Topic 1: Cell Structure and Organisation

Cell Structure:

Cell Organelle:	Appearance:	Functions:
Cytoplasm	- Aqueous ground substance	- Acts as **site for chemical reactions** in cell - Contains organelles
Nucleus	- Largest organelle - **Double layered** nuclear membrane	- **Controls and directs** activities e.g. **cell growth, reproduction, repairing of cells**
Cell Membrane	- **Selectively permeable** membrane	- **Controls** substances entering or leaving cell - Acts as **receptor sites** for recognising external stimuli and chemicals
Mitochondria	- Bound by **double membrane** - Mostly spherical, rod-shaped	- **Releases** energy in the form of ATP during **cellular respiration** for activities such as **growth, cell division, active transport**
Vacuole	- Fluid filled - **Large and central** (plant) - **Smaller, numerous, less permanent** (animal)	- **Provides support** for plants when filled with water by maintaining turgidity of cell - **Temporarily stores** waste products, food reserves (dissolved in)
Chloroplast	- Bounded by	- **Stores starch grains** converted from

	double membrane	excess glucose made during photosynthesis (other starch found in cytoplasm) - Contains pigment **chlorophyll** to t**rap sunlight** during **photosynthesis** producing **glucose**
Cell Wall	- Made of **cellulose** - Inelastic, inflexible, **fully permeable**	- Provides **mechanical support** - Protects cell from **overexpansion**
Ribosomes	- **Found in cytoplasm, some attached to Rough ER**	- **Synthesises** proteins
Rough ER	- **Covered with ribosomes** - Granular appearance - Sheet-like - Numerous in enzyme secreting organs e.g. pancreas	- **Transports** secretory proteins manufactured by ribosomes on ER surface
Smooth ER	- **Lacks ribosomes** - More tubular - Numerous in liver, skin oil glands	- **Synthesises** fats, steroids (sex hormones) - **Detoxification** of harmful substances into harmless materials - Give rise to golgi body

Golgi Apparatus	- Compact **stack** - Has convex face, concave face - Normally **1 in animal cell, many in plant cell**	- **Chemically modifies** substances made by ER - **Stores, packages substances in vesicles** for secretion out of cell e.g. Carbohydrates added to protein to form glycoproteins (mucus)

<u>Cell Differentiation:</u>

- Definition: Process whereby a cell becomes specialised for a specific function

Advantages:	Disadvantages
- A specialised cell is able to carry out its tasks more efficiently	- As a specialised cell normally loses its ability to carry out other functions, it is less able to change its function if an unusual need arises

Examples:
Root hair cell: **Long and narrow** to **increase surface area to volume ratio** for absorption of **water and minerals**.

Human RBC: **Biconcave shape** to **increase surface area to volume ratio** and increase the rate of **oxygen absorption and release.** Contains red pigment **haemoglobin** which binds to oxygen, and **lacks a nucleus** to allow **more haemoglobin** (not oxygen) to be packed in.

Muscle cell: Elongated and cylindrical in shape, contains many **mitochondria** to **release energy during cellular respiration** for **contraction**, contains **contractile protein fibres** that contract and relax to bring about movement.

Different Levels of Organisation:

- Most organisms are made of many cells, said to be **multicellular**

Levels of Organisation:	Description:
Tissue	- A group of cells of the **same structure and origin** which come together to **perform a particular function**. - Classified into simple tissue (e.g. epidermis)/complex tissue (e.g. blood)
Organ	- Different tissues being grouped together to perform a function (e.g. Stomach = Epithelium tissue(skin) + Glandular tissue(enzymes) + Muscular tissue(churning) + Nervous tissue(nerves) + Connective tissue (to connect all tissues)
Organ System	- A group of different organs working together for a particular function (e.g. Digestive System)
Organism	- Various organ systems together make up the entire living organism

Cell ⇒ Tissue ⇒ Organ ⇒ Organ System ⇒ Organism

Topic 2: Movement of Substances

Cell Membrane:

- Current model accepted is **fluid (movable phospholipids) mosaic (immobile proteins embedded) model**
- Model contains **phospholipid bilayer** arranged with **hydrophobic tails facing inwards**
- Phospholipids move within bilayer (fluid)

- Mosaic of immobile proteins embedded or attached to bilayer of phospholipids (mosaic)

Functions:

- **Selectively permeable**, controls movement of substances moving in and out of the cell
- Forms boundary between contents of cell and external environment, ensuring **constant internal environment** within cell is maintained for more efficient chemical reactions
- Responsible for **cell-to-cell communication**: equipped with receptor proteins that receive chemical messenger molecules from other cells.

<u>Membrane Proteins:</u>

- Two types:
    - **Integral** proteins: embedded within bilayer
    - **Peripheral** proteins: loosely attached to surface of membrane

Functions:

- Transport proteins move specific molecules across the membrane by acting as **channel or carrier proteins**
- Some proteins are **enzymes** with active sites exposed to substances on either side of membrane
- Act as **receptors** to receive chemical messenger from other cells(e.g. hormone), relays message to inside of cell
- Determine if other cells encountered are alike or different from itself (e.g. WBC recognising bacteria/viruses)
- Attaches to protein on adjacent cells to hold together

<u>Diffusion, Facilitated Diffusion, Osmosis (energy not required):</u>

Process:	Definition:	Feature:
Diffusion	- **Net movement** of particles from a region of **higher** concentration to a region of **lower** concentration,	- **Passive** process - Slow process

	down a concentration gradient	
Facilitated Diffusion	- Substance aided across a membrane **by transport proteins** (channel/carrier proteins)	- For **charged particles** (e.g. ions), **relatively large polar molecules** (e.g. amino acids, sugars, fatty acids, glycerol) - **Channel proteins** provide hydrophilic passage for polar molecules by shielding from hydrophobic bilayer - **Carrier proteins** binds to ion/molecule, causing change in shape of protein forming hydrophilic channel
Osmosis	- **Net movement** of **water molecules** from a solution of **higher** water potential to a solution of **lower** water potential, **down a water potential gradient** through a **selectively permeable membrane**	- **Passive** process

Plant cell in solution with higher water potential:

- Cell sap has a **lower water potential** than its surrounding solution
- **Water** enters cell by **osmosis** through **selectively permeable cell membrane**
- Large central vacuole **increases** in size
- Cytoplasm gets pushed against cell wall, resulting in **turgor pressure**
- Cell is **turgid**

Turgor/turgidity in plant cells help to:

- Keep stems upright
- Keep leaves flat so they can better absorb sunlight

Animal cell in solution with higher water potential:

- Cell has a **lower water potential** than its surrounding solution
- **Water** enters cell by **osmosis** through **selectively permeable cell membrane**
- Cell **expands** and **bursts** as cell membrane ruptures due to absence of cell wall
- Cell has **lysed**
- Process termed **Lysis**.

Plant cell in solution with lower water potential:

- Cell sap has a **high water potential** than its surrounding solution
- **Water** leaves cell by **osmosis** through **selectively permeable cell membrane**
- Large central vacuole **decreases in size**
- Cytoplasm and cell membrane **shrinks away from cell wall**, termed **plasmolysis**
- Cell is **plasmolysed** and **flaccid**
- Can be reversed by placing in solution of higher water potential

Animal cell in solution with lower water potential:

- Cell has a **higher water potential** than its surrounding solution
- **Water** leaves cell by **osmosis** through **selectively permeable cell membrane**
- Cell **shrinks** and **little spikes appear** on cell membrane
- Cell is **crenated**, process is termed **crenation**

Factors affecting rate of **passive** transport:

- Concentration gradient (**conc. grad. ↑, rate ↑**)
- Surface area to volume ratio (**s.a. to vol, ratio ↑, rate ↑**)
- Temperature (**temp ↑, rate ↑**) (due to increase of kinetic energy causing movement)
- Distance (**dist travelled by molecules ↑, rate ↓**)

Active Transport, Bulk Transport (energy required):

Process:	Definition:	Features:
Active Transport	- Active transport is **energy-consuming** process of moving substances from a region of **lower concentration** to a region of **higher concentration**, **against a concentration gradient**	- Performed by specific carrier proteins in membrane - **Independent** of concentration gradient - **Faster**
Bulk Transport: Exocytosis	- Process of releasing **large** molecules from cells by **packaging in vesicles** and crossing cell membrane in bulk	- Transport **vesicle** carrying molecules for export moves to perimeter of cell - **Vesicle fuses to cell membrane** - Contents of vesicle expelled to intercellular space
Bulk Transport: Endocytosis	- Process of releasing **large** molecules from cells by **packaging in vesicles** and crossing cell membrane in bulk	**Phagocytosis:** - Materials taken up in **solid** form - Particles in vesicle usually **digested** by enzymes in cell - **Selective** process, will only take up specific particles (e.g. WBC digesting bacteria)
		Pinocytosis: - Material taken up in **liquid** form - Process is **non-selective**
		Receptor-mediated endocytosis:

		- Material to be taken up **binds** to **receptor proteins** on cell membrane - **Selective** process (only specific shape of material will fit receptor protein)

Exocytosis:

1. Transport **vesicle** carrying molecules for export moves to the perimeter of the cell.
2. Vesicle **fuse** with the plasma membrane.
3. The contents of the vesicle are expelled out into the intercellular space.

Endocytosis:

1. Materials that are to be collected and brought into the cell are engulfed by an **invagination** of plasma membrane.
2. Vesicle buds off from the plasma membrane.
3. Vesicle carry molecules into the cell. Contents may be digested by enzymes delivered to vesicle by **lysosomes** (vesicles with enzymes produced by golgi body)

Topic 3: Biological Molecules — Nutrients

<u>Carbohydrates:</u>

- Made up of **Carbon (C), Hydrogen (H), Oxygen (O)**
- General formula of $\mathbf{C_nH_{2n}O_n}$ (ratio of Carbon, Oxygen 1:1, ratio of Hydrogen, Oxygen 2:1)
- Includes:
    - Single sugars (monosaccharides)
    - Double sugars (disaccharides)
    - Complex sugars (polysaccharides)

Saccharides:	Examples:	Features:
Single sugars	- Glucose - Fructose - Galactose	- **All** has formula of $C_6H_{12}O_6$ (but arranged differently) - **Glucose** is substrate in **cellular respiration**, oxidation of glucose releases energy
Double sugars	- Maltose (glucose+glucose) - Sucrose (glucose+fructose) - Lactose (glucose+galactose)	- Single sugars joint with **glycosidic linkage** (covalent bond) - **Sucrose** is transport form of sugars in plants
Complex sugars	- Starch - Glycogen - Cellulose	- Consists of hundreds to thousands of single sugars (commonly glucose) - Some serves as **storage**, broken down when needed (e.g. plants store excess glucose as **starch** in **cytoplasm, chloroplasts**, humans store excess glucose as **glycogen** in **muscles, liver**

Starch vs Glucose vs Glycogen:

Starch:	Glucose:	Glycogen:
- Less reactive - Does not affect water potential - **Larger** (unable to leave cell via cell membrane) - Complex sugar - **Long straight or branched chain** of glucose molecules - Storage form of glucose in **plants** - Found in roots, stem	- More reactive - Affects water potential of cell - **Smaller** (able to leave cell via cell membrane) - Substrate for **cellular respiration** - Synthesises lubricants, flower nectar - Needed for formation of nucleic acid - Basic unit for formation of cellulose cell wall - Able to convert to other organic molecules in plants	- Complex sugar - **Highly branched chain** of glucose molecules - Storage form of glucose in **animals** - Found in **liver, muscles** (energy for contractions of muscle from glucose)

<u>Fats:</u>

- Made up of **Carbon (C), Hydrogen (H), Oxygen (O)**
- **No** general formula unlike carbohydrates
- Contain **much less oxygen** in proportion to hydrogen
- **Little to no** affinity for water
- Formed from **3 fatty acids joined to 1 glycerol** (not glycogen)
- Joined by **ester linkage**

Functions:

- **Storage of energy**
    - 1g of fats store 2x as much energy as 1g of complex sugars
    - Stored in **adipose cells** under skin, around stomach for mammals
- **Adipose tissue** functions to **cushion vital organs**
- Fats can function as **insulation**
- **Phospholipids** are major components of **cell membranes** (Topic 2)

<u>Protein:</u>

- Made up of **Carbon (C), Hydrogen (H), Oxygen (O), Nitrogen (N),** sometimes **Sulphur (S)**
- Made from **amino acids** (basic unit of protein)
- Caused by 20 different kinds of amino acids joined together by **peptide bonds**
- Short-chain proteins known as **polypeptides**

Functions:

- Synthesis of **new protoplasm** (cell) for growth and repair of body
- Synthesis of **enzymes** and some **hormones**
- Formation of **haemoglobin** (binds oxygen)
- Formation of **antibodies** (defends against foreign substances)
- Formation of **support structures** (e.g. collagen, hair)
- Formation of **storage structures** (e.g. ovalbumin in eggs, casein in milk)
- Includes **membrane proteins** that move molecules across phospholipid bilayer (Topic 2)

<u>Nucleic Acids:</u>

- Made up of **Carbon (C), Hydrogen (H), Oxygen (O), Nitrogen (N), Phosphorus (P)**
- Genetic materials where genetic information are encoded
- Belongs to a class of biological molecules
- Consists of **nucleotides:**
    - **Pentose sugar**
    - **Nitrogenous base**
    - **Phosphate group**

- 2 types of nucleic acids in eukaryotic, prokaryotic cells, viruses:
    - Deoxyribonucleic acid (DNA)
    - Ribonucleic acid (RNA)
- **4** types of Nitrogenous base:
    - **Adenine ⇔ Thymine, Cytosine ⇔ Guanine**

Food Tests:

<table>
<tr><td>Food Test:</td><td>For Solid Sample:</td><td>For Liquid Sample:</td></tr>
<tr><td rowspan="2">Iodine Test: Starch</td><td>1. Place 1cm^3 of crushed/chopped food pieces onto white tile
2. Place 2 drops of iodine solution onto chopped food pieces
3. Observe, record changes in colour of iodine solution</td><td>1. To 1cm^3 of sample solution, add 2 drops of iodine solution
2. Observe, record changes in colour of iodine solution</td></tr>
<tr><td colspan="2">Blue black: starch present
Brown: starch absent</td></tr>
<tr><td>Benedict’s Test: Reducing Sugar</td><td>1. Place 1cm^3 of crushed/chopped food pieces into clean test tube, label appropriately
2. Add 2cm^3 of water to the tube to dissolve reducing sugar in the sample. Decant.
3. Add 2cm^3 of Benedict’s Solution to solution with</td><td>1. To 2cm^3 of sample solution add equal volume of Benedict’s Solution, shake to mix.
2. Place the tube in a boiling water bath for 2-3 min.
3. Remove tubes.
4. Observe, record colour changes of mixture</td></tr>
</table>

