Cells

- To view organelles, electron microscope (x200000) is used, as compared to light microscope (x1000)
- Longitudinal section: cutting across the length of the cell, vice versa for transverse section
- The protoplasm consists of the cytoplasm and the nucleus

Part	Function & Structure	
Plasma Membrane	Made of lipids and proteins	
	Partially permeable membrane	
	Controls substances entering and leaving the cell by allowing only substances smaller than its pores to pass through	
Cytoplasm	Site of most cell activities	
	Contains organelles:	
	Rough Endoplasmic Reticulum (R.E.R.)	Site of protein synthesis
		Network of flattened spaces lined with a membrane
		Appears rough because small ribosomes are attached to its outer surface
		Outer surface is continuous with the nuclear envelope
	Smooth Endoplasmic Reticulum	Tubular and do not have ribosomes
		Synthesises fats and steroids
		Converts harmful substances into harmless materials via detoxification
	Ribosomes	Attached ribosomes (R.E.R.) synthesise proteins that are transported out of cells
		Free ribosomes (cytoplasm) synthesise proteins that are used within the cell

	Golgi Apparatus	Stack of flattened spaces surrounded by a membrane
		Chemically modifies substances made by the endoplasmic reticulum
		Stores and packages them in vesicles for secretion out of the cell
	Vesicles	Tiny spherical spaces enclosed by a membrane
		Transport substances within the cell:
		1. Small vesicles containing substances made by the endoplasmic reticulum are pinched off from the endoplasmic reticulum
		2. The small vesicles fuse with the Golgi apparatus and release their contents into the Golgi apparatus
		3. The Golgi apparatus chemically modifies the substances made by the endoplasmic reticulum
		4. Secretory vesicles containing the chemically-modified substances are pinched off from the Golgi apparatus
		5. The secretory vesicles move to the plasma membrane
		6. The secretory vesicles fuse with the plasma membrane and their contents are released out of the cell
	Mitochondrion	Sausage-shaped
		Performs aerobic respiration in which

		glucose is oxidised in the presence of oxygen to release energy
	Chloroplasts	Contains chlorophyll which absorbs and converts light energy to chemical energy during photosynthesis
Nucleus	Consists of nucleolus and chromatin in nucleoplasm, which is surrounded by a nuclear envelope	
	Controls cell activities such as cell growth and repair of worn-out parts	
	Essential for cell division	
	Nuclear Envelope	Separates the contents of the nucleus from the cytoplasm
	Nucleoplasm	Dense material within the nucleus
	Nucleolus	Make proteins in the cell
	Chromatin	Made up of deoxyribonucleic acid that stores hereditary information
		Chromatin threads condense into chromosomes during cell division
Cell Wall	Made of cellulose	
	Fully permeable membrane and inelastic	
	Protects the cells from injuries	
	Give plant cells a fixed shape	
Vacuole	(Animal cells) Numerous small vacuoles containing water and food substances, which exists temporarily	
	(Plant cells) One large, central vacuole containing cell sap (sugars, mineral salts and amino acids), that is surrounded by the partially permeable tonoplast	

- Only plant cells have a cell wall, chloroplasts and a large, central vacuole
- Only animal cells have centrioles and numerous small vacuoles

- Differentiation is the process by which a cell becomes specialised for a specific functions (e.g. red blood cells, xylem vessel and root hair cells)
- Different ___ forming ___ work together to perform a specific function (except in the case of cells of the same type forming simple tissues)

Cells	→	Simple Tissue / Comple x Tissue	→	Organs	→	Organ System	→	Organ -ism

Movement of Substances

	Diffusion	Osmosis	Active Transport
Direction of net movement	From a region of higher concentration to a region of lower concentration	From a solution of higher water potential to a solution of lower water potential	From a region of lower concentration to a region of higher concentration
	Down the concentration gradient	Down the water potential gradient	Against the concentration gradient
Particles involved	Any	Water molecules	Any
Energy?	Not required		Required
Partially permeable membrane?	Not required	Required	

