances in the blood such as glucose, amino acids, mineral salts, O_2 and CO_2, waste, hormones and plasma proteins
Red Blood Cells	**Biconcave**	Increases **SA:V** for O_2 to **diffuse** in/out of the cell faster
	Lacks a nucleus	More space to pack in more **haemoglobin**
	Flexible	To squeeze through tiny **capillaries**, in which, it can become **bell-shaped**, further increasing **SA:V**

White Blood Cells - Phagocytes	• Can have a lobed nucleus • Can have tendril-like protrusions	**Phagocytosis:** Where phagocytes engulf **foreign particles** and destroy them
White Blood Cells - Lymphocytes	Have a large nucleus	Produce **antibodies**, which: • Cause foreign particles to **clump** together **(agglutination)**, promoting **phagocytosis** • Bind to and **neutralises** harmful **toxins** that pathogens produce **Tissue rejection:** When **lymphocytes** produce **antibodies** against a **transplanted** organ
Platelets	Membrane-bound bodies (Not considered cells)	Promotes blood clotting **(coagulation)**

[Memory hack]

- How to remember which is coagulation and agglutination
  - **A**gglutination: Due to **A**ntibodies in the blood
  - **C**oagulation: blood **C**lotting

How blood clots (Coagulation)

- When blood vessels are damaged, **damaged tissues** and **platelets** release **Thrombokinase**.
- **Thrombokinase** converts **Prothrombin** to **Thrombin,** in the presence of **Calcium ions.**
- **Thrombin** then converts **Fibrinogen** into **Fibrin**, forming **long insoluble Fibrin threads**,
- Which trap **red blood cells,** forming a **clot** at the site of injury.

[Memory hack]

- Blood clotting process:
  - **K:** starting point is thrombo**K**inase
  - **F:** end point is **F**ibrin
  - **C:** this requires the presence of **C**alcium ions

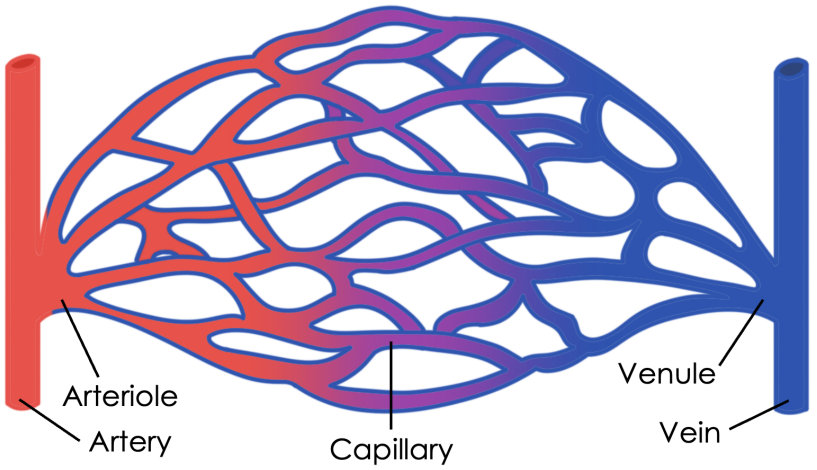
3. Blood groups and their compatibilities

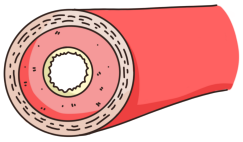
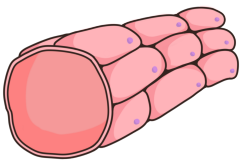
	A	B	AB	O
Red Blood Cell Type				
Antibodies in Plasma	 Anti-B	 Anti-A	None	 Anti-A and Anti-B
Antigens on Red Blood Cell	 A antigen	 B antigen	 A and B antigens	None
Who can donate to this blood group	A, O	B, O	A, B, AB, O	O

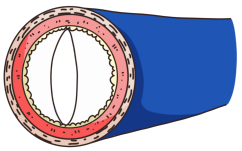
How to remember intuitively:

- The body will naturally produce **antibodies** of the other blood types, except against its own RBC's **antigens** (or it will kill its own RBCs!)
- If you transfer blood into a recipient who does not have **antibodies** against the donor's blood type, the transfusion will be safe.
- **Special blood types:**
  - AB is the **universal acceptor** - can receive from all, but cannot donate to any
  - O is the **universal donor** - can donate to all, but cannot receive from any

4. Structure and function of arteries, capillaries and veins



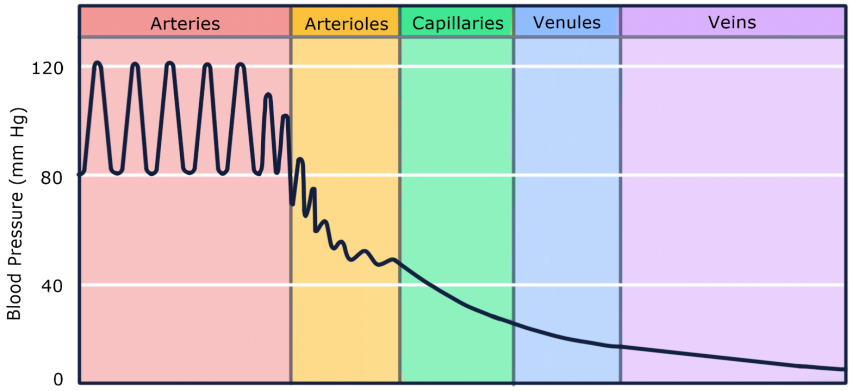
Type of vessel	Structure	Function
Arteries		• Carries blood **away** from the heart • Usually carry **oxygenated** blood, except for **pulmonary artery** • Have **thick**, elastic **muscular** walls to **accommodate** and **maintain** the **high blood pressure** exerted by the heart • Arteries branch out into **arterioles,** then into capillaries
Capillaries		• Are present near almost every cell in the body • Walls are made of endothelial cells • Endothelium is **one-cell thick**, to minimise **diffusion distance**, increasing **diffusion** rate • Capillaries **branch repeatedly,** increasing **SA:V**, hence increasing rate of **diffusion** of substances in and out of them

Veins		• Capillaries converge into **venules,** then into veins • Veins carry blood **back to** the heart • Usually carry **deoxygenated** blood, except for **pulmonary vein** • Have **semi-lunar valves** to prevent **backflow** of blood, which is likely due to low **blood pressure** in veins • Larger **lumen** to reduce **resistance** to bloodflow • **Thinner** elastic and muscular walls as **blood pressure** is lower • Contraction of **skeletal muscles** exerts pressure on veins, moving blood along more quickly

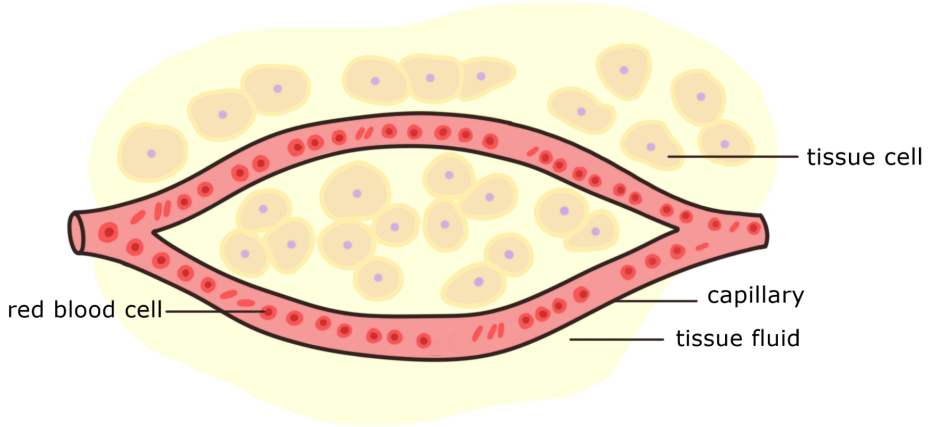
**Pro Tip: The innermost layer of all blood vessels is the endothelium, which is the same tissue that makes up capillary walls.*

Graph of Blood pressure against location

- The further from the **aorta**, the lower the blood pressure due to **loss of energy**
- In the **arteries** and **arterioles**, blood pressure **fluctuates** as they are directly connected to the **left ventricle**. Blood pressure increases during **ventricular systole**, and decreases during **ventricular diastole**.

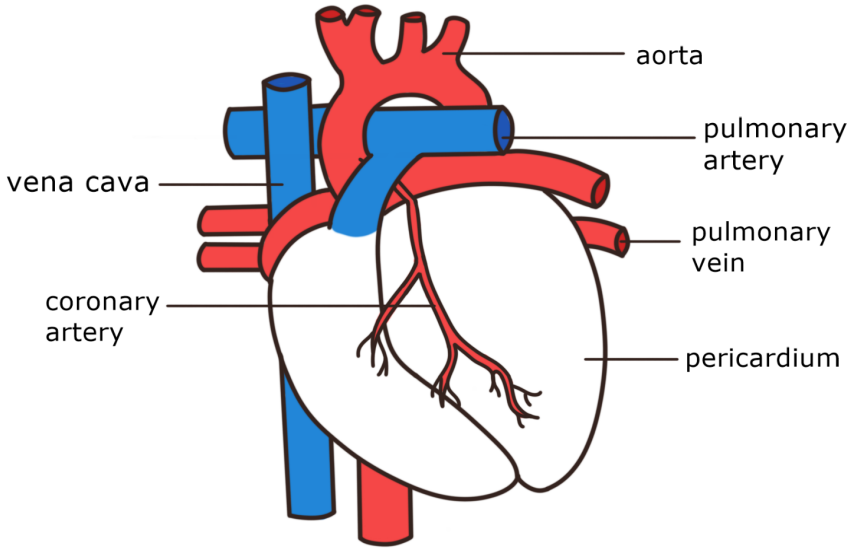


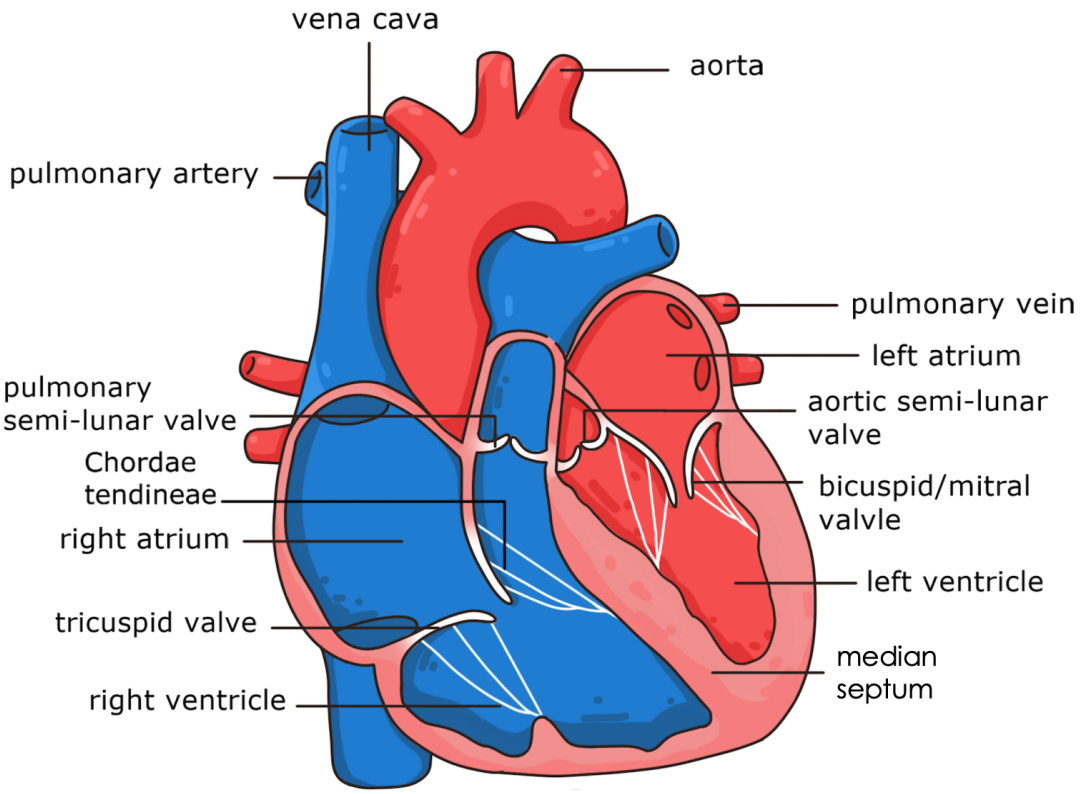
5. Transfer of materials between capillaries, tissue fluid and cells



- **Capillaries** bring **nutrients** and **O_2**, which **diffuse** from the **blood plasma** to the **tissue fluid**
- These then **diffuse** from **tissue fluid** into cells
- Conversely, **waste products** and **CO_2 diffuse** out of the cells into the **tissue fluid**, then into the **blood plasma** of capillaries.

6. Structure and function of the heart + types of circulation





[Memory hack]

- How to remember bicuspid valve is on the left side of the heart, tricuspid is on the right
  - We always read words from **L**eft to **R**ight
  - Bicuspid valve has **2** flaps (hence "bi-"), tricuspid valve has **3** flaps (hence "tri-")
  - So remember Left --> 2, Right --> 3.

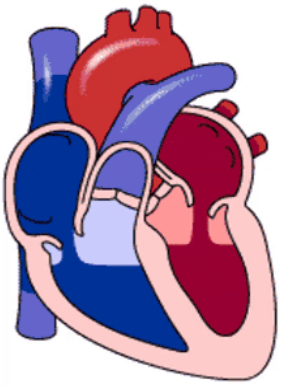
Parts of the heart	Function
Atria	• Have thinner walls then ventricles
Ventricles	• Left ventricle has thicker **muscular walls** as it has to generate **high pressure** to pump blood around entire body • Right ventricle has **thinner muscular walls**, as it does not need to generate very high pressure to pump blood to **lungs** **Pro Tip: Use ventricular thickness to identify which side of the diagram is right/left. Usually, diagrams are a mirror image.*
Chordae tendineae	• Attaches valves to the heart walls
Medium septum	• Separates left and right sides, so deoxygenated and oxygenated blood stay separate
Pericardium	• Is a double membrane that surrounds the heart, reducing friction when the heart beats

Type of circulation	Single	Double
Definition	Blood passes through heart once in complete circuit	Blood passes through heart twice in complete circuit

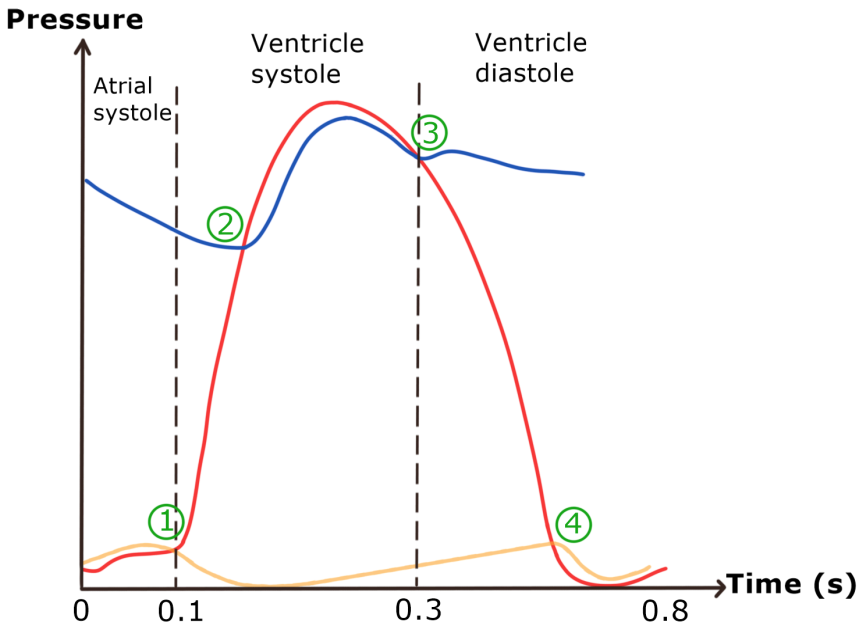
Advantages/ Disadvantages	Blood **loses pressure** significantly after passing through **gas exchange tissues**	• Blood is **repressurised** after passing through heart the second time, so blood is pumped to the rest of the body at **high pressure**, hence blood is distributed **faster** • Advantages of **pulmonary circulation** (see table below)
Examples	Fish	Mammals

Stage of circulation	Features
Pulmonary (To the lungs)	• As walls of RV has thinner **muscular walls**, blood is pumped at a **lower pressure**, hence moves at **lower speed** • Lower speed allows **more time** for blood to get rid of more CO_2 and take in more O_2, more efficient gas exchange
Systemic (To the rest of the body)	• As LV has thicker **muscular walls**, blood is pumped at **high pressure**, hence blood moves at **higher speed**, to be quickly distributed to the rest of the body

7. Cardiac Cycle



(Link for the above GIF to visualise heartbeat: https://media.tenor.com/dO9JYv5q8xsAAAAC/heart-heart-pumping.gif)



From Graph:

(1) Atrioventricular valves close

(2) Semi-lunar valves open

(3) Semi-lunar valves close

(4) Atrioventricular valves open

- **Systole** = contraction
- **Diastole** = relaxation
- RA = **Right atrium,** LA = **Left atrium,** RV = **Right ventricle,** LV = **Left ventricle**

Atrial systole (+Ventricular diastole)

- Both atria contract, pushing blood past the **atrioventricular valves** into the ventricles
  - **LA** pumps blood past the **mitral/bicuspid valve** to the **LV**
  - **RA** pumps blood past the **tricuspid valve** to the **RV**

**Pro Tip: AV valves were already open before atrial systole, as they opened near the end of ventricular diastole.*

Ventricular systole (+Atrial diastole)

- Ventricles contract

    - **Pulmonary semi-lunar valve** is forced open, blood moves from **RV** to the **pulmonary artery**, and is sent to the lungs.
    - **Aortic semi-lunar valve** is forced open, blood moves from **LV** to the **aorta**, and is sent to the rest of the body.
- At the same time, **atrioventricular valves** close, preventing **backflow** of blood from ventricles to the atria.
    - This causes the first '**lub**' sound.
- Meanwhile, atria relax,
    - Blood from **pulmonary vein** flows into **LA**
    - Blood from **vena cava** flows into **RA**

Ventricular diastole (+Atrial diastole)

- Ventricles relax
    - **Semi-lunar valves** close, preventing **backflow** of blood from the **pulmonary artery** and **aorta** back into the ventricles.
    - This causes the second '**dub**' sound.
- Blood fills the relaxed atria and ventricles again

- Typical duration of each cardiac cycle: 0.8s = 75 beats per min
- **Pro Tip: When the heart pumps faster, such as during exercise, the duration of each cardiac cycle will be shorter.*

8. Coronary artery disease

- **Atherosclerosis:** The disease where fatty deposits accumulate on the inner walls of arteries, narrowing the lumen.
- **Coronary artery:** An artery that branches out of the aorta, sending oxygen and nutrients to the heart muscles.
- **Coronary artery disease:** When atherosclerosis occurs in a coronary artery.

Heart attack

- If a **fatty deposit** ruptures in a **coronary artery**, a **blood clot** (**thrombosis** = a blood clot in a blood vessel) could form, blocking the **artery.**
- Blood with **oxygen** and **nutrients** cannot reach the **heart muscles**, which **die**, resulting in a **heart attack**.

Preventive measures

- Adopt a diet low in **saturated fats** and **cholesterol**
- Not smoking

    - **Carbon monoxide** in cigarette smoke damages the **endothelium**, increasing rate **fatty deposits** accumulate.
    - **Nicotine** stimulates **adrenaline** release, increasing **blood pressure**, which also increases the rate **fatty deposits** accumulate
- Stress management
- Regular exercise

6. Transport in Humans CAQs

Important Definitions
Q: Define the term atherosclerosis.
Advantages of Double Circulation
Q: Describe the advantages of having double circulation in mammals. [5]

Route Taken By Blood
Q: Describe the route taken by the blood from the intestine to the kidney. List the major blood vessels and organs involved. [4]

- **Related Questions:**
  - Q: Explain how a drug injected into rats was transported to the heart muscle. [4]

Blood Vessel Structures
Q: Explain the differences in the structures of arteries and veins, with reference to their functions. [6]

Capillary Adaptations
Q: Explain how capillaries are adapted for their function. [4]

From Capillaries To Cells
Q: Describe how substances move between capillaries and cells. [3]
Blood Flow in Veins
Q: Blood has near zero pressure when it reaches veins. Explain how blood returns to the heart from the veins. [2]

Red Blood Cells
Q: Explain how red blood cells are adapted to their function. [3]

White Blood Cells
Q: Describe the role of white blood cells in protecting the body from disease. [3]

Clotting of Blood (Coagulation)
Q: Explain how a blood clot is formed. [4]

Blood Type Incompatibility
Q: What will happen if a patient with blood group O is given a transfusion of blood type AB? [3]

- **Related Questions:**
  - Q: Explain what causes the incompatibility of blood between certain donors and recipients. [2]

  - Q: Describe and explain the undesirable consequence to the recipient when the blood type is not compatible. [2]

Valve Opening/Closing
Q: Explain how the (bicuspid) valve opens. [2]
Q: Explain how the (aortic semi-lunar) valve closes. [2]

- **Related Questions:**
  - Q: State what happens when the pressure in the atrium in higher than the pressure in the ventricle.

  - Q: Describe how blood from the lungs is forced through the heart into the aorta.

Coronary Artery Disease
Q: Explain how a heart attack usually occurs. [3]

- **Related Questions:**
  - Q: Sometimes blood clots can form inside a blood vessel and can be carried in the blood to the brain. The arteries in the brain may become blocked by the clot. Suggest how this blockage may affect the brain.

7. Nutrition in Plants

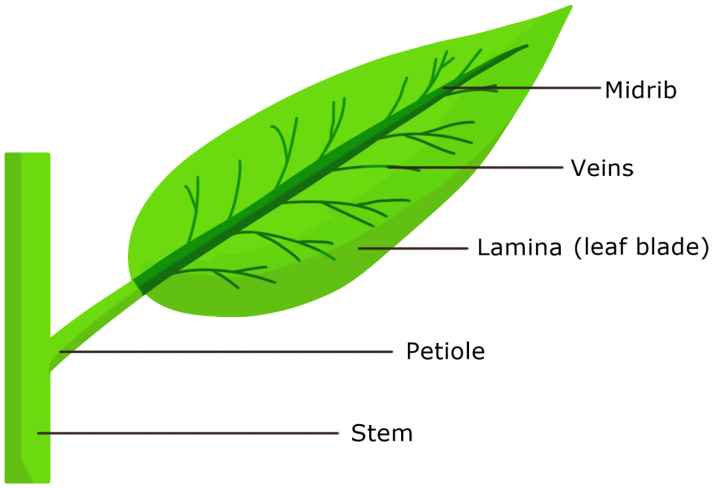
Learning Outcomes:

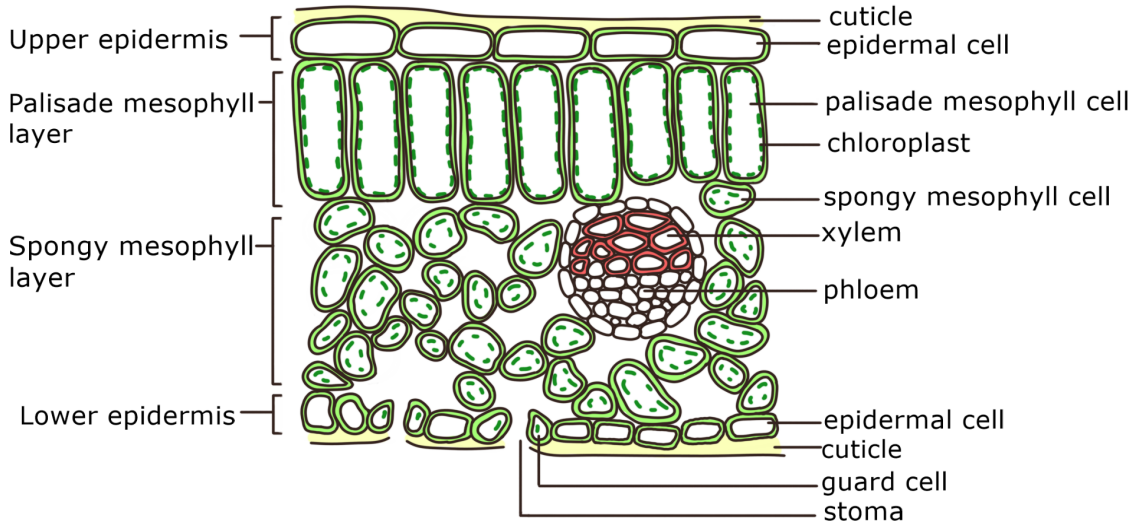
1. Structure of a dicotyledonous leaf
2. Photosynthesis
3. Factors affecting rate of photosynthesis: light intensity, CO_2 concentration, temperature
4. Bonus: Procedure for leaf starch test in experiment

Keywords:

- Waxy cuticle, intercellular air spaces, thin film of moisture
- Light energy, chlorophyll, chemical energy, byproduct
- Photolysis, hydrogen atoms, reduce
- Cylindrical, vertically arranged, irregularly shaped
- Gaseous exchange, turgid
- Light intensity, limiting factor

1. Structure of a dicotyledonous leaf





Part of leaf	Structure and Function
Waxy Cuticle	• **Transparent**, allows light to reach **mesophyll cells** for **photosynthesis** to occur • **Waterproof**, reduces water loss via **evaporation** from leaf surfaces
Upper Epidermis/ Lower Epidermis	• Both layers are made of closely packed **epidermal cells** and produce the **waxy cuticle** • Upper epidermis does not have any **chloroplasts** • Lower epidermis has **chloroplasts** only in the **guard cells**

Stoma *(pl. Stomata)*	• Tiny openings formed by two **guard cells**, which allow **gaseous exchange** to occur
	• Stoma size is controlled by **guard cells**:
	  ◦ In the presence of light, guard cells **photosynthesise**, forming **glucose**, which is used to release **energy.**
	  ◦ This energy is used to pump **potassium ions** into the cells, lowering their **water potential.**
	  ◦ Water flows in via **osmosis,** making the cells **turgid** and they **change shape**, opening the **stomata.**

Palisade Mesophyll Layer	• Just under upper epidermis, so they can receive the most **sunlight** for maximum **photosynthesis**. • Contain **many chloroplasts**, so more **photosynthesis** can be carried out per cell • **Long, cylindrical** and **vertically** arranged, so that many of them can be packed together, increasing the total amount of light absorbed by their **chloroplasts**
Spongy Mesophyll Layer	• Fewer chloroplasts than palisade mesophyll cells • Consists of **irregularly** shaped cells that have **large intercellular air spaces** between cells
Intercellular Air spaces	• Mesophyll cells are coated with a **thin film of moisture**, which allows **CO_2 to dissolve** in it before **diffusing** into mesophyll cells. • **Intercellular air spaces** have large **SA:V**, for **carbon dioxide** and **oxygen** to quickly **diffuse** in and out of mesophyll cells
Vascular bundle	<u>Consists of:</u> • **Xylem:** Brings water and mineral salts absorbed from the soil from the roots to leaves for photosynthesis • **Phloem:** Translocation of food made by the leaves to the rest of the plant

Leaf shape	• Thin and wide **lamina** increases **SA:V** of the leaf, maximising light absorbed for **photosynthesis**. • Being thin decreases the **diffusion distance** for gases to reach all **mesophyll cells** quickly, • and allows light to easily **penetrate** through the leaf to reach all **mesophyll cells**.