<table>
<tr><td></td><td>nutrient, shake to mix.
4. Place the tube in a boiling water bath for 2-3 min.
5. Remove tubes.
6. Observe, record colour changes of mixture</td><td></td></tr>
<tr><td></td><td colspan="2">Brick-red precipitate: A lot of reducing sugars present
Orange precipitate: Reducing sugars present
Yellow: Some reducing sugars present
Green: Traces of reducing sugars present
Blue: No reducing sugars present</td></tr>
<tr><td>Test for Non-reducing Sugars (sucrose)</td><td colspan="2">1. Test sample for reducing sugars.
2. Reducing sugars absent: use fresh sample solution, heat 2cm^3 of sample solution with dilute hydrochloric acid (HCl) for a few minutes (to break down glycosidic bonds).
3. Neutralise with sodium hydrogen carbonate (sodium bicarbonate).
4. Perform Benedict’s Test.</td></tr>
<tr><td>Biuret Test: Proteins</td><td>1. Place 1cm^3 of crushed/chopped food pieces into a clean, dry test tube, label appropriately.
2. Add 2cm^3 of water to the tube, shake thoroughly, decant.
3. Add in equal volume sodium hydroxide solution to solution, shake.
4. Add 1% copper sulphate solution drop by drop, shake test-tube after each</td><td>1. To 2cm^3 of sample solution add equal amounts of sodium hydroxide solution, shake.
2. Add 1% copper sulphate solution drop by drop, shake after each drop.
3. Observe, record any colour change.</td></tr>
</table>

	drop. 5. Observe, record any colour change.	
	Blue: No proteins present **Violet**: Proteins present	
Ethanol Emulsion Test: Fats	1. Place 1cm^3 of chopped food pieces into a test tube, label appropriately. 2. Add 3cm^3 of ethanol into the mixture. 3. Shake thoroughly. 4. Record changes in solution. 5. **Decant 1cm^3 of mixture** into another test tube. 6. Add **equal volume** of water to the liquid portion. 7. Observe, record any change	1. Add **1cm^3 of ethanol** 2. Shake thoroughly. 3. Add **1cm^3 of water** to the liquid. 4. Observe, record any change
	White emulsion formed: Fats present **No white emulsion formed**: No fats present	

Topic 4: Biological Molecules — Enzymes

<u>Metabolism:</u>

- Made up of **Catabolism** and **Anabolism**

    - **Catabolism**: Release energy by **breaking down** complex molecules to simpler compounds (e.g. cellular respiration)
    - **Anabolism**: Uses energy to **build** larger complex molecules from smaller simpler ones (e.g. synthesis of proteins from amino acids)
- Begins with specific molecule in reactions catalysed by **enzymes**

Enzymes:

- **Biological catalysts**: change rate of chemical reactions **without** being chemically changed at the end
- **Increases** rate of reaction by **lowering activation energy** required
- **Enzymes are reusable**

Activation Energy:

- Definition: The **amount of energy** required to bring the reactant molecules to its **transition state**

Lock and Key Hypothesis:

- **Substrate: the reactant that the enzyme acts on**
- Reaction catalysed by each enzyme is **very specific**
- Enzyme **binds** to substrate with **complementary shape** that can fit into the **active site** to form **enzyme-substrate complex**
- Catalytic action converts substrate to the **products**
- Enzyme is the “lock”, substrate is the “key”
- Enzymes can both **break down and form** products
- Specificity of enzyme due to **3D shape**
- Only **active site** binds with substrate

Ways to Measure Rate of Enzyme Activity:

- Measuring rate of **formation of products** (e.g. using catalase, $2H_2O_2 \rightarrow 2H_2O + O_2$, measure volume of O_2 produced)

- Measuring rate of **disappearance of substrate** (e.g. using iodine test to measure disappearance of starch)

Factors of Rate of Enzyme Reactions:

- **Temperature (temp extremeness ↑, rate ↓)**
  - **Low temp**: enzymes **inactive**, activity **slow**
  - Reason: As temperature increases, molecules gain **kinetic energy** and **move more rapidly**, increasing **frequency of collisions** between substrates and active sites. The **optimum temperature** causes the **maximum** rate of reactions.
  - Reason: At high temperatures, weak enzyme bonds **break down**, enzyme is **denatured**.
  - **Denaturation** is irreversible
  - Enzymes usually twice as active for every 10℃ increase until optimum temperature
- **pH Level (pH extremeness ↑, rate ↓)**
  - Each enzyme has **optimum pH level** mostly between 6-8
  - Extreme pH **denatures** enzymes
- **Concentration of substrate (conc. ↑, rate ↑ until saturated)**
  - At certain levels of substrate concentrations, active sites of enzymes all **occupied**.
    - Enzyme is **saturated**, concentration of enzyme is **limiting factor**
    - Rate determined by rate at which active site can convert substrate to product
- **Concentration of enzyme (conc. ↑, rate ↑)**
  - Reason: increase in enzymes lead to increase in number of **active sites** available, thus more **enzyme-substrate complexes**
  - **No** plateau, **limitless**

Topic 5: Nutrition in Humans

Nutrition:

- **2 types** of nutrition:
    - **Autotrophic nutrition**: an organism that can **produce its own food** using light, H_2O, CO_2 or other chemicals
    - **Heterotrophic nutrition**: an organism that is unable to produce organic substances from inorganic ones, depend on autotrophs indirectly or directly for nutrients, energy
- Definition: the **intake** of food and **processes** that convert food substances into living matter
- Processes:
    - **Ingestion**: act of **feeding** and intake of food into body
    - **Digestion**: process of **breaking down large food molecules** into **smaller, soluble and diffusible** molecules that can be absorbed into the body cells
        - 2 types: physical (chewing, churning), chemical (enzymes)
    - **Absorption**: intake of small molecules from digestive tract after digestion
    - **Assimilation**: using absorbed food molecules to **provide energy**, form **new protoplasm**
    - **Egestion**: **removal** of **undigested** material from body (due to no enzymes for digestion)

Alimentary Canal Organs:

Organs:	Processes:
Mouth, Buccal Cavity, Salivary Glands **(digests starch)**	- Both **physical** and **chemical** digestion begins in **buccal cavity** - During chewing, teeth cut, grind food into **smaller pieces** to **increase** surface area exposed to enzymes - **Starch in food gets broken down to maltose by amylase** - Tongue rolls food into **bolus** for swallowing
Oesophagus	- **Bolus** gets pushed along **oesophagus** to stomach by **peristalsis**: **rhythmic waves of contraction** by smooth

	muscles - **No digestion** other than continuation of amylase activity from mouth

Stomach
 	
(digests proteins)
	- Gastric glands secrete **gastric juices**
	- Mixes food with secretion by **churning action** of smooth muscles in stomach wall
	- **Gastric juice** contains:
	  - **Hydrochloric Acid (HCl)**: low pH **kills most bacteria**, **denatures amylase**
	  - **Protease (pepsin):** enzyme works well in acidic environments, breaks down **peptide bonds** in proteins, forming **polypeptides**
	- Stomach lining contains coating of **mucus** (present throughout gut) to **protect stomach lining**
	- After churning, enzymes, stomach contents become **chyme**

Small Intestine, Pancreas, Liver, Gallbladder
 	
(digests proteins, fats, starch)
	- **Duodenum**:
	  - **Chyme** mixes with **pancreatic juice**, **bile**
	  - **Pancreatic juice** contains **protease (trypsin), amylase, maltase, lipase**
	  - **Pancreatic juice** is **alkaline** (to neutralise chyme)
	- **Ileum**:
	  - Mainly for **absorption** of digested food molecules, water
	- **Liver**:
	  - **Produces bile** (stored in **gallbladder**)
	  - Bile contains **bile salts** that **emulsifies big fat droplets** into **smaller droplets**, which **increases surface area to volume ratio** for digestion by **lipase**

Large Intestine	- Also known as **Colon** - **Reabsorbs** water, mineral salts that entered alimentary canal - **Faeces** become more solid as they are moved along colon by **peristalsis**

	- **Dietary fibre** (cellulose) cannot be digested - Diet lacking in fibre causes **constipation** - Virus or bacterial irritation in **colon** lining causes **diarrhoea** - End of colon called **rectum**, opening called **anus** - Faeces leaving anus known as **egestion**

Peristalsis:

- Occurs **throughout** alimentary canal
- **Waves of contraction** by smooth muscles are involuntary
- Oesophagus contains 2 muscles:
    - **Circular Muscles** (inner layer)
    - **Longitudinal Muscles** (outer layer)
- Muscles work **antagonistically** (when 1 contracts, the other relaxes)

Description of Peristalsis:

1. When the circular muscles **contract**, the longitudinal muscles **relax**
2. The walls of the oesophagus **constricts behind bolus** to push bolus down
3. When circular muscles **relax**, longitudinal muscles **contract**
4. The walls of the oesophagus **dilates in front of bolus** to let bolus pass through

Digestion in Organs:

- Digestion of **Carbohydrates**:
    - In **Buccal Cavity**: Starch to Maltose using Amylase
    - In **Duodenum**: Starch → Maltose using Amylase, Maltose → Glucose using Maltase
- Digestion of **Protein**:
    - In **Stomach**: Protein → Polypeptide using Protease
    - In **Duodenum**: Protein → Polypeptide using Protease, Polypeptide → Amino Acids using Protease
- Digestion of **Fats**:
    - In **Duodenum**: Fats → Glycerol + Fatty Acids using Lipase

Absorption of Food in Small Intestine:

- **Amino Acids, Glucose** absorbed into **bloodstream**
- **Glycerol, Fatty Acids** absorbed into **lymphatic system**

Absorption of Amino Acids, Glucose:

1. Absorption of amino acids, glucose into **blood capillaries** of villi is by **diffusion**
2. Also absorbed by **active transport**, which allows for much more absorption of nutrients than passive diffusion
3. Capillaries drain nutrients away, **converge into larger blood vessels**
4. Eventually transports nutrients to **hepatic portal vein** which leads to the **liver**

Absorption of Glycerol, Fatty Acids:

1. Absorption of glycerol, fatty acids is by **diffusion** into **epithelial cells**
2. **Recombined** into fat molecules within cells
3. Fats transported into **lacteals** of each villus (part of lymphatic system)

Adaptations of Small Intestine:

- **Large surface area** to **increase** rate of absorption of nutrients
    - **Large circular folds** in lining contain **villi**
    - Each **epithelial cell** of villus contain many **microvilli** to **further increase** surface area for absorption
- **Net of blood capillaries, a lacteal** in each villus to **transport** absorbed nutrients, maintaining steep diffusion gradient
- **Wall of villi (epithelium)** only **1 cell thick** for decreased distance for osmosis, active transport
- **Many mitochondria** in **epithelial cells** to provide energy for active transport of nutrients

Functions of Liver:

- **Carbohydrate Metabolism**

    - Liver regulates **blood glucose concentration**
        - When blood sugar high, **insulin** secreted to **stimulate conversion of excess glucose to glycogen**
        - When blood sugar low, **glucagon** secreted to **stimulate conversion of glycogen to glucose**
- **Fat Digestion**
    - Liver secretes **bile** (stored in **gall bladder**)
    - (Refer to Alimentary Canal Organs)
- **Breakdown of hormones**
    - Hormones broken down in liver after used
- **Metabolism of amino acids**
    - **Excess amino acids** produced
    - **Amino group -NH_2 removed** from main structure of amino acid
    - Process called **deamination**
    - Product of reaction is **ammonia**
    - **Ammonia converted to urea**
    - **Urea** excreted via kidneys as urine
    - **Carbon residues** from reaction converted to **glucose**, stored as **glycogen**

<u>Breakdown of Alcohol, Effects of Excessive Alcohol Consumption:</u>

- **Liver** can also **remove toxic substances** from blood during **detoxification**
- **Liver cells** contain **enzyme** which breaks down alcohol to useful compounds

Effects of Excessive Alcohol Consumption:

- Short-term effects:
    - **Slowing down** brain functions
    - **Poor** muscular coordination
    - **Lack** of judgement
    - **Slower** reaction time
    - **Reduced** self control, **increased** risk taking
    - **Blurred** vision
- Long-term effects:
    - **Increased** risk of gastric ulcer

- Brain damage
- **Liver Cirrhosis** (liver cancer) that can lead to liver damage, liver failure

Topic 6: Transport in Humans

<u>Transport System:</u>

- Reason:
  - **Larger** organisms have **smaller** surface area to volume ratio
  - Glucose, amino acids move **longer distances** to reach inner cells
  - **Diffusion** too slow to meet needs
- Factors to evolve transport system:
  - **Shape** of organism
    - ↑ compactness of organism, ↓ diffusion distance, ↑ rate of diffusion
  - **Metabolism** of organism
    - ↑ metabolic activity, ↑ need to transport glucose, oxygen around body
- Consists of:
  - **Heart** (muscular pump)
  - **Circulatory fluid** (blood, lymph)
  - **Blood vessels** (artery, vein, capillaries, etc.)
- **Closed** circulatory systems
  - Found in vertebrates
  - **Blood** as circulatory fluid
  - Heart pumps blood in continuous circuit
  - Blood transported can be at **higher pressures**, thus **higher speed**, thus more efficient transport of oxygen, glucose
- Human transport system:
  - Consists of:
    - **Blood** system
      - **Double** circulation
        - **Pulmonary** circulation (to heart)

        - **Systemic** circulation (to body)
    - **Lymphatic** system
        - One way system

Components of Blood:

- **Fluid tissue**
- Made up of:
    - **Plasma**
        - Pale **yellowish** solution
        - Mostly **water**
        - Carries **digested food**, **waste products**, **gases**, **hormones**
        - **Distributes heat** around body for constant internal environment
    - **Red blood cells**
        - **Circular biconcave** in shape: ↑ s.a. to vol. Ratio for faster absorption of oxygen
        - **No nucleus**: allows RBC to carry more **haemoglobin** (not oxygen)
        - **Flexible plasma membrane**: able to squeeze through capillaries
        - **Small sized**: able to squeeze through lumen of capillary, thinness allows efficient diffusion
        - Produced by bone marrow
        - Contains red pigment **haemoglobin**
            - Allows RBC to **transport oxygen**
            - Contains porphyrin ring with **iron** (rust taste)
            - Maximum of **4 oxygen molecules** carried by each haemoglobin molecule
            - Destroyed in **spleen**, transported to **liver** to be broken down

Transport of Oxygen by Red Blood Cells:

1. **Blood** passes through **lungs** of high oxygen concentration
2. Oxygen **diffuses** from **alveoli** into RBC

3. Haemoglobin has **great affinity** for oxygen
4. Combines with oxygen to form **oxyhaemoglobin**
5. Blood transports oxygen to rest of body
6. **Oxyhaemoglobin** releases oxygen when passing through tissues of **low oxygen concentration**