- At equilibrium, there is no net movement of substances across the partially permeable membrane, but there is still movement of substances across the partially permeable membrane due to Brownian motion
- Only soluble substances can affect the water potential of a solution

<table>
<tr><td>Solution</td><td>Dilute</td><td>Same Concentration</td><td>Concentrated</td></tr>
<tr><td>Water potential</td><td>Higher than cell</td><td>Same as cell</td><td>Lower than cell</td></tr>
<tr><td>Type of solution</td><td>Hypotonic</td><td>Isotonic</td><td>Hypertonic</td></tr>
<tr><td rowspan="2">Direction of movement of water molecule</td><td>From surrounding solution into the cell via osmosis</td><td rowspan="2">No net movement of water molecules</td><td>From the cell into the surrounding solution via osmosis</td></tr>
<tr><td>Down the water potential gradient</td><td>Down the water potential gradient</td></tr>
<tr><td rowspan="5">Final appearance of cell</td><td colspan="3">Animal Cells</td></tr>
<tr><td>Cell expands and bursts</td><td>Cell remains the same as the original state</td><td>Cell shrink in size and becomes crenated</td></tr>
<tr><td colspan="3">Plant Cells</td></tr>
<tr><td>Vacuole increases in size and pushes against the cell wall, exerting turgor pressure on the inelastic cell wall</td><td rowspan="2">Cell remains the same as the original state</td><td>Vacuole decreases in size and shrinks away from the cell wall and the cell is plasmolysed</td></tr>
<tr><td>Cell expands and becomes turgid</td><td>Cell shrink in size and becomes flaccid</td></tr>
</table>

- When a cell bursts, it is irreversible because the cytoplasmic contents are released into the solution
- Importance of turgidity:
    1. Plants remain upright due to turgor pressure within their cells

2. Loss of turgidity causes plants to wilt

- To reverse plasmolysis, water is added to dilute a hypertonic soil solution
- Factors affecting rate of diffusion and osmosis:
    1. The steeper the concentration / water potential gradient, the faster the rate of diffusion / osmosis
    2. The higher the surface area to volume ratio, the higher the rate of diffusion / osmosis
- As active transport requires energy, it only occurs in respiring living cells

Nutrients

<table>
<tr><td>Importance of</td><td colspan="2">Humans</td><td>Plants</td></tr>
<tr><td rowspan="2">Nutrients</td><td colspan="3">Provide energy for metabolic activities</td></tr>
<tr><td colspan="3">Supply raw materials for repair of worn-out tissues</td></tr>
<tr><td rowspan="3">Water</td><td colspan="2">Solvent in which chemical reaction takes place</td><td>Photosynthesis</td></tr>
<tr><td>Control body temperature through the removal of latent heat when sweat evaporates</td><td>Keeping plant cells turgid, and hence plants upright</td></tr>
<tr><td colspan="3">Transport dissolved food substances</td></tr>
</table>

<table>
<tr><td>Organic Compound</td><td>Carbohydrates</td><td>Fats</td><td>Proteins</td></tr>
<tr><td>Elements</td><td colspan="2">Carbon, hydrogen (H) and oxygen (O)</td><td>Carbon, hydrogen, oxygen and nitrogen</td></tr>
<tr><td>Ratio of H: O</td><td>2:1</td><td colspan="2" rowspan="2">Nil</td></tr>
<tr><td>General</td><td>$C_nH_{2n}O_n$</td></tr>
</table>