2. Photosynthesis

$$\text{Carbon dioxide + Water} \xrightarrow[\text{Chlorophyll}]{\text{Light Energy}} \text{Glucose + Oxygen}$$

$$6CO_2 + 6H_2O \xrightarrow[\text{Chlorophyll}]{\text{Light Energy}} C_6H_{12}O_6 + 6O_2$$

Definition: The process whereby carbon dioxide and water are converted into glucose and oxygen, in the presence of light energy and chlorophyll.

Light stage:

- **Light energy** is absorbed by **chlorophyll**, then converted into **chemical energy**
- **Photolysis** of water occurs: **water** is split into **hydrogen** and **oxygen** atoms, forming O_2

Dark stage:

- Using **hydrogen atoms** and **chemical energy** obtained from the light stage, CO_2 is **reduced** to form **glucose**
- **Glucose** can be stored as other carbohydrates like **starch**, or converted to other molecules like **fats** and **amino acids**.

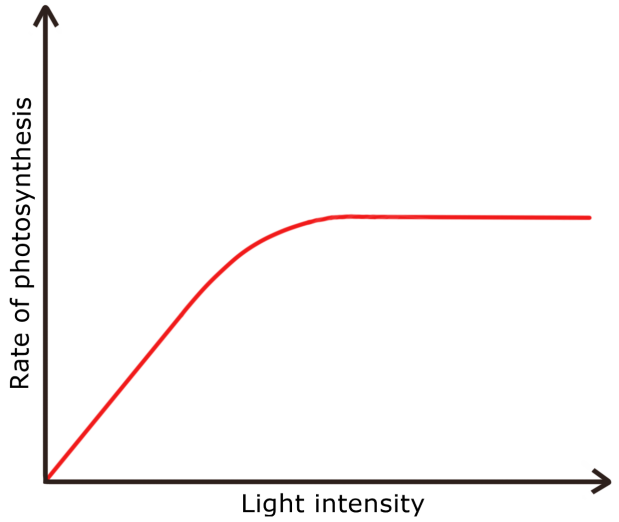
**Pro Tip: Enzymes are involved in both the light and dark stages*

3. Factors affecting rate of photosynthesis: light intensity, CO_2 concentration, temperature

Limiting factor: A factor that directly affects the process if its quantity is increased

Light intensity

- As light intensity increases, more **light energy** is absorbed by **chlorophyll** and converted into **chemical energy**, increasing **photosynthesis** rate.
- At very high light intensity, further increasing it has **no effect** on rate. Light intensity is **no longer a limiting factor** (some other factor is limiting).



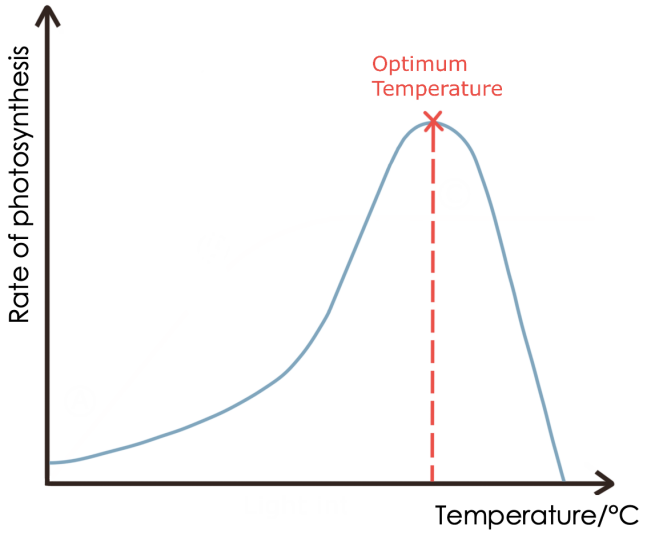
CO_2 concentration

- As CO_2 concentration increases, there is more CO_2 available to be **reduced** into **glucose**, increasing **photosynthesis** rate.
- At very high CO_2 concentration, increasing it further has **no effect** on rate. CO_2 concentration is **no longer a limiting factor** (some other factor is limiting).

**Pro Tip: Atmospheric concentration is around 0.03-0.04%, while concentration where CO_2 no longer becomes limiting is 0.13% onwards.*

Temperature

- Since **enzymes** are involved in photosynthesis, the photosynthesis-temperature graph looks the **same** as an enzyme-temperature graph.



4. Bonus: Procedure for leaf starch test in experiments (useful for practical)

- Place plant in dark room for 2 days, this **de-starches** the plant
- Carry out the experiment (e.g. whether photosynthesis works if leaf is placed in a sealed bag)
- Place the leaf in **boiling water** for 2min to kill the cells, **stopping further photosynthesis**.
- Place the leaf in a boiling tube with **ethanol** into boiling water bath, **removing chlorophyll** so that the green colour of chlorophyll does not affect any colour change later on
- Place leaf into **boiling water** for 1 min to **soften the leaf** and **remove alcohol**
- Add a few drops of **iodine** onto the leaf to **test for starch**

**Pro Tip: Variegated leaves which have a white outer layer will only have starch on the inside when tested.*

7. Nutrition in Plants CAQs

Important Definitions
Q: Define the term photosynthesis.

Role of Chlorophyll
Q: Describe the role of chlorophyll in photosynthesis. [2]

Process of Photosynthesis
Describe how light energy is converted to chemical energy and stored as carbohydrates in plants. [3]

- **Related Questions:**
  - Q:Describe the process of photosynthesis. [3]

Temperature and Photosynthesis
Q: Describe and explain the effect of temperature on photosynthesis from 0°C to 60°C. [6]

Increasing CO2 vs Photosynthesis
Q: Explain how increasing CO2 concentration affects the rate of photosynthesis. [2]

Increasing light intensity vs Photosynthesis
Q: Explain how increasing light intensity affects the rate of photosynthesis. [2]

- **Related Questions:**
  - Q: Suggest why light is a major factor affecting the growth rate of the trees.

Stomata
Q: The stomata of most plants stay open in daylight. Explain why having stomata open in daylight is an advantage to plants. [2]
Stomata size

Q: Describe how guard cells control the movement of substances in and out of the leaf. [4]

8. Transport in Plants

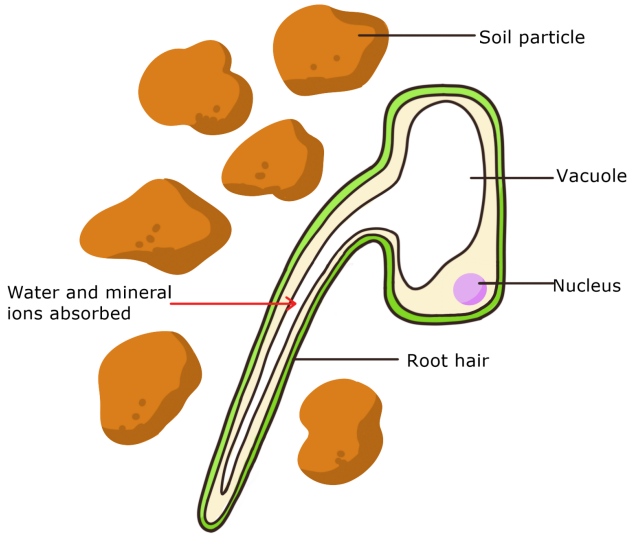
Learning Outcomes:

1. Root hair cells
2. Xylem and phloem: positions throughout plant and their function
3. Outline how water is transported from roots to leaves
4. Effects of temperature, light intensity, humidity and wind of transpiration rate
5. Wilting
6. Bonus: Adaptations to reduce transpiration rate

Keywords:

- Water potential, mineral salts
- Lignified, pits, collapse, end walls, unobstructed flow, maturity, protoplasm
- Translocation, manufactured food substances, sap
- Unidirectional, bidirectional, porous
- Root pressure, capillary action, transpiration, transpiration pull
- Intercellular air spaces, thin film of moisture, evaporates, water vapour
- Humidity, air movement, more/less steep concentration gradient
- Wilting, leaf surface area

1. Root hair cells

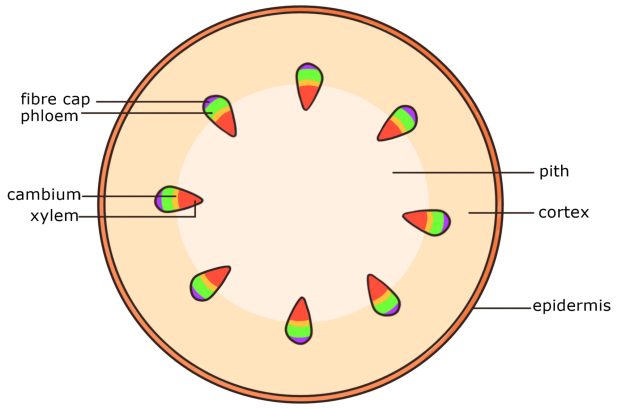


Feature of root hair cells	Function

Have a **long** and **narrow** root hair	Increases **SA:V** for faster absorption of water and mineral salts
Contain many **mitochondria**	More **cellular respiration** to meet high **energy** demand required for **active transport** of mineral salts
Vacuole has high concentration of mineral salts	Creates a region of low **water potential** for water to enter via **osmosis**

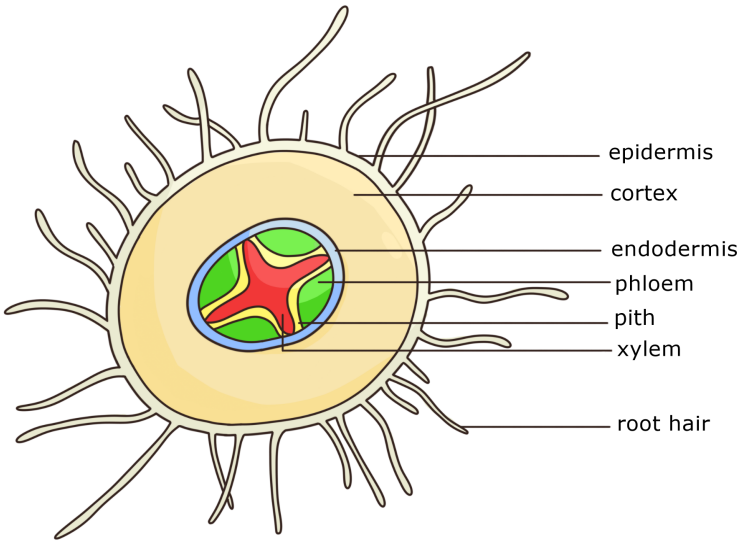
2. Xylem and phloem: positions throughout plant and their function

Cross-section of stem

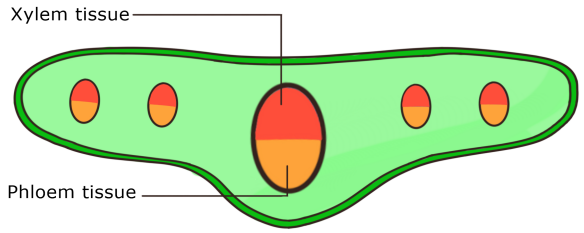


**Pro Tip: Cambium differentiates into new phloem and xylem tissues*

Cross-section of root



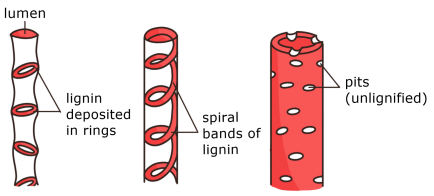
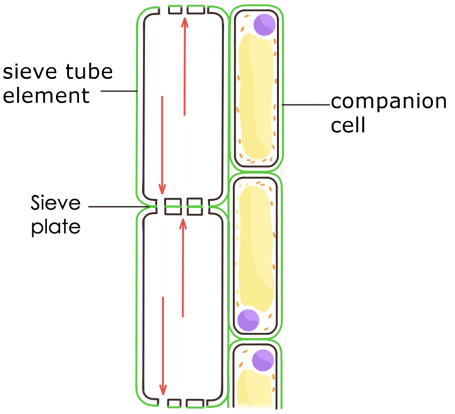
Cross-section of leaf



**Pro Tip: How to remember - picture the stem's vascular bundle curling outwards to form the leaf's vascular bundle. That's why xylem would be on top, phloem below.*

Xylem vs phloem - structure and function

Type of vascular tissue	Xylem	Phloem

Structure	 *Pro Tip: Pits allow water to flow to adjacent xylem vessels*	
Position in stem vascular bundle	Inner	Outer
Position in leaf vascular bundle	Top	Bottom
Position in stele of root	Inner 'cross'	Outer 'nodules'
Transports	**Water** and **mineral salts** from roots to rest of the plant	• **Translocation:** The transport of **manufactured food substances** such as **sucrose** and **amino acids** from leaves to rest of the plant • Substance within phloem is called **sap**

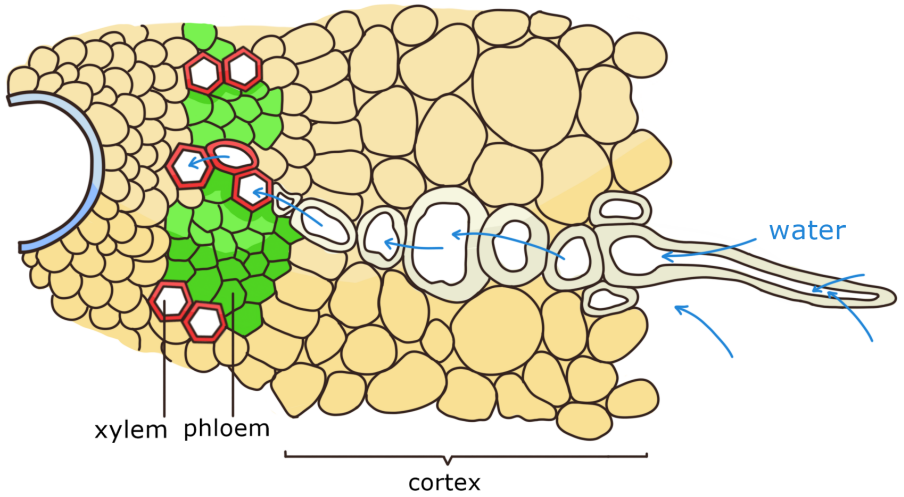
Lignified walls?	• Yes, deposited in xylem walls to **strengthen** it, prevents xylem from **collapse**. • Can be deposited in **rings/spiral** bands/entire wall except for **pits**	No
Energy required?	No, substances are transported passively	Yes, **active transport** involved
Direction of transport	**Unidirectional** (upwards only)	**Bidirectional** (both up and down)
Alive or dead at maturity?	Dead, no **protoplasm**	Yes, but **sieve tube elements** lack **nucleus** and many **organelles**
Companion cells	-	Have many **mitochondria**, to provide a lot of **energy** needed for **sieve tube elements** to transport manufactured food substances
End walls	None, to allow **unobstructed flow** of water	Yes - sieve plates, which are **porous**

3. Outline how water is transported from roots to leaves

- Water is transported up the xylem in 3 ways: Root pressure, Capillary action, Transpiration pull.

Root pressure: The upward pressure generated by constant osmosis of water from living cells into xylem vessels at the roots, due to the active transport of mineral salts.

- Water enters root hair cells via **osmosis** --> root hair cells have higher **water potential** than the inner **cortex** cells, water moves via **osmosis** to inner cells
- This process of osmosis repeats until water reaches the **xylem vessels**



Capillary action: The phenomenon in which water tends to move up narrow tubes

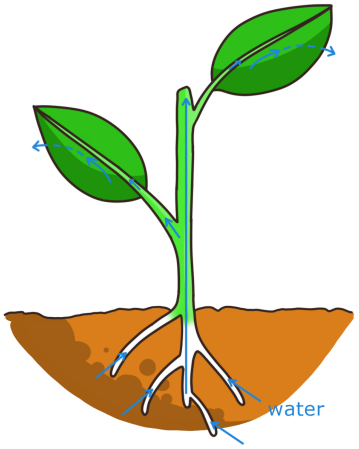
- This is due to the cohesive and adhesive forces of water
- Capillary action aids in the movement of water up the xylem

Transpiration pull

- Transpiration pull is the main force that pulls water from the roots to leaves
- **Transpiration:** The loss of water vapour from the aerial parts of a plant, mainly through the stomata in its leaves
    - Transpiration is a **consequence** of **gaseous exchange**, in the presence of light **stomata** open wider to allow more CO_2 to enter for **photosynthesis**, however this also increases the rate that **water vapour diffuses** out
- In leaves, water moves out the **mesophyll** cells, forming a **thin film of moisture**, which **evaporates** into **water vapour** in the **intercellular air spaces**
- It **diffuses** out of leaves via **stomata**, down its **concentration gradient**.
- **Water potential** of mesophyll cells has decreased, hence water moves from **xylem vessels** in leaves to **replace** water lost in mesophyll cells
- This causes a **whole column of water** to be pulled up xylem vessels from roots to leaves, by **transpiration pull**
    - **Transpiration pull:** The suction force created due to transpiration that pulls water and mineral salts up the xylem

[Memory shortcut]

- Transpiration process [Fake Vampire Drinks Red Water]
  - **F:** thin **F**ilm of moisture
  - **V:** water **V**apour
  - **D:** **D**iffuses out via stomata
  - **R:** water in xylem **R**eplaces water lost from mesophyll cells
  - **W:** causes **W**hole column of water to be pulled up



4. Effects of temperature, light intensity, humidity and wind of transpiration rate

- **Temperature**
  - As temperature increases, kinetic energy of water molecules increases
  - Water **evaporates** faster from the **thin film of moisture** into **intercellular air spaces**, more **water vapour diffuses** out of **stomata**, increasing transpiration rate

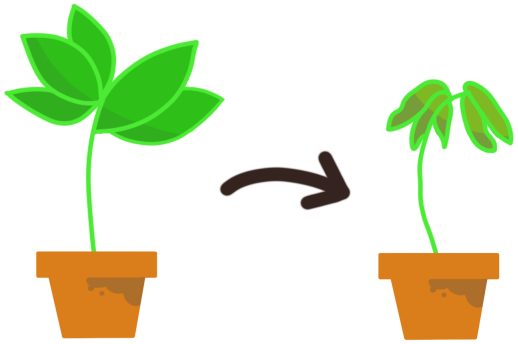
- **Light intensity**
  - As light intensity increases, **guard cells** become **turgid**, opening the **stomata**
  - This allows **water vapour** to **diffuse** out of the leaf faster, increasing transpiration rate

- **Humidity:** The amount of water vapour already in the air
  - As humidity increases, **concentration gradient** of **water vapour** between **intercellular air spaces** and surrounding air becomes **less steep**
  - Water vapour **diffuses** out slower, decreasing transpiration rate

- **Wind/air movement**
  - More wind/air movement blows **water vapour** away from air around leaves, decreasing **humidity**
  - **Concentration gradient** of **water vapour** between **intercellular air spaces** and surrounding air becomes **steeper**
  - Water vapour **diffuses** out faster, increasing transpiration rate

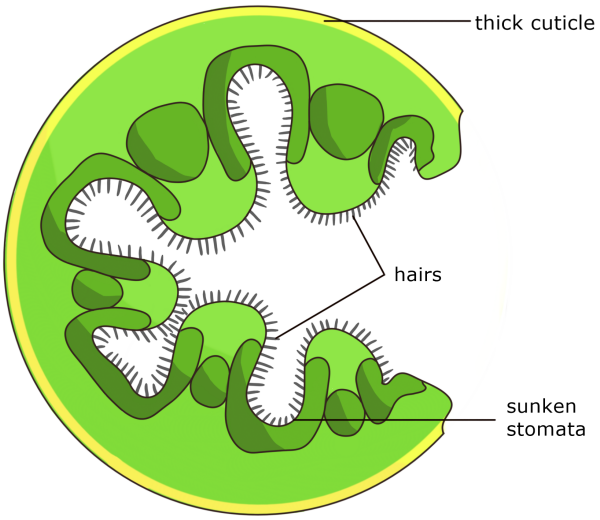
5. Wilting

- **Usually, mesophyll cells of the leaf are turgid**
  - This keeps leaves **firm** and **spread widely** for maximum **surface area**
  - **Turgidity** keeps the plant **upright** to reach for maximum sunlight (especially plants with non-woody stems)
- **Wilting occurs when rate of transpiration > rate of water uptake**
  - Due to a **net loss** of water to the plant, **central vacuoles** of cells shrink, mesophyll cells lose **turgor pressure** and become **flaccid**
  - This results in the wilted look of the plant
- **Causes**
  - Too high light intensity
  - Too high heat
  - Too much fertiliser that lowers soil **water potential** below that of root cells, resulting in water leaving the roots
- **Pros and cons of wilting**
  - Pros: Reduced **leaf surface area** + **flaccid** guard cells close **stomata** reduces **transpiration rate**, which helps conserve water
  - Cons: Due to closed **stomata**, less CO_2 enters leaves. Due to reduced **leaf surface area**, less light is captured, leading to reduced **photosynthesis** rate.



6. Bonus: Adaptations to reduce rate of transpiration

- Hairs and a curled/rolled leaf structure traps water vapour around the sunken stomata
- Small leaf surface area/Leaves reduced to spines
- Thick cuticle
- Few leaves
- Succulent leaves that can store water



^Leaf of Marram grass, adapted to hot and dry locations

8. Transport in Plants CAQs

Important Definitions
Q: Define the term transpiration.
Q: Define the term transpiration pull.
Q: Define the term translocation.

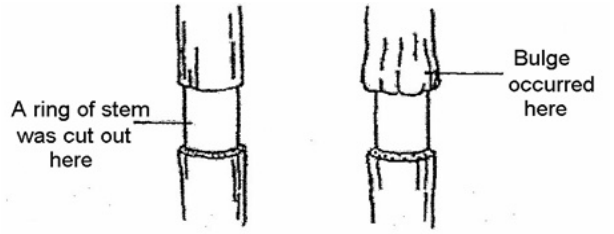
Root Hair Cell Adaptations
Q: Explain how root hair cells are adapted for their function. [2]

How Root Hair Cells Absorb Water and Mineral Salts
Q: Root hair cells have a high ion concentration. Explain how this is maintained and its importance. [3]

Xylem vs Phloem
Q: State the differences between xylem and phloem. [6]

- **Related Questions:**
  - Q: Describe the similarities and differences in the function of xylem tissue and phloem tissue.

Tree Ringing



Q: A ring of bark was removed from a tree. Explain the appearance of the swollen stem above the ringed area after a few days. [3]

Water Moving From Root Hair Cell to Xylem
Q: Describe how water moves from root hair cells to reach a xylem vessel. [2]

Transport of Water From Roots To Leaves
Q: Explain how water moves from the roots to leaves. [6]

Process of Transpiration
Q: Describe the process of transpiration. [4]

- **Related Questions:**
  - Q: Explain how water passes from a mesophyll cell to the atmosphere.

Factors Affecting Transpiration Rate
Q: Explain how temperature affects the rate of transpiration. [3]

Q: Explain how light intensity affects the rate of transpiration. [2]
Q: Explain how humidity affects the rate of transpiration. [2]

Q: Explain how air movement/wind affects the rate of transpiration. [3]

More Stomata on Lower Surface of Leaf
Q: Explain why there are usually more stomata on the lower surface of a leaf. [2]
Process of Wilting
Q: Explain how a plant may wilt on a hot sunny day. [3]
Advantages of Wilting
Q: Explain how wilting may be beneficial to a plant. [3]
Adaptations of Plants in Hot Climates
Q: Describe the possible structural features of a plant that is adapted to survive in hot and dry conditions. Explain how each feature enables the plant to do so. [4]

9. Respiration

Learning Outcomes:

1. Aerobic and anaerobic respiration
2. Identify parts of the respiratory system and their roles in breathing
3. The alveoli + inspired vs expired air
4. Transport of O_2 and CO_2
5. Smoking

Keywords:

- Aerobic, anaerobic, oxygen debt, oxidise, lactic acid, additional energy
- Alveolar air space, one-cell-thick, film of moisture
- Inspiration/inhalation, expiration/exhalation, thoracic volume, air pressure
- Haemoglobin, oxyhaemoglobin, carbaminohaemoglobin
- Carbonic anhydrase, carbonic acid, dissociates, bicarbonate/hydrogen carbonate ions
- Nicotine, addictive, social responsibilities
- Carbon monoxide, irreversibly, carboxyhaemoglobin
- Tar, carcinogen, chronic bronchitis, partition walls, emphysema

1. Aerobic and anaerobic respiration

- Living things need to respire to release energy for cellular activities, such as:
  - Muscular contractions, cell division, active transport, etc.