- Adaptations at high altitudes:
    - **Higher** RBC concentration
        - ↑ amt of haemoglobin in blood
        - ↑ volume of oxygen transported per unit time
        - Known as **acclimatisation**

Effects of Carbon Dioxide and Carbon Monoxide:

1. Haemoglobin can also combine with CO, CO_2
2. **Not efficient** to bond with CO_2 due to plasma already transporting as HCO_3^-
3. CO **stronger affinity** to haemoglobin than O_2
4. If too much bonds into **carboxyhaemoglobin**, less haemoglobin available for O_2
5. **Death** may occur

- **White blood cells**
    - **Larger** than RBC
    - **Less** in numbers than RBC
    - **Colourless**
    - Two types:
        - **Lymphocytes**
            - Produced by **bone marrow**
            - Transported directly to **lymph nodes**
            - **Large, rounded nucleus**
            - **Small** amount of cytoplasm
            - **Limited** movement, does not squeeze through capillary wall
            - Produce **antibodies** in response to **antigens** from **pathogens**

        - Causes bacteria to **agglutinate** (clump together) to facilitate ingestion by **phagocytes**
        - **Neutralises toxins** from bacteria
        - **Ruptures** bacterial cell membrane
        - Allows recovered person to be **immune** to future infection
    - **Phagocytes**
        - Produced by **bone marrow**
        - **Bean shaped**
        - **Multi-lobed nucleus**
        - Able to squeeze through capillary walls, move anywhere in body
        - **Shorter** life span than **lymphocytes**
        - Able to **ingest** foreign particles via **Phagocytosis** (Chpt 2)
- **Blood Platelets**
    - Fragments of **cytoplasm**
    - Initiate **blood clotting**
        - Prevents **excessive** loss of blood
        - Prevents **entry** of harmful bacteria
    - Prevented by:
        - **Anticoagulants** (e.g. heparin, etc)
        - Chemicals which suppresses activation of platelets (e.g. nitric oxide, etc)

    Blood Clotting Process:

    1. Blood platelets release **enzyme** called **thrombrin**
    2. **Thrombin** catalyses conversion of **soluble protein fibrinogen** to **insoluble fibrin threads**
    3. Fibrin threads **entangle** blood cells, whole mass forms scabs

    Recovery Process:

    1. Injury site **synthesises collagen fibres** to form new tissue
    2. Capillaries grow into new tissue
    3. Scab eventually falls off

ABO Blood Groups

- Classified into a **blood group** based on **types of antigens** on surface of RBC
- Blood plasma contains antibodies that does not react with antigens on RBC
- Consists of 4 types:
    - **Blood group A**: antigen A on RBC, antibody B in plasma
    - **Blood group B**: antigen B on RBC, antibody A in plasma
    - **Blood group AB**: antigen A and B on RBC, no antibodies in plasma
    - **Blood group O**: no antigens on RBC, antibody A and B in plasma
- **Agglutination** is **clumping** of RBC which can lead to death
    - Occurs if antigen A reacts with antibody A
    - Occurs if antigen B reacts with antibody B
- **Same blood groups** can donate to each other
- **Blood group O** can be donated to **all**
- **Blood group AB** cannot be donated at all

Organ Transplant and Tissue Rejection:

- Medical procedure
- If transplanted organ **not compatible** to patient's original tissues, will lead to **tissue rejection**
- **Incompatible organ** treated as **foreign body** by immune system, attacked by **antibodies** by **lymphocytes**
- Risk of rejection reduced by:
    - Ensuring both tissues genetically **similar**
    - Using **immunosuppressive drugs** to inhibit immune system response
        - Causes **reduced resistance** to other infections (more prone to diseases)

Blood Vessels:

- General flow of blood after heart: Artery → Arteriole → Capillary → Venule → Vein

Blood Vessel:	Structure:	Functions:
Artery	- **Thicker** muscular walls	- Brings about **constriction**, **dilation** of artery to maintain pressure Muscles contract → artery constricts → lumen narrower → less blood flows, vice versa - When heart contracts, arteries constrict to propel blood further
	- **Elastic** walls	- To withstand **high blood pressure** from **ventricular contractions of heart** - Allows **stretching**, **recoiling** of artery wall to push blood along, give rise to **pulse**
Arteriole	N.A.	- Connects arteries to capillaries
Capillary	- **Microscopic** - Found between **cells**	N.A.
	- **1 cell thick** walls	- Enables **faster** movement of substances across - **Shortens** diffusion distance
	- Wall made up of cells called **endothelium**	N.A.
	- **Partially permeable** endothelium	- Enables smaller substances to **diffuse** quickly across

	- **Highly, repeatedly** branched	- **Large surface area** for exchange of substances
		- **Increases** cross-section area
		  - **Lowers** blood pressure
		  - **Slows down** blood flow for **more** time for exchange of substances

Venule	N.A.	- Connects capillaries to veins
Vein	- **Less** muscular, elastic walls than artery - **Bigger** lumen size	- Blood flows **more slowly, more smoothly**
	- Contains **semi-lunar valves**	- Semi-lunar valves to **prevent backflow** of blood when **closed**
	- Surrounded by skeletal muscles	- Assists movement of blood flow - Muscle **contractions** exert pressure on vein wall, pushes blood back to heart

<u>Transfer of Materials:</u>

- Exchange of substances done at **capillaries**
- Tiny spaces between cells contain colourless fluid called **tissue fluid**
- Tissue fluid caused by **higher** blood pressure forcing **fluid (mostly plasma)** out of arterial capillary end
- Acts as **medium for transfer** of substances between **capillaries and cell**
- **Dissolved food**, **O_2 diffuses** from capillaries into tissue fluid, into cells
- **Waste products**, **CO_2 diffuses** from cells into tissue fluid, into capillaries
- Tissue fluid eventually **returned** to blood at **venous end of capillary network**, at **lymphatic capillaries** to **maintain water potential** of plasma

- **Swelling** and **accumulation** of tissue fluid in organs and tissues of body occurs when blood loses too much fluid (known as **oedema**)

Double Circulation:

- **Double circulation** consists of **pulmonary** circulation, **systemic** circulation
- Blood passes through the heart **twice**
- Advantages:
    - Blood enters lungs at **lower pressure** for **more** time for **gaseous exchange**
    - Heart pumps **oxygenated** blood at **higher pressure** to the rest of the body to be distributed to the tissues **more quickly**

Human Heart:

- Roughly conical in shape, slanted to left side
- Surrounded by **two-layered bag** called **pericardium**
    - Pericardial fluid between layers reduce friction
- Consists of **4 chambers:**
    - **2 atria** (upper chambers)
    - **2 ventricles** (lower chambers)
- Right side separated from the left side by a muscular wall called **median septum** to prevent **mixing** of oxygenated and deoxygenated blood
- Atria has **thinner walls** than ventricles due to **less contraction force** needed
    - Due to distance between atria and ventricles being **short**, thus less cardiac muscles needed to pump blood at **lower pressure** from atria to ventricles during **atrial systole**
- Left ventricle has **thicker** walls than right ventricle
    - Due to left ventricle pumping blood at **higher pressure** to the **rest of the body** compared to right ventricle pumping blood to **lungs**
- Heart valves **prevent backflow** and ensure a **one-way flow** through the heart
- **Bicuspid valve** is located between **left atrium** and **ventricle**, is made up of **2 flaps**
- **Tricuspid valve** is located between **right atrium** and **ventricle**, is made up of **3 flaps**
- Both valves collectively known as **atrio-ventricular valves**

Path of Blood Through the Heart:

1. **Deoxygenated** blood from body returned to **right atrium** by **vena cavae**
2. Right atrium **contracts** to push blood into the **right ventricle**
3. **Tricuspid valve opens** when **pressure** in right ventricle becomes **lower** than in right atrium
4. Flaps of tricuspid valve are attached to ventricle wall by tendons called **chordae tendineae**
5. Right ventricle **contracts**
6. Blood pressure causes tricuspid valve to **close**, preventing **backflow of blood** into atrium
7. Chordae tendineae **prevents valves from opening** into atrium when right ventricle contracts
8. Blood leaves right ventricle through the **pulmonary arteries** to the **lungs**
9. Blood pressure causes **semi-lunar valves** in pulmonary arteries **close** to prevent **backflow of blood** into right ventricle
10. **Oxygenated** blood from lungs is returned to **left atrium** through **pulmonary veins**
11. Left atrium **contracts** to push blood into **left ventricle**
12. **Bicuspid valve** opens when **pressure** in left ventricle becomes lower than in left atrium
13. Left ventricle **contracts**
14. Blood pressure causes bicuspid valve to **close**, preventing **backflow of blood** into left atrium
15. Blood leaves left ventricle through the **aorta** to **rest of the body**
16. Blood pressure causes semi-lunar valves in aorta to **close** to prevent **backflow of blood** into left ventricle

Cardiac Cycle:

- Definition: The sequence of events that takes place in **one heartbeat**
- Contraction of ventricles is known as **ventricular systole**
- Relaxation of ventricles is known as **ventricular diastole**
- 1 ventricular systole + 1 ventricular diastole = 1 heartbeat

Stage 1: **Diastole**

- **Resting period** of heart chambers
- All muscles are **relaxed**
- **Oxygenated** and **deoxygenated** blood flows into the **left atrium** and **right atrium**
- **Bicuspid and tricuspid valves open** (due to pressure difference)
- Blood flows **passively** (not via pumping) into ventricles

Stage 2: **Atrial Systole**

- **Atria** muscles **contract**, **ventricle** muscles remain **relaxed**
- **Bicuspid and tricuspid valves fully open** (due to pressure difference)
- Blood is **pumped** into ventricles from the atria
- **Aortic and pulmonary valves** (semi-lunar valves) remain **closed**

Stage 3: **Ventricular Systole**

- **Ventricle** muscles **contract**, **atria** muscles **relax**
- **Bicuspid and tricuspid valve** forcefully **closes** (due to pressure difference)
- Valve closing forcefully produce the first **loud** heart sound “lub”
- **Aortic and pulmonary valves open** (due to pressure difference)
- Blood is **pumped** into the aorta from the left ventricle, and into the pulmonary artery from the right ventricle

Stage 4: **Ventricular Diastole**

- **Ventricles** start to **relax**
- **Pressure** in ventricles **fall**
- **Aortic and pulmonary valves close** (due to pressure difference)
- Valves closing forcefully produce the second **softer** heart sound “dub”

<u>Major Blood Vessels:</u>

- **Pulmonary artery**
    - Carries **deoxygenated** blood with **high concentration of CO_2**
    - Carries blood from **heart** to **lungs**
- **Pulmonary vein**

    - Carries **oxygenated** blood with the **highest O_2** and **lowest CO_2 concentration**
    - Carries blood from **lungs** to **heart**
- **Aorta**
    - **Main** artery of body
    - Carries **oxygenated** blood at **high pressure** to rest of the body
- **Hepatic artery**
    - Carries **oxygenated** blood to the **liver**
- **Hepatic vein**
    - Carries blood with **regulated concentration** of **food substances** into circulation
    - Carries **detoxified** and **deoxygenated** blood from liver to heart
- **Hepatic portal vein**
    - Carries blood with **absorbed digested food** from **digestive system** to **liver**
- **Renal vein**
    - Carries blood with **reduced urea concentration** into circulation
- **Renal artery**
    - Carries **oxygenated** blood with **high urea concentration** to **kidneys**

<u>Coronary Heart Disease:</u>

- **Coronary arteries** emerge from **aorta** and runs on **outside** of the heart
- Function: To supply **oxygen** and **glucose** to the **cardiac muscles**
- Caused by **atherosclerosis** (**deposit** of **fatty substances** on the **inner surface** of an **artery**)

Process:

1. Accumulation of **cholesterol** and **polysaturated fats** as plaques on **inner wall** of **coronary arteries**
2. **Lumen** of arteries **narrow**, causing blood pressure to **increase**
3. Arteries develop a **rough inner surface**, becomes **stiffer**
4. Risk of **thrombosis (blood clot)** being trapped **increases**
5. Supply of blood with **O_2** and **glucose** for heart muscles is **reduced**
6. Cardiac muscles **die** due to **lack of O_2**, leading to a **heart attack** (myocardial infarction)

- Risk factors:

- **Unhealthy diet** high in cholesterol and saturated fats
- **Emotional stress**
- **Smoking**
- **Sedentary lifestyle**

Topic 7: Respiration

Respiration:

- Definition: The **breakdown of glucose** through **oxidation** in living cells, with the **release of energy**
- Examples:
  - Muscular contractions
  - Active transport
  - Synthesis of polymers from monomers (e.g. proteins from amino acids)
  - Cell division and growth
  - Transmission of nerve impulses
- Some energy is released as **heat** which is circulated around the body **to keep us warm**
- Plants:
  - Only **respiration** occurs in the dark
  - **Both** respiration and photosynthesis occurs in daylight
  - Point where **rate of respiration** is **equal** to the **rate of photosynthesis** is known as the **compensation point**

Respiration:	Photosynthesis:
Energy is **released**	Energy is **stored** in **carbohydrate** molecules
O_2 is used, **CO_2** and **H_2O** given off	**CO_2** and **H_2O** are used, **O_2** given off
Catabolic process	**Anabolic** process
Occurs at **all times** in **all cells**	Occurs only in cells with **chlorophyll**

Sunlight not needed	Sunlight needed
Results in **loss** of glucose	Leads to **gain** of glucose

Aerobic Respiration and Anaerobic Respiration:

- **Aerobic respiration**:
  - Definition: The **breakdown** of glucose in the **presence** of **oxygen** with release of a **large amount** of energy, and **carbon dioxide** and **water** released as **waste products**
- **Anaerobic Respiration**:
  - Definition: The **breakdown** of glucose in the **absence** of **oxygen** with release of a **small** amount of energy
  - Forms **lactic acid** during process
  - Muscles respire aerobically first, but limit in rate of breathing, heartbeat causes lack of oxygen
  - Skeletal muscles begin anaerobic respiration
  - Muscles incur **oxygen debt** (the amount of oxygen needed to break down all the lactic acid)
  - Lactic acid builds up, eventually causes **fatigue**
  - Rate of breathing remains **high** during rest to repay oxygen debt
  - Oxygen breaks lactic acid to release **energy** used to convert remaining lactic acid into **glucose**, stored as **glycogen**

Gaseous Exchange:

- Definition: The **exchange of gases** between an **organism** and the **environment**
- Reason:
  - Unicellular organisms:
    - Have a **larger** surface area to volume ratio
    - Do not need special gas exchange system
    - O_2 and CO_2 can be **efficiently** exchanged via **diffusion**

- Large animals:
    - Have a **smaller** surface area to volume ratio
    - Uses **special organs** such as lungs and gills
    - Organs have **enlarged surface area** and thin coverings
- Leaves of plants have **large** surface area to volume ratio, thus **diffusion** is used in **stomata**