<table>
<tr><td>formula</td><td colspan="2"></td><td></td></tr>
<tr><td rowspan="4">Simple molecules</td><td colspan="3">Formed via hydrolysis in chemical digestion: a water molecules is needed to break up a complex molecule into smaller molecules</td></tr>
<tr><td rowspan="3">Monosaccharides
A. Glucose
B. Fructose
C. Galactose</td><td rowspan="2">Fatty Acids</td><td>Amino group
(-NH_2)</td></tr>
<tr><td rowspan="2">Acidic group
(-COOH)</td></tr>
<tr><td rowspan="2">Glycerol</td><td>Side chain
(R)</td></tr>
<tr><td colspan="3">Cannot be further digested into smaller molecules</td></tr>
<tr><td colspan="3">Small enough to pass through the pores of plasma membrane</td></tr>
<tr><td rowspan="3">Complex molecules</td><td colspan="3">Formed via condensation reaction: two simple molecules are joined together to form a larger molecule with the removal of one water molecule</td></tr>
<tr><td>Disaccharides:
● Maltose (A + A)
● Lactose (A + C)
● Sucrose (A + B)</td><td rowspan="2">Nil</td><td>Amino acids link up by peptide bonds to form polypeptides</td></tr>
<tr><td>Polysaccharides:
● Starch (A)
● Cellulose (A)
● Glycogen (A)</td><td>Polypeptides coil to form a 3D-molecule</td></tr>
<tr><td rowspan="2">Tests</td><td colspan="3">Cut food into smaller pieces, add 1 cm^3 of water, mix well and decant to prepare a food sample</td></tr>
<tr><td>Reducing sugar:</td><td>Ethanol emulsion</td><td>Biuret Test</td></tr>
</table>

	Benedict's test	test	
	Starch: Iodine test		
Uses	Provide energy for cell activities		Synthesis of new protoplasm for growth and repair
	Synthesise lubricants	Insulating material to prevent excessive heat loss	Synthesis of enzymes and hormones
	Form nucleic acids in DNA	Reduce water loss from skin surface	Synthesis of antibodies to combat diseases

- Benedict's test:
    1. Add 2 cm^3 of Benedict's solution to 2 cm^3 of food sample
    2. Shake the mixture and boil it for 2 mins
    3. Observations:

Colour Change	Amount of Reducing Sugar
Blue solution remains blue	No reducing sugar
Blue to green precipitate	Traces of reducing sugar
Blue to yellow precipitate	Moderate amount
Blue to brick-red precipitate	Large amount

- Iodine test:
    1. Add a few drops of iodine solution
    2. Positive test: blue-black
       Negative test: no change in colour
- Ethanol emulsion test:
    1. Add 2 cm^3 of ethanol to 2 cm^3 of food sample and shake the mixture
    2. Positive test: cloudy white emulsion
       Negative test: solution remains clear
- Biuret test:

1. Add 2 cm^3 of sodium hydroxide solution to 2 cm^3 of food sample and shake the mixture
2. Positive test: violet colouration
   Negative test: no change in colour

- Glucose and fructose can be found in both plants and animals, while galactose is only found in milk sugar in mammals
- Disaccharides consists of two monosaccharide molecules, while polysaccharides consists of many monosaccharides joined together
- Complex carbohydrates (polysaccharides):

<table>
<tr><th></th><th>Structure</th><th>Function</th><th>Occurrence</th></tr>
<tr><td rowspan="2">Starch</td><td rowspan="6">Made up of several thousand glucose molecules joined together</td><td>Storage form of carbohydrates in plants</td><td rowspan="2">Storage organs of plants (e.g. tapioca)</td></tr>
<tr><td>Digested to glucose to provide energy for cell activities</td></tr>
<tr><td rowspan="2">Cellulose</td><td>Forms the cell wall</td><td rowspan="2">Cell wall of plants</td></tr>
<tr><td>Cannot be digested in our intestines as it does not have cellulase</td></tr>
<tr><td rowspan="2">Glycogen</td><td>Storage form of carbohydrates in mammals</td><td rowspan="2">Liver and muscle of mammals</td></tr>
<tr><td>Digested to glucose to provide energy for cell activities</td></tr>
</table>

- Adaptations of glycogen and starch as storage materials in cells:
  1. Insoluble in water, thus unable to change the water potential in cells

2. Large molecules which cannot diffuse through plasma membrane and be lost
3. Easily hydrolysed to glucose when needed during tissue respiration
4. Compact shape, thus occupying less space than all the individual glucose molecules that makes up a glycogen or starch molecule