- **Aerobic respiration:** The process where food substances are broken down into carbon dioxide and water, in the presence of oxygen, releasing a large amount of energy.
  - Glucose + oxygen --> carbon dioxide + water + large amount of energy
  - $C_6H_{12}O_6 + \mathbf{6}O_2$ --> $\mathbf{6}CO_2 + \mathbf{6}H_2O$ + large amount of energy

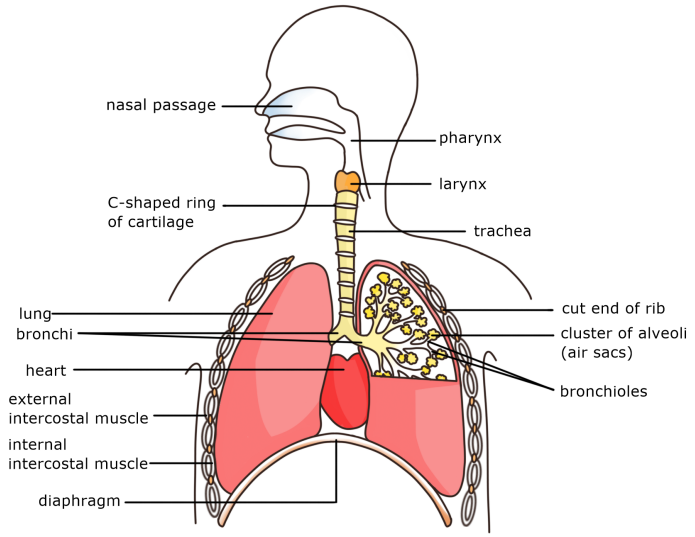
- **Anaerobic respiration (yeasts):** The process where food substances are broken down into carbon dioxide and ethanol, in the absence of oxygen, releasing a small amount of energy.
  - Glucose --> carbon dioxide + ethanol + small amount of energy
  - This process is also called **alcoholic fermentation**

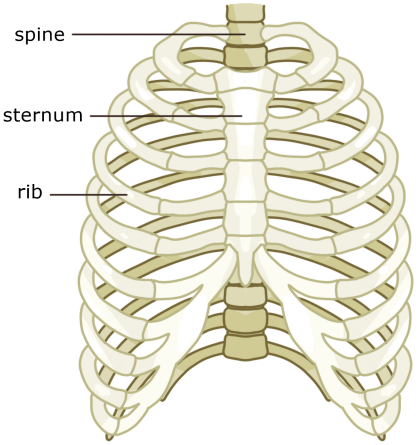
- **Anaerobic respiration (mammals):** The process where food substances are broken down into lactic acid, in the absence of oxygen, releasing a small amount of energy.
    - Glucose --> Lactic acid + small amount of energy

- **The effect of lactic acid in muscles**
    - During **vigorous** exercise, muscles demand more **energy** than can be generated by **aerobic respiration**
    - **Additional energy** is generated by **anaerobic respiration**, resulting in accumulation of **lactic acid** in muscles
        - An **oxygen debt** is incurred
    - This causes **fatigue** and **muscular pain**

- **Converting lactic acid back into glucose**
    - **Lactic acid** is removed from muscles via the bloodstream and transported to the liver.
    - **Oxygen debt:** The amount of oxygen needed to **oxidise** lactic acid built up in the body back into **glucose**, at the liver.
    - The conversion of some lactic acid back into glucose releases energy, and this energy is then used to **oxidise** the remaining lactic acid to glucose.
    - Hence immediately after exercise, the person consumes more oxygen compared to at rest, to repay the **oxygen debt.**

2. Identify parts of the respiratory system and their roles in breathing





Structure	Function
Cilia	• Cilia are hair-like structures on **ciliated** cells • Found on inner walls of **trachea**, **bronchi** and larger **bronchioles** • Mucus secreted by **mucosal/gland cells** traps **dust** and **foreign particles** • Cilia sweeps mucus with the trapped particles up the **trachea** to be swallowed, **neutralising** any pathogens due to the stomach's **acidic pH**
C-shaped rings of cartilage	• Structural support: prevents collapse of the trachea • Rings are incomplete: allows trachea to collapse partially during swallowing

Breathing

Event	Inspiration (Breathing in)	Expiration (Breathing out)
Diaphragm	Contracts and flattens downwards	Relaxes upwards

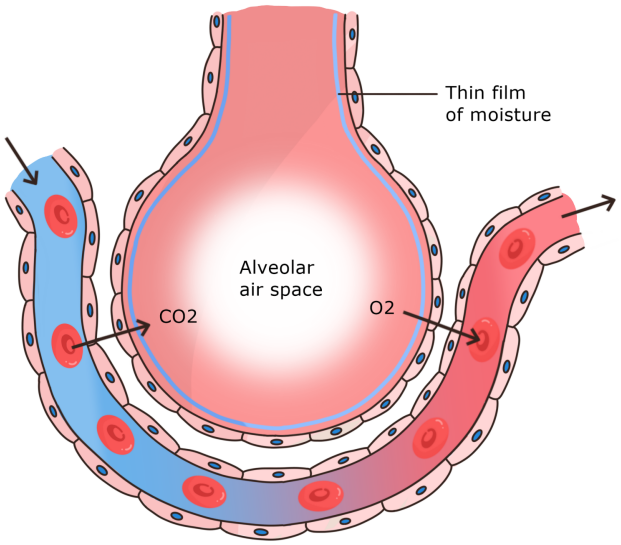
Intercostal muscles	Internal*	Relax	Contract
	External*	Contract	Relax
Ribcage		Moves up and out	Moves down and in
Thoracic **V**olume		Increases	Decreases
Air pressure in lungs		Lower than surrounding air, causing air to rush in	Higher than surrounding air, causing air to rush out

**Pro Tip: These muscles are antagonistic*

[Memory Shortcut]

- Inspiration/expiration process [DIRVA]
  - **D: D**iaphragm
  - **I: I**ntercostal muscles (internal + external)
  - **R: R**ibcage
  - **V:** thoracic **V**olume
  - **A: A**ir pressure in lungs

Adaptations of alveoli



Feature	Function

One-cell-thick	Minimises distance O_2 and CO_2 have to travel, increasing **diffusion** rate
Small and numerous	Increases their **SA:V**, increasing **diffusion** rate
Surrounded by network of capillaries	Provides continuous blood supply, **oxygenated** blood is quickly carried away to maintain the **concentration gradients*** for O_2 to **diffuse** from **alveolar air space** into blood and CO_2 to **diffuse** out
Thin film of moisture lining alveolar air space	Gases **dissolve** in it before **diffusing** across

**Pro Tip: Concentration gradients are also maintained by fresh air being breathed in and old air breathed out*

3. Inspired vs expired air

Component of air	Inspired air	Expired air
Oxygen	21%	16%
Carbon Dioxide	0.03%	4%
Nitrogen	78%	78%
Water Vapour	Varies	Saturated
Dust Particles	Present	Almost none
Temperature	Varies	~37°C

4. Transport of O_2 and CO_2

Oxygen

- A small percentage (2%) **dissolves** and is transported by **blood plasma**

- Most O_2 (98%) is transported by **RBCs**
- When O_2 concentration is high, O_2 combines with **haemoglobin** (forming oxyhaemoglobin)
- When blood passes through oxygen-poor areas, O_2 **dissociates** from **haemoglobin** and **diffuses** into the **tissue fluid**, then into cells

Carbon dioxide

- A small percentage (5%) **dissolves** in and is transported in **blood plasma**
- Some CO_2 (25%) binds to **haemoglobin** (forming carbaminohaemoglobin) and is transported by **RBCs**
- Most CO_2 (70%) is transported as **bicarbonate ions/hydrogen carbonate ions**, HCO_3^-
    - **Carbonic anhydrase** in RBCs combine CO_2 and H_2O to form H_2CO_3, **carbonic acid**
    - This then **dissociates** into H^+ and HCO_3^-
    - HCO_3^- ions **diffuse** out of RBCs into the **plasma**, where they are carried to the lungs
    - At the lungs, the reverse process occurs, CO_2 **diffuses** out of the capillaries into **alveolar air space** and is expelled during **exhalation**

Breathing Rate

- Is controlled by (and directly proportional to) blood CO_2 concentration
- During exercise, **muscle** cells undergo more **aerobic respiration** more, more CO_2 is released by cells into the blood
- Breaths become **faster** and **deeper** to quickly remove excess CO_2

5. Smoking

Health impacts caused by chemicals in tobacco smoke

Chemical in Tobacco smoke	Negative Effects

Nicotine	• **Addictive**, resulting in social problems • Stimulates **adrenaline** secretion, increasing **blood pressure*** • Increases **ease of blood clotting**, increasing the risk of **heart attacks** **Pro Tip: This also increases rate of fatty deposits accumulating in arteries.*
Carbon Monoxide	• Binds **irreversibly** with **haemoglobin** such that it cannot transport O_2 anymore, reducing the ability of blood to transport O_2 • Damages **endothelium** of blood vessels, hence increasing the rate that **fatty deposits** accumulate in **arteries**, increasing the risk of **heart attacks**

Tar	• Paralyses **cilia,** dust particles cannot be expelled, which can result in:
	  ◦ **Chronic bronchitis** (where the **epithelium** lining the airways are inflamed + persistent coughing)
	  ◦ Persistent and violent coughing can lead to **Emphysema** (when **partition walls** between **alveoli** break down, making it hard to breathe)
	• Tar is a **carcinogen***, increases chances of **lung cancer**
	
	**Pro Tip: Carcinogen = something that causes cancer*

9. Respiration CAQs

Important Definitions
Q: Define the term aerobic respiration.

Q: Define the term anaerobic respiration (yeasts).

Q: Define the term anaerobic respiration (mammals).

Breathing In
Q: Explain how air is made to enter the lungs. [4]

Breathing Out
Q: Describe the process of expiration/exhalation. [4]

Adaptations of Alveoli
Q: Describe how alveoli are adapted for the exchanges of gases. [4]
Role of Cilia
Q: Describe the role of cilia in the trachea and bronchi. [2]
Transport of Carbon Dioxide
Q: Describe how carbon dioxide produced by cells is eventually removed at the lungs. [6]

- **Related Questions:**
  - Q: Describe the role of carbonic anhydrase in the excretion of carbon dioxide. [4]

Oxygen Consumption During Exercise
Q: Explain why the oxygen used increases as the level of exercise increases. [3]

- **Related Questions:**
  - Q: Explain why the volume of air breathed in during exercise is different from at rest.

Oxygen Debt

Q: An athlete just finished a race. Explain why the amount of oxygen he uses does not immediately go back to resting levels, even though exercise has stopped. [4]

- **Related Questions:**
  - Q: Explain why the rate and depth of breathing after exercise is different from normal breathing in the person. Give 2 reasons. [2]

Smoking harmful chemicals and effects
Q: Describe the harmful effects of tobacco smoke. [6]

- **Related Questions:**
  - Q: Describe 3 ways in which smoking damages the lungs. [3]

10. Excretion

Learning Outcomes:

1. Importance of excretion
2. Structure of kidneys and nephrons
3. Osmoregulation and ADH
4. Dialysis

Keywords:

- Anabolic, catabolic, metabolism, waste/excretory products, urea
- Basic functional unit, afferent/efferent arteriole, ultrafiltration, high (hydrostatic) blood pressure
- Selective reabsorption, filtrate, more permeable to water
- Osmoregulation, osmoreceptors, osmotic pressure, permeability
- Kidney failure, partially permeable, dialysate

1. Importance of excretion

- **Excretion:** The process whereby metabolic waste products and toxic substances are removed from the body
  - **Importance:** They must be excreted as they can harm the body if they accumulate to high concentrations.
- Our **metabolism** results in metabolic waste products/excretory products
  - **Anabolic** = smaller molecules form a larger molecule
  - **Catabolic** = large molecule broken down into smaller molecules

[Memory hack]

- How to remember anabolic vs catabolic
  - In the movie Frozen, **Anna** (Elsa's sister) always wants to build a snowman. So **Ana**bolic = building, small molecules form a larger molecule.

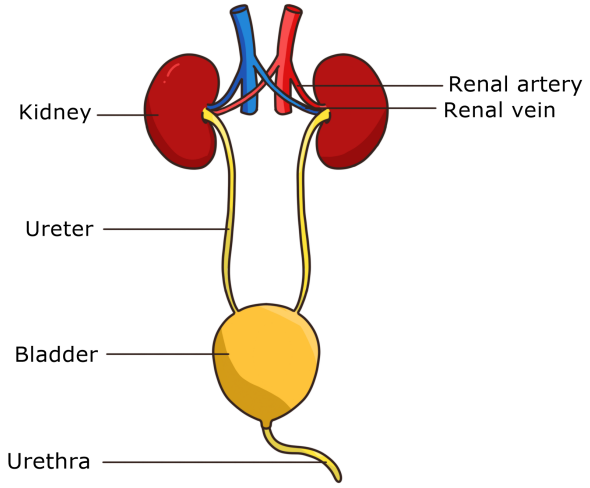
Examples of excretion in humans

- Unicellular organisms use **diffusion** for excretion, multicellular organisms need organs
  - **Lungs** excrete CO_2 during **expiration**

- **Urea** (product of deamination) is filtered out by **kidneys** and excreted in **urine**
- Excess **water** excreted by **sweating**, **expiration** and in **urine**
- **Bile pigment** excreted through **faeces**

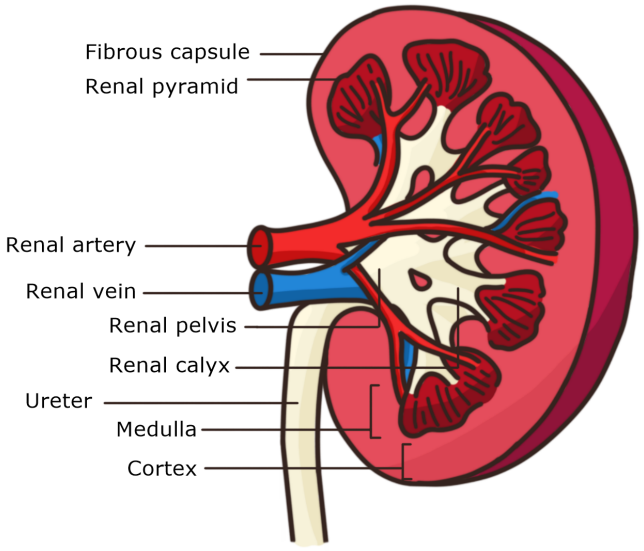
2. Structure of kidneys and nephrons

Urinary system



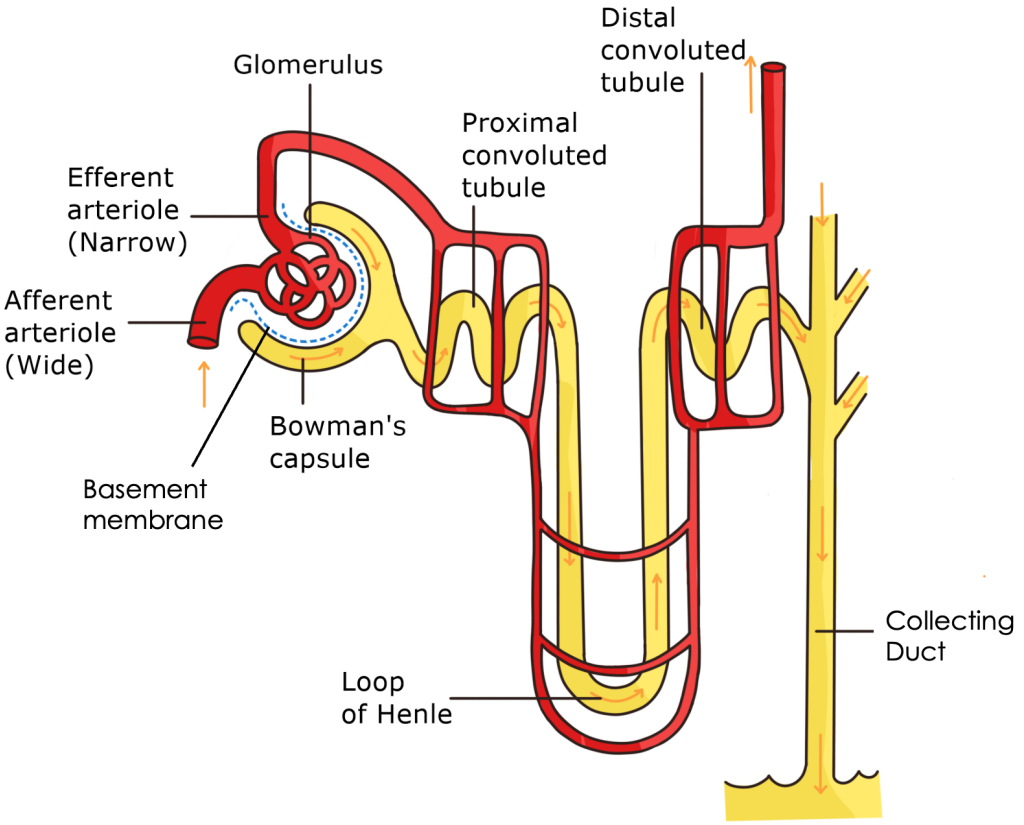
- **Renal artery** brings blood to kidney, **renal vein** carries blood away
- Kidneys act as filters, removing unwanted substances
- **Ureter** carries urine to **bladder** where it is temporarily stored
- **Urethra** carries urine outside of body

Parts of a kidney



Pro Tip: Medulla is the inner region of the kidney where the renal pyramids are found.

Parts of a nephron



Formation of urine

- A **nephron** is the **basic functional unit** of the kidney that filters and removes waste substances from the blood to form urine.
- The processes involved that make this possible are **ultrafiltration** and **selective reabsorption**.

Ultrafiltration: The process where most of the blood plasma and dissolved substances are forced out of the glomerulus into the bowman's capsule byhigh (hydrostatic) blood pressure.

- Blood enters the **glomerulus** through the **afferent arteriole** and leaves through the **efferent arteriole**
- **Lumen** of **efferent arteriole** is smaller, generates **high (hydrostatic) blood pressure** which forces out most of the **blood plasma** and its **dissolved substances** (glucose, amino acids, mineral salts, urea, toxins, medicine).
- These substances enter the **Bowman's capsule**

- Large molecules such as blood cells, platelets and proteins cannot pass through the **basement membrane** that lines the glomerular capillaries

Selective reabsorption: The process where certain substances are reabsorbed from the filtrate back into the blood as they pass through nephrons.

- Useful substances are **selectively reabsorbed** while unwanted substances (or substances in excess) stay in the **filtrate** and become urine
- Water is reabsorbed* via **osmosis**
  - **Pro Tip: Since water is not reabsorbed using energy, do not say it is "selectively reabsorbed", only "reabsorbed"*
- Glucose, amino acids, and some mineral salts are reabsorbed via **diffusion** and **active transport**

Part of nephron	Reabsorption of substances
Proximal Convoluted Tubule	Some water, some mineral salts, all glucose and all amino acids reabsorbed
Loop of Henle	Some water reabsorbed
Distal Convoluted Tubule	Some water and some mineral salts reabsorbed
Collecting Duct	Some water reabsorbed

3. Osmoregulation and ADH

Osmoregulation: The process where the amount of water and concentrations of solutes in blood are controlled to maintain constant water potential in the body.

- **Osmoreceptors** are cells in the **hypothalamus** that detect changes in blood **water potential**
- More/less **Antidiuretic Hormone (ADH)*** is secreted by the pituitary gland in response to a change detected
  - **Pro Tip: How to remember what ADH does? A diuretic is something that makes you pee more. Therefore Anti-diuretic means anti-pee, so you pee less and urine becomes more concentrated.*
- Kidneys are considered **osmoregulators** as they aid in **osmoregulation**

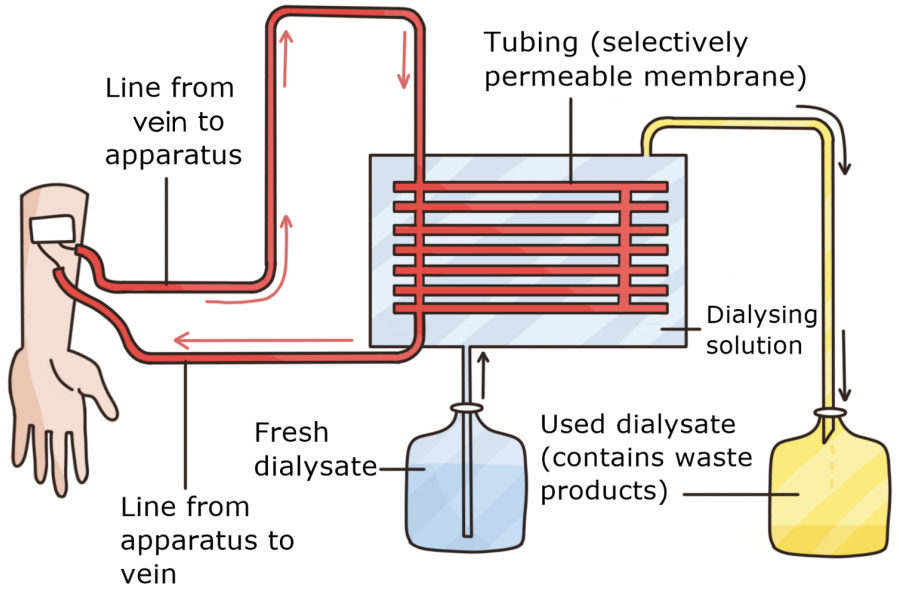
- Osmoregulation works by **negative feedback**, and attempts to restore the set-point of blood **water potential/osmotic pressure**
    - **Pro Tip: Osmotic pressure and water potential are inversely related, i.e. when water potential is high, osmotic pressure is low.*

Water potential	Water potential **increases**/osmotic pressure falls	Water potential **decreases**/osmotic pressure rises
Osmoreceptors	In the Hypothalamus detect this	In the Hypothalamus detect this
ADH secretion	Pituitary gland secretes **less** ADH	Pituitary gland secretes **more** ADH
Collecting ducts	Cells in the walls of collecting ducts become	Cells in the walls of collecting ducts become
Permeable	**Less permeable** to water, hence reabsorb less water from filtrate back into blood	**More permeable** to water hence reabsorb more water from filtrate back into blood
Dilute	Becomes **more dilute**/less concentrated	Becomes **less dilute**/more concentrated

[Memory shortcut]

- ADH explanation [Wealthy Otters Ate Custard Pudding Dessert]
    - **W: W**ater potential
    - **O: O**smoreceptors
    - **A: A**DH secretion
    - **C: C**ollecting ducts
    - **P: P**ermeable
    - **D:** urine becomes more/less **D**ilute

4. Dialysis



Procedure

- Patients with **kidney failure** need to use a **dialysis machine** to filter waste products out of their blood
  - ~3 times per week, 4h each time
- Blood is drawn from the **vein** in patient's arm into a **partially permeable** tube
  - Tube does not allow large substances such as blood cells and platelets to pass through, but allows small substances such as waste products to diffuse out.
- Tube enters machine where it is bathed in **dialysis fluid/dialysate**
  - Dialysate contains zero waste products, hence waste products from blood **diffuse** out down their concentration gradients.
  - Dialysate has same concentration of useful substances (glucose, amino acids, mineral salts) as healthy blood, so there is no **net diffusion**.
  - Tubing is **long**, **narrow** and **coiled**, increases **SA:V**, increasing **diffusion** rate.
  - Dialysate flows **opposite direction** to blood, so that a concentration gradient for diffusion of waste products is maintained along the entire length of the tube.
- Cleaned blood is returned via the **vein** in patient's forearm.

[Memory shortcut]

- Dialysis machine features [ZERO]
  - **Z:** Zero waste products in fluid
  - **E:** Equal concentration of useful substances in fluid

- **R:** Tubing has high surface area to volume **R**atio
- **O:** blood and dialysate flow in **O**pposite directions

10. Excretion CAQs

Important Definitions
Q: Define the term excretion and state its importance in the functioning of the body.
Q: Define the term ultrafiltration.
Q: Define the term selective reabsorption.
Q: Define the term osmoregulation.