<u>Gaseous Exchange in Humans:</u>

- **Passage of air**: **mouth & nose** → pharynx → larynx (voice box) → **trachea (windpipe)** → bronchi → bronchioles → **alveoli**

Organ:	Defensive Features:	Defensive Function:
Nose	- **Hairs** - **Mucous membrane** - **Small sensory cells**	- Hairs and mucous membrane **trap dust and bacteria** in the air - Sensory cells **detect harmful chemicals**
Trachea (Windpipe)	- **Gland cells** (goblet cells) - **Cilia**	- Gland cells secrete **mucus** to **trap dust and bacteria** - Cilia **sweep mucus upwards** into pharynx, which is **swallowed**
Bronchi		

- Lungs:
    - Contains **bronchioles**, **alveoli**

Transport of oxygen from lungs to tissues:

1. Oxygen **dissolves** in **moisture lining** alveolar walls
2. Dissolved oxygen **diffuses** through alveolar wall into capillaries
3. Oxygen enters blood plasma
4. Oxygen combines with **haemoglobin** to form **oxyhaemoglobin**
5. Oxygenated blood is transported away from lungs

6. Oxygen is **released** from oxyhaemoglobin at tissues and **diffuses** out into tissue cells

- Alveoli:
    - **Continuous** blood flow to alveoli capillaries
    - **Slow** blood flow at capillaries for sufficient time for gas exchange
    - **Numerous alveoli** for **large surface area**
    - **One cell thick** alveolus wall for **shorter diffusion distance**
    - Thin layer of **moisture** on alveolar surface for **oxygen to dissolve**
    - **Richly vascularised** to transport gases quickly

<u>Thoracic Cavity:</u>

- Structure:
    - 2 sets of **antagonistic** muscles (**internal and external intercostal muscles**) between ribs
    - Thorax separated from abdomen by **diaphragm**
- Breathing consists of **inhalation** and **exhalation**
- Stimulus for breathing is a **high CO_2 concentration** causing **lowered pH** (not oxygen deficit)

Breathing Mechanism:	Inspiration:	Expiration:
Intercostal Muscles	- **External** intercostal muscles **contract** and **shorten** - **Internal** intercostal muscles **relax** and **lengthen**	- **External** intercostal muscles **relax** and **lengthen** - **Internal** intercostal muscles **contract** and **shorten**
Ribs and Sternum	- Move **upwards** and **outwards**	- Move **downwards** and **inwards**

Diaphragm	- **Contracts** and **flattens**	- **Relaxes** and **arches upwards**
Thorax	- Volume **increases**	- Volume **decreases**
Lungs	- Pressure **increases**	- Pressure **decreases**
Movement of Air	- Atmospheric pressure **higher** than lung pressure - Air flows into lungs **passively**	- Atmospheric pressure **lower** than lung pressure - Air flows out of lungs **passively**

Effects of Tobacco Smoke:

Chemical:	Chemical Properties:	Effects on the Body:
Nicotine:	- Addictive drug - Causes release of adrenaline - Makes blood **clot** easily	- Increases **heartbeat** and **blood pressure** - Increases risk of **blood clots**
Carbon Monoxide:	- Combines with haemoglobin to form **carboxyhaemoglobin** - Increases rate of **fatty deposits** on arterial wall - Damages capillary lining	- Death in higher concentrations - Increases risk of **atherosclerosis** (coronary heart disease) - Increases risk of **blood clots**
Tar:	- **Carcinogenic**	- Paralyses cilia lining - Blocks air sacs
Irritants:	N.A.	- Increases risk of **chronic bronchitis** - Inflamed epithelium lining

		- Excessive mucus secretion - Blocked airways - Increased risk of **lung infections** - Increased risk of **emphysema** - Violent coughing breaks air sac partition walls - Air sacs surface area decrease - Breathing becomes difficult

Topic 8: Excretion

<u>Purpose of Excretion:</u>

- Definition: Process where **metabolic** waste products and **toxic** materials are **removed** from the body of an organism
- Metabolic wastes known as **excretory products**
    - Examples:
        - Urea — deamination
        - Carbon dioxide — respiration
        - Oxygen — photosynthesis
        - Bile pigments — haemoglobin breakdown
        - Water — tissue respiration
- Accumulation of excretory products can lead to:
    - Alter **pH**, **water potential** of body fluids
    - **Poison** enzyme systems

Excretion vs Egestion:

Excretion:	Egestion:

- Removal of **metabolic** wastes
- Examples:
  - Urination
  - Exhalation
	- Removal of **undigested** wastes
	- Examples:
	  - Defecation

Human Urinary System:

Structure:	Appearance:	Function:
Kidneys	- Located in abdominal cavity - Reddish-brown in colour - Bean shaped - Made up of **many capillaries**, **nephrons**	- Remove nitrogenous wastes - Maintain constant water potential in blood
Renal Artery	N.A.	- Carries **oxygenated** blood to kidneys - Blood contains **lesser CO_2**, **more urea**
Renal Vein	N.A.	- Carries **deoxygenated** blood back to heart - Blood contains **more CO_2**, **less urea**
Ureter	- 25 cm long tube	- **Transports** urine from kidneys to bladder
Bladder	- Distensible sac - Has a wall of smooth muscle	- Temporarily stores urine from kidneys

	- Contains sphincter muscle that keeps bladder closed	
Urethra	- Muscular tube - Emerges from base of bladder	- Allows urine to pass out of body

Nephron	- Contains:
	  - **Bowman's capsule**
	  - **First convoluted tubule**
	  - **Loop of Henle**
	  - **Second convoluted tubule**
	  - **Glomerulus**
	- Opens into collecting duct
		- **Filters** blood of metabolic wastes

<u>Filtration Procedure:</u>

- Involves 2 main processes:
  - **Ultra-filtration**
    - **High** hydrostatic blood pressure required
      - Due to difference in diameter of arterioles
    - **Partially permeable** membrane required
      - Partially permeable **basement membrane** wraps around glomerulus
      - Basement membrane separates glomerulus from Bowman's capsule to act as a filter
  - **Selective reabsorption**

Ultra-filtration:

1. **Afferent** arteriole is **wider** than **efferent** arteriole
2. **Heart** and **difference in diameter** create **high** pressure in **glomerulus**
3. Pressure forces blood **plasma** through **capillary walls** into **Bowman's capsule**
4. **Water**, **smaller molecules** (glucose, amino acids, minerals, urea) forced into Bowman's capsule
5. **Larger molecules** (RBC, WBC, platelets, fats, proteins) too large to pass out, **stays** in capillaries

Selective Reabsorption:

1. **Glomerular filtrate** moves from Bowman's capsule to **first convoluted tubule**, then **loop of Henle**, then **second convoluted tubule**
2. Capillaries surrounding tubules **reabsorb** useful materials back into blood by **active transport**
3. **Glucose, amino acids** are **all** reabsorbed
4. **Mineral salts** are **mostly** reabsorbed
5. Remaining fluid containing **excess water**, **excess salt**, **urea**, **uric acid**, **creatinine** flows into **collecting duct**
6. Fluid flows into renal pelvis as urine

<u>Osmoregulation:</u>

- Definition: The control of **water** and **solute concentrations** in blood to maintain a **constant water potential** in body
- Regulated by **anti-diuretic hormone** (vasopressin)
- Hormone produced by **hypothalamus** in brain, released by **pituitary gland** when water potential in plasma decreases
- ADH **increases permeability** of **second convoluted tubule** and **collecting duct** (not loop of Henle, first convoluted tubule) to enhance water reabsorption into blood
- Water potential of blood affects blood pressure (↑ water potential, ↑ blood volume, ↑ blood pressure)

Kidney Dialysis:

- Caused by **kidney failure**
    - Caused by hypertension, diabetes, alcohol abuse, external injury
    - Causes tubules to not be able to filter blood
    - Glomeruli damage causes large molecules to possibly escape into filtrate, end up in urine
    - Treated with **dialysis**, **kidney transplant**
- Dialysis:
    - **Dialysis machine** works by **diffusion** to perform filtration, selective reabsorption
    - **Blood** is drawn from a **vein** in human arm, allowed to flow through tubing of dialysis machine
    - **Pump** is used to **facilitate movement** of blood into machine
    - Pump **prevents backflow** of blood without using valves
    - Tubing of dialysis machine is surrounded by **dialysis fluid** (dialysate)
    - Features:
        - **Selectively permeable** tubing walls to allow small molecules to pass through
        - **Narrow, long, coiled** tubing to increase **surface area to volume ratio** to increase **rate of exchange of substances** between blood and dialysis fluid
        - **Same** concentration of substances as healthy blood plasma in dialysis fluid (no urea) for **higher concentration gradient**
        - **Counter current system** with **opposite** direction of blood flow to dialysis fluid to **maintain diffusion gradient**
- Kidney transplant:
    - Original kidneys left in their usual positions
    - Tissue matching required to avoid tissue rejection by WBC
    - Immunosuppressive drugs needed for kidneys without tissue matching
        - Also reduces patient's resistance to pathogens

Topic 9: Homeostasis and Hormonal Control

Homeostasis:

- Definition: The **maintenance** of a **constant internal environment**
- Enables body to be **independent** from **external environmental changes** and to operate at **optimal level**
- Regulates :
    - pH level
    - Blood sugar level
    - Water potential
    - Blood pressure
    - Temperature
- Control mechanism contains a **receptor**, **control centre** and **effector**
    - Receptor **detects** any changes in normal set value of condition, sends information to control centre
    - Control centre **instructs** effector to direct appropriate corrective **response** to return system to normal set value
    - Known as **negative feedback** when **opposite counterchange** is used to restore original state

Examples of Homeostasis:

Regulation of Blood Glucose Level:

- Blood glucose concentration increases temporarily after a meal
- Stimulates **Langerhans □-cells** in **pancreas** to release **insulin**
- Insulin diffuses from pancreas into blood, transported to liver and muscles
    - Promotes excess glucose **conversion** into glycogen for storage
    - Causes **increased cellular respiration**
    - Increases **permeability** of cell membranes to glucose for faster glucose taken in by muscles, liver cells
- Allows blood glucose level to return to norm
- Remaining insulin sent to **liver** to be destroyed, removed via **kidneys**

Regulation of Blood Water Potential in Humans:

- **Osmoregulation** controlled by **antidiuretic hormone**
- ADH produced by **hypothalamus** in brain
- ADH released by **pituitary gland** into blood
- Increases permeability of second convoluted tubule, collecting duct
- Constant water potential of blood prevents **lysis** or **crenation** of RBC

<u>Hormones:</u>

- Definition: A **chemical** substance produced by an **endocrine gland**, carried (not transported) by **blood**, which **alters** activity of one or more specific **target organs** and is then destroyed by the liver
- Involves 2 systems:
    - **Nervous system** (nerves & impulses)
    - **Endocrine system** (hormones)
- Most secreted by **exocytosis** into bloodstream

<u>Endocrine System:</u>

- Contains endocrine glands
    - **Ductless** due to direct **diffusion** of hormones into blood
    - **Richly vascularised** to transport hormones to specific target organs
- Endocrine glands:
    - **Pituitary gland**
        - Secretes, produces many hormones
        - Produces **ADH**
    - **Hypothalamus**
        - Regulates secretion of some pituitary hormones
    - **Pancreas**
        - Contains **Islets of Langerhans**
            - Islets of Langerhans secrete **insulin** and **glucagon**
    - **Ovaries**
        - Secrete oestrogen, progesterone

- **Testes**
    - Secrete testosterone

<u>Insulin and Diabetes:</u>

- Produced in **Islets of Langerhans**
    - Made up of **α-cells** and **β-cells**
    - β-cells produce **insulin**
        - Targeted for **liver** and **muscles**
        - Over-secretion can lead to hypoglycemia
    - α-cells produce **glucagon**
        - Targeted for **liver** and **muscles**
        - Stimulates conversion of **glycogen to glucose**
        - Stimulates conversion of **fats** and **animo acids into glucose**
- Diabetes mellitus caused by **deficiency of insulin** or **decreased response** to insulin at target tissues
    - Consists of 2 types:
        - **Type 1 Diabetes**:
            - Caused by individual not producing **enough** insulin (faulty pancreas)
            - Due to **immune system** destroying β-cells in pancreas
            - Treated by:
                - Reducing carbohydrate intake
                - Regular insulin injections
        - **Type 2 Diabetes**:
            - Caused by failure of target cells to respond **normally** to insulin (e.g. insulin resistance)
            - Influenced by:
                - Heredity
                - Excess body weight
                - Lack of exercise
            - Treated by:
                - Exercising
                - Healthy diet
                - Medications

- Signs and symptoms of diabetes:
    - Persistently high blood glucose level
    - Presence of glucose in urine (due to some glucose not reabsorbed after ultrafiltration)
    - Wounds that do not heal
    - Frequent urination
    - Weight loss
    - Lethargy
    - Thirst
- Preventive measures:
    - Healthy diet low in calories, high in fibre
    - Regular physical exercise
    - Healthy body weight

<u>Human Skin:</u>

- Consists of **epidermis** (outer layer), **dermis** (inner layer)
- Functions:
    - Thermoregulation
    - Thermal insulation
    - Protection from physical damage, dehydration, UV rays
    - Energy reserves
    - External stimuli reception
    - Vitamin production
    - Nitrogenous excretion
- Epidermis:
    - Outermost layer of **dead cells** which is **waterproof**, constantly replaced
    - Inner layer of living cells pigmented with **melanin** to **absorb UV rays** and protect body from effects
- Dermis:
    - Consists of:
        - Hair
            - Produced by **hair follicles**
            - Made up mainly of keratin

        - **Hair erector muscle** attached to base of hair
            - Contraction of hair erector muscle causes hair to stand on end, leading to goosebumps (heat-loss prevention in furry animals)
    - Blood vessels
        - Arteries, arterioles carry blood to **surface capillaries** near skin surface
        - Arteries, arterioles undergo **vasodilation** and **vasoconstriction** to regulate temperature
    - Sebaceous glands
        - Secretes **sebum** to lubricate, waterproof skin and hair
            - Has bactericidal, antiseptic properties
    - Sweat glands
        - Exocrine glands that secrete **sweat**
        - Sweat flows through sweat duct to skin surface
        - **Evaporation of water** in sweat removes **latent heat of vapourisation** to cool skin
    - Sensory receptors
        - Detects **external changes** or **stimuli**
        - Temperature receptors known as thermoreceptors
- Layer of **subcutaneous fat** below dermis containing **adipose tissue**
    - Acts as **energy storage**
    - **Insulates** body against heat loss, heat gain

<u>Thermoregulation:</u>

- Controlled by **hypothalamus** in brain by monitoring temperature of blood flowing through it
    - Also **receives signals** from other **thermoreceptors** and sends **nerve impulses** to **effectors** when needed
- Humans gain heat mainly from **metabolism in tissues**, **absorption of solar energy**
    - Heat from environment mainly from **radiation**, **convection**, **conduction**
    - **Excess** heat produced during exercise by muscles
- Heat mainly lost through **evaporation** of water in sweat and **radiation**