Enzymes

- Properties:
    1. Is a protein, thus it is affected by temperature and pH
    2. Functions as a biological catalyst which speed up chemical reactions by providing an alternative pathway with lower activation energy
    3. Specific in action
    4. Remains chemically unchanged at the end of the reaction
- Characteristics:
    1. Speed up chemical reactions
    2. Required in minute amounts as they are chemically unchanged at the end of the reaction
    3. Specific in action due to the 'Lock-and-Key' hypothesis
- 'Lock-and-Key' hypothesis:
    1. The enzyme is the 'lock' while the substrate is the 'key'
    2. An enzyme has a specific 3D shape, which contains an active site
    3. Only substrates with a 3D shape complementary to that of the active site can fit into the enzyme to form an enzyme-substrate complex
    4. Chemical reactions occur and the substrate is converted into products
    5. At the end of the reaction, the products detach from the active sites and the enzyme remains chemically unchanged
- How temperature affects enzyme-catalysed reactions:
    1. At very low temperatures, the enzyme is inactive as the kinetic energy is low, thus chances of substrate molecules colliding with the enzyme is very low

2. As temperature rises, the kinetic energy of molecules increases, increasing the chances of collision between substrate and enzyme molecules, increasing the rate of formation of enzyme-substrate complex, thus enzyme activity increases
3. Beyond the optimum temperature, the high temperature breaks the bond within the enzyme and changes its 3D shape, thus it loses its active site and is denatured

- How pH affects enzyme-catalysed reactions:
  1. At the optimum pH of pH _, enzyme activity is the highest
  2. As the solution becomes more acidic or alkaline, the enzyme activity decreases
  3. Beyond an extremely low pH of _ and an extremely high pH of _, the enzyme's 3D shape is changed, thus it loses its active sites and is denatured
- When enzymes are denatured, it loses its active site, thus substrate molecules no longer fit into its active site and no enzyme-substrate complex can be formed, hence no chemical reaction occurs

Nutrients in Humans

- Nutrition is the process by which organism obtain food and energy for growth, repair and maintenance of the body
- Organs of the alimentary canal: mouth, pharynx, oesophagus, stomach, small intestine and large intestine

Ingestion		
Mouth	Food enters the body through the mouth, which leads to the buccal cavity	
Digestion		
	Physical Digestion	Chemical Digestion
Process	Mechanical break-up of large pieces of food into smaller pieces	Large and insoluble food substances are broken down into smaller and soluble molecules that can be absorbed

<table>
<tr><td rowspan="2"></td><td>No new products formed</td><td>New products formed</td></tr>
<tr><td>No enzymes involved</td><td>Involve digestive enzymes</td></tr>
<tr><td>Importance</td><td>Increase surface area to volume ratio for rapid chemical digestion by digestive enzymes</td><td>Allow food substances to be small enough to pass through the intestinal wall and enter the bloodstream</td></tr>
<tr><td rowspan="3">Mouth</td><td>Physical Digestion</td><td>Chemical Digestion</td></tr>
<tr><td>Tongue rolls food into boli</td><td rowspan="2">Carbohydrate digestion:
Tongue mixes food with saliva that contains salivary amylase and mucus
Starch
↓
Salivary amylase
↓
Maltose
The mucus softens the food</td></tr>
<tr><td>Chewing action of food + (Process & Importance)</td></tr>
<tr><td colspan="3">Propulsion</td></tr>
<tr><td rowspan="2">Pharynx</td><td colspan="2">Swallowing</td></tr>
<tr><td colspan="2">• During breathing, the larynx moves downwards while the epiglottis moves upwards and opens the glottis, allowing air to enter the trachea
• During swallowing, the larynx moves upwards while the epiglottis moves downwards and covers the glottis, preventing food from entering the trachea</td></tr>
<tr><td rowspan="2">Oesophagus</td><td colspan="2">• It is a narrow, muscular tube extending to the stomach
• It is made up of a pair of antagonistic muscles
1. Inner circular muscles
2. Outer longitudinal muscles</td></tr>
<tr><td colspan="2">Peristalsis</td></tr>
</table>