Formation of Urine
Q: Describe the formation of urine. [5]

- **Related Questions:**
  - Q: Describe the function of a nephron. [4]

Absence of Substances in Urine
Q: Explain the absence of protein/blood cells/platelets in urine. [2]
Q: Explain the absence of glucose/amino acids in urine. [2]

Person Drinks Too Little/Too Much Water (ADH)
Q: Explain the effect on urine concentration when a person drinks too little water. [4]

- **Related Questions:**
  - Q: Briefly explain the negative feedback mechanism when a person drinks too little water. [4]

Q: Explain the effect on urine concentration when a person drinks too much water. [4]

Dialysis Treatment
Q: When a person suffers kidney failure they are given dialysis. Describe the mechanism of kidney dialysis. [6]

- **Related Questions:**

- Q: Explain what makes a dialysis machine efficient in purifying a patient's blood. [4]

11. Homeostasis

Learning Outcomes:

1. Homeostasis and negative feedback
2. Parts of skin
3. Temperature regulation

Keywords:

- Internal environment, internal temperature, negative feedback
- Stimulus, receptor, thermoreceptors,
- Control centre, set-point/normal condition, corrective mechanism
- Dilate, constrict, arterioles, shunt vessels
- Conduction, convection, radiation, latent heat
- Poor conductor of heat, metabolic rate, thermoreceptors

1. Homeostasis and negative feedback

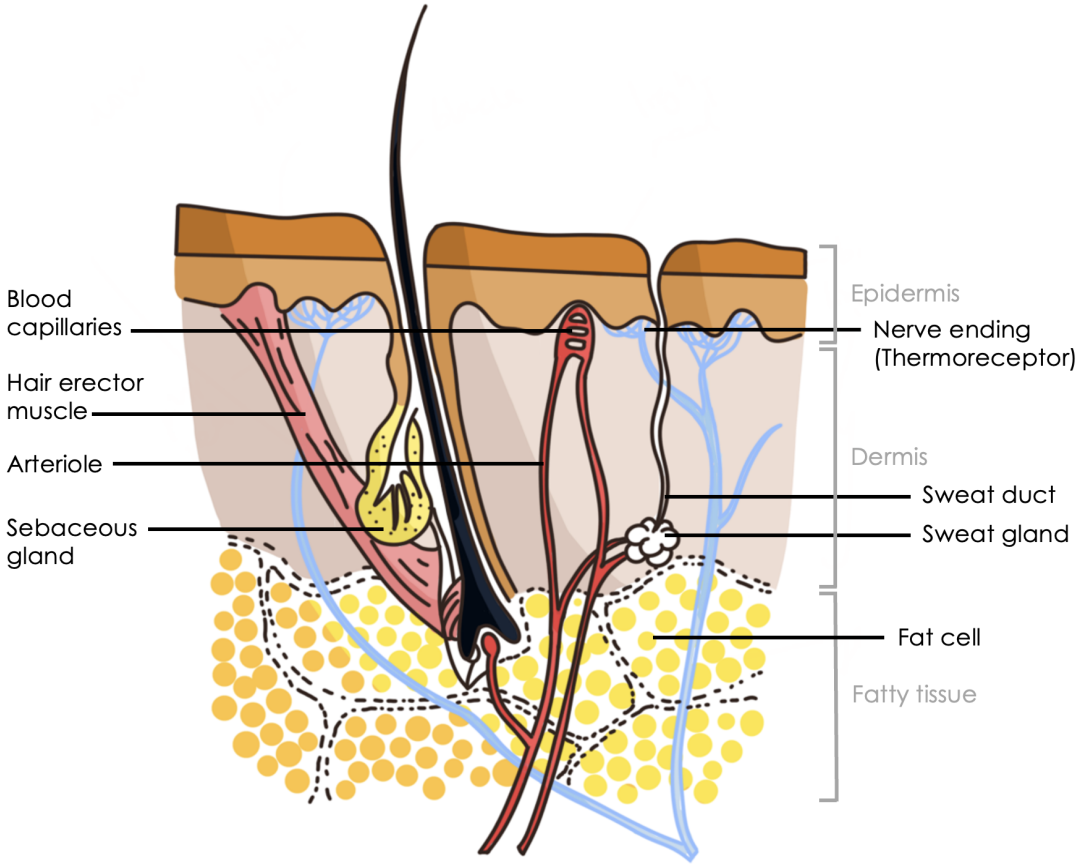
Homeostasis: The maintenance of a constant internal environment.
Negative feedback: A type of regulation where the end result of a process removes the stimulus for that process.

- There is a change in internal environment (this is the **Stimulus**)
- A **Receptor/sensor** detects the change in internal environment
- The **Control centre** receives the information and triggers corrective mechanisms
- Response is a **Corrective mechanism** that removes the stimulus
- Internal environment returns to its **Normal condition/set-point**
- Receptor detects that set-point is reached and **Stops** corrective mechanism

[Memory Shortcut]

- Negative feedback process [Sneaky Rabbit Chews Carrot Non Stop]
  - **S:** **S**timulus
  - **R:** **R**eceptor
  - **C:** **C**ontrol centre
  - **C:** **C**orrective mechanism
  - **N:** **N**ormal condition/set-point restored
  - **S:** **S**top corrective mechanism once receptor detects set-point restored

2. Parts of skin



Sweat

- Contains water, salts (mainly sodium chloride) and small amounts of urea
- Hence sweating is a means of **excretion**

Adipose (fat) tissues

- Fat is a **poor conductor** of heat, reducing heat loss through the skin

3. Temperature regulation

Negative feedback is involved

- Changes in internal temperature are the **stimulus**
- Detected by **thermoreceptors** in **hypothalamus**, hypothalamus sends **nerve impulses** to **effectors** that carry out **corrective mechanisms** to counteract the change in internal temperature
- Once **set-point** is restored, thermoreceptors detect this and send nerve impulses to hypothalamus to **stop** the **corrective mechanisms**

Responses to changes in internal temperature

Response	Too cold	Too hot	Explanation
Metabolic Rate	Increases	Decreases	Higher rate of **aerobic respiration** by mitochondria releases more **heat** energy; **shivering** (rapid contraction of skeletal muscles) facilities this
Arterioles in the skin	• Constrict • Shunt vessels* dilate	• Dilate • Shunt vessels constrict	**Constriction** of arterioles in the skin and **dilation** of shunt vessels reduces bloodflow to capillaries near the skin surface, decreasing heat loss through **conduction, convection and radiation**
Sweat Glands	Secrete less sweat	Secrete more sweat	When sweat glands secrete more sweat, more water in sweat **evaporates**, hence more **latent heat** is lost
Hair erector muscles	Contract	Relax	When hair erector muscles contract, hairs stand up, trapping a layer of **air** which is a **poor conductor of heat** above the skin, reducing heat loss

**Pro Tip: Shunt vessels directly connect arteries to veins, allowing blood to bypass capillaries*

[Memory Shortcut]

- Responses to changes in temperature [MASH]
  - **M:** Metabolic rate
  - **A:** Arterioles
  - **S:** Sweat glands
  - **H:** Hair erector muscles

11. Homeostasis CAQs

Important Definitions
Q: Define the term homeostasis.

Q: Define the term negative feedback.

Negative Feedback
Q: Explain why the regulation of body temperature is an example of a negative feedback system. [2]

Responses to Decreased Body Temperature
Q: Describe the responses to a decrease in body temperature. [4]

Responses to Increased Body Temperature
Q: Describe the responses to an increase in body temperature. [4]
Sweat glands in temperature regulation
Q: Describe the role of sweat glands in body temperature regulation. [3]
Explaining negative feedback cycle in detail
Q: Describe how the hypothalamus coordinates the maintenance of a constant body temperature. [3]

- **Related Questions:**
  - Q: Explain how **the skin** is involved **in returning** the body temperature to normal when the body overheats. [5]

12. Coordination and Response

Learning Outcomes:

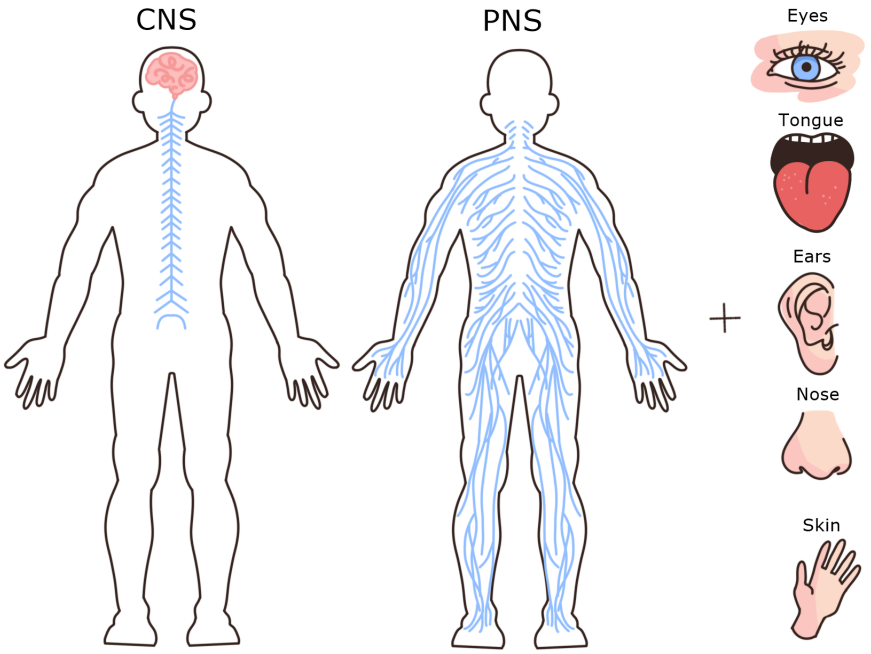
1. Central and Peripheral nervous system
2. Neurones
3. Reflex actions
4. The human eye
5. Hormones
6. Diabetes mellitus
7. Bonus: Nervous system vs Endocrine system

Keywords:

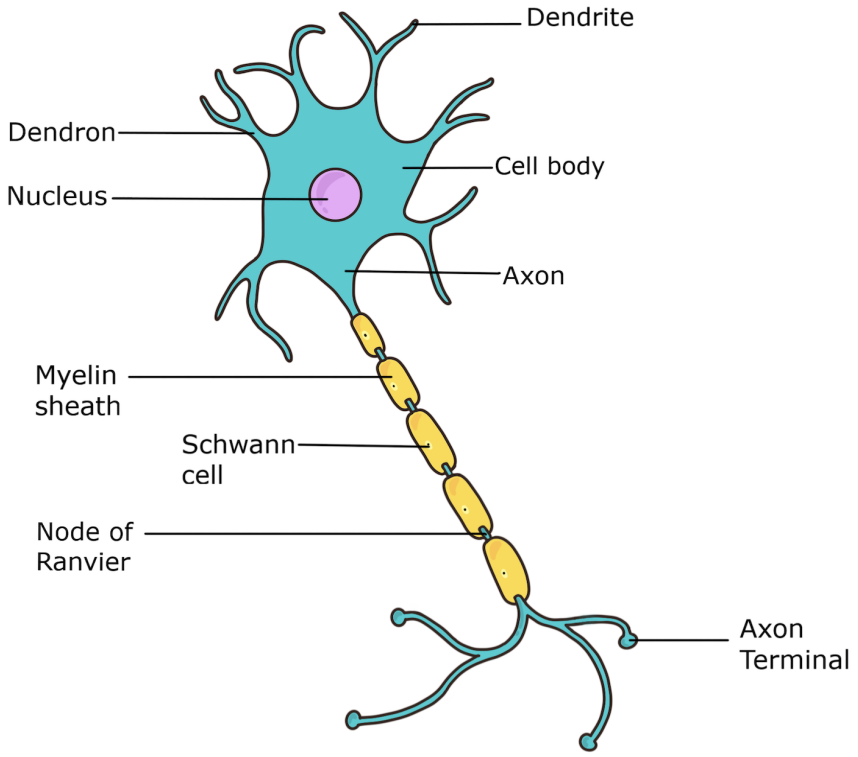
- Central/peripheral nervous system, cranial/spinal nerves, sense organs
- Nerve impulses, stimulus, receptor, effector, transmitted across a synapse
- Sensory, relay, motor, white/grey matter
- Motor end plate, muscle fibres
- Reflex arc, involuntary, conscious control, reflex centre,
- Internal reflection of light, refract
- Taut, slacken, convex, focal length, sharply focussed
- Endocrine, target organs, blood glucose concentration, permeability to glucose
- Fight-or-flight response, emotions

1. Central and Peripheral nervous system

- **Central Nervous System (CNS)** consists of **Brain** and **Spinal cord**
- **Peripheral Nervous System (PNS)** consists of:
  - **Cranial nerves** (from the brain)
  - **Spinal nerves** (from spinal cord)
  - **Sense organs** (eyes, nose, tongue, ears, skin)



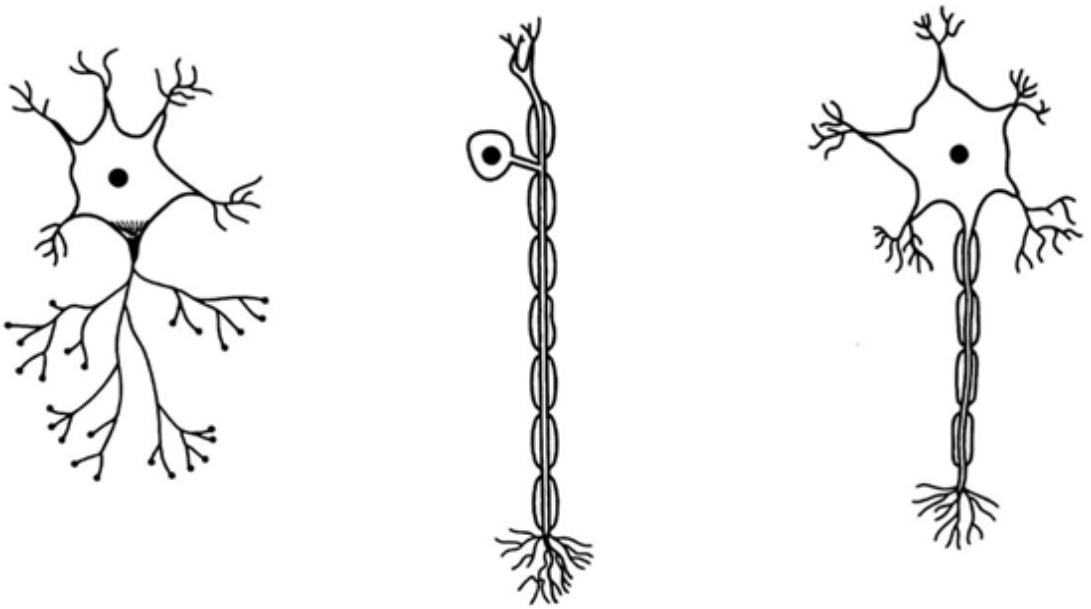
2. Neurones



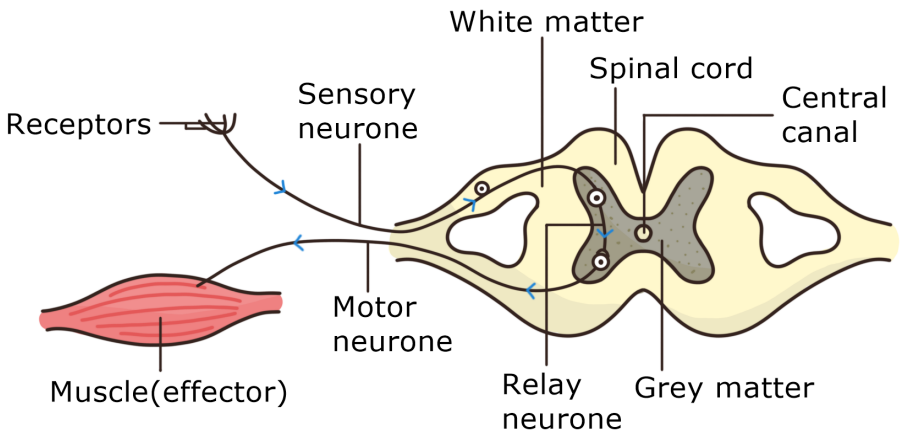
Part of Neurone	Function

Dendrites	The endings of dendrons. Transmit **nerve impulses** towards the cell body
Dendron	Transmits **nerve impulses** towards cell body
Axon	Transmits **nerve impulses** away from cell body
Axon terminals	The endings of axons
Myelin sheath	A fatty substance that **insulates** nerve fibres, produced by Schwann cells.
Node of Ranvier	Are the **unmyelinated** portions between Schwann cells. They allow nerve impulses to 'jump' from one node to the next, speeding up transmission of nerve impulses.
Synapse	The junction between an **axon terminal** of one neurone and **a dendrite** of another neurone. Chemicals/neurotransmitters are released and **diffuse** across, transmitting **nerve impulses** across the synapse.
Motor end plate/ Neuromuscular junction	The junction between **axon terminals** and **muscle fibres**, where axon terminals will release chemicals to stimulate **muscle fibres** to contract.

Sensory, relay and motor neurones



Neurone Type	Transmits nerve impulses from	Transmits to
Sensory (Centre)	Receptor	Relay neurone
Relay (Left)	Sensory neurone	Motor neurone
Motor (Right)	Relay neurone	Effector



White vs Grey matter (in brain/spinal cord)

- Grey matter consists of mainly **cell bodies**

- White matter consists of mainly **nerve fibres**

3. Reflex actions

- **Reflex action:** An immediate response to a specific stimulus without conscious control.
- Involves a **reflex centre** (either brain or spinal cord).
  - **Spinal reflexes** use spinal cord as reflex centre, e.g. knee jerk reflex, withdrawal reflex when touching a hot object
  - **Cranial reflexes** use the brain as reflex centre, e.g. Blink reflex, accommodation reflex, pupil reflex, sneezing, coughing
- **Reflex arc:** The shortest pathway for nerve impulses to travel from receptor to effector during a reflex action.

- Examples of reflex actions: Knee jerk reflex*, pupil reflex, touching hot/sharp object, blink reflex, grasp reflex, cough reflex, sneeze reflex, production of gastric juice, production of saliva, secretion of adrenaline
- **Pro Tip: For the knee jerk reflex, this is a stretch reflex. When there is a tap on the tendon below the knee, stretch receptors detect this and result in the contraction of the quadriceps muscle (to prevent the muscle from overstretching and being injured)*

Pathway of nerve impulses questions:

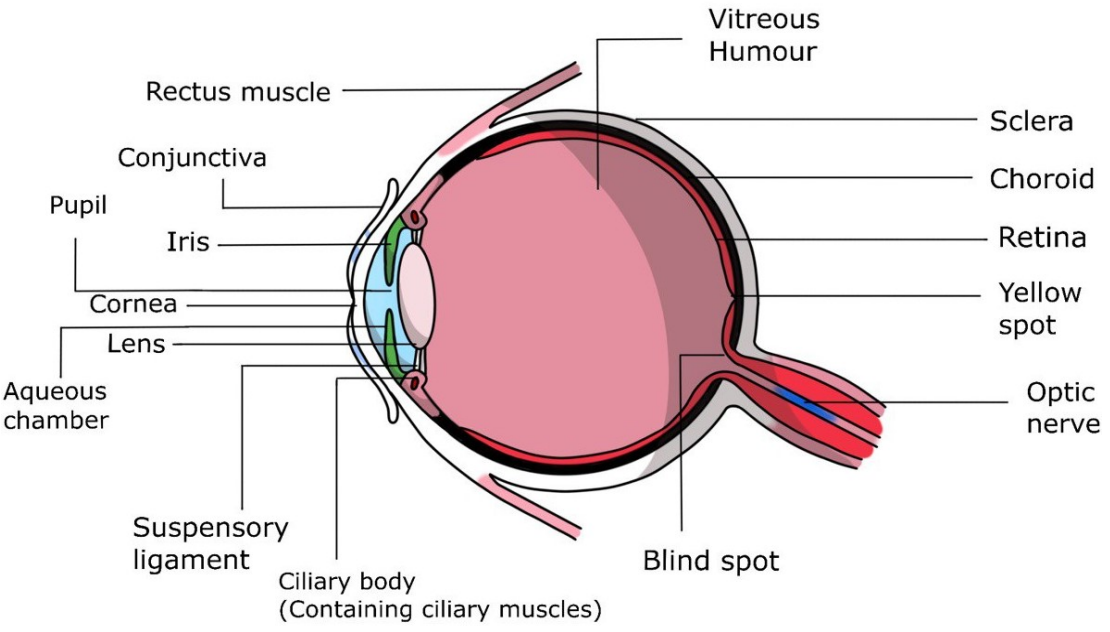
- When _____ (incident), _____ (receptors) detect this, **nerve impulses** are generated and travel along a **sensory neurone.**
- They are **transmitted across a synapse** to a **relay neurone,** in the _____ (either brain/spinal cord), which is the **reflex centre.**
- Nerve impulses are then transmitted across another synapse to a **motor neurone.**
- They travel along it until they reach its **axon terminals**, chemicals/neurotransmitters are released across the **motor end plate/neuromuscular junction** (synapse)*,
  - **Pro Tip: Motor end plate is a special synapse, where the effector is a muscle*

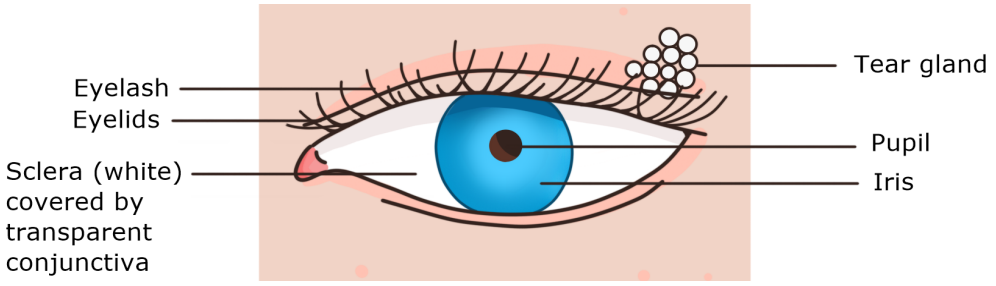
- Triggering the _____ (thing that does the action) which is the **effector** to _____ (response triggered), so that _____ (where possible, the purpose for the reflex action).

[Memory shortcut]

- Pathway of nerve impulses during reflex action [IRS RC MAN'S ERP, *IRS agents storm into an RC to collect a MAN'S ERP*]
  - **I:** Incident
  - **R:** Receptor
  - **S:** Sensory neurone
  - **R:** Relay neurone
  - **C:** Centre (reflex centre)
  - **M**: Motor neurone
  - **A:** Axon terminals
  - **N:** Neurotransmitters
  - **S:** Synapse (Motor end plate if effector is muscle)
  - **E:** Effector
  - **R:** Response
  - **P:** Purpose

4. The human eye





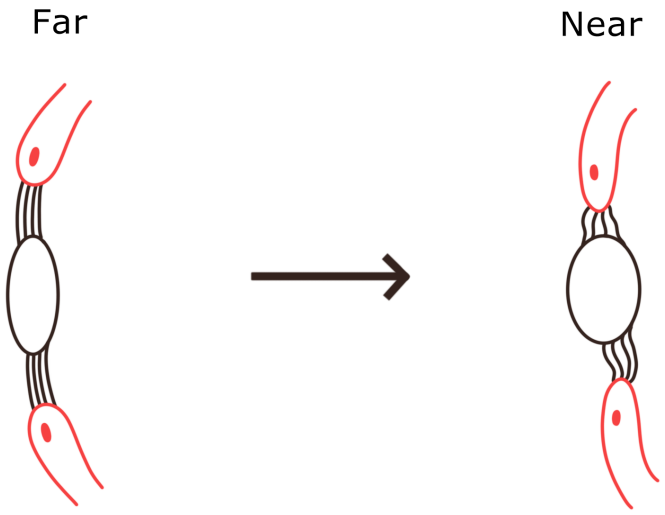
Part of eye	Function
Sclera	Protects eyeball from mechanical damage
Choroid	• Pigmented black to prevent **internal reflection of light** • Rich in blood vessels, bringing nutrients to eyeball
Retina	Contains **photoreceptors** that detect light and generates **nerve impulses**, which are sent to the brain. • **Rods** see in black and white • **Cones** see in colour (red, green and blue) How they detect light: • **Visual pigments** (proteins) in rods and cones **change shape** (aka bleached) when they absorb light • This shape change causes **nerve impulses** to be generated in the photoreceptors
Yellow spot/fovea	• An area of the **retina** with a **high concentration of cones** • Light is mainly focussed here as the image that is produced here is the sharpest.
Blind spot	An area of the retina right above the **optic nerve**, where there are no **photoreceptors**
Cornea	**Refracts** light into the eye
Conjunctiva	• Protects eye from microbes • Lubricates eye by secreting mucus

Aqueous humour	• A watery substance found in the aqueous chamber, gives the eyeball its shape • **Refracts** light into pupil • Nourishes cornea
Lens	• Focusses light onto the **retina** • Is flexible to focus on objects at varying distances
Vitreous humour	• A jelly-like substance found in the vitreous chamber, gives the eyeball its shape • **Refracts** light onto **retina**
Rectus muscles	Controls eye movement

How light enters the eye

- Light is refracted by the **cornea** into the eye
- The **aqueous humour** refracts light into the **pupil** (a hole)
- The **lens** refracts light towards the **retina**
- The **vitreous humour** refracts light onto the **retina**

Focussing/Accommodation reflex



Object	Near	Far

Ciliary muscles	Contract*	Relax
Suspensory ligaments	Slacken	Taut
Lens shape	Thicker and more convex	Thinner sand less convex
Focal length	Decreases	Increases

**Pro Tip: Think of ciliary muscles contracting towards lens, hence suspensory ligaments slacken*
**Pro Tip: Do not say lens becomes more concave, you must say less convex.*
[Memory Shortcut]

- Accommodation reflex [Cats Scratch Leather Furniture]
  - **C: C**iliary muscles
  - **S: S**uspensory ligaments
  - **L: L**ens shape
  - **F: F**ocal length

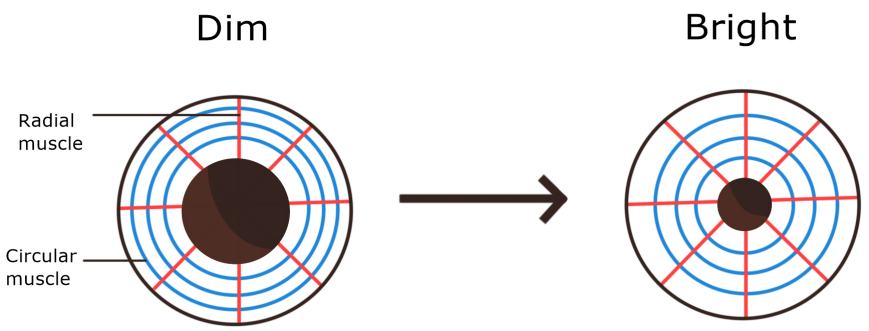
[Memory hack]
How to remember whether ciliary muscles contract or relax

- When you focus on a near object, you are 'straining' your eyes, so ciliary muscles contract to focus on near objects.
- When you focus on a far object, you are 'relaxing' your eyes, so ciliary muscles relax to focus on far objects.