Response to Increase of Body Temperature:

1. **Sweat glands** are activated
2. Sweat is released onto skin surface
3. **Evaporation** of **water** in sweat removes **latent heat of vapourisation**
4. Reduces body temperature
5. **Arterioles** undergo **vasodilation** to **increase blood flow** to **surface capillaries**
6. Increases excess heat lost via **radiation**
7. **Metabolic rate** also **decreases**
8. (Mammals) Hair erector muscles relax so that hairs lie flat

Response to Decrease of Body Temperature:

1. Involuntary muscle contractions begin (e.g. **shivering**)
2. **Metabolic rate** increases to **produce more heat**
3. **Arterioles** undergo **vasoconstriction**
4. Less blood is carried to surface capillaries
5. Reduces heat loss via **radiation**
6. **Sweat glands** become **less active**
7. **Adipose tissues** act as layer of **insulator**
8. (Mammals) Hairs can be raised by contracting erector muscles
9. (Mammals) Causes layer of air to be trapped
10. (Mammals) Air is a poor conductor of heat
11. (Mammals) Reduces heat loss by radiation

Topic 10: Nervous System and Eye

<u>Sensitivity:</u>

- Definition: The ability to **detect change** and to **respond** appropriately to it
    - Changes known as **stimuli**
- Examples:
    - Withdrawal of hand after touching hot object
    - Movement of plants towards light

    - Movement of bacterium towards food
- Detection, response caused by **nervous system** and **endocrine system** coordinating
- Actions can be **voluntary** or **involuntary** or **mixed** (e.g. throwing a ball, breathing)

Nervous System:

- Consists of:
    - **Central nervous system**
        - Made up of **brain** and **spinal cord**
    - **Peripheral nervous system**
        - Made up of **nerves**, sense organs
        - Connects organs and CNS

Structure:	Description:

Neurone	- Specialised cells
	- Serve as **pathways** of communication between brain and body
	- Allows **nerve impulses** to transmit from **organs receiving stimuli** at **receptors** (e.g. nerve endings in skin) to **organs effecting change** at **effectors** (e.g. muscles, glands)
	- Consists of 3 types:
	  - **Sensory neurone**
	  - Transmits nerve impulses from **sense organs** to **central nervous system**
	  - **Relay neurone**
	  - Receives impulses from **sensory neurones** or **other relay neurones** to relay to **motor neurones** or **other relay neurones**
	  - Found within CNS
	  - **Motor neurone**
	  - Transmits nerve impulses from **CNS** to **effectors**

Nerve Fibre	- Part of a neurone - Strand of **cytoplasm** extending from cell body

	- Specialised for **transmitting nerve impulses**

Nerve	- Bundle of **nerve fibres** within sheath of **connective tissue**
	- Consists of 3 types:
	  - **Sensory** nerve fibres conduct nerve impulses from **sense organs**
	  - **Motor** nerve fibres conduct nerve impulses to **effectors**
	  - **Spinal** nerves contain **mixed fibres**, made up of **sensory** and **motor** nerve fibres

Synapse	- A **junction** between **2 neurones** or **neurone and effector** - Impulse cannot transmit directly between neurones - Nerve impulses transmitted **electrically** through neurones but **chemically** between neurones through synapses - To ensure one way flow of impulses - Contains **neurotransmitters** within **synaptic vesicles** to carry impulses across
Spinal Cord	- Part of the CNS - Relays impulses in and out of the spinal cord - Relay impulses up and down the body, to and from the brain

<u>Types of Actions:</u>

- Can be **voluntary** or **involuntary**
  - Involves different pathways

Voluntary vs Involuntary:

Voluntary:	Involuntary:
- Deliberate, controlled by will, does not happen automatically - Pathway: Brain → relay neurone (in spinal	- Not controlled by will - Reflex actions: An **immediate response** to a **specific stimulus** without **conscious**

cord) → motor neurone → effector	**control**
	- Uses **reflex arc**: shortest pathway of nerve impulses from receptor to effector
	  - Receptor → sensory neurone → relay neurone (in spinal cord/brain) → motor neurone → effector
	- Consists of 2 types:
	  - **Spinal** reflexes (controlled by spinal cord)
	  - **Cranial** reflexes (controlled by brain without consciousness)

- Relatively **slow** - Involves brain - With conscious control - **No** sensory neurones involved - **No** stimulus involved	- Relatively **fast** - Involves **brain or spinal cord** - Without conscious control - Involves sensory neurone - Involves stimulus

Withdrawal Reflex (Touching Hot Object):

1. **Heat** stimulates **receptors** on skin
2. **Nerve impulses** are produced, transmitted along **sensory neurone** to **spinal cord**
3. In spinal cord: nerve impulses transmitted across **synapse** to **relay neurone**, across another **synapse** to **motor neurone**
4. At the same time: nerve impulses transmitted to brain
5. **Motor neurone** transmits impulses to **effector**
6. **Effector muscle contracts** to withdrawal hand from hot object

Cranial Reflex:

- E.g. pupil reflex
- Nerve impulses transmitted to brain instead of spinal cord
  - Used for sense organs closer to brain (in head) for **shorter** travel time

Hormonal vs Nervous Controls:

- Both consists of:
    - Receptor (detects stimulus)
    - Impulse or chemical signal (transmitted)
    - Effector (carries out response)

Differences:

Hormonal Control:	Nervous Control:
- Involves hormones (**chemical**) - Hormones transported by **blood** - **Slow** response - Responses can be **short-lived** or **long-lived** - Always **involuntary** - May affect **more than 1** target organ	- Involves nerve impulses (**electrical**) - Impulses transported by **neurones** - **Quick** response - Response **short-lived** - May be **voluntary** or **involuntary** - Usually **localised** to 1 target

Structure of a Human Eye:

- Attached to skull in socket by **rectus muscles**
    - Also controls eye movements
    - Works **antagonistically**
- Wall of eye made up of **sclera**, **choroid**, **retina**
- Filled with **aqueous humour**, **vitreous humour**

Structure:	Description:	Function:
Cornea	- Dome-shaped layer - Transparent	- **Refract** light rays into eyes - Causes **the most** refraction of light - Myopia caused by changes in shape causing blurred vision

Conjunctiva	- Mucous membrane - Covers **sclera**	- Mucus keeps front of eyeball moist
Aqueous Humour	- Transparent liquid - Between cornea and lens	- Maintains interior **pressure** in eye for shape - Provides **nutrients** for **cornea**, **lens**
Pupil	- Rounded opening - In centre of **iris**	- Allows light to enter eye - Used in pupil reflex
Iris	- Consists of **circular muscles**, **radial muscles** (antagonistic) - Pigmented	- **Controls** amount of light entering eye by changing **pupil size** - Gives eye colour (e.g. brown eyes, blue eyes)
Lens	- Transparent - Circular - Biconvex	- Changes **thickness**, **curvature** to refract light onto retina
Suspensory Ligament	- Series of **fibres** (non-elastic)	- Connects **ciliary muscles** to **lens**
Ciliary Muscles	N.A.	- Controls **shape of lens**
Choroid	- Middle layer of eye - Pigmented **black** - Contains capillaries	- **Transports oxygen**, **nutrients** to eye - **Removes metabolic wastes** from eye - Black pigment **prevents reflection** of light inside eyeball
Vitreous Humour	- Transparent - Jelly-like substance - Between lens and retina	- Maintains interior **pressure** in eye for firmness - **Refracts light** onto **retina**
Retina	- Innermost layer of eye - Consists of:	- Photoreceptors **form images** - Photoreceptors send nerve

	- Neurones - **Photoreceptors** (**rods**, **cones**)	**impulses** to **nerve fibres** in **optic nerve** to brain
Blind Spot	- **No photoreceptors**	- Region where nerve fibres meet and become optic nerve
Fovea	- Near centre of retina - **Most concentrated** amount of **cones** - **No rods**	- Images **focused** here - Allows for **most acute** vision
Sclera	- Outermost layer of eye - Tough coat	- Protects eye - Attached to **rectus muscles**
Eyelid	N.A.	- **Protects** cornea from damage - Prevents excess light entering by squinting - Spreads tears over eyes to clear dust by blinking
Eyelashes	- Short hairs - At border of eyelid	- **Protect** eyes from dust - **Protect** eyes from excess light

Tear Gland	N.A.	- Secretes tears
		  - Wash away dust
		  - Keep cornea moist
		  - Lubricate conjunctiva

<u>Photoreceptors:</u>

- Rods:
  - Used during **low light intensity**
  - Contains photosensitive pigment **visual purple**
    - Breaks down when **exposed to light**
    - Reforms in **absence of light**

        - Causes eyes to have to adapt to darkness after bright light
- Cones:
    - Used in **high light intensity**
    - Used in **differences of wavelength** (**colour vision**)
    - Made up of 3 types: Red, green, blue cones
    - **Most concentrated** at **fovea**

<u>Pupil Reflex:</u>

- Definition: The **involuntary** change of **pupil size** by the **iris** to **control the amount of light** entering the eye
- Iris controlled by 2 **involuntary** muscles: **circular muscles** and **radial muscles**
    - Muscles are **antagonistic**
- Pathway: Stimulus (change in light intensity) → receptor (retina) → sensory neurone in optic nerve → brain → motor neurone → effector (iris)

Eye in Bright Light:

1. Circular muscles of iris **contract**
2. Radial muscles of iris **relax**
3. Pupil diameter **decreases**
4. Less light enters eyes

Eye in Dim Light:

1. Circular muscles of iris **relax**
2. Radial muscles of iris **contract**
3. Pupil diameter **increases**
4. More light enters eyes

<u>Formation of Images:</u>

- Light rays **refracts** when passing through **cornea**, **aqueous humour** onto lens
- Light rays **further refracted** onto **retina** after passing through **lens**, **vitreous humour**
- Impulse generated by **photoreceptors**, impulses transmitted via **optic nerve** to brain

- Images formed are:
    - Inverted (upside down)
    - Laterally reversed (flipped horizontally)
    - Diminished (smaller)
- Brain reverses image back to original form

Accommodation:

- Definition: The **reflex** mechanism where light rays from an object are **brought to focus** on the **retina**
- **Thickness**, **curvature of lens** are adjusted to focus light rays
- Allows clear and sharp image to be formed on retina

Accommodation of Distant Objects:

1. **Parallel** light rays from **distant** object enters eyes
2. Ciliary muscles **relax**
3. Suspensory ligaments become **taut** (not contract)
4. Lens becomes **thinner** (less convex)
5. Light rays focuses on retina
6. Photoreceptors stimulated
7. Nerve impulses produced
8. Impulses transmitted via optic nerve to brain
9. Brain interprets impulses
10. Person sees distant object

Accommodation of Near Objects:

1. **Diverging** light rays from **near** object enters eyes
2. Ciliary muscles **contract**
3. Suspensory ligaments **slacken** (not relax)
4. Lens becomes **thicker** (more convex)
5. Light rays focuses on retina
6. Photoreceptors stimulated
7. Nerve impulses produced
8. Impulses transmitted via optic nerve to brain

9. Brain interprets impulses
10. Person sees near object

Topic 11: Infectious Diseases in Humans

<u>Diseases:</u>

- Definition: A condition that causes the body to **function less effectively**
- Can cause **signs**, **symptoms**
    - Signs: **observable**, **measurable** (e.g. rashes, blood pressure, coughing)
    - Symptoms: **felt**, **described** by patient (e.g. pain, nausea, fatigue)
- Spread by:
    - Airborne droplets
        - During sneezing, talking, coughing
        - Prevented by masks
    - Direct contact
        - Exchange of body fluids
        - Contact with infected blood, mucus
        - Skin to skin touching
    - Contaminated food, water

<u>Bacteria and Viruses:</u>

- Bacteria:
    - Single-celled organism
    - Can be pathogenic or non-pathogenic
    - Can be motile or non-motile (able to move on its own)
    - **No** nucleus
    - Cell wall is **present**
    - Contains **singular loop of DNA**
    - Contains **plasmids** (smaller rings of DNA)
    - Can be killed by **antibiotics**
- Viruses:

        - Not considered cells (acellular)
        - Made up of **1 nucleic acid** (DNA or RNA) surrounded by **protein coat**
        - Always **parasitic**
        - Reproduce only **inside host cell**
        - **Cannot** be killed by antibiotics
        - Managed by **antiviral drugs**
- Prevented by vaccines:
    - Definition: Contains an **agent** that **resembles a pathogen** and **prevents infectious diseases** by stimulating WBC to quickly **produce antibodies** when pathogen invades
    - Received orally, via injections

How vaccines work:

1. Agent contains **antigens** on surface
2. Lymphocytes produce **antibodies** which fit antigens
3. Causes **agglutination** of agents
4. Antibody production becomes more efficient
5. More WBC also produced
6. WBC remains in body for future infections

- Bacteria managed by antibiotics:
    - Definition: A compound **made by microorganisms** that **kills** or **inhibits growth** of bacteria or fungi
    - **Ineffective** against viruses due to **lack of cell walls**, **cell membranes**, **ribosomes**
    - Works by:
        - Preventing **cell wall production** (e.g. penicillin) causing **water to enter cell via osmosis** causing **lysis**
        - Disrupting **normal functioning of cell membrane** (e.g. polymyxin) causing **lack of protection** of bacteria against environment
        - Inhibiting **production of enzymes** (e.g. sulfa) **required for synthesis of nutrients** causing **inhibition of growth**
    - Effectiveness can be reduced by:
        - Misusing, overusing antibiotics

        - Not completing full course of prescriptions
        - Using antibiotics when unnecessary
    - Not antibodies (produced by body)

Topic 12: Nutrition and Transport in Flowering Plants

<u>Photosynthesis:</u>

- Definition: A process in which **light energy** is **absorbed** by **chlorophyll found in chloroplasts** and transferred to **chemical energy** in glucose
- Done in chloroplasts:
    - Double membraned
    - Contains **lamellae** and **thylakoids**:
        - To increase surface area
- Contains 2 stages:
    - Light-dependent:
        - Light energy absorbed, converted to chemical energy
        - Light energy used to split **H_2O** into **H_2** and **O_2** (photolysis)
    - Light-independent:
        - H_2 produced reduces CO_2 to glucose

Test for Presence of Photosynthesis:

1. Test for presence of **starch** (easier than benedict's test)
    a. Blue-black indicates starch is present
2. **Destarch** the plant to ensure starch is **absent** before experiments
    a. Put plant in **dark** for 2 days so starch is converted into glucose, used up

- Uses chlorophyll:
    - Appears green
        - Lowest absorption of green light
    - Absorbs **bluish**, **reddish** light
- Produces glucose:
    - Used for **cellular respiration**