<table>
<tr><td rowspan="3"></td><td colspan="2">

- It is the rhythmic, wave-like muscular contractions in the wall of the alimentary canal
- It pushes food along the gut
- It enables food to be mixed with digestive juices

</td></tr>
<tr><td>At the upper end of bolus</td><td>At the lower end of bolus</td></tr>
<tr><td>

- Circular muscles contract
- Longitudinal muscles relax
- Gut becomes longer and narrower, thus it constricts
- This pushes the bolus forward

</td><td>

- Circular muscles relax
- Longitudinal muscles contract
- Gut becomes shorter and wider, thus it dilates
- This allows the bolus to enter the lumen

</td></tr>
<tr><td colspan="3">Digestion</td></tr>
<tr><td rowspan="3">Stomach</td><td colspan="2">

- The stomach is a distensible, muscular bag that stores food
- When the stomach is fully distended, stretch receptors in the stomach sends a signal to the hypothalamus in the brain that it is sated
- The stomach has numerous pits that lead to gastric glands which secrete gastric juice
- Gastric juice contains hydrochloric acid and the enzyme pepsin
- Importance of hydrochloric acid:
  1. Stops the action of salivary amylase
  2. Converts inactive pepsinogen to active pepsin
  3. Provides an acidic environment of optimum pH in the stomach so that pepsin activity is at its highest
  4. Kills harmful microorganisms in the food

</td></tr>
<tr><td>Physical Digestion</td><td>Chemical Digestion</td></tr>
<tr><td>Churning action: strong muscular walls and peristalsis + (Process & Importance)</td><td>Protein digestion:
Proteins
|
Pepsin</td></tr>
</table>

<table>
<tr><td></td><td></td><td>↓
Polypeptides
The partially digested food is liquefied, forming chyme</td></tr>
<tr><td colspan="3">Propulsion</td></tr>
<tr><td>Pyloric Sphincter</td><td colspan="2">• It is the ring of muscle located at where the stomach joins the small intestine
• When it contracts, the entrance to the small intestine closes
• When it relaxes, the entrance to the small intestine opens, allowing chyme to pass into the duodenum of the small intestine</td></tr>
<tr><td colspan="3">Digestion</td></tr>
<tr><td rowspan="3">Small Intestine</td><td colspan="2">• The small intestine consists of:
1. U-shaped duodenum where most of the digestion occurs
2. Jejunum and much coiled ileum where absorption of digested food occurs
• When chyme enters the duodenum, it stimulates the secretion of:
1. Pancreatic juice by the pancreas, which contains amylase, trypsin and lipase
2. Intestinal juice by the epithelial cells of the small intestine, containing maltase, sucrase, lactase, erepsin and lipase
3. Bile by gallbladder
• Pancreatic juice, intestinal juice and bile are alkaline:
1. Neutralise acidic chyme
2. Provide an alkaline environment of optimum pH so that pancreatic and intestinal enzyme activity is at its highest</td></tr>
<tr><td>Physical Digestion</td><td>Chemical Digestion</td></tr>
<tr><td>Bile emulsify large fat molecules into smaller fat globules + (Importance)</td><td>Carbohydrate digestion:
Starch</td></tr>
</table>

|
Pancreatic amylase
↓
Maltose

Maltose
|
Maltase (intestinal)
↓
Glucose

Lactose
|
Lactase (intestinal)
↓
Glucose + Galactose

Sucrose
|
Sucrase (intestinal)
↓
Glucose + Fructose

Protein digestion:

Proteins
|
Trypsin
↓
Polypeptides

Polypeptides
|
Erepsin (intestinal)
↓
Amino acids

Fat digestion:

Emulsified fats
|
Lipase (pancreatic & intestinal)