[Memory hack]
How to remember whether to write focal length increases/decreases

- When you focus on a near object, near = short distance so write focal length decreases
- When you focus on a far object, far = long distance so write focal length increases

Pupil reflex



Light conditions	Bright	Dim
Radial muscles	Relax	Contract
Circular muscles	Contract	Relax
Pupil	Constricts	Dilates
Effect on eye	Allows less light in, prevents damage to retina	Allows more light in to see better

**Pro Tip: Iris contains circular and radial muscles (antagonistic), which control size of the pupil*

[Memory Shortcut]

- Pupil reflex [Really Cool Pupil Effect]
  - **R: R**adial muscles
  - **C: C**ircular muscles
  - **P: P**upil
  - **E: E**ffect on eye

[Memory hack]

How to remember what radial muscles are doing:

- Radial muscles are "afraid of the dark", so when it's dark they tense up in fear, hence they contract.
- When you're in a bright place, they relax

5. Hormones

- **Endocrine gland:** A ductless gland that secretes its products directly into bloodstream.
- **Hormone:** A chemical substance produced by an endocrine gland, and is carried in the bloodstream. It causes responses in one or more target organs, and is destroyed by the liver.

Blood glucose regulation

Hormone	Insulin	Glucagon
Stimulus	High blood glucose level	Low blood glucose level
Detected by	Cells* in islets of Langerhans	Cells* in islets of Langerhans
Secreted by	Cells* in islets of Langerhans	Cells* in islets of Langerhans
Target organs	Liver and muscles	Liver only
Responses to insulin	• Increases **permeability** of liver and muscle cells to glucose, glucose **diffuses** in, decreasing blood glucose levels • **Glucose** is converted into **glycogen** in liver and muscles	• **Glycogen** is converted to **glucose** in liver (but not in muscles), and glucose is released into the **bloodstream**
Overall effect	Decreases blood glucose level until set-point	Increases blood glucose level until set-point

**2 different types of cells of the islets of Langerhans are responsible for secreting insulin and glucagon respectively.*

Adrenaline/Epinephrine

- Stimulated by **emotions** of fear, anger, excitement, stress
- Prepares the body for a **fight-or-flight** response
- Detected by **hypothalamus**, which sends **nerve impulses** to effectors
- Effectors are the **adrenal glands**, located above the kidneys

Effects of adrenaline

Effect	Purpose
Stimulates conversion of glycogen to glucose in the liver, increasing blood glucose concentration	More glucose is readily available for muscles to use to release **energy** for **muscular contractions**
Increases heart rate and blood pressure	Blood is pumped faster around the body to quickly deliver **nutrients** and $\mathbf{O_2}$ to muscles
Increases breathing rate and volume/depth	Increases available $\mathbf{O_2}$ in the blood for muscles to use during **aerobic respiration**, and increases the rate $\mathbf{CO_2}$ is removed at the lungs
Increases ease of blood clotting	Prevents excessive blood loss in case of injury during the fight-or-flight event
Constriction of arterioles to alimentary canal and skin, dilation of arterioles to muscles	Decreases blood flow to non-essential systems while increasing blood flow to muscles
Pupils dilate	Allows more light into eyes for better vision
Hair erector muscles contract	(More applicable for hairy animals) Hairs stand up, making animal appear larger to intimidate enemies

6. Diabetes mellitus

Diabetes mellitus: The condition where the body is unable to maintain blood glucose level within normal range.

Type 1

- **Pancreas** cannot produce insulin/enough insulin

- Develops at a young age

Type 2

- **Target organs** (liver and muscles) **lose sensitivity** to insulin
- Develops at an older age, linked to unhealthy lifestyle

Symptoms

- Persistent high blood glucose
- Glucose found in urine
- Frequent urination
- Feeling dizzy, fatigue
- Unexpected weight loss
- Wounds take longer to heal

Treatment

- There is currently no cure for diabetes
- Type 1: Insulin injections
- Type 2: Control blood glucose level
  - Diet lower in carbohydrates
  - Exercise regularly
  - If condition worsens, have to inject insulin/take medication to improve body's sensitivity to insulin

7. Bonus: Nervous system vs Endocrine system

System	Endocrine	Nervous
Signal	Hormones	Nerve impulses
Mode of transmission	Bloodstream	Neurones
Speed	Relatively slower	Relatively faster
Duration of responses	Longer-lasting	Short-lived
Voluntary?	Involuntary	Either
Affected areas	Usually more than one target organ	Usually localised

12. Coordination and Response CAQs

Definitions
Q: Define the term reflex action.
Q: Define the term reflex arc.
Q: Define the term endocrine gland.
Q: Define the term hormone.
Q: Define the term diabetes mellitus.
Nervous system Questions
Q: Describe the similarities and differences between a voluntary action and a reflex action. [4]

Q: Describe the pathway of nerve impulses in a **named** reflex action. [6]

Synapses Questions
Q: Describe how the nerve impulses are transferred from the sensory neurone to the next neurone in the nervous system. [3]

Q: Explain how the nerve impulses travel from a sensory neurone to a motor neurone. [2]

Pupil Reflex
Q: Describe **and** explain how the pupil of the eye responds to an increase in light intensity. [4]

- **Related Questions:**
  - Q: Describe the changes that occur in the eye when walking into a bright room. [2]

Accommodation Reflex
Q: Describe how the eye focusses on a near object. [3]
Q: Describe how the eye focusses on a far object. [3]
Visual Pigments Bleached

Endocrine vs Nervous System
Q: Describe the differences between endocrine and nervous control. [6]

Q: Explain why hormonal responses are generally slower than reflex actions. [2]

Adrenaline Secretion
Q: Suggest **and** explain why blood adrenaline concentration increases during a fight. [3]
Blood Glucose Regulation
Q: Describe how the homeostatic control of glucose occurs in the human body. [6]

- **Related Questions:**
  - Q: Describe the roles of insulin and glucagon in the human body. [6]

13. Reproduction in Plants

Learning Outcomes:

1. Sexual vs Asexual Reproduction
2. Bonus: Pros and Cons of Asexual Reproduction
3. Parts of a flower
4. Pollination
5. Fertilisation

Keywords:

- Asexual, sexual, fertilisation, fusion, sex nuclei
- Genetically identical, genetically different, genetic variation
- Self/cross-pollination, bisexual, unisexual
- Long and pendulous, large and feathery,
- Small, smooth, light, spiky, rough, hairy back and legs
- Germinate, diploid zygote

1. Sexual vs Asexual Reproduction

- **Asexual Reproduction:** The process that produces genetically identical offspring from one parent, without the fusion of male and female sex nuclei.
  - Examples: Binary fission (bacteria), budding (yeasts), reproducing by spores, vegetative propagation*
  - **Pro Tip: Vegetative propagation is when a fragment of a parent plant regrows into an entire new plant.*

- **Sexual Reproduction:** The process that involves the fusion of male and female sex nuclei to form a zygote, producing genetically different offspring.
  - Examples: Humans, flowering plants, etc.

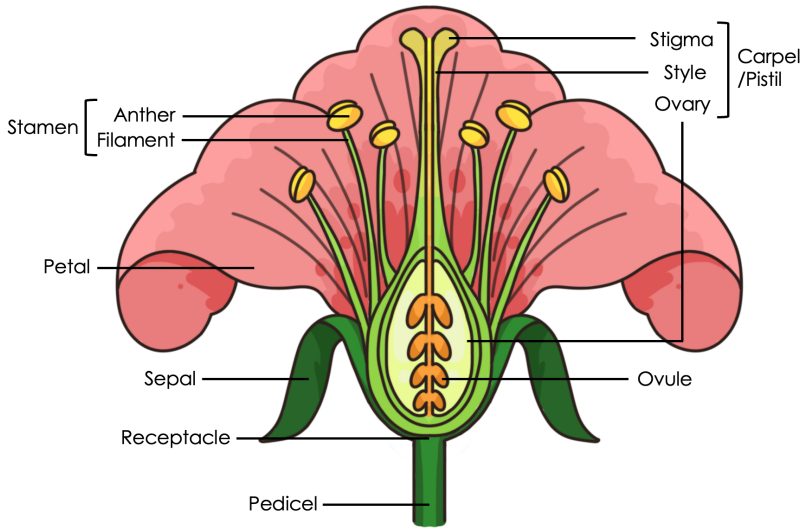
2. Bonus: Pros and Cons of Asexual Reproduction

Advantages	Disadvantages

Favourable traits are passed on as offspring are **genetically identical**	Less **genetic variation** hence more susceptible to disease/environmental change wiping out population*
No need to spend energy on **reproductive organs**	
Reproduction is faster, can colonise an area quickly	

**Pro Tip: On the other hand, sexual reproduction results in more genetic variation, and the species can adapt to environmental changes faster, increasing their chances of survival.*

3. Parts of a flower



**Pro Tip: Receptacle is the base of the flower where the parts of the flower are attached*

Structure	Function
Sta**men** (Remember it is male part of flower because of **men**)	Consists of the male parts of the flower
Filament	Holds the **anther** in a good position to release **pollen grains**

Anther	Produces **pollen grains**
Carpel/Pistil	Consists of the female parts of the flower
Stigma (Remember, **stick**y)	Receives **pollen grains**
Style	Holds **stigma** in good position to receive **pollen grains**
Ovary	Produces and protects **ovules**, and becomes the **fruit** after **fertilisation**
Ovule	• Becomes a seed after **fertilisation** • Contains an **ovum**, the female gamete
Receptacle	The base of the flower where the other parts of the flower are attached
Sepal (All sepals = Calyx)	Protects the flower during the bud stage
Petal (All petals = Corolla)	• Can be colourful to attract **pollinators** • Can have **nectar guides**

4. Pollination

- **Pollination:**The transfer of pollen grains from an anther to a stigma.

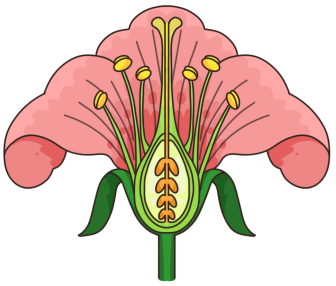
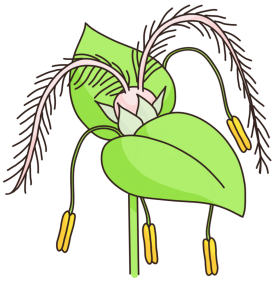
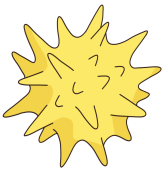
Type	Self-pollination	Cross-pollination
Difference	Occurs within the **same plant**	Occurs between **different plants** of the same species

[Memory shortcut] Features of flowers that favour self/cross pollination [MOP] **M:** Male and female parts **M**ature at same time? **O:** Flowers may not **O**pen **P:** **P**osition (anther higher/lower than stigma)	**M:** Bisexual flowers, both male and female parts mature at same time **O:** Flowers may not Open (ensuring self-pollination) **P:** Position (anther higher than stigma so pollen can fall on stigma)	**M:** Male or female parts mature at different timings/Unisex flowers **O:** Flowers open **P:** Position (anther lower than stigma)
Parent plants involved	1	2
Genetic variation	Less*	More
Chance of occurring	Higher	Lower
Energy expenditure	Lower	Higher, need to produce a lot more pollen

*Pro Tip: ***Self-pollination is NOT asexual reproduction.*** *It involves fertilisation = it is sexual reproduction, hence there is still genetic variation, just lesser variation than cross-pollination.*

Insect vs wind pollination

Pollinating Agent*	Insects	Wind

How it works	• Insects visit flowers to obtain **nectar** • **Anthers** brush against insects, pollen grains stick onto their **hairy** bodies/**hairy back and legs** (more suitable for bees) • Pollen grains are transferred from the insect to **stigma** of the same/different flower	• Pollen grains are picked up by wind • They land on the stigmas of another flower
Stigma	Small	Large and feathery
Odour/scent	Sweet-smelling	Odourless (No smell)
Anthers	Small	Large
Protruding reproductive parts?	No 	Yes 
Filament	Shorter	Long and pendulous (hangs loosely)
pollen **G**rains	• Relatively fewer • Larger and rough/spiky 	• Very numerous • Small, light and smooth 
Nectar	Present	Absent

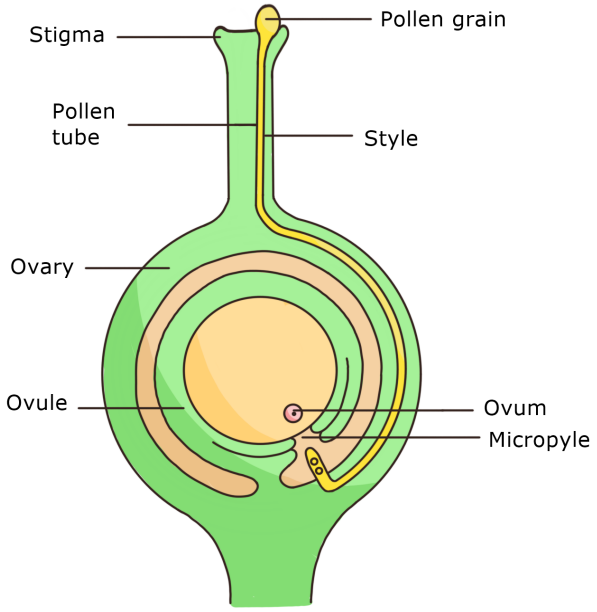
Colour (petals)	Bright and colourful petals to attract insects	Petals are dull/absent

[Memory shortcut]

- Features of insect/wind-pollinated flowers [SOAP GNC]
  - **S: S**tigma
  - **O: O**dour
  - **A: A**nthers
  - **P: P**rotruding reproductive parts
  - **G:** Pollen **G**rains
  - **N: N**ectar (and nectar guides)
  - **C: C**olourful petals

5. Fertilisation

Fertilisation: The fusion of male and female sex nuclei, resulting in a diploid zygote.



Process leading to fertilisation:

- After pollination, stigma produces a **sugary fluid**, stimulating pollen grain to **germinate**.
- A **pollen tube** grows from the pollen grain, secreting **enzymes** to digest a path through **stigma**, **style** and **ovary wall**.
- Pollen tube enters an **ovule** via the **micropyle**.

- Pollen tube (absorbs sap and) bursts, releasing two **male sex nuclei**, one of which* fuses with the **ovum** forming a **diploid zygote**.
    - **Pro Tip: (FYI) The other nuclei helps form the endosperm, which will be the food reserves for the seedling.*

[Memory shortcut]

- Fertilisation process in flowers [STEM-2D]
    - **S:** **S**ugary fluid
    - **T:** pollen **T**ube
    - **E:** **E**nzymes secreted
    - **M:** **M**icropyle
    - **2:** **2** nuclei released, 1 of which fuses with ovum
    - **D:** **D**iploid zygote

After fertilisation

- Flower withers
- Ovary turns into a fruit
- Ovules turn into seeds
    - If fertilisation does not occur in an ovule, it degenerates when the ovary turns into a fruit
    - At least 1 ovule must be fertilised for the ovary to turn into a fruit

13. Reproduction in Plants CAQs

Important Definition
Q: Define the term asexual reproduction.
Q: Define the term sexual reproduction.
Q: Define the term pollination.
Q: Define the term self-pollination.
Q: Define the term cross-pollination.
Q: Define the term fertilisation.

Sexual vs Asexual Reproduction
Q: State the differences between sexual and asexual reproduction. [4]

Insect & Wind Pollination
Q: Describe how insect pollination occurs. [2]
Q: Describe how wind pollination occurs. [2]

Insect vs Wind Pollination
Q: State two differences between wind-pollinated and insect-pollinated flowers. Give a reason for each difference. [4]

Pros and Cons of Self and Cross-pollination
Q: Describe the advantages and disadvantages of self-pollination compared to cross-pollination. [4]

Advantage of Genetic Variation
Q: A new disease breaks out amongst 2 plant populations. Population A are all self-pollinated and population B are all cross-pollinated. It is observed that population A failed to survive, while population B survived. Explain why. [4]
Fertilisation Process
Q: Outline the process leading to fertilisation after pollination. [4]

14. Reproduction in Humans

Learning Outcomes:

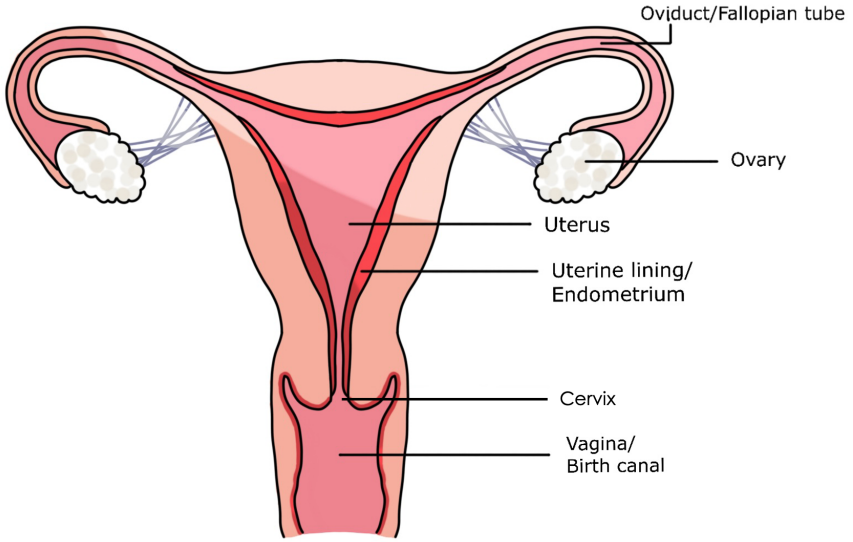
1. Male and female reproductive system
2. Describing the menstrual cycle
3. Fertilisation
4. Foetal development
5. Human Immunodeficiency Virus (HIV)

Keywords:

- Erectile, ejaculation, testosterone, sexual intercourse
- Gametes, fertilisation, fusion of sex nuclei
- Oestrogen, progesterone, mature ovum, ovulation, repair, further thickening
- Peristaltic action, sweeping action
- Activate, nourish, neutralise, acidic environment
- Puberty, menstruation, pregnancy
- Zygote, embryo, implantation, foetus
- Finger-like projections, immunity, muscular development
- Sexually transmitted infection, mucous membrane, human immunodeficiency virus, acquired immune deficiency syndrome
- Abstinence, physical barrier, sterilise

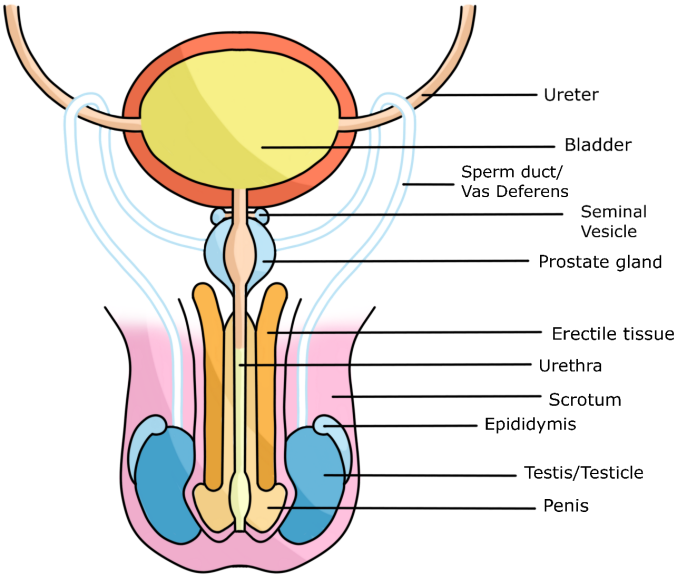
1. Male and female reproductive system

Female reproductive system



Structure	Function
Vagina (birth canal)	Where sperms are deposited during **sexual intercourse**
Cervix	The opening between the uterus and vagina (allows sperm from vagina to enter uterus, as well as menstrual blood to pass from uterus to vagina)
Uterus (womb)	• The uterine lining sheds during **menstruation** • An **embryo** embeds itself in the uterine lining during **implantation** • **Foetus** develops here during **pregnancy** • During **childbirth**, its elastic muscles contract to push out the **foetus**
Oviduct/Fallopian tube	• Where **mature ovum** are released • Site of **fertilisation**
Ovary	• Site of where **eggs** mature • Produces **oestrogen** and **progesterone**

Male reproductive system



Structure	Function

Testis*/testicle (plural: testes/testicles)	Produces **sperm** and **testosterone**
Scrotum	The skin sac containing testes (which need to be outside of the body to be 2°C cooler for sperm production)
Sperm duct	Carries sperm from the testes to the prostate gland
Seminal vesicles + Cowper's gland	Secretes fluids that later make up **semen**
Prostate gland	Mixes sperm with a fluid to **nourish** and **activate** sperms
Urethra	The duct for urine/semen to exit
Penis	The male **erectile** organ, which deposits **semen** into vagina during **sexual intercourse**

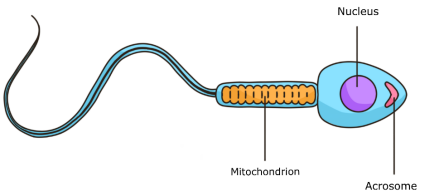
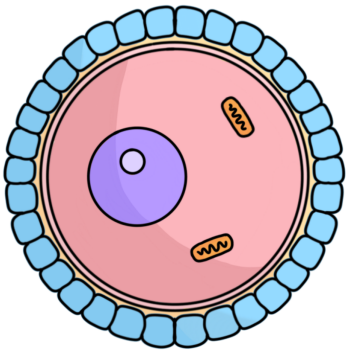
Semen = Sperm + fluids from the seminal vesicles, cowper's gland and prostate gland.

[Memory shortcut]

- Functions of fluids in semen [LANE]
  - **L:** **L**ubricates, making it easier for sperm to swim to ovum
  - **A:** **A**lkaline, neutralises acidic environment of the vagina to protect sperm
  - **N:** **N**ourishes sperm with nutrients like glucose, mineral salts
  - **E:** **E**nzymes from prostate gland activate sperm to swim actively

Comparing male and female gametes (sex cells)

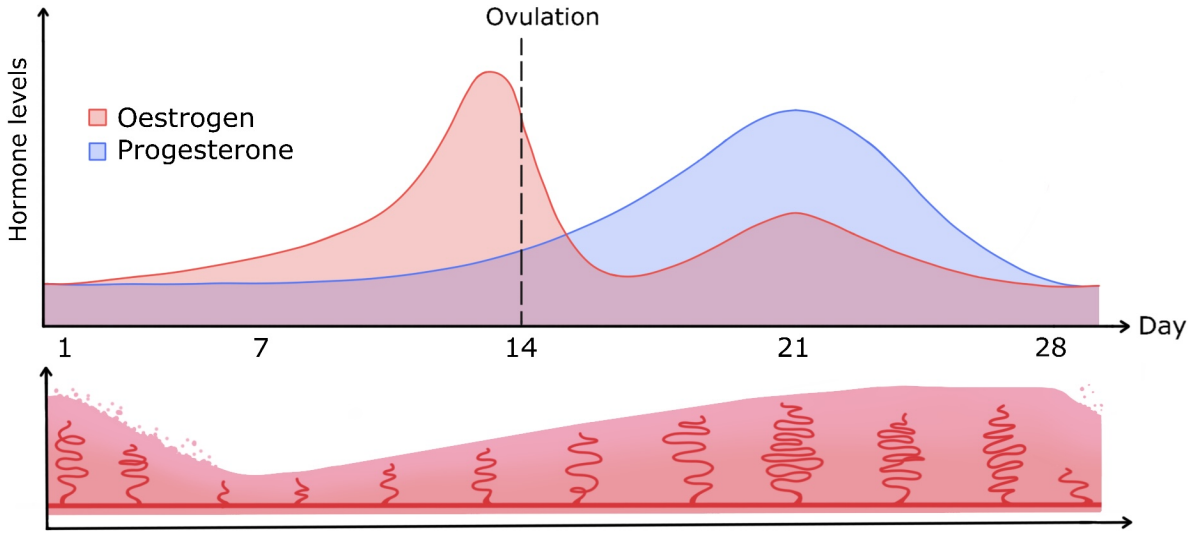
Gamete	Male (sperm)	Female (ovum)

Appearance*		
Size	Smaller	Larger
Number	~250 million per ejaculation	1 released per ovulation
Motility (ability to move)	Yes, using its flagellum	No, is moved by cilia and peristalsis in the oviduct

**Pro Tip: Knowing the detailed parts of the sperm and egg are not required.*

2. Menstrual cycle

- Begins when a female hits **puberty** (the stage where an adolescent becomes physically mature)
- Typical menstrual cycle = 28 days, but it varies. It could vary more or stop completely if the person is experiencing high stress/poor diet/poor sleep, etc.