    - Used to **form cellulose cell walls**
    - Excess glucose converted to **sucrose** for **transport** in storage organs
    - Excess glucose stored as **starch grains** in stroma, cytoplasm of chloroplasts
    - Converted to other sugar forms (e.g. fructose in fruits)
    - Reacts with **nitrates** (from soil) to form **amino acids** for **proteins**
    - Forms **fats** for storage, cellular respiration, protoplasm synthesis
- Makes chemical energy available to animals, other organisms (ecology, food web)
- Maintains constant level of O_2, CO_2 in atmosphere (environment, ecosystem)
- Stores energy from sun as chemical energy in fossil fuels (environment)

<u>Limiting Factors of Photosynthesis:</u>

- **Light intensity**
    - Light intensity ↑, rate of photosynthesis ↑
- **Concentration of CO_2**
    - CO_2 concentration ↑, rate of photosynthesis ↑
- **Temperature**
    - Temperature extremeness ↑, rate of photosynthesis ↓
    - Photosynthesis is **enzyme-controlled**
        - Enzymes denature/become inactive in extreme temperatures

<u>Structure and Function of Leaf:</u>

- Consists of:
    - Leaf blade
        - Flat for **large surface area** for maximum absorption of sunlight
    - Leaf vein
        - **Transports water, mineral salts** to leaves
        - **Transports food** away from leaves
    - Leaf stalk
        - Positions leaf **away from stem** for maximum absorption of sunlight
- Leaf is made up of:
    - **Upper epidermis**
        - **Single** layer of cells

    - Covered by **waxy transparent cuticle**
        - Reduces **water loss**
        - Transparent to allow sunlight to reach mesophyll layer
- **Palisade mesophyll**
    - **One/two** layers of **closely packed long** and **cylindrical** cells
        - For maximum packing of cells
    - Contains **maximum chloroplasts** for most photosynthesis
- **Vascular bundle**
    - Contains **xylem** to transport water, mineral salts to leaf
    - Contains **phloem** to transport sugars away from leaf
- **Spongy mesophyll**
    - **Multiple** layers of **loosely packed irregular** cells with **intercellular air spaces** in between
    - For **gaseous exchange**
    - Contains **a few** chloroplasts
    - Cells covered with **thin film of moisture**
- **Lower epidermis**
    - **Single** layer of **closely packed** cells
    - Covered by outer **cuticle** to reduce water loss
    - Contains **stomata**
        - Opening controlled by **guard cells**
            - Sausage shaped
            - Joined at ends only
            - Contains chloroplasts, vacuole
        - Allows **CO_2** to **enter**, **O_2** to be **released**

Control of Stomata by Guard Cells:

- In presence of light:
    1. Guard cells photosynthesise, **produce glucose**
    2. Glucose **lowers water potential** in cells
    3. Water moves in via **osmosis** until **turgid**
    4. **Unevenly thickened cell walls** (thick inner, thin outer cell walls) cause stoma to **open** when turgid
- In absence of light:

1. Glucose is **used up** or **converted** into starch
2. **Water potential increases**
3. Water exits via **osmosis** until **flaccid**
4. Stomata **closes**

Entry of CO_2, H_2O into Leaf:

1. CO_2 **used up** in leaf during **photosynthesis**
2. CO_2 concentration in leaf is **lower** than atmosphere
3. CO_2 **diffuses** into leaf via **stomata**
4. CO_2 **dissolves in film of water** surrounding mesophyll cells, then diffuses into cells
5. Water, mineral salts move into leaf via **xylem**
6. Water, mineral salts move from **cell to cell** through leaf mesophyll

<u>Transport in Flowering Plants:</u>

Structure:	Appearance:	Function:
Xylem	- Made up of **xylem vessels** - **Empty**, **hollow** tubes - **Thicker** cell walls - Xylem vessels strengthened with **lignin deposits**	- Conducts **water**, **dissolved mineral salts** from **roots to leaves** (one-directional) - Xylem vessels provide **mechanical support** for plant **collectively** - Hollow tubes provide **continuous lumen** to **reduce resistance** to water - Lignin prevents vessel collapse
Phloem	- Contains **sieve tubes**, **companion cells** - Sieve tube cells have **sieve plates** with pores	- Transports **sucrose**, **amino acids** from leaves, cells with chloroplasts to other parts - Companion cells have **numerous mitochondria** to

		release energy for **active transport** of sugars from leaf into phloem sieve tubes

Structure:	Position of xylem, phloem:
Root	- Xylem, phloem not bundled together - Located at **centre** of roots with xylem, phloem **alternating**
Stem	- Xylem, phloem grouped to form **vascular bundles** - **Vascular bundles** arranged in a **ring** around centre - Phloem is **outside** xylem with tissue called cambium between - Cambium cells divide, differentiate to form new xylem and phloem tissue

<u>Movement of Substances in Plants:</u>

- **Translocation**: **Transport** of **sucrose** and **amino acids** in a **solution**, in the **phloem**, from the source to sink

  Movement of Water in Root:
  1. Entry of water **dilutes** root hair's cell sap
  2. Sap has **higher water potential** than next cell further inside root
  3. Water passes via **osmosis** into inner cell, down water potential gradient
  4. Process continues until water reaches xylem vessels

- **Transpiration**: **Loss** of **water vapour** mainly through **stomata** of **leaves** via **diffusion**
  - Most lost from stomata
  - Small amount lost from surface of epidermis (cuticular transpiration)
  - **Transpiration pull** is main **suction force** that draws water up xylem (due to cohesion-tension theory)
  - Consequence of **gaseous exchange** due to opening of stomata for CO_2

- Transports water, dissolved mineral salts up the plant from roots
- Cools plant by removing latent heat of vapourisation (like sweating)
- Supplies water to cells for photosynthesis, respiration
- Keeps cells turgid

Transpiration in Moving Water Up Xylem:

1. Water continuously moves out of mesophyll cells to form **thin film of moisture** over surface
2. Water **evaporates** from film into **intercellular air spaces**
3. Air spaces has **high concentration** of **water vapour**
4. Water vapour **diffuses** through stomata out of leaf **down a concentration gradient**
5. Water potential of cell sap decreases
6. Mesophyll cells absorb water via **osmosis** from cells deeper inside
7. Those cells absorb water from xylem vessels
8. Constant **suction force pulls column of water up** xylem

- Affected by:
    - **Temperature** (temp ↑, rate ↑)
        - **Kinetic energy** of water molecules increase, so evaporation increases
    - **Humidity** (humidity ↑, rate ↓)
        - Concentration of water vapour in air increases
        - Concentration gradient becomes **less steep**
        - Rate of diffusion decreases
    - **Wind** (wind ↑, rate ↑)
        - Wind **blows away** water vapour accumulated outside stomata
        - Concentration gradient becomes **steeper**
        - Rate of diffusion increases
    - **Light intensity** (intensity ↑, rate ↑)
        - Guard cells undergo more photosynthesis
        - They become more turgid, opens wider
        - Size, number of stomatal openings increase
        - Rate of diffusion increases

- Excessive transpiration causes **wilting**:
    - When rate of water loss exceeds rate of water absorption
    - Cells are **plasmolysed**, loses **turgor pressure**
    - Leaves fold up
        - Reduces water loss from transpiration
    - Temporary **defence mechanism** against **dehydration**
    - Prolonged wilting leads to death
        - Surface area exposed to sunlight reduced
        - Rate of photosynthesis decreases
        - Stomata closes
        - CO_2 unable to enter leaf, photosynthesis cannot occur

Topic 13: Organisms and Their Environment

<u>Ecology:</u>

- Definition: Study of how organisms interact with each other and their environment
- Consists of:
    - **Abiotic** environment: Physical factors (e.g. light intensity, water availability, oxygen content, pH of soil and water)
    - **Biotic** environment: Living things that an organism interacts with
- **Population**: A group of organisms of the **same species** living in a particular **habitat**
- **Community**: Populations of organisms living and interacting with each other
- **Ecosystem**: abiotic environment, biotic environment, energy and nutrients
- Organisms are **interdependent** within communities
- Niche: The position a species occupies in its habitat (e.g. physical space, its effects)
- **Symbiosis**: The close and **long-term** interaction between two species
    - 5 types of symbiotic relationships:
        - **Commensalism**: One benefits, the other not affected
        - **Competition**: One benefits, lowers survivability of the other
        - **Mutualism**: Both benefit
        - **Parasitism**: One benefits, the other suffers
        - **Predation**: One absorb energy, nutrients from the other

Nutritional Groups:

- Consist of:
    - **Producers** (**autotrophs**)
        - Able to synthesise organic substances from raw materials (e.g. photosynthesis)
    - **Consumers** (**heterotrophs**)
        - Feed on tissues, products, remains of organisms
        - Consist of:
            - **Herbivores**: Eat plants
            - **Carnivores**: Eat flesh
            - **Parasites**: Live in/on host and feeds on tissues
            - **Detrivores**: Eat detritus (decomposing organic matter) (e.g. earthworms, crabs)
            - **Omnivores**: Eat flesh and plants
            - **Decomposers**: Break down organic matter into inorganic nutrients (e.g. bacteria, fungi)
            - **Scavengers**: Eat dead plants and animals (e.g. vultures)

Food Chains and Webs:

- Always starts with the **producer**
- Each stage of a food chain or food web is called a **trophic level**
- **Producers** form **first** trophic level
- **Primary consumers** form **second** trophic level
- **Secondary consumers** form **third** trophic level
- **Tertiary consumers** form **last** trophic level
- Arrows indicate **energy transfer** (eaten by)
    - Energy transfer is **non-cyclical** (**one way**)
    - **Most lost as heat** between trophic levels
    - Also lost in **faeces**, **excretory products**, **uneaten parts**
    - Only ~10% of energy transferred

- Due to:
    - High amounts of **indigestible lignin, cellulose** by animals due to lack of enzymes
    - **Poisonous plant compounds** not consumed
    - **Inaccessible plant parts** (e.g. roots) not eaten

Carbon Cycle:

- Nutrients are **recycled** (opposite of energy)
- **Carbon** is constantly **removed from** and **released into the atmosphere** as **CO_2**
- Importance:
    - Allows for **continuous supply** of **CO_2** for **photosynthesis**
    - Allows **energy** to flow through via **photosynthesis** and **feeding**
- CO_2 released by **respiration** and **decomposition**
- Lack of decomposition causes accumulation of **fossil fuels**
- **Combustion of fossil fuels**, **deforestation** increase **atmospheric CO_2**
- CO_2 is a **greenhouse gas** capable of **absorbing infrared radiation** to **trap heat** in atmosphere, leading to **global warming** (**greenhouse effect**) increasing global temperature
- **Carbon sink**: An area that **stores more carbon compounds** than it **releases** for an **indefinite period of time**
    - Carbon sinks remove atmospheric CO_2
    - Includes:
        - Oceans: dissolved CO_2, fossil fuels (e.g. oil, natural gas)
        - Forests: glucose, cellulose, etc.

Pyramid of Numbers, Biomass, Energy:

- Known as **ecological pyramids**
- “Draw/sketch”: Blank space provided
- “Plot”: Grids provided
    - Legend needed (e.g. one grid represents n organisms)

Name:	Function:	Limitations/Considerations:
Pyramid of Numbers	- Shows the **number** of organisms for each species at each trophic level **at any one time** - Number represented by **length of bar** - **Inverted pyramid** means **producer is a large tree** or **one trophic level is parasitic**	- Does not consider **size of organism** - Only representative of **that particular time** of measurement - **Easy** to measure (purely counting)
Pyramid of Biomass	- Shows **total standing mass** of organisms at each trophic level **at any one time** - **Dry mass** (without water) is estimated - **Inverted pyramid** means **rapidly reproducing organism** - Overall **always upright**	- **Difficult** to measure (requires drying organism in oven) - Only representative of **that particular time** of measurement - Takes into consideration **size** of organism to give **more accurate** representation of food chain
Pyramid of Energy	- Shows **total energy content** of each trophic level **over a certain period of time** - **Always upright** as **energy is lost**	- **Very difficult** to measure (requires burning in calorimeter) - **Valid for generalisations of population** due to time period involved - Size of organism not relevant in

	between trophic levels	measurement

Effects of Humans on the Ecosystem:

- Deforestation
    - Loss of soil (topsoil lost due to lack of roots to hold)
    - Reduction in biodiversity (less organisms in habitat)
    - Climate changes (less trees → less transpiration → drier weather)
    - **Global warming**
        - Due to increased levels of greenhouse gases in atmosphere
        - Caused by:
            - Deforestation (less plants to absorb CO_2 via photosynthesis)
            - Combustion of fossil fuels
            - Combustion of plastic waste
            - Emissions from motor vehicles
        - Known as **greenhouse effect**
        - Affects:
            - Rise in sea levels
            - Climate changes
            - Loss in biodiversity
            - Acidic aquatic systems (from dissolved CO_2 creating carbonic acid)
- Water pollution
    - Definition of pollution: The process where **harmful substances**, also known as **pollutants** are **added into the environment**
    - Caused by:
        - **Untreated sewage**
            - Contains pathogenic **bacteria** which infects population
        - **Excess insecticides**
            - Fertiliser rich in **phosphates** and **nitrates** lead to **eutrophication** where water enriched with nutrients allow for **algal bloom** and **bacteria**

        - **Submerged plants** die of **lack of sunlight** (from algal layer on surface)
        - Bacteria **grow rapidly**, **use up dissolved O_2** during **decomposition** of dead plants
        - Marine organisms **die from lack of O_2**
        - **DDT** (Dichlorodiphenyltrichloroethane) used as **pesticides** is **non-biodegradable**
        - Organisms **consume DDT** and DDT is stored in **adipose tissues**
        - Concentration of DDT in the body **increases** over time as organism consumes food containing DDT (**bioaccumulation**)
        - Concentration of DDT **increases up the food chain** with each trophic level as predators consume prey containing DDT (**bioamplification**)
        - Apex predators contain **highest concentration** of DDT in bodies
        - DDT is **toxic**, has harmful effects
    - **Inorganic waste materials** (e.g. plastics)
        - Plastics are hazards to marine organisms
        - May be mistaken as food and consumed
        - Chemicals from buried plastic wastes may leach into water

<u>Conservation:</u>

- Definition: Efforts to **preserve** and **restore** the **natural environment** and its **resources**
- Reasons:
    - To **prevent extinction** of plant and animal species
    - To maintain a **stable** and **balanced ecosystem** by preventing disruptions of natural cycles
    - To maintain a **large gene pool** by improving agricultural produce with favourable genes
    - To maintain a source of **food**
    - To maintain **scientific value** of our ecosystem and study it
    - To preserve nature for people during **recreation**
    - To maintain **biodiversity** for resources with **economic** and **medicinal** purposes
- Examples:

- **Regulation** of timber logging (laws)
- **Reforestation** of native trees
- Designating **forest reserves** to prohibit damaging
- **Recycling** efforts
- **Research** to improve forests

Topic 14: Molecular Genetics

<u>Structure of Deoxyribonucleic Acid (DNA):</u>

- DNA is a **macromolecule**
- Exists in the form of a 3-dimensional **double helix**
- Wound into **chromosomes** via **DNA packaging** (46 per human)
    - DNA wraps around **proteins** called **histones** for compacting
        - DNA-protein complex called **chromatin**
    - **1 chromosome** is made up of **1 DNA molecule**
    - **1 chromosome** contains **many genes**
- Consists of **deoxyribonucleotides**:
    - 1 **nitrogenous base**
        - **Adenine** (A), **Thymine** (T), **Guanine** (G), **Cytosine** (C)
        - **A⇔T, G⇔C**
        - Bases bonded by **hydrogen bonds**
    - 1 **deoxyribose sugar** (pentose sugar)
    - 1 **phosphate group**
    - Chains of deoxyribonucleotides form polynucleotides creating a **sugar-phosphate backbone**
        - 2 polynucleotides in DNA which are **complementary** (not same/similar)
- Contains **genes**:
    - Definition: A **sequence of DNA nucleotides** which codes for the synthesis of **a single polypeptide** (for proteins e.g. enzymes), and is the **basic unit of inheritance**
    - Polypeptide coded depends on sequence of bases

Structure of Ribonucleic Acid (RNA):

- Contains **ribose** instead of deoxyribose for sugar
- Contains **uracil** (U) instead of **thymine** for bases
- RNA is **single-stranded**
- DNA directs RNA synthesis and RNA controls protein synthesis

Transcription and Translation:

- Process linking gene to protein
- Transcription:
    - Process of synthesis of **messenger RNA** (mRNA)
    - Takes place in **nucleus**

      Transcription:
        1. DNA strands **untwist** and **unzips**, **H-bonds** between strands **break**
        2. DNA provides template for synthesis of **complementary** (not identical) RNA strand
        3. RNA synthesised following **base-pairing rules**
        4. **Uracil is complementary to adenine** (no thymine)
        5. mRNA molecule is produced
        6. mRNA **leaves nucleus** and enters cytoplasm

    - mRNA base **triplets** are called **codons** (sequence of **3** bases)
- Translation:
    - Cell interprets codons to build a **polypeptide** (not protein) per mRNA molecule
    - Takes place in **ribosomes in cytoplasm** or **on rough ER**

      Translation:
        1. mRNA **attaches to ribosome**
        2. Each **codon** codes for **a specific amino acid**
        3. **Transfer RNA** (tRNA) molecules **transport specific amino acids** to the **ribosome**

4. **Anti-codons** on tRNA and **codons** on mRNA match up to form **complementary base pairs**
5. Ribosome **adds each amino acid** carried by tRNA to growing end of polypeptide chain
6. **Peptide bonds** form between amino acids

After Translation:

1. Protein is passed from the **ribosome** (on the rough ER) to the **golgi apparatus inside vesicles**
2. Golgi apparatus **modifies and packages proteins** into a **secretory vesicle** which will **move towards the cell membrane**, **fuse with the phospholipid bilayer**, **and release the protein out of the cell** (exocytosis)

- mRNA contains a **start codon** (AUG methionine) and **stop codons** (UAA, UGA, UAG)
    - Start codon and stop codons indicate **start of translation** (beginning) and **end of translation** (termination) respectively

<u>Gene Mutation:</u>

- Definition: **Random changes** in the **genes of a cell**
- May be inherited if mutation occurs in a **gamete** or **cell which produces gametes**
- Can be **beneficial** or **detrimental** to organism
- E.g. **sickle-cell anaemia**
    - Caused by mutation of **a single base pair** in a gene coding for **one polypeptide of haemoglobin**
    - Causes sickle shape of RBCs, decreasing surface area to volume ratio
- Caused by **mutagens** of **chemicals** and **radiation** (*If examples are asked, provide “chemicals” and “radiation” not examples e.g. “tar”)

Recombinant DNA Technology:

- Used to insert segments of DNA from a different species into another species in vitro
- Uses **vectors**: a DNA molecule, bacterium or virus that **can carry foreign DNA** (gene of interest) **into a host cell**

Modifying a Bacterial Plasmid:

1. DNA is isolated and removed from cell (e.g. bacterial plasmid)
2. **2 pieces of DNA** (1 from donor and 1 from receiver) are **cut** using the same **restriction enzyme** at restriction site
3. **Sticky ends** are produced on each piece
4. Sticky ends of the **gene of interest** (gene being donated) are **attracted** to the remaining **sticky end of the plasmid** by hydrogen bonds
5. **DNA ligase** (enzyme) **seals the strand** together
6. This produces a **recombinant plasmid**
7. Plasmid is returned to the bacterial cell
8. This produces a **recombinant bacterium**
9. Every time the bacterium reproduces the recombinant plasmid is replicated too

- Is relied on by **insulin production**

Advantages of Bacterial Insulin:	Disadvantages of Animal Insulin:
- Human insulin produced (optimal for bodies) - Faster, more efficient than extracting insulin from pigs/cows - No risk of rejection by body (human insulin produced)	- Religious prohibitions - Risk of disease - Allergic reactions

- Part of **genetic engineering**

Topic 15: Reproduction in Plants

<u>Reproduction:</u>

- Made up of:
    - **Asexual reproduction**
        - Definition: Process resulting in the **production** of **genetically identical offspring** from **one parent**, **without fusion** of **nuclei** of **two gametes** (fertilisation)
        - Involves **mitosis**
            - Definition: A type of **cell division** resulting in **genetically identical daughter cells** where the **chromosome number** is **maintained** (2n → 2n)
                - Produces **diploid** cells
                    - Have **two complete sets** of chromosomes, with **46 chromosomes** (2n)
            - Used in production of new cells
                - For **growth**
                - For **repairing tissue/organisms** (not itself/the cell)
        - Produces **clones** (genetically identical offspring)
    - **Sexual reproduction**
        - Definition: Process involving the **fusion** of the **nuclei** of **two gametes** to **form a zygote**, with **two parents**, producing **genetically dissimilar offspring**
            - Gametes produced by **meiosis**
                - Definition: A type of **cell division** resulting in **genetically dissimilar daughter cells** where the **chromosome number is halved** (2n → n)
                - Gametes have 23 chromosomes, are **haploid**
                    - Have **one complete set** of chromosomes, with **23 chromosomes** (n)
        - Involves **homologous chromosomes**
            - Chromosomes with the **same shape, size, sequence of genes**

	Sexual Reproduction	Asexual Reproduction
Parents	- Involves **two** parents	- Only **one** parent needed
Gametes	- Utilises **gametes** (reproductive cells) whose **nuclei fuses** into a **zygote** (fertilisation)	- No reproductive cells, fertilisation needed
Offspring	- Produces **genetically dissimilar offspring** - From **gamete formation** (meiosis) and **gamete fusion** (gamete fusion is random)	- Produces **genetically identical offspring** (clones)
Advantages	- **Increases genetic variation** of offspring - Offspring inherit beneficial characteristics	- **Faster** than sexual reproduction - Only **one** parent needed - Ensures **survival** of offspring in the **same** environment
Disadvantages	- **Two** parents needed - **Slower** than asexual reproduction	- **Lacks genetic variation** - Adverse conditions (e.g. disease) affects all members due to all having same traits - Causes **overcrowding**, **competition** for resources

<u>Flowers:</u>

- Reproductive organ of the **flowering** plant (sexual reproduction)
- **Bisexual** flowers have **male and female** parts

- **Unisexual** flowers have **male or female** parts
- **Monoecious** plants contain **male and female** unisexual flowers
- **Dioecious** plants contain **male or female** unisexual flowers
- **Superior** flowers have ovaries outside the receptacle
- **Inferior** flowers have ovaries within the receptacle

Parts:		Features:	Functions:
Petal		Insect-pollinated: - **Brightly coloured** - Contains **nectar guides** (lines/markings) - **Scented** - **Large** - Contains nectaries Wind-pollinated: - **Small** - **Inconspicuous** - **Dull-coloured** - **Unscented**	Insect-pollinated: - **Attracts insects** - Nectar guides **guide insects to nectar** (from nectaries) - Acts as a **landing platform** for insects
Sepal		- Green	- **Protects** flower during bud stage - Photosynthesises
Stamen (male) - One or more per flower	Filament	- Contains **vascular bundle** Insect-pollinated: - **Enclosed** within flower - **Short** Wind-pollinated:	- Holds **anther** in **best** position to release pollen grains (containing male gametes) - Transports food, water to anther for **production** of **pollen grains**

		- **Long** - **Pendulous** to easily dislodge pollen - Hangs **downwards** - **Exposed** to surroundings	
	Anther	- Bilobed Insect-pollinated: - **Enclosed** within flower - **Tightly attached** to filament - Generally **smaller** Wind-pollinated: - **Exposed** to surroundings (not enclosed) - **Loosely attached** to filament - Generally **larger**	- **Produces** and **contains pollen grains** (containing male gametes) - Splits along line of dehiscence to release pollen
Carpel (female) - One or more per flower	Stigma	- **One or more** per flower Insect-pollinated: - **Small** - **Sticky** - **Enclosed** within flower Wind-pollinated: - **Largely branched** to increase surface area - **Feathery** to increase	- **Receives pollen grains** - Secretes sugary fluid to stimulate **germination** of **pollen grains** (to grow out **pollen tube**)

		surface area - **Exposed** outside flower	
	Style	Insect-pollinated: - Short Wind-pollinated: - Long	- Holds **stigma** in **best** position to trap pollen grains
	Ovary	- **Produces one or more ovules** - **Protects** ovules	
	Ovule	- **Produces female gamete** (ovum)	
Receptacle		- Point of attachment for flower parts	
Flower stalk		- Holds the flower	

<u>Pollination:</u>

- Definition: The **transfer** of **pollen grains** from **anther to stigma**
- Facilitated by **pollinating agents** e.g. **wind** or **insects** (not animals)
    - Wind-pollinated pollen:
        - **Large quantities** used to **increase chances** of pollination
        - **Light** and **small** pollen grains (buoyancy)
        - Pollen grains have **dry** and **smooth** walls (reduction of air resistance)
    - Insect-pollinated pollen:
        - **Less** pollen produced
        - Relatively **large** and **heavy** pollen grains
        - Pollen grains have **spiny**/**rough walls**, are **sticky** (increases effectiveness of attachment onto insect body)
- 2 types of pollination:
    - **Self pollination**
    - Definition: **Transfer** of **pollen grains** from the **anther to stigma** of the **same flower** or **different flower** on the **same plant**

- **Cross pollination**
    - Definition: **Transfer** of **pollen grains** from the **anther to stigma** of **a flower** on **one plant to another plant** of **the same species**
- Cross pollination preferred due to **genetic diversity**
    - Features to favour cross pollination:
        - **Dioecious** plants (only male or female flowers on one plant)
        - Anthers and stigmas **maturing at different times**
        - **Positions** of stigmas and anthers **situated from each other** (on flower)

Cross Pollination:

Advantages:	Disadvantages:
- Offspring **inherits valuable qualities from parents** - Offspring have **greater genetic variation** which will **increase chances of survival** of at least one during **changes of environment**	- **Two** parent plants needed - **External factors** (for pollination) needed - **Less likely** to happen than self pollination - **More energy, pollen** needed than self pollination

Steps for Insect Pollination:

1. An insect is **attracted** to the flower and **lands on the petal**
2. Insect **follows nectar guide** into flower towards nectaries to collect nectar
3. **Pollen grains** are **deposited** onto insect back when **anther brushes** against it
4. **Pollen grains from same or another flower** are also **deposited** onto **sticky stigma**

<u>Fertilisation:</u>

- Definition: The **fusion** of the **nuclei** of the **male and female gametes** to **form a zygote**
- Pollination **may not** lead to fertilisation:

- Pollen is from a different species
- Stigma is immature

Fertilisation:

1. **Pollen grain lands on** compatible **stigma** of flower of the same species
2. **Sugary fluid secreted** by **mature stigma** stimulates **germination** of **pollen grain**
3. Pollen grain grows out a **pollen tube**, **secretes enzymes** to **digest tissue** of stigma and style
4. Pollen tube grows down style into **ovary**
5. Pollen tube **enters ovule** through **opening in ovule wall** called the **micropyle**
6. **Tip** of **pollen tube** absorbs sap and bursts, **releasing male gamete**
7. **Nucleus** of **male gamete fuses** with **nucleus** of **ovum** to **form a zygote** (fertilisation)

- **One pollen grain per ovule**
    - All ovules do not need to be fertilised for the flower to turn into a fruit
- After fertilisation changes:
    - **Ovary** develops into the **fruit**
    - **Ovule** develops into the **seed**
        - Consists of:
            - Seed coat
            - Cotyledon (contains nutrients)
            - Seed vein
            - Seed shoot (develops into leaves)
            - Seed root (develops into roots)
    - **Zygote** develops into the **embryo**
    - **Petals**, **style**, **stigma wither** and drop off

Topic 16: Inheritance

Genes:

- Definition: A **segment of DNA** which **codes for 1 polypeptide**, **controls a characteristic** and is **a unit of inheritance**
- **Alleles** are **alternative forms** of a gene
    - Consists of:
        - **Dominant** alleles (heterozygous genotype needed for expression)
        - **Recessive** alleles (homozygous genotype needed for expression)
    - 2 alleles represent **genotype** (e.g. Tt)
        - 2 **identical** alleles produce **homozygous** genotypes
        - 2 **differing** alleles produce **heterozygous** genotypes
- Genotype and environment determines **phenotype** (observable, physical characteristics)

Monohybrid Inheritance:

- Involves **P** (parental) generation, **F1** generation (1st offspring generation), **F2** generation (2nd offspring generation)
- **Genotype** of offsprings follow **expected ratios** based off pairing of parental genotypes, expected ratio is **theoretical**
    - Commonly TT:Tt:tt = 1:2:1
    - Observed ratios differ from expected ratios during small numbers of progeny due to **small sample size**, ratio figures based off **chance** and **probability**

    Drawing **genetic diagrams**:
    1. Labelling: **Parent phenotype**, **parent genotype**, **gametes** (not alleles), **F1 genotype**, **F1 phenotype**, **F1 genotypic ratio**, **F1 phenotypic ratio**
    2. Phenotype to include more than colour (e.g. “purple flowers” instead of “purple”)

- 2 types of dominance:
    - **Incomplete dominance**
        - Heterozygotes show **distinct intermediate phenotype**

- Phenotype **may not be a mix** of homozygous phenotype (e.g. red (TT), blue (Tt), white (tt)