Pro Tip: You must be familiar with the hormone graph
[Memory shortcut]

- Stages of menstrual cycle [Mother Orders Restaurant, Father Pays Bill]
  - **M:** **M**enstruation (Day 1-5)
  - **O:** **O**estrogen is the dominant hormone in the 1st half
  - **R:** which **R**epairs and thickens uterine lining
  - **F:** **F**ertile period (Day 11-16) surrounds ovulation (Day 14)
  - **P:** **P**rogesterone is the dominant hormone in the 2nd half
  - **B:** which causes growth of more **B**lood vessels within lining

Day	Stage	Events
1-5	Menstruation	The **uterine lining** and **unfertilised egg** are broken down and discharged out of the vagina as **menses**
6-13	Repair + Growth	• **Oestrogen** levels increase • Uterine lining **repairs** and **thickens**
11-16	Fertile period + Ovulation (Day 14)	• Upon **ovulation**, one ovary releases a **mature ovum** into the oviduct, which survives for 2-3 days unless **fertilised** • **Sexual intercourse** during this period has highest chance of **pregnancy**, since sperms survive up to 3 days
15-28	Growth + Maintenance	• **Progesterone** levels increase • Uterine lining thickens further and more blood vessels grow within it, preparing for possible **implantation** • Nearing the end of the menstrual cycle, **oestrogen** and **progesterone** levels fall, causing the **uterine lining** to shed, starting the next menstrual cycle

Hormones involved in menstruation

- **Oestrogen**
  - Stimulates **repair** and **thickening** of uterine lining
  - Inhibits another **ovulation** during second half of the menstrual cycle

- **Progesterone**
  - **Maintains** thickness and stimulates **further thickening** of uterine lining
  - Stimulates **growth of more blood vessels** in uterine lining
  - Inhibits another **ovulation** during second half of the menstrual cycle

3. Fertilisation

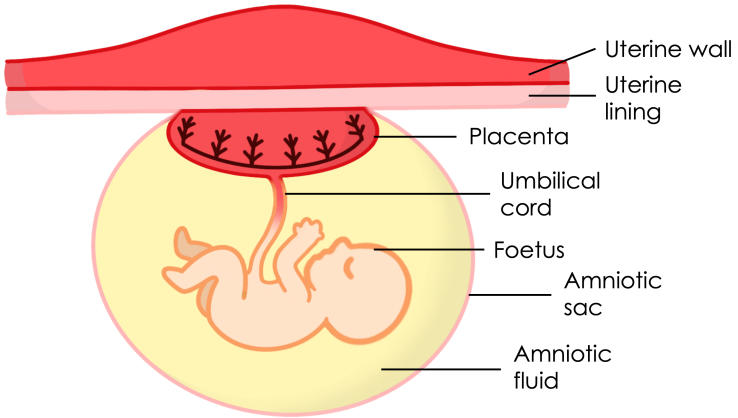
Fertilisation: The fusion of nuclei of a sperm and ovum, forming a diploid zygote.

- Occurs in the oviduct/fallopian tube

Implantation: The process whereby the embryo embeds itself in the uterine lining.

- **Zygote** travels toward uterus via **peristaltic action** of the **oviduct** walls and **sweeping action** of **cilia**
- The zygote undergoes **mitosis**, forming an **embryo** (a ball of cells)
- Embryo reaches uterus 5 days after fertilisation, floats around for 2 days. On Day 7, **embeds** itself into uterine lining during **implantation**.
- The placenta, amniotic sac and foetus then develops.

4. Foetal development



Placenta

- After implantation, **finger-like projections**, called **villi**, grow into the uterine lining, forming the **placenta**.
- Placenta secretes **progesterone** to maintain thickness of the uterine lining, supporting pregnancy.
- **Oxygen** and **nutrients** such as glucose, amino acids **diffuse** from maternal to foetal capillaries
- **Metabolic waste products** such as urea and carbon dioxide **diffuse** from foetal to maternal capillaries

- Some **antibodies** diffuse from maternal to foetal capillaries, giving the foetus **immunity** against some diseases
- Maternal and foetal blood do not mix, because:
    - Mother's blood pressure > foetus, would kill foetus
    - Mother and foetus may have incompatible **blood types**

Amniotic sac/Amnion

- Contains amniotic fluid and the foetus
- Amniotic fluid
    - **Supports** and **cushions** foetus by absorbing shock
    - Allows some movement, promoting **muscular development**
    - **Lubricates** birth canal during childbirth
    - Trains the **digestive** system, as the foetus drinks the fluid and urinates it

**Pro Tip: When a pregnant woman's 'water bag' bursts nearing labour, it means the amniotic sac broke.*

Umbilical cord

- Carries nutrients and oxygen from **placenta** to **foetus**
- Carries **metabolic waste products** from foetus to placenta
- Umbilical cord has 2 arteries *(from foetus to placenta) and 1 vein (toward foetus)

**Pro Tip: Umbilical arteries carry deoxygenated blood, because artery carries blood away from foetus' heart, to placenta*

5. Human Immunodeficiency Virus (HIV)

- HIV is a sexually transmitted infection (STI)
- HIV attacks a certain type of white blood cells, decreasing their number
- The resulting condition = **Acquired Immune Deficiency Syndrome** (AIDS) as the immune system is weakened, and body is susceptible to common infections that would otherwise not be as severe.

Modes of HIV transmission:

- Unprotected sexual intercourse with infected individual
    - Where **semen** containing HIV comes into contact with the **mucous membrane** of an uninfected female's **vagina**, OR

    - When **vaginal fluids** containing HIV come into contact with the **mucous membrane** of an uninfected male's **urethra**.
- Sharing of contaminated needles
- **Blood transfusions** where the donor's blood has the virus
    - **Pro Tip: This is why in professional/public health services, donated blood is always screened.*
- Passed from mother to foetus during **pregnancy**

STIs can be prevented by:

- Abstinence (no sexual intercourse)
- Have only 1 sexual partner/avoiding casual sex
- Using condoms (physical barrier prevents transmission)
- Not sharing needles/sterilising needles whenever used

14. Reproduction in Humans CAQs

Important Definitions
Q: Define the term fertilisation (in the context of humans).
Q: Define the term implantation.
Menstrual Cycle
Q: Explain the changes in the thickness of the uterine lining throughout a typical menstrual cycle. [4]

Hormone levels if Fertilisation Occurs
Q: If fertilisation occurs, what will happen to the thickness of the uterine lining after day 28? Explain your answer. [3]
Fertile Period
Q: On which days of the menstrual cycle is the woman most fertile? Explain your answer. [4]

Importance of Semen Fluids
Q: During the formation of semen, fluids secreted from seminal vesicles, cowper's gland and the prostate gland are mixed with sperm. Explain the importance of these fluids. [4]

Development Of Foetus
Q: Describe the sequence of events that occur after a human egg cell after it is fertilised, which enable it to develop and survive in the uterus. [5]

- **Related Questions:**
  - Q: Describe the process of fertilisation and outline the early development of the embryo. [5]

Placenta Functions
Q: Describe the functions of the placenta during pregnancy. [4]

Maternal and Foetal Blood Do Not Mix
Q: Explain why the maternal and foetal blood vessels are not directly connected. [2]

STI Transmission
Q: Describe the ways in which HIV can be transmitted. [4]

15. Cell Division

Learning Outcomes:

1. Mitosis
2. Meiosis
3. Bonus: Amount of DNA/number of chromosomes at each stage
4. Genetic variation

Keywords:

- Mitosis, nuclear division, diploid, genetically identical, genetically different
- DNA replication, genes, mutation, uncontrolled cell division, cancer
- Prophase, metaphase, anaphase, telophase, cytokinesis
- Sister chromatids, centromeres divide, daughter chromosomes
- Mitotic spindle, opposite poles, equator of cell, unravel
- Meiosis, haploid, reduction division, diploid condition
- Homologous chromosomes, gene loci, centromere position, synapsis
- Crossing over, corresponding sections of DNA, non-sister chromatids, new combinations of alleles, chiasmata
- Independent assortment of chromosomes, orientation of homologous pairs, random fertilisation

1. Mitosis

Mitosis: A form of nuclear division which produces two genetically identical daughter nuclei, containing the same number of chromosomes as the parent nucleus.

- Usually occurs in **diploid** cells
  - **Diploid:** Having two complete sets of chromosomes, one from each parent.
- Before mitosis occurs, **DNA replication** occurs

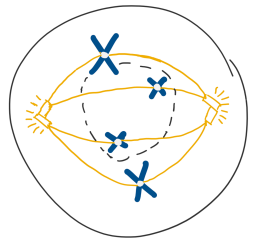
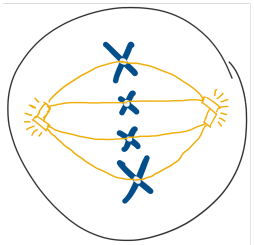
Importance

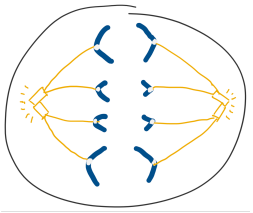
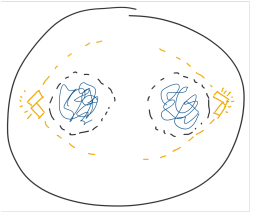
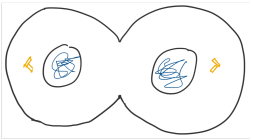
- Mitosis is needed for **growth**, **repair**, and in **asexual reproduction**
- Mitosis results in **genetically identical** cells:
  - Ensuring proper development of the **embryo** from the **zygote**
  - Preventing **genes** from changing (**mutations**), which can lead to cells appearing foreign hence being attacked by the **immune system**

- Prevents **mutations**, which can lead to **uncontrolled cell division** and subsequently **cancer**

Mitosis Stages
[Memory hack]

- Mitosis stages [Pee on the Mat]
  - **P:** **P**rophase *(preparing)*
  - **M:** **M**etaphase *(middle)*
  - **A:** **A**naphase *(away)*
  - **T:** **T**elophase *(two nuclei)*

Stage of Mitosis	Events occurring
Prophase 	• **Chromatin** condenses into **chromosomes** • **Nuclear envelope** disintegrates, **nucleolus** disappears • **Centrioles** begin migrating to **opposite poles** • Chromosomes begin migrating to **equator** of the cell • **Spindle fibres/microtubules** begin to form, **asters** form around centrioles ◦ Function of asters is to anchor the centrioles down to the poles of the cell ***[Memory hack]*** • Aster sounds like "a star" and they look like the shining beams of a star
Metaphase 	• Chromosomes have aligned at the **equator** of the cell • **Centrioles** are found at **opposite poles** • **Mitotic spindle** fully formed with **microtubules** attached to the **centromeres** of chromosomes

Anaphase 	• **Microtubules** shorten, **centromeres** of chromosomes **divide**, each **sister chromatid** is now a **daughter chromosome**, pulled to opposite poles
Telophase 	• **Daughter chromosomes** have reached **opposite poles** and unravel into **chromatin** • **Nuclear envelope** reforms around chromatin, **nucleolus** reappears • **Microtubules** disintegrate • One **centrosome** (centrosome = a pair of centrioles) is found at each pole
Cytokinesis* 	**Cytoplasm** divides into two, resulting in two **diploid** daughter cells **Pro Tip: Cytokinesis is not considered as part of mitosis. It occurs during or after telophase.*

[Memory hack]

- Aspects of Mitosis/Meiosis stages [Child Naughty Call Mother]
  - **C: C**hromosomes
  - **N:N**ucleus + Nucleolus
  - **C: C**entrioles
  - **M: M**icrotubules

2. Meiosis

Meiosis: A form of nuclear division which produces four genetically different haploid nuclei, containing half the number of chromosomes as the parent nucleus.

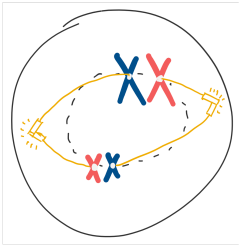
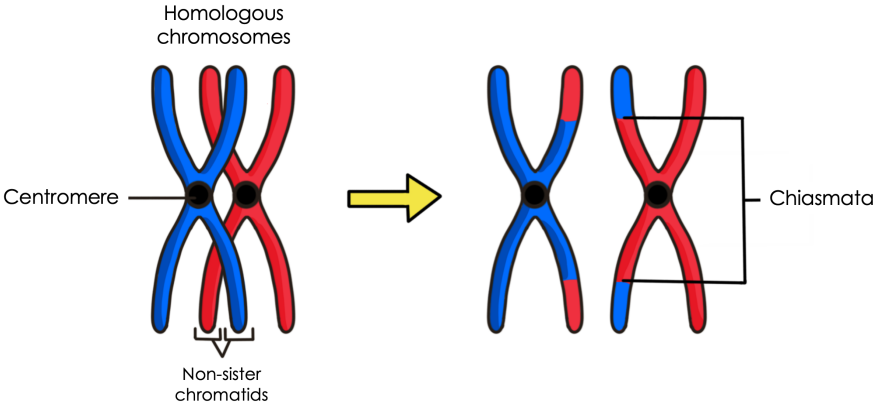
- Occurs during the formation of **sex cells/gametes**.
- Consists of 2 divisions, Meiosis I and Meiosis II
- 1 **diploid parent cell** at the start of Meiosis becomes 4 **haploid daughter cells** after Meiosis is complete
  - **Haploid:** Having only one complete set of chromosomes.

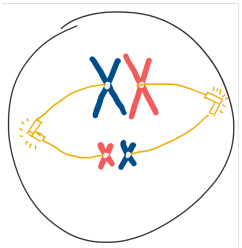
**Pro Tip: Being haploid is defined by the number of chromosomes, not the amount of DNA.*

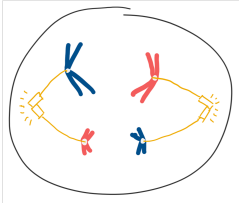
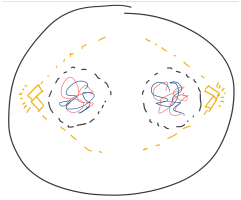
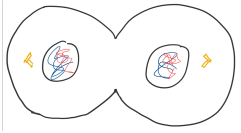
Meiosis I

- Before Meiosis I, **DNA replication** occurs
- Meiosis I is also known as **reduction division**, as it results in daughter cells having half the number of chromosomes as before
- **Homologous chromosomes:** A pair of chromosomes, one from each parent. They have the same length, centromere position, and same gene loci, although they may have different alleles.
    - In diploid cells, there are 2 chromosomes for each chromosome number
    - Each of these pairs is called a **homologous** pair
- **Importance of reduction division:**
    - During **fertilisation**, nuclei of **gametes** fuse into 1 nucleus
    - **Haploid** gametes (23 chromosomes) fuse to give a **diploid** zygote (46 chromosomes), restoring the **diploid condition**
    - This ensures that chromosome number stays constant and does not double with every successive generation

Stage of Meiosis I	**Events** (Details repeated in mitosis have been simplified)

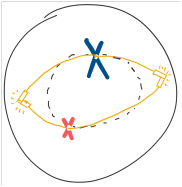
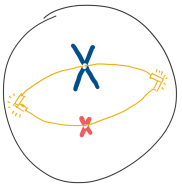
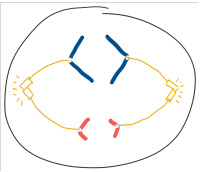
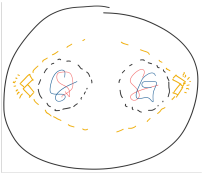
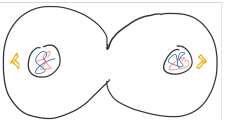
Prophase I
 
	• **Synapsis** occurs: **Homologous chromosomes** pair up
	• **Crossing over:**
	  ◦ During **Prophase I**,crossing over may occur, exchanging **corresponding sections** of DNA between **non-sister chromatids** of homologous chromosomes,
	  ◦ resulting in **new combinations of alleles** and forming **chiasmata**.
	
	[Memory Shortcut]
	• Crossing over explanation [PENAC]
	  ◦ **P:** **P**rophase I
	  ◦ **E:** **E**xchange of sections of DNA between
	  ◦ **N:** **N**on-sister chromatids of homologous chromosomes
	  ◦ **A:** new combinations of **A**lleles
	  ◦ **C:** **C**hiasmata
	
	**Pro Tip: Chiasmata = plural of chiasma. Chiasmata = places where crossing over has occurred*
	 

Metaphase I 	• **Homologous pairs** align along the **equator** of the cell, each chromosome is attached to **one microtubule** from **one pole**

Anaphase I 	• **Homologous chromosomes** separate to **opposite poles** ◦ (notice that centromeres did not divide)
Telophase I 	• Chromosomes reach opposite poles of the cell and **unravel** into **chromatin** • No DNA replication after Meiosis I
Cytokinesis I 	Results in the formation of 2 **haploid** daughter cells

Meiosis II

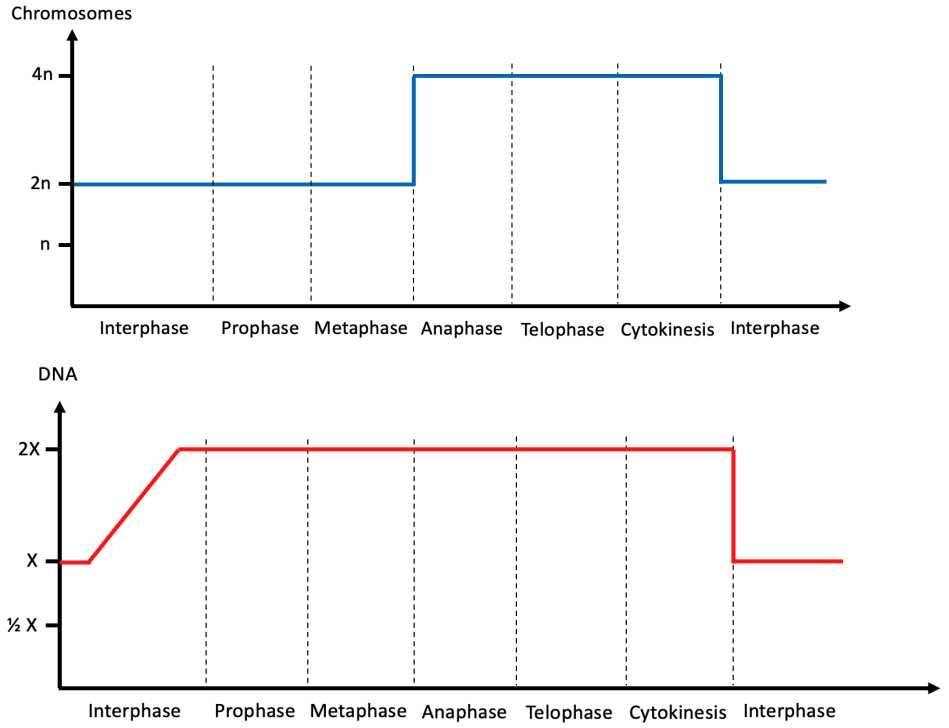
- The events of meiosis II are very similar to that of Mitosis:

Prophase II	Metaphase II	Anaphase II	Telophase II	Cytokinesis II
				 4 **haploid** daughter cells (**gametes**) produced

3. Bonus: Amount of DNA/Number of chromosomes at each stage

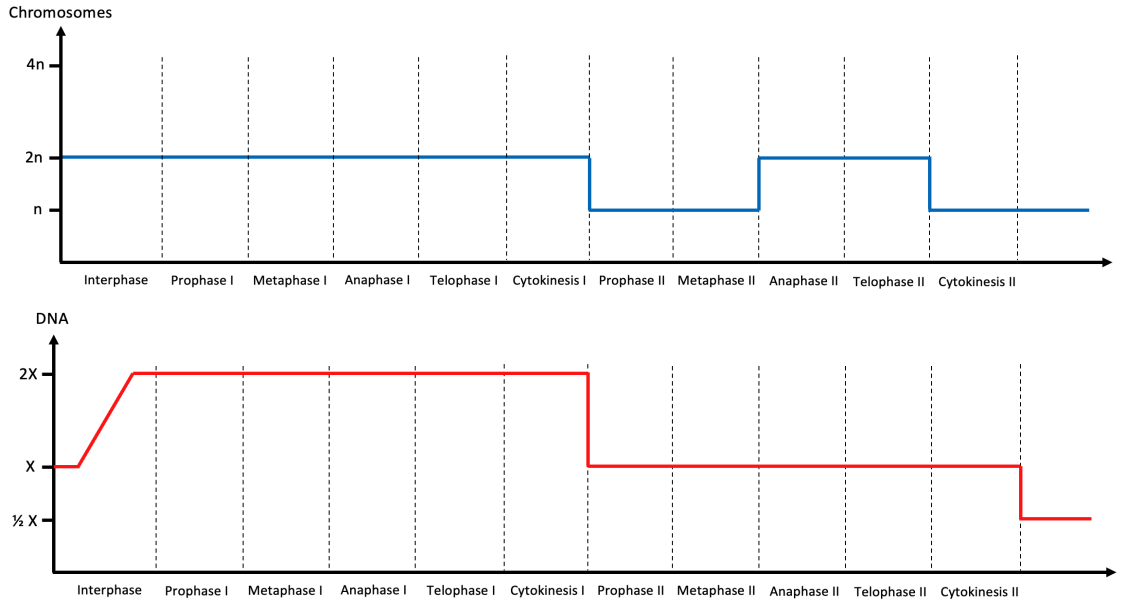
- Let amount of DNA per cell be **x**
- Let original number of chromosomes per cell be **2n**

Mitosis



**Pro Tip: Number of chromosomes are counted by the number of centromeres present. This is why chromosome number doubles during Anaphase and Anaphase II.*

Meiosis



**Pro Tip: Youtube animations to visualise mitosis and meiosis better:*

- Mitosis: https://www.youtube.com/watch?v=DwAFZb8juMQ&ab_channel=Bifrost
- Meiosis: https://www.youtube.com/watch?v=nMEyeKQClqI&ab_channel=DailyMedEd

4. Genetic variation

- Genetic variation is advantageous as the species is less susceptible to sudden environmental changes as it can better adapt and survive

Independent assortment of chromosomes during metaphase I

- **Orientation** of homologous pairs of chromosomes is independent of other pairs
- Maternal/paternal chromosome could be **segregated** into either daughter cell
- (As a result, there are 2^23 possible genetic combinations for human sperm and ovum.)

Crossing over

- During **Prophase I**, **crossing over** may occur, exchanging **corresponding sections** of DNA between **non-sister chromatids** of **homologous chromosomes**,

- resulting in **new combinations of alleles** and **forming chiasmata**, increasing the **genetic variation** of the gametes

Random fertilisation

- Each parent produces **genetically different** gametes
- During fertilisation, a random sperm and a random egg meet, increasing the number of **offspring variants**

15. Cell Division CAQs

Important Definitions
Q: Define the term diploid.
Q: Define the term haploid.
Q: Define the term mitosis.
Q: Define the term meiosis.
Q: Define the term homologous chromosomes.

Importance of Mitosis
Q: Give 2 reasons why mitosis is important in living organisms. [2]

Importance of Reduction Division/Meiosis I
Q: Explain the importance of reduction division. [3]

- **Related Questions:**
  - Q:Explain why meiosis is important in organisms that reproduce sexually. [3]

Mitosis vs Meiosis
Q: Describe the similarities and differences between mitosis and meiosis I. [4]

- **Related Questions:**
  - *Questions can ask for similarities/differences even between specific stages, Eg: Describe 2 differences between Telophase I and Telophase II. [2]*

Sources of Genetic Variation
Q: Explain the mechanisms that create genetic variation in offspring. [6]

16. Molecular Genetics

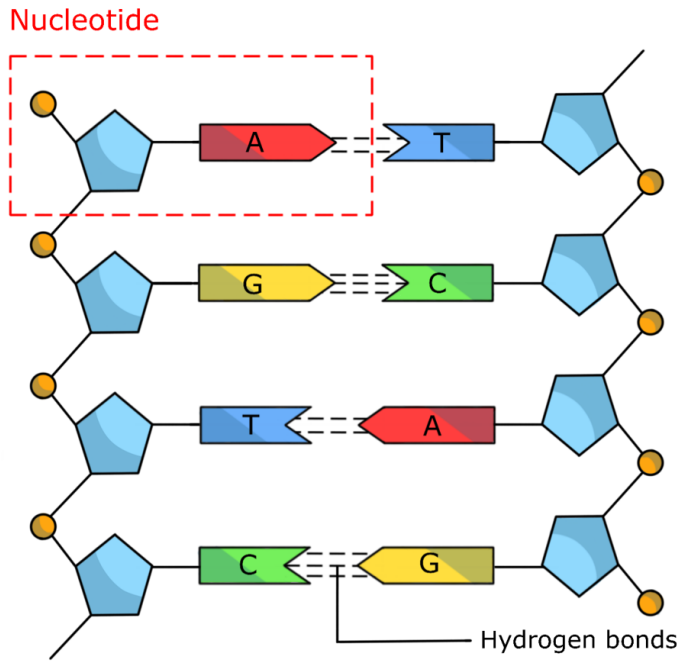
Learning Outcomes:

1. DNA structure
2. DNA to protein
3. Genetic Engineering
4. Implications of Genetic Engineering
5. Bonus: Genetic Engineering vs Artificial Selection

Keywords:

- Deoxyribonucleic acid, double helix, anti-parallel, nucleotide, polynucleotide
- Nitrogenous base, Adenine, Thymine, Guanine, Cytosine
- Hydrogen bond, complementary base pairing
- Gene, codon, sequence of amino acids, specific polypeptide, transcription, translation
- Donor, recipient, transgenic organism, foreign genes, anneal, vector, plasmid
- Restriction enzyme, restriction site, sticky ends, recombinant plasmid, heat/electric shock

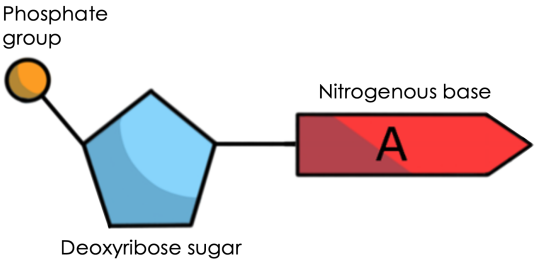
1. DNA (Deoxyribonucleic Acid)



Structure of DNA

- DNA contains genetic information

- DNA is made of two **anti-parallel** polynucleotide strands wound together forming a **double helix**
- Is made of **nucleotides**, which have:
  - **Deoxyribose** sugar
  - **Phosphate group**
  - **Nitrogenous**/nitrogen-containing **base** (Adenine/Thymine/Guanine/Cytosine)



- The strands are held together by **complementary base pairing**, with **hydrogen bonds** between:
  - **Adenine** and **Thymine**
  - **Guanine** and **Cytosine**
  - Therefore ratio of A:T and G:C must = 1:1

[Memory hack]

- Remembering which nitrogenous bases pair together
  - **Adenine** + **Thymine**: Picture an **Adder** (a type of snake) bites a person's **Thigh**.
  - **Guanine** + **Cytosine**: Picture **Guava** slices inside a cell's **Cytoplasm**.

DNA vs Gene vs Allele vs Chromosome vs Chromatin

- **DNA**: DNA is a type of molecule, just like carbohydrates, proteins and fats are types of molecules.
  - DNA can be very short, or very long
- **Gene:** A sequence of nucleotides that codes for a specific polypeptide
  - A long DNA molecule can consist of many genes along it
  - **Pro Tip: Gene has a more detailed definition in the topic Inheritance.*
- **Allele**: A different/alternative form of the same gene.
  - Alleles usually have slight **nucleotide** differences, but are otherwise very similar.
- **Chromatin**: In the nucleus, DNA is loosely-packed and coiled around proteins. This form of DNA is called chromatin.

- **Chromosome**: A chromosome is a very long strand of DNA.
    - In the nucleus, chromosomes are not yet condensed, and are in the loose form of chromatin. Chromosomes condense during cell division.

2. DNA to Protein

Transcription: The process where DNA is used as a template to synthesise a strand of mRNA.

- The 2 strands of DNA are separated
- One of the strands are used as a template to make a complementary strand of mRNA
- On mRNA, each **Thymine** (T) base is replaced with a **Uracil** (U) base.

Translation: The process where mRNA is used as a template to synthesise a sequence of amino acids, forming a polypeptide.

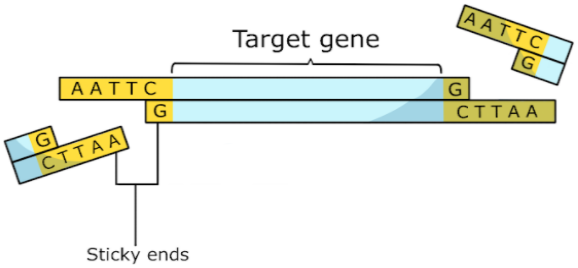
- mRNA leaves the nucleus to the cytoplasm
- **Ribosomes** attach to the mRNA, and read the sequence to decide how to synthesise the polypeptide
- Every 3 nucleotides of mRNA is called a **codon**, and mRNA codon codes for an **amino acid**
- mRNA dictates the **sequence of amino acids** in the **polypeptide**, which in turn determines the structure and function of the protein.

**Pro Tip: Do not worry about the details of transcription and translation. Only a brief understanding is needed to answer questions.*

3. Genetic Engineering

Genetic Engineering: The technique used to transfer genes from one organism to another.

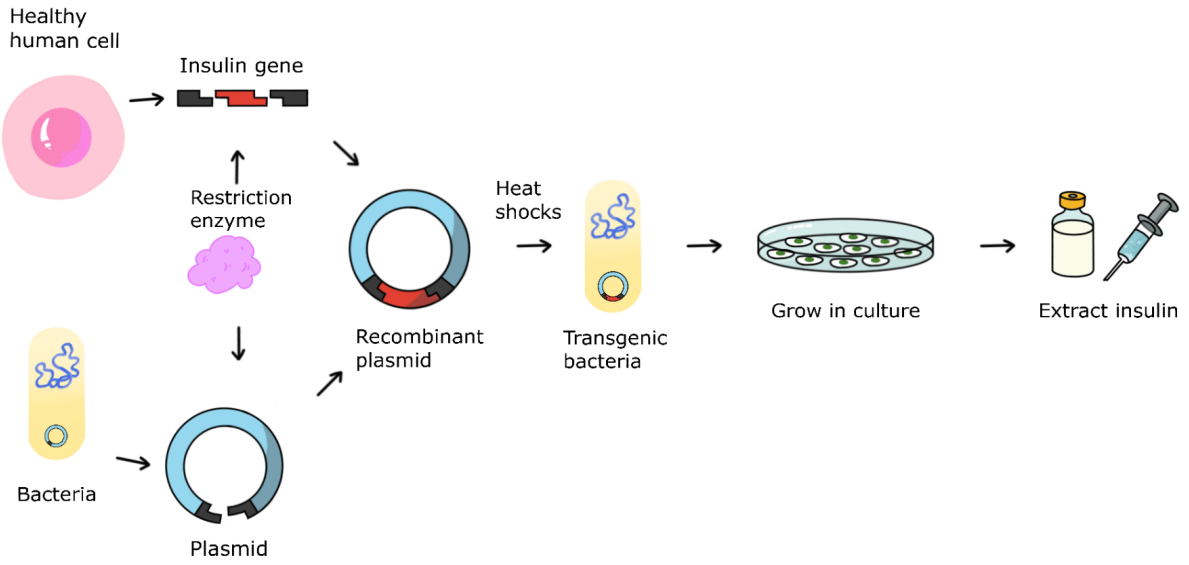
- Requires a **vector** (a vehicle that transfers genes)
- A commonly used vector is a **plasmid** (small, extrachromosomal circular DNA found in bacteria)
- **Transgenic organism:** An organism which contains foreign genes after gene transfer.



Restriction enzymes

- Naturally found in bacteria as defences against viruses
- Recognise a specific short nucleotide sequence, the **restriction site**
- They cut DNA there, resulting in **sticky ends** (where unpaired nucleotides can complementary base pair with another such strand to form double stranded DNA)

Genetic Engineering of bacteria to produce human insulin



Inserting gene into plasmid

- A **restriction enzyme** is used to cut a section of DNA containing the human **insulin gene**, creating **sticky ends**
- The same **restriction enzyme** is used to cut a **plasmid**, creating **sticky ends**
- Plasmid and DNA are mixed, allowing them to **anneal** via **complementary base pairing** at the sticky ends
- **DNA ligase** is added to bond them together, the result is a **recombinant plasmid** which carries the insulin gene

Inserting recombinant plasmid into bacteria

- **Heat/electric shock** treatment is applied to the bacteria that create **pores** in their **plasma membranes** so they can uptake the **recombinant plasmids**
- Those bacteria become **transgenic** bacteria, and will produce insulin as part of their **metabolic processes**

**Pro Tip: Only a small percentage of bacteria will successfully uptake plasmids. They can be isolated by mixing with an antibiotic that the recombinant plasmids make them resistant to.*

[Memory Shortcut]

- Genetic engineering process [Really Talkative PALS]
  - **R:** **R**estriction enzyme
  - **T:** **T**arget gene
  - **P:** **P**lasmid
  - **A:** **A**nneals via complementary base pairing
  - **L:** DNA **L**igase
  - **S:** **S**hock treatment

Creating transgenic plants

- Use a **restriction enzyme** to cut the desired gene from the **donor organism**
- Use the same **restriction enzyme** to cut a **plasmid**
- Mix them together so they **anneal** via **complementary base pairing**. Add **DNA Ligase**, forming a **recombinant plasmid**
- Using **heat/electric shock** treatment, insert the **recombinant plasmid** into a bacteria that infects plant cells
- Allow bacteria to infect plant cells, the desired gene will be inserted into the plant's DNA
- Induce the cells to grow into plants. They will produce the desired gene product.

3. Implications of Genetic Engineering

- **Biological implications:** Impact on living things due to biological reasons

- **Social implications:** Impact on society, usually social/economic, but also includes health benefits/unforeseen health problems caused to humans who consume GM products
- **Ethical implications:** How genetic engineering could be morally questionable

Advantages of Genetic Engineering	How is it a benefit?
Low-cost production of medicine, such as insulin	Saves lives and is affordable
Can be used to treat genetic diseases	Saves lives
Crops that can grow in extreme weather conditions	Increase crop yields, avoiding food shortages, especially in light of climate change
Crops that have higher nutritional value, e.g. Golden rice, higher vitamin A	Decreasing malnutrition, especially in poorer countries
Crops produce their own pesticide	Less pesticides need to be sprayed on crops, environmentally-friendly.
Crops resistant to herbicide, e.g. soybeans	Herbicides can be used to efficiently kill weeds, increasing crop yields

Disadvantages of Genetic Engineering	How is it a disadvantage?
New proteins in GM food may cause allergies in some people	Some people may suffer allergic reactions
Unforeseen consequences: Unwanted metabolic reactions may result, producing harmful toxins	May be toxic or cancer-causing to people who eat them

Useful insects such as butterflies and honey bees, which feed on nectar of GM crops, may die due to the crop producing pesticide	Loss of biodiversity
Possibility of use for biological warfare	Can be used as weapons of mass destruction
Some companies *(e.g. Monsanto)* engineer GM crops to have seeds that cannot germinate, so farmers must constantly buy seeds from the companies	Financial exploitation of farmers
Some companies can set patents on medicines made using genetic engineering, and make medicines very expensive.	Medications too expensive for those who need them and cannot buy/ financial exploitation as people have no choice but to pay the high prices

**Pro Tip: These advantages and disadvantages are not exhaustive lists.*

4. Bonus: Genetic Engineering vs Artificial Selection

Genetic Engineering	Artificial Selection
Involves the insertion of **genes** into the **DNA** of the organism	Does not involve any insertion of **genes** into the **DNA** of the organism
Only requires **one** of the target organism	Requires at least **two** of the target organism, one **male** and one **female**, so that breeding can occur.
Desired outcome is **immediate**, as traits are expressed upon successful insertion of genes	Desired outcome is achieved **gradually**, as traits become more desirable with each generation
Requires precise lab techniques and equipment	Does not require any special lab equipment

Can introduce new traits that were previously non-existent in the organism's **species**	Only can manipulate traits already present in the **species**
Foreign genes can come from a completely different **species** as the target organism	Can only be done within a **species**

16. Molecular Genetics CAQs

Important Definitions
Q: Define the term gene.

Q: Define the term transgenic organism.

Genes, DNA and Chromosomes
Q: Outline the relationship between genes, DNA and chromosomes. [3]

- **Related Questions:**
  - Q: Outline the relationship between genes, alleles and chromosomes. [3]

Structure of DNA
Q: Describe the structure of DNA. [6]
Calculating Percentage of Bases
Q: A scientist analysed a double stranded DNA sample, and found that 15% of its nitrogenous bases were adenine, Calculate the percentage of the other nitrogenous bases in the DNA sample. Explain your answer. [2]

DNA to Protein
Q: Describe how genes control the production of proteins. [3]

Genetic Engineering Process
Q: Explain how E. coli bacteria which produce human insulin can be made. [6]

- **Related Questions:**
  - Q: Explain how a transgenic organism can be produced.

Advantages of Genetic Engineering
Q: Suggest 3 reasons for the development of transgenic organisms. [3]

Disadvantages of GM Crops
Q: People have opposed the use of genetic engineering to improve crop yield. Give 3 reasons that can be used as arguments against this type of genetic engineering. [3]

Social/Ethical implications of genetic engineering

Q: Medical biotechnology can be used to produce chicken eggs that contain human proteins. These proteins can be used in medicines. Discuss 2 social and 2 ethical implications of using chickens to produce human proteins. [4]

17. Inheritance

Learning Outcomes:

1. Inheritance terms and concepts
2. Monohybrid cross
3. Bonus: All monohybrid cross combinations (O levels)
4. Sex determination, sex-linked inheritance
5. Genetic mutation
6. Variation
7. Natural and Artificial Selection

Keywords:

- Phenotype, genotype, allele, gene locus, dominant, recessive
- Homozygous, heterozygous, co-dominance, multiple alleles
- Monohybrid, expected/observed offspring ratio, chance, discrepancy, sample size
- Mutation, mutagens, radiation, sickle-cell anaemia, down syndrome, non-separation/non-disjunction
- Continuous/discontinuous variation, additive effect, intermediates, few and distinct
- Natural selection, selection pressure, favourable traits, evolution
- Artificial selection, selective breeding, hybridisation, inbreeding

1. Inheritance terms and concepts

Gene: A unit of inheritance that determines a specific trait in an organism. It is a sequence of nucleotides that codes for specific polypeptide, and has a particular gene locus.

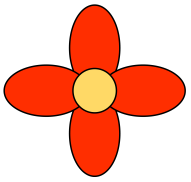
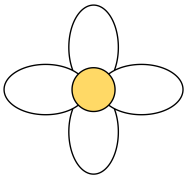
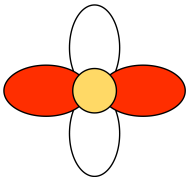
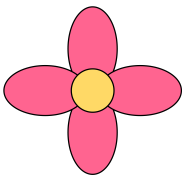
- **Gene locus:** The location of a gene along a chromosome

Genotype: The combination of alleles an individual has for a trait
Phenotype: The trait that is expressed as a result of genotype

Allele: One of the alternative forms of a gene

- **Homozygous:** Two copies of an allele for a trait are present
- **Heterozygous:** One of each allele for a trait is present

    - **Pro Tip: AA = homozygous dominant. aa = homozygous recessive. Aa = heterozygous, there is no such thing as heterozygous dominant/heterozygous recessive.*
- **Dominant allele:** Always expressed regardless whether the individual is homozygous or heterozygous for the trait
- **Recessive allele:** Only expressed if the individual is homozygous recessive for the trait

Genotype	I^RI^R	I^WI^W	I^RI^W **(If co-dominant)**	I^RI^W **(If incomplete dominance)**
Phenotype				

Co-dominance*:When two different alleles for a particular trait are both expressed in an organism and influence phenotype.

- Let allele for red flower be I^R
- Let allele for white flower be I^W
- In a **heterozygous** individual (I^RI^W), if the phenotype turns out to be flowers with both red and white petals, these alleles are **co-dominant**.

Incomplete dominance*: When two different alleles are expressed resulting in phenotype being an intermediate between the two.

- Let allele for red flower be I^R
- Let allele for white flower be I^W
- In a **heterozygous** individual (I^RI^W), if the phenotype turns out to be pink flowers, these alleles show **incomplete dominance**.

**Pro Tip: Co-dominance and incomplete dominance can only be observed if individual is heterozygous for the trait.*

Multiple alleles: When three or more alleles exist for a gene.

- e.g. for blood type there are the alleles: I^A I^B I^O

- I^A I^B are co-dominant
- I^O is recessive to I^A and I^B

**Pro Tip: For co-dominance, incomplete dominance, multiple alleles and sex-linked inheritance, we represent alleles with superscripts, such as I^R, I^W.*

2. Monohybrid cross

- Monohybrid cross involves 1 trait, with 2 alleles
- Genetic crosses can predict expected offspring ratios

Discrepancy between observed and expected ratios

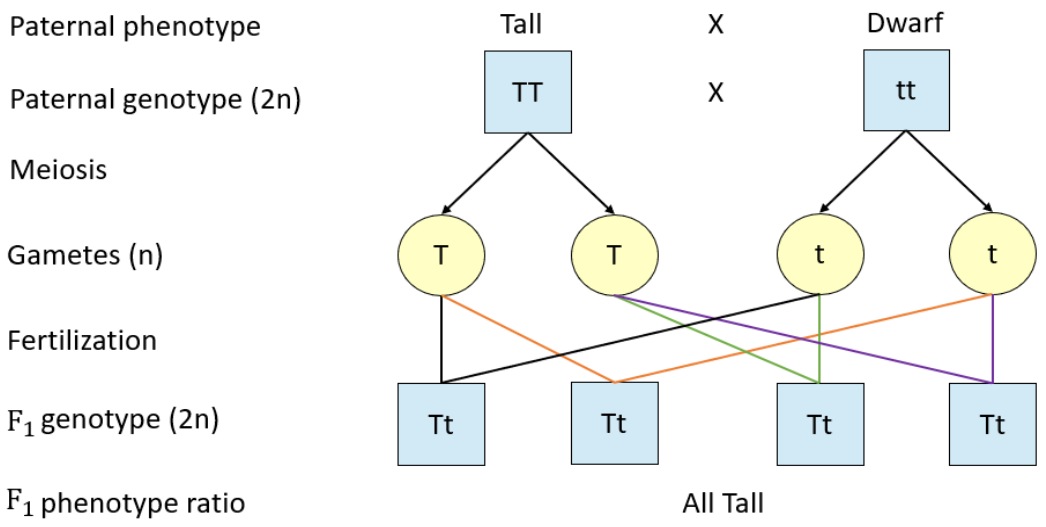
- As **fertilisation** is a **random** process, the **genotype** of each offspring is based on **chance**
- The smaller the **sample size** of offspring, the greater the **discrepancy** would be

Cross #1: 2 homozygous parents (pure-bred) with different alleles

- **Pro Tip: Pure-bred means offspring are homozygous for certain traits*

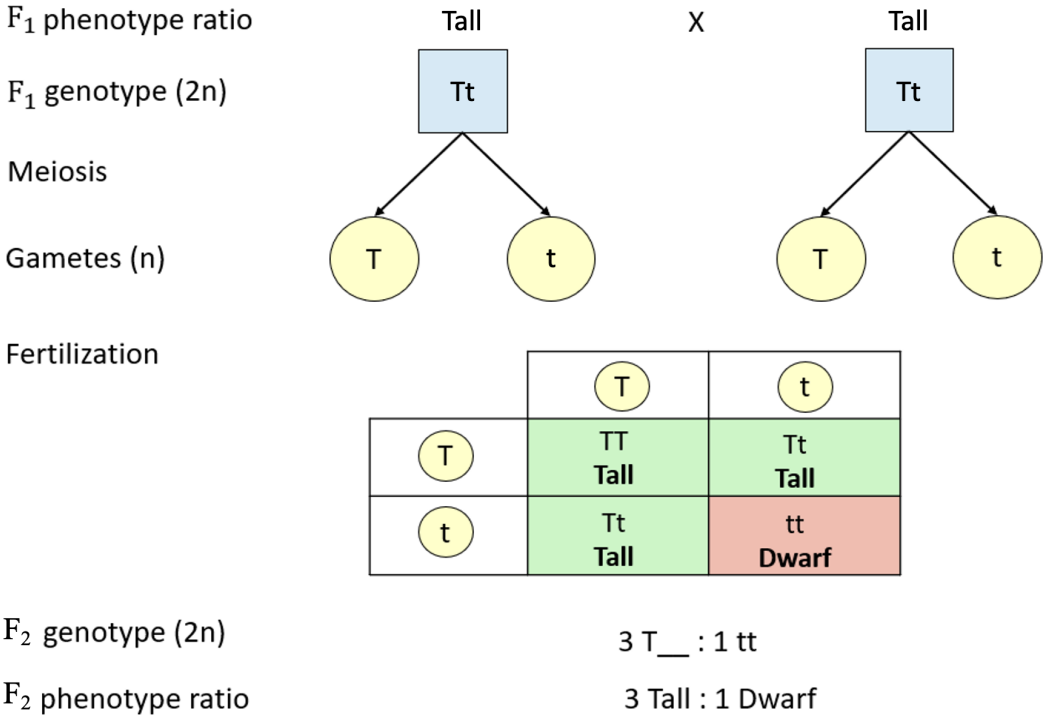
Let T represent allele for tall plant (dominant)
Let t represent allele for tall plant (recessive)

- **Pro Tip: If letter used has capital and small letters which look very similar, (e.g. c and C), use c' for the recessive allele to avoid ambiguity*



replace F_1 with 'offspring'.

Cross #2: 2 plants from F_1 generation



[Memory shortcut]

- Full genetic diagram steps [Lockdown Period, Grab Food Only]
  - **L:** **L**et... (define your alleles, unless question already did)
  - **P:** **P**arents phenotype and genotype
  - **G:** **G**ametes are formed from parents
  - **F:** **F**ertilisation
  - **O:** **O**ffspring genotype and phenotypic ratio

Test Cross

- Used to determine the **genotype** of an individual, as **heterozygous** and **homozygous dominant** individuals appear the same
- The individual is crossed with a **homozygous recessive** individual, eg **??** X **tt**
  - If individual is **homozygous dominant**, offspring would all express the dominant phenotype
  - If individual is **heterozygous**, offspring ratio would be 1:1

3. Bonus: All monohybrid cross combinations (O levels)

- *Let A be the allele for Tall plant*
- *Let a be the allele for dwarf plant*

Parents Crossed	Offspring Genotypes	Offspring Phenotypic Ratio
AA x AA	All AA	All Tall
aa x aa	All aa	All dwarf
AA x aa	All Aa	All Tall
Aa x Aa	1 AA, 2 Aa, 1 aa	3 Tall : 1 Dwarf
Aa x aa	2 Aa, 2 aa	1 Tall: 1 Dwarf
Aa x AA	2 Aa, 2 AA	All Tall

4. Sex determination, sex-linked inheritance

Sex determination

- Sex chromosomes are either X or Y
  - XX is female
  - XY is male*
- Each chromosome comes from each parent
  - The mother's ovum definitely contains an X chromosome, as the mother's diploid cells have XX
  - The father's sperm can contain either an X or Y chromosomes, as the father's diploid cells have XY
  - Therefore sex of the zygote formed depends on the sperm, and there is a 50% chance of the zygote being a boy or a girl.

Sex-linked inheritance

- As the X and Y chromosomes are different, there may be genes on the X chromosome that do not have a corresponding gene loci on the Y chromosome.
- Sex-linked traits are often passed via the X chromosome, e.g. colourblindness
  - Let X^N be the normal allele (dominant)
  - Let X^C be the disease allele (recessive)
- X^NX^C: Normal female, as X^N is dominant over the recessive X^C allele
- X^CX^C: Colourblind female
- X^NY: Normal male
- X^CY: Colourblind male. Although the X^C allele is recessive, the male only has 1 X chromosome, hence the recessive condition is expressed.
- **Pro Tip: Since this is inherited via the X chromosome, no superscript is needed for the Y chromosome.*

5. Genetic mutation

- **Mutation:** A sudden change in the structure of a gene or chromosome number
- **Mutagen:** An environmental agent that increases mutation rate
  - E.g. Ultraviolet **radiation**, Nuclear **radiation**, toxic **chemicals** such as **tar** in cigarette smoke
  - **Pro Tip: Mutagens simply cause more mutations in DNA, while **carcinogens** cause mutations that increase chances of cancer.*

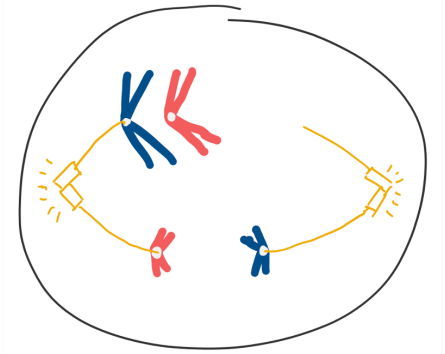
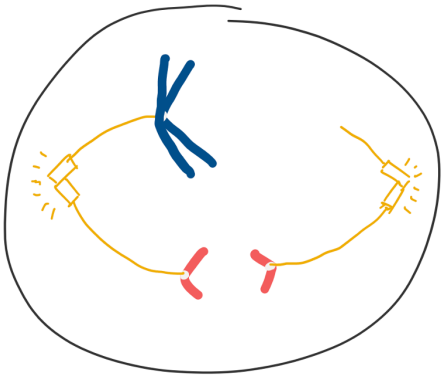
Sickle-cell anaemia

- A genetic disease caused by **single base substitution** in the **haemoglobin gene**, resulting in a different amino acid being coded for
- Normal haemoglobin (HbA) becomes mutated haemoglobin (HbS)
- At **low oxygen concentrations**, mutated haemoglobin molecules **clump** together, causing the cell to become **sickle-shaped**
- Results in **anaemia** (cells get insufficient oxygen) because:
  - Sickled RBCs are more **fragile**, break easily
  - Cannot carry O_2 efficiently
  - Are actively destroyed by the **spleen**, leading to low RBC count
- Benefit to **heterozygous** individuals (HbAHbS)
  - Their RBCs have low occurrence of sickling
  - More resistant to **malaria**

    - Hence they **survive** and **reproduce** better (passing on HbS allele)
    - Thus the sickle-cell **allele** is most abundant in malaria-stricken regions (e.g. sub-Saharan Africa)

Down Syndrome

- During formation of sperm/egg, **non-disjunction/non-separation*** results in the resultant **gamete** having two copies of chromosome 21
- This can happen during anaphase I or anaphase II
    - **Pro Tip: The older the mother, the higher the chance of non-disjunction occurring*
- **Fertilisation** with a normal **gamete** then results in **zygote** having three copies of chromosome 21, causing Down Syndrome.
- Symptoms: Eyes that slant upward, flattened face, short neck, small ears, small hands and feet

Anaphase I	Anaphase II
	

6. Variation

Type of variation	Discontinuous	Continuous
Phenotypes	**Few** and **distinct** phenotypes	A **range** of phenotypes, with many intermediate forms

Number of genes involved	1 or few	**Multiple genes**, which have an **additive effect**
Environment	No effect on phenotype	Affects phenotype
Examples	Sex, blood type, ability to roll tongue, lobed or attached ears, eye colour	Skin/hair colour, height

7. Natural and Artificial Selection

Natural selection: The process whereby organisms better adapted to their environment tend to survive and reproduce.

- **Variation** exists between individuals
- Organisms face **selection pressures**
  - eg. competition for limited resources, predators, disease outbreaks
- Individuals with favourable traits have a **selective Advantage**
- And are more likely to **Survive and reproduce**
- Hence passing on their **favourable alleles** to their **offspring**
- Over **Time**, more and more of the population have the favourable trait
- [OR, if question says evolution occurred, replace the above statement with this]: Accumulation of new genes by **mutation** and **natural selection** resulted in the evolution of the **species**.
  - **Pro Tip: Natural selection is needed for evolution to occur, but natural selection can occur without evolution.*

[Memory shortcut]

- Explaining natural selection process [VAST]
  - **V:** **V**ariation exists between individuals
  - **A:** selective **A**dvantage
  - **S:** **S**urvive and reproduce, passing favourable alleles to offspring
  - **T:** over **T**ime, more and more of the population has the favourable trait

Artificial selection: The process whereby humans select and breed species to have desirable traits.