- **Codominance**
  - Heterozygotes have **both alleles simultaneously**, **equally**, **distinctly expressed** in phenotype
  - E.g. ABO blood groups (AB blood type)
    - I^A and I^B dominant to I^O
    - I^A and I^B are codominant
      - AB blood type contains both A and B antigens

Blood Group:	Genotypes:
A	I^AI^A, I^AI^O
B	I^BI^B, I^BI^O
AB	$\mathbf{I^AI^B}$
O	I^OI^O

- Involved in **sex determination**:
  - Females have XX, males have XY (not all animals)
  - Chance of male, female is 50/50

Father, Mother Genotype	X	Y
X	XX	XY
X	XX	XY

<u>Mutations:</u>

- Definition: **Random changes** in **DNA sequence** where **one base** is **deleted**, **substituted**, **added**, or in **chromosomal number** or **chromosomal sequence**

- Increases **genetic variation** of species
- E.g. Sickle cell anemia
    - Beta globin gene is mutated
    - Hemoglobin is deformed causing sickle shaped red blood cells
- E.g. Down syndrome
    - **3 copies** of **chromosome 21** produced, thus **47 chromosomes** in total
- Factors include **radiation**, **chemicals** (e.g. X-rays, tar from cigarettes)

Variation:

- Consists of:
    - **Discontinuous variation**
        - Definition: Variation where **phenotypes are distinct** with **no intermediates**, controlled by a **single pair of genes** or a **small number of genes without additive effect**, where **phenotypes cannot be changed by environment**
        - E.g. Attached/free earlobes, Straight/Widow's peak hairline, Straight/hitchhiker's thumb, blood group, gender, eye colour
    - **Continuous variation**
        - Definition: Variation where there are **no distinct phenotypes** but a **range of possible intermediates**, controlled by **2 or more independent pairs of genes** which affect trait in **additive fashion**, which is affected by the **environment**
        - E.g. Height, skin tone, weight, intelligence

Topic 17: Evolution

Variation:

- Arises from:
    - **Meiosis** (production of gametes)
    - **Fertilisation of gametes** (fertilisation is random)
    - **Mutation** (Definition: **Random changes** in **DNA sequence** caused by **addition**, **deletion** or **substitution** of **bases**, or in **chromosomal number**)

        - Provides **new alleles** to the gene pool for natural selection
- Genetic variation important to help species **adapt** and **survive** in **changing environments** as it allows for **different chances of survival**

<u>Natural Selection:</u>

- Definition: The phenomenon that the **environment** would **select for** individuals **most adapted** for it to **survive** and **reproduce**, and that the **environment selects against** individuals that are **not adapted** for it to **die**
    - **Better genetic variants** have a **selective advantage**
        - Leads to **survival of the fittest** (i.e. best adapted to environment)
    - Individuals selected against will **die**, thus **not being able** to **pass down its alleles**, **genotype** and **phenotype**
    - Individuals selected for will **reproduce** and **pass on** their **advantageous alleles**, **genotype**, **phenotype** to **offspring**
        - Offspring will become **fitter** (more able to survive and reproduce)
- As environment changes, **appearance** and **characteristics** of individuals in a population will **change**

Explanation:

1. Environment exerts **selection pressure** (e.g. **diseases**, **weather**, **predators**, etc)
2. **Variation** within species exists due to **meiosis**, **fertilisation (sexual reproduction)**, **mutations**
3. Different **alleles** are within **gene pool**
4. **Fitter** individuals with **alleles coding for traits best** suited for **changed environment** are **better adapted**, **more likely to survive**, at **selective advantage**
5. Will more likely **survive** long enough to **reproduce**
6. **Advantageous alleles**, **genotype**, **phenotype** are **passed down** to offspring
7. Offspring **inherits advantageous traits**, **characteristics**, **favourable alleles** from parents
8. Offspring will more likely to be **successful** if the **environment remains constant**
9. [vice versa for selection against]

- Part of **evolution**

    - Definition: The **gradual change** in the **inheritable characteristics** of **a population over time**, **through generations**
    - Speed of change dependent on organisms' **lifespans**
        - More generations formed allows more changes in same amount of time
- If **significant changes** have accumulated, organisms may be classified as a **new species**

During **environmental changes:**
Existing variation ⇒ Survive (Natural selection) ⇒ Pass down genes ⇒ Evolution ⇒ Species divergence

- Environmental selection:
    - **Competition for survival**
        - Members of a species **compete with each other for resources** (e.g. food, shelter, mates, etc.)
        - **Better adapted** individuals will be **more successful**, **survive long enough to reproduce** (higher chances of survival)
        - **Poorly adapted** individuals **die**
- Case studies:
    - White and Black melanic peppered moths
        - White moths well camouflaged on lichen on tree trunks, black moths at selective disadvantage
        - Black moths came from spontaneous random mutation
        - During industrial revolution, soot from factories covered tree trunk
        - Black moths selected for, white selected against
    - Sickle cell anaemia
        - Haemoglobin gene undergoes gene mutation to form haemoglobin S
        - Sickle RBC stick together, obstruct blood flow, reducing oxygen-carrying capacity of body (selective disadvantage)
        - Sickle RBC more fragile, rupture easily (selective disadvantage)
        - Heterozygous Hb^AHb^S people have malaria resistance (selective advantage)
    - Bacterial antibiotic resistance
        - Antibiotics cause selection pressure on bacteria

        - Antibiotic resistance gene possessed due to chance mutation
- Darwin's finches
    - Finches on Galapagos Islands have different types of beaks
    - Finches evolved from one common ancestor to fill food niches
    - Different beak types allow for different diet
    - Finches occupy different niches on food web
    - Less competition between members of a species

Topic 18: Reproduction in Humans

Male Reproductive System:

Organs:	Function and Description:
Testes	- **Produces sperm** - **Produces** male sex hormone **testosterone**
Scrotum	- Holds testes **outside body cavity** at a temperature lower than abdomen (for optimum temperature)
Sperm duct	- **Pathway travelled by sperms** after they are released **from the testes** and opens **into urethra**
Prostate gland	- **Produces fluid to sperm** to form **semen** - Fluid contains **nutrients** that **nourish sperm** and **enzymes** that **activate the sperm** (to swim)
Urethra	- Muscular tube which extends from urinary bladder, through penis, to outside of the body - For **urine** and **semen** to pass out
Penis	- Contains **urethra** and spongy erectile tissue which **fills with blood** - **Deposits sperm** into **vagina**

Female Reproductive System:

Organs:	Function and Description:
Ovaries	- **Produces eggs** (**ova**) - **Produces** female sex hormones **oestrogen**, **progesterone**
Oviduct	- **Pathway** for **eggs** during **ovulation** (connects ovaries to uterus) - **Contains cilia**, undergoes **peristalsis** to **move egg** through oviduct **from ovary to uterus**
Uterus	- Organ where **fetus develops** during pregnancy - Uterus wall made of **smooth muscle** - **Contracts** to **push out baby**
Uterine lining (endometrium)	- Contains **rich blood supply**, **highly vascularised** - **Thickens** for **implantation of embryo** - **Embryo/fetus** (not zygote) **obtains nutrients** from endometrium
Cervix	- Circular ring of **muscles** at **lower end** of **uterus** - Opens into **vagina** - **Dilates** during labour for baby to pass through

Vagina (birth canal)	- Semen deposited within during copulation
	  - Canal is **acidic**
	  - Prevents **bacterial growth**

Gametes:

- Definition: **Reproductive cells** e.g. **sperm** and **eggs** containing **haploid chromosomal number** in nucleus, produced through **meiosis**, which **fuses** to form a **zygote**
- Haploid:
  - Cells containing **1 complete set** of **chromosomes**, with **23 chromosomes**

- To ensure that the **chromosomal number** in the **zygote** can be **maintained**, to restore **diploid number** during **fusion of gametes** (**fertilisation**) to form a **zygote**

- Consists of:
  - **Sperm**
    - Male gamete
    - Made up of a **head**, **middle piece**, **tail** (flagellum)
      - Head contains **haploid nucleus**, **small amount** of **cytoplasm**
        - Little cytoplasm needed as **most nutrients derived from semen**
      - Middle piece contains **numerous mitochondria** to **release energy** through **cellular respiration** for **sperm to swim**
      - Tail allows **sperm to swim** towards egg in fluid medium of semen
  - **Egg** (**ovum**)
    - Female gamete
    - Made up of **haploid nucleus**, **cytoplasm**, **cell surface membrane**
      - Nucleus contains **1 complete set** (23) of **chromosomes**
      - Cytoplasm contains **small amount** of **yolk** with **nutrients** for **nourishment** for **zygote development**
      - Cell surface membrane surrounded by **outer membrane**

Sperm:	Egg:
- Very little cytoplasm	- Large amount of cytoplasm

- Very active
  - Swims with tail towards egg
	- Immobile
	  - Moves with peristalsis, sweeping action of cilia in oviduct

- Large number released at once	- Only one released per month
- EIther X or Y chromosome	- Only X chromosome

Menstrual Cycle:

- Definition: A **28-day cycle** experienced by **females** to **release** an **egg from ovary**, **prepare the body** for **fertilisation**, **implantation** of **embryo**, and **pregnancy**
- Function:
  - To **release egg** from **ovary**
  - To **thicken endometrium** for **implantation** and **pregnancy**
- Average span around **28 days**
  - Days **11-17** is **fertile period**
- Starts from puberty to **menopause** (45-55 years old)

<table>
<tr><td>Hormone with high concentration:</td><td>Stages:</td><td colspan="2">Process:</td></tr>
<tr><td rowspan="2">Oestrogen</td><td>Days 1-5:</td><td>- Menstruation takes place
- Endometrium breaks down, flows out of body</td><td rowspan="2">- Ovary:
- Primary follicle develops into graafian follicle containing a mature egg</td></tr>
<tr><td>Days 6-14:</td><td>- Repair and growth of endometrium caused by oestrogen from developing follicle</td></tr>
<tr><td>[Oestrogen, Progesterone]</td><td>Day 14:
Ovulation</td><td colspan="2">- Ovary:
- Graafian follicle ruptures to release mature egg into oviduct
- Oviduct:
- Peristalsis, cilia’s sweeping action moves egg towards uterus</td></tr>
<tr><td>Progesterone</td><td>Day 14-28:</td><td>- Thickening and</td><td>- Ovary:</td></tr>
</table>

	Corpus luteum	**maintenance** of **endometrium** caused by **progesterone**, **oestrogen** from **corpus luteum** - Endometrium supplied with **blood capillaries** from progesterone	- Graafian follicle develops into **corpus luteum** - Corpus luteum **produces oestrogen** and **progesterone** - Progesterone **inhibits ovulation** to ensure 1 egg per cycle - Hormones **maintain thickness** of **endometrium** during pregnancy
	Day **21-28**: End phase	- Ovary: - If **fertilisation does not occur**, **corpus luteum** will **break down**	

If fertilisation occurs:

1. Fertilised egg becomes **zygote** (single fertilised cell)
2. Zygote undergoes **mitosis** to form **embryo** (ball of cells)
3. Embryo **secretes hormone** (hCG) to **stimulate ovary** to **continue secreting progesterone** (Days 21-28)
4. Ovary secretes **oestrogen**, **progesterone** from **corpus luteum** until **placenta forms**
5. Placenta **takes over** production of oestrogen, progesterone

If fertilisation did not occur:

1. Egg **breaks down**
2. **Ovary stops** secreting **progesterone**, **oestrogen**
3. **Endometrium breaks down**
4. Endometrium **discharged** with **blood through vagina** (**menstruation**)
5. Menstrual cycle repeats

Sexual Reproduction:

- Definition: Production of **genetically dissimilar offspring** from **2 parents** involving **fusion** of **nuclei** of **two gametes** to form a **zygote**

Process of Sexual Reproduction:

1. Semen enters vagina, **neutralises acidic canal**
2. Sperm **swims** up canal in fluid medium semen
3. Sperm swims into **oviduct**
4. Sperm releases **enzymes** to **break down egg membrane**
5. **Haploid nucleus** of **sperm fuses** with **haploid nucleus** of **egg** (fertilisation) to form **diploid nucleus** of zygote
6. Once one sperm enters egg, **egg membrane changes** so that no other sperm can penetrate
7. **Zygote** is formed

- **Identical** twins produced from **one** fertilised egg
    - Zygote divides by **mitosis** into **two identical zygotes**
- Non-identical twins produced from **two** fertilised eggs by **two** sperm

Embryonic Development and Implantation:

Process of Implantation:

1. **Zygote** travels down oviduct by **ciliary action** and **peristalsis**
2. Zygote divides by **mitosis**, develops into **embryo**
3. Embryo reaches **uterus**, gets **embedded** in **endometrium**

- Sperm + Egg → Zygote → Embryo → Fetus

- After implantation:
    - **Placenta** involved:

- Definition: The **site of exchange** between **maternal** and **fetal blood circulations** of **nutrients** and **waste products** (e.g. **glucose**, **amino acids**, **CO_2**, **O_2**, **water**, **urea**, **antibodies**), formed from **embryonic villi** and **endometrium**
- **Embryonic villi** grow **from embryo into endometrium** to come into close contact with **maternal blood spaces**
    - Blood **do not mix**:
        - **Blood pressure** of mother is **too high** for fetus (stronger heart)
        - **Blood type** of mother and fetus may be **different**, **agglutination** possible
- Function:
    - Exchanges:
        - **Water** (via osmosis)
        - **CO_2**, **O_2** (via diffusion)
        - **Antibodies** from mother (IgG)
        - **Nutrients** (e.g. glucose, amino acids)
        - **Waste** products (e.g. urea)
    - Produces **progesterone** to **maintain thickness** of **endometrium**

- **Umbilical cord** involved:
    - Attaches embryo to placenta
    - Contains **2 arteries**, **1 vein**
    - Function:
        - **Umbilical arteries** transport **deoxygenated** blood, **metabolic waste products** (e.g. **CO_2**, **urea**) **from fetus to placenta**
        - **Umbilical vein** transport **oxygenated** blood, **nutrients** (e.g. **glucose**, **amino acids**), **antibodies from placenta to fetus**
- **Embryonic membrane** involved:
    - Function:
        - **Encloses fetus** in **fluid-filled space** called **amniotic cavity**
            - Mostly water
            - Function of amniotic fluid:
                - **Absorbs shock**, protects against mechanical injury
                - **Lubricates birth canal** during birth

- Allows fetus to **move freely**
- **Maintains constant temperature** for fetus

Sexually Transmitted Infections:

- E.g. Acquired Immunodeficiency Syndrome (AIDS)
    - Caused by **Human Immunodeficiency Virus** (HIV)
    - Mode of transmission:
        - Unprotected **copulation** with infected person
        - Sharing of **hypodermic needle** with infected person (e.g. drug abuse)
        - Having **blood transfusion** with infected person
        - **Substance exchange** at **placenta** (from mother to fetus)
            - Virus small enough to pass through from placenta to fetus