- Is also known as **selective breeding**
- Is done either through **hybridisation** or **inbreeding**

- Examples where artificial selection is used:
    - Wolves with desirable traits (docile/small/cute) were selectively bred, over time resulting in today's modern dogs.
    - Soybeans with high oil content
    - Breeding wagyu cows, for wagyu beef

Hybridisation

- Crossing different varieties (of the same species) to produce new varieties which have desired traits from both parents
- E.g. crossing a plant which has good fruit flavour with another that has attractive flower colour to yield plants that have both of the desired traits.

Inbreeding

- Plants/animals with desirable traits (e.g. higher yield crops/cuter animals) are chosen, and bred together
- **Offspring** with desired traits are **inbred** repeatedly over many generations (**inbreeding** involves crossing **closely related varieties**)

**Pro Tip: Inbreeding is often used following hybridisation.*

17. Inheritance CAQs

Important Definitions

Q: Define the term gene.

Q: Define the term allele.
Q: Define the term dominant allele.
Q: Define the term recessive allele.
Q: Define the term co-dominance.
Q: Define the term genotype.
Q: Define the term phenotype.
Q: Define the term heterozygous.
Q: Define the term homozygous.
Q: Define the term mutation.

Genes, DNA, alleles and Chromosomes

- **Pro Tip: For questions on genes vs chromosomes vs DNA vs alleles, see Molecular Genetics CAQs*

Genetic Diagrams

Q: Pure-breeding Tall (T) and Dwarf (t) pea plants were crossed. Their offspring were crossed again. Draw the full genetic diagram for these two crosses. [6]

Discrepancy Between Observed and Expected Ratio

Q: Explain why there is a discrepancy between the observed an expected offspring ratio. [2]

Explaining Genotype of Individuals in Family Tree

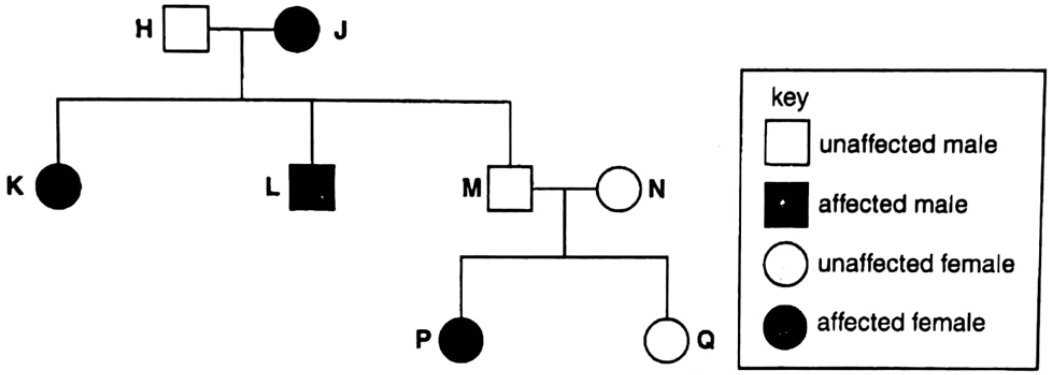


Fig. 2.1

Q: Explain whether this is a dominant or recessive condition. [2]
Q: Explain the genotype of M. [2]

Continuous vs discontinuous variation

Q: Contrast continuous and discontinuous variation. [4]

Non-disjunction/Non-separation

Q: Explain how a mutation takes place to cause a child with Down syndrome during:
a) Meiosis I. [3]
b) Meiosis II. [3]

Sex Determination

Q: Explain whether the male or female gamete determines the sex of a child. [3]

Evolution by Natural Selection

Q: A population of normal rabbits migrated to a dense forest. Explain how they could evolve to have small body size and dark fur. [5]

Natural Selection: Sickle-Cell Anaemia

Q: People with sickle-cell anaemia are less affected by malaria. Explain why, in regions where malaria is present, there are many people with the sickle-cell allele. [3]

18. Ecology

Learning Outcomes:

1. Food chains and food webs
2. Non-cyclic energy flow
3. Ecological pyramids
4. Carbon cycle
5. Impact of Man on the Ecosystem
6. Conservation

Keywords:

- Biotic, abiotic, food chain, food web
- Producers, primary, secondary, tertiary consumers, trophic level
- Growth and repair, carbon compounds, uneaten parts, decomposers, non-cyclic
- Food chain, food web, ecological pyramid, biomass
- Carbon cycle, fossil fuels, organic matter, combustion, decompose, carbon sink
- Shells, exoskeleton, soluble in water
- Bioaccumulation, bioamplification/biomagnification, biodegradable
- Deforestation, soil erosion, flooding, desertification, greenhouse gas, global warming
- Dissolved oxygen, aerobic bacteria, submerged plants
- Biodiversity, extinction, endangered species, indiscriminately, mesh size

1. Food chains and food webs

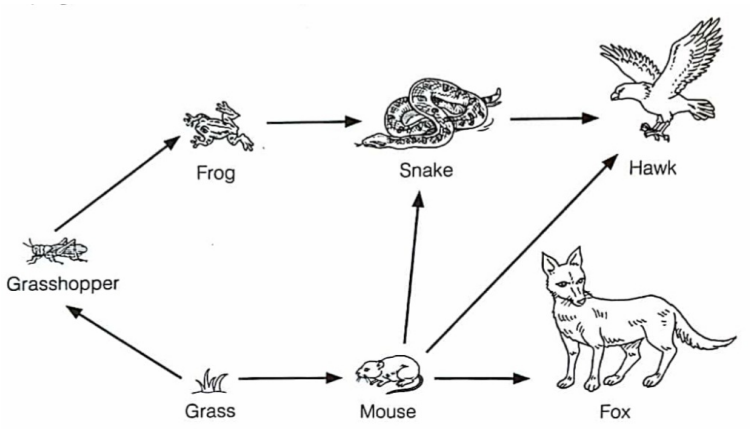
- **Population:** A group of organisms of the same species that live together in a habitat
- **Habitat:** The place an organism lives
- **Community:** Comprises all the populations living and interacting with one another in a habitat
- **Ecosystem:** A community of organisms interacting with one another and with its abiotic environment
- **Biotic environment:** All the living organisms that an organisms interacts with in its habitat
- **Abiotic environment:** The climate and physical features of the surroundings in the habitat

Food Chain: A series of organisms through which energy is transferred in the form of food

- Producer (1st trophic level) --> Primary Consumer --> Secondary Consumer --> Tertiary Consumer etc.
- Each step in the food chain is a **trophic level** (the diagram above has 4 trophic levels)
    - **Trophic level:** The feeding position that an organism occupies in a food chain.
- **Producers:** Organisms that make their own food from inorganic materials
- **Consumers:** Organisms that obtain food by feeding on other organisms

Food Webs:

- Made of interlinked food chains
- Shows the feeding relationships in a community



2. Non-cyclic energy flow

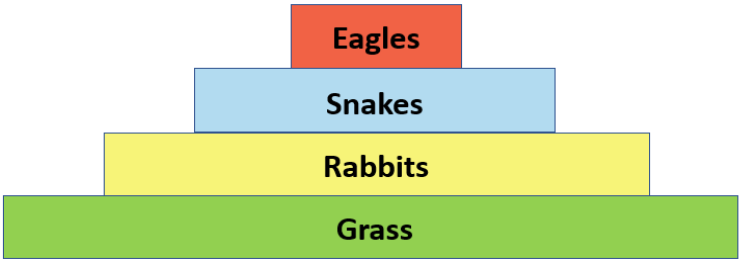
- **Producers** are **photosynthesising** plants that obtain their energy from the Sun
    - This energy is transferred up the food chain in the form of **carbon compounds** when **producers** are eaten by **consumers**
- Some energy is used by organisms for **growth** and **repair**

- The rest is **lost** via:
  - As **heat** to the surroundings due to **cellular respiration**
  - As chemical energy trapped within **excreted** and **egested** substances (eg. urine and faeces)
  - As chemical energy trapped in the **uneaten parts** when an organism dies (e.g. bones)
  - **Pro Tip: Decomposers will use the above substances for cellular respiration, releasing energy as heat.*
- Therefore, only **10%** of energy is actually passed on from one **trophic level** to the next
- Energy flow is thus linear and non-cyclic
- As energy is lost to the abiotic (non-living) environment, energy must be constantly provided (by the sun) to maintain ecosystems

3. Ecological pyramids

Pyramid of Energy

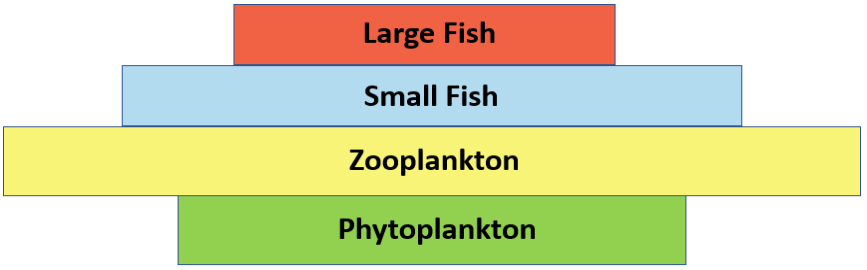
- Since energy is lost each round, the pyramid gets narrower further up
- As energy transfer is ~10% efficient, energy of trophic level is 1/10th that of the trophic level under it



**Pro Tip: All food chains have an upright pyramid of energy!*

Pyramid of Biomass

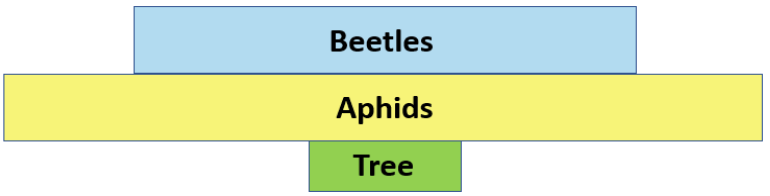
- Biomass at each trophic level = total mass of all individuals of that organism type
- Usually, populations lower down the food chain are larger, their biomass is larger. This is why biomass pyramids are often upright
- Exception: Marine ecosystems, which have a smaller producer biomass (phytoplankton) compared to primary consumer (zooplankton).



Pro Tip: At any one point in time, when measured, the biomass of phytoplankton is smaller than zoo plankton. That is due to the fast rate that phytoplankton are being eaten. The ecosystem is still sustainable because phytoplankton reproduce very quickly, and many of them can be eaten by each zooplankton. The pyramids of energy and numbers for this food chain is still an upright one.

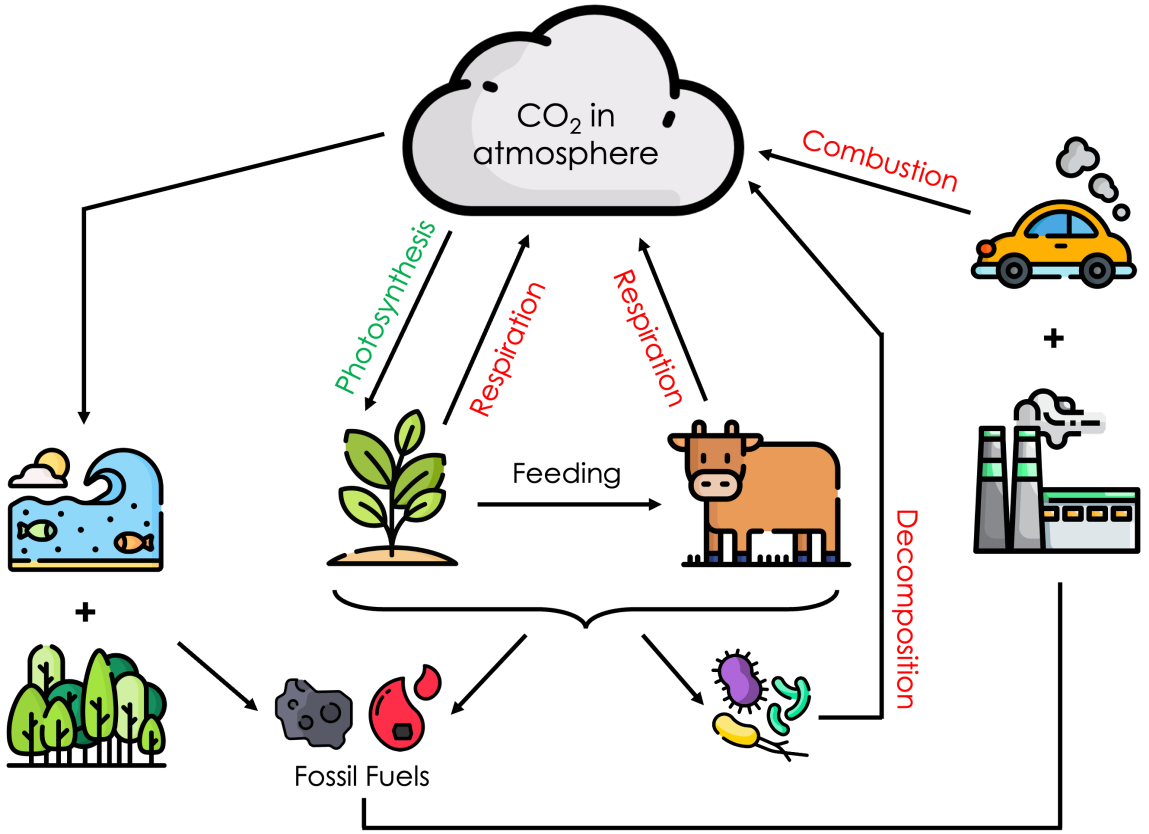
Pyramid of Numbers

- Usually, this pyramid is upright, as there are fewer organisms the higher the trophic level
- However if the producer is very large (e.g. a tree), can support large number of small consumers, pyramid shape will vary.
    - *Pro Tip: The pyramid of biomass and energy are still upright for this food chain.*
- A skewed shape also frequently occurs when the top predator is fed on by parasites, eg lice, such that the number of lice is a lot greater than the number of predators



Pro Tip: Skewed pyramids of numbers often happen in parasitic feeding relationships

4. Carbon cycle



Carbon entering the Biotic system

- CO_2 from the atmosphere is absorbed by plants, **reduced** to form **glucose** during **photosynthesis**
- Glucose is also converted to other **carbon compounds** (e.g. starch)
- When consumers eat plants, **carbon** is transferred up the **food chain**
  - Allowing **energy** to passed from one organism to another in the form of **carbon compounds**

Carbon re-entering the Abiotic system

- CO_2 is released into atmosphere during **aerobic respiration** by producers, consumers and decomposers
  - This maintains CO_2 concentration in the atmosphere, so there is a constant supply of CO_2 for **photosynthesis**
- **Fossil fuels** come from dead **organic matter** buried over long periods of time. When burnt for energy (**combustion**), it releases CO_2 into the atmosphere

Carbon Sink: An area which stores carbon as carbon compounds indefinitely, and releases less carbon than it takes in.

- Forests
  - Trees take in CO_2 through **photosynthesis** and use it to grow
  - Trees can be buried and become **fossil fuels** after they die
- Oceans
  - Carbon is used to make **shells** of shellfish such as clams, and the **exoskeletons** of corals, which stores carbon even after the organism has died
  - **Phytoplankton** take in $CO_2$from the air during **photosynthesis**, and transfer their carbon to other organisms in the ocean when eaten
  - As CO_2 is **soluble in water**, it **dissolves** into the ocean
  - Dead organisms may be buried at the **seabed** and become **fossil fuels**

[Memory shortcut]

- How oceans act as carbon sinks (**SPDF** "Singapore Police Defence Force")
  - **S**hells (shellfish, corals)
  - **P**hotosynthesis
  - **D**issolve
  - **F**ossil fuels

5. Impact of Man on the Ecosystem

Pollution: The addition of substances to the environment that damage it, making it unfit for life.

Bioaccumulation: The process where certain substances are not excreted, and accumulate in the bodies of organisms over time.

- Toxic chemicals are taken up by organisms in contaminated water/when they eat food or prey containing these chemicals.
- Some toxic chemicals cannot be **excreted**, so they accumulate in organisms' bodies, **bioaccumulation** has occurred.
  - These substances are usually non-biodegradable
  - Biodegradable = capable of being decomposed by bacteria or other living organisms

Bioamplification/Biomagnification: The process where a substance increases in concentration higher up the food chain.

- **Consumers** in each **trophic level** have to consume many organisms of the lower trophic level (due to inefficient energy transfer).
- Hence they ingest the toxic chemicals present in multiple organisms, and toxic chemicals accumulate in high concentrations within consumers. **Bioamplification/biomagnification** has occurred.
- The top consumer is most affected by the toxic chemicals as they are present in the highest concentrations, and could die if present in lethal concentrations.

Deforestation

- **Soil erosion**
  - Tree roots hold soil together, and the forest canopy protects topsoil from force of rain
  - With less trees, soil is more likely to be washed away
- **Flooding**
  - Eroded soil may be deposited in rivers, blocking the flow of water
  - Water level rises and floods surrounding areas
- **Desertification**
  - After topsoil is eroded, barren land cannot support plant life
- Loss of **biodiversity**
  - Organisms lose their habitats and may become extinct
- Increased **global warming**
  - With fewer trees to absorb CO_2 via photosynthesis, more CO_2 would remain in the atmosphere
  - Cutting of trees also releases CO_2 when the remains are decomposed
  - Since CO_2 is a **greenhouse gas**, more of it in the atmosphere increases global warming

Uncontrolled fishing

- Catching too much fish leads to decline of their populations
- Eventually, certain species of fish may go extinct

Eutrophication: The process where a body of water receives excessive nutrients, leading to excessive growth of algae and floating water plants.

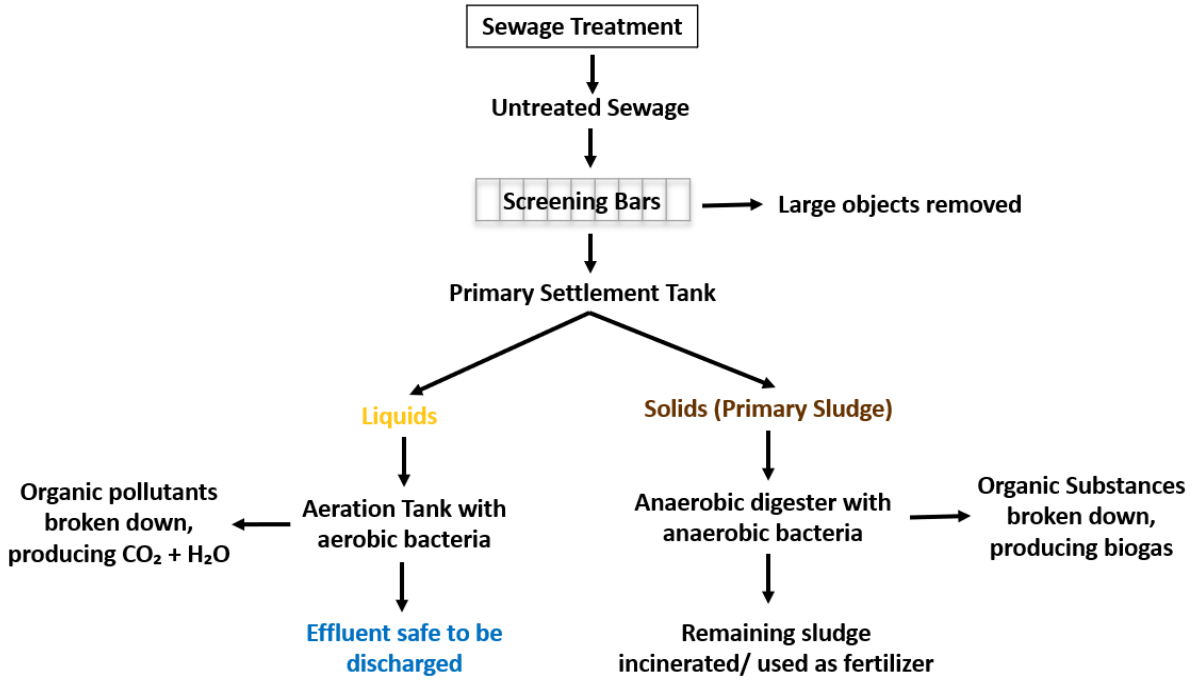
- Untreated sewage is dumped/fertilisers are washed by rain into a body of water

- **Nutrients** (**Nitrates** and **phosphates**) in the untreated sewage/fertilisers allow **algae**/floating water plants to grow rapidly across the water surface (algae bloom)
- They block **sunlight** from reaching below, **submerged plants** have insufficient light for **photosynthesis** and die
- Other animals also die due to the lack of **dissolved oxygen**.
- **Aerobic bacteria** decomposes the dead **organic matter**, further decreasing **dissolved oxygen**.
- Hence, many organisms in the river die due to the lack of **dissolved oxygen** in area.

[Memory shortcut]

- Eutrophication process [NASA]
  - **N:** **N**utrients (Nitrates and Phosphates)
  - **A:** **A**lgae bloom
  - **S:** **S**ubmerged plants
  - **A:** **A**erobic bacteria

Sewage treatment



Separation

- First, large materials are separated from sewage
- Solids suspended in sewage are then allowed to settle at the bottom of a tank (the **primary settlement tank**), these solids are called **sludge**

Liquids

- Liquid at the top flows into an **aeration tank**, where air is pumped in.
- The air provides **oxygen** for **aerobic bacteria** to break down **organic pollutants** in the water
- The cleaned water, called **effluent**, is then discharged into water bodies and will not cause **eutrophication**.

Solids

- Meanwhile, **sludge** at the bottom of the **primary settlement tank** is moved into an **anaerobic digester**.
- **Anaerobic bacteria** breakdown **organic matter** into **biogas** (mostly methane) which can be used as **fuel**.
- The remaining **sludge** is used as **fertiliser** or **incinerated**

Environmental Biotechnology: The use of biological processes to solve environmental problems.

- Eg. the use of microorganisms in sewage treatment
- Eg. using bacteria to clean up oil spills

6. Conservation

Reasons for conservation

- To preserve **biodiversity** (the range of species found in an ecosystem)
  - **Extinction** of one species could affect the balance of the ecosystem
- Useful information can be obtained through scientific research of diverse organisms
- We rely on wild plants for certain medicines
- For obtaining food and raw materials sustainably (eg. fish, timber)
- Our crops rely on natural **pollinators** to reproduce
- Conserving **biodiversity** maintains a large **gene pool**, allowing us to improve crops and livestock by **cross-breeding** different varieties of wild plants with **favourable traits**
- Preserve natural scenery, which also brings economic benefits through tourism

Means of conservation

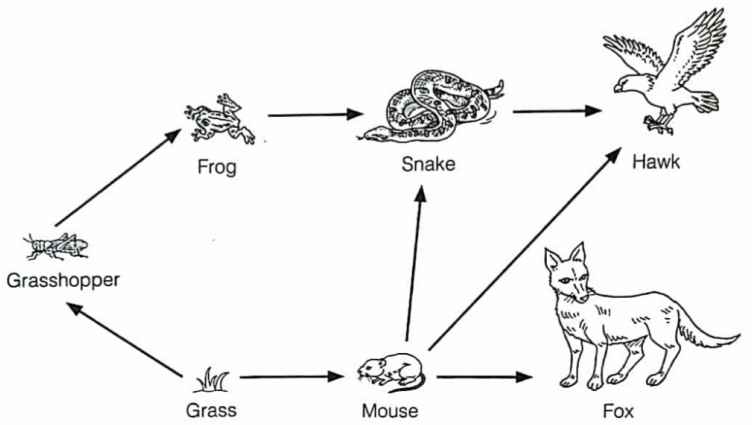
- Conserving fisheries

    - Ban fishing of **endangered species**
    - Raise endangered species in **hatcheries**, then release them into **fishing grounds** to increase their population size
    - Limit the periods of time when fishing can be done to allow fish to repopulate
    - Ban **drift nets/dredges** as they trap all kinds of marine life **indiscriminately**
    - Regulate size of fishing ships to limit how much they can catch
    - Use nets of larger **mesh size** so young fish are not caught
- Conserving forests
    - Cut trees selectively at a controlled rate
    - Do not cut down young trees
    - Plant seedlings to replace trees cut down
    - Set up protected forest reserves

18. Ecology CAQs

Important Definitions
Q: Define the term producer.
Q: Define the term consumer.
Q: Define the term trophic level.
Q: Define the term carbon sink.
Q: Define the term bioaccumulation.
Q: Define the term bioamplification/biomagnification.

Disturbances in A Food Web



Q: Explain the impact on hawks if foxes were suddenly removed from the food web. [2]

Non-cyclic Energy Flow
Q: State the ways energy is lost between trophic levels. [3]

Short Length of Food Chains
Q: Explain why are food chains usually not very long. [3]

- **Related Questions:**
  - Q: Explain why there are usually very few predators of tertiary consumers. [3]

Carbon Cycle
Q: Describe the importance of respiration and photosynthesis in the carbon cycle. [2]

Q: Describe the role of bacteria and fungi in the carbon cycle. [2]

Carbon sinks
Q: Explain how the ocean acts as a carbon sink. [5]

Bioaccumulation and Biomagnification
DDT, dichloro-diphenyl-trichloroethane, is a pesticide which is no longer in use today due to it being a health hazard to organisms. It is known to accumulate in the tissues of organisms.

- Food chain: Caterpillars --> Sparrows --> Eagles

Q: Explain why eagles had highest concentration of DDT in their bodies when DDT was sprayed on caterpillars. [4]

- **Related Questions:**
  - Q: Discuss the importance of controlling the use of pesticides.

Eutrophication
Q: Explain how discharging sewage into a river could lead to the death of organisms in the river. [4]

- **Related Questions:**
  - Q: Discuss the importance of proper treatment of sewage before discharge.

Environmental Biotechnology
Q: Explain how the treatment of sewage makes use of environmental biotechnology. [2]

Conservation
Q: Discuss the importance of conserving species to maintain biodiversity. [3]