<table>
<tr><td></td><td></td><td>↓
Fatty acids + glycerol</td></tr>
<tr><td colspan="3">Egestion</td></tr>
<tr><td rowspan="4">Large Intestine</td><td colspan="2">• The large intestine consists of the colon, rectum and anus
• The appendix joining the colon and small intestine have no specific function, and causes appendicitis when it is infected
• The intestinal wall secretes mucus to act as a lubricant to move faeces along</td></tr>
<tr><td>Colon</td><td>Rectum</td></tr>
<tr><td rowspan="3">Excess water and mineral salts are absorbed into the bloodstream</td><td>It stores undigested and unabsorbed matter</td></tr>
<tr><td>Anus</td></tr>
<tr><td>These matter are discharged as faeces through the anus via egestion</td></tr>
<tr><td colspan="3">Absorption</td></tr>
<tr><td colspan="3">Absorption is a process whereby digested food materials are absorbed into body cells</td></tr>
<tr><td rowspan="5">Small Intestine</td><td>Adaptation</td><td>Function</td></tr>
<tr><td>Very long at 7m</td><td rowspan="3">Increase the surface area to volume ratio for rapid absorption</td></tr>
<tr><td>Folded</td></tr>
<tr><td>Presence of villi and microvilli</td></tr>
<tr><td>One-cell thick epithelium</td><td>Provide a short distance for rapid diffusion of digested food materials into the blood capillaries</td></tr>
<tr><td>Villi richly supplied with</td><td>Allow rapid transport of glucose and amino acids away from the small</td></tr>
</table>

<table>
<tr><td rowspan="7"></td><td>blood vessels</td><td colspan="2">intestine, maintaining a steep concentration gradient, thus allowing rapid diffusion of glucose and amino acids</td></tr>
<tr><td>Villi contain lacteals</td><td colspan="2">Allow rapid transport of fats away from the small intestine, maintaining a steep concentration gradient, thus allowing rapid diffusion of fats</td></tr>
<tr><td>Process</td><td colspan="2">Nutrients Absorbed</td></tr>
<tr><td rowspan="3">Diffusion</td><td>Glucose & Amino acids</td><td>Diffuse into blood capillaries</td></tr>
<tr><td rowspan="2">Fatty Acids & Glycerol</td><td>Diffuse into epithelium, then combine to form minute fat globules which enter the lacteal</td></tr>
<tr><td>Lacteals merge to form larger lymphatic vessels which carry fat droplets away from the ileum into the bloodstream</td></tr>
<tr><td rowspan="2">Active transport</td><td rowspan="2">Glucose & Amino acids</td><td>Concentration in small intestine is lower than that in blood capillaries</td></tr>
<tr><td>Absorbed into blood capillaries by active transport</td></tr>
<tr><td colspan="4">Assimilation</td></tr>
<tr><td colspan="4">Assimilation is the process whereby some of the absorbed food substances are converted into new protoplasm or used to provide energy</td></tr>
<tr><td>Nutrient</td><td>Transport</td><td>Usage</td><td>Excess</td></tr>
</table>

<table>
<tr><td>Glucose</td><td rowspan="3">From small intestine to liver by the hepatic portal vein</td><td>Leaves the liver and transported to body cells to be oxidised during aerobic respiration to release energy</td><td>Transported back to liver for storage as glycogen</td></tr>
<tr><td rowspan="2">Amino acids</td><td>Converted into new protoplasm used for growth and repair of worn-out cells</td><td rowspan="2">Broken down in the liver via deamination</td></tr>
<tr><td>Form enzymes and hormones</td></tr>
<tr><td rowspan="2">Fats</td><td rowspan="2">-</td><td>Build protoplasm when glucose is sufficient</td><td rowspan="2">Stored in adipose tissue</td></tr>
<tr><td>Broken down to provide energy when glucose is insufficient</td></tr>
</table>

- Organs associated with the alimentary canal (accessory organs): liver, pancreas and gallbladder

Function	Elaboration
Regulation of blood glucose concentration	• The islets of Langerhans in the pancreas produces the hormones insulin and glucagon • When blood glucose concentration is too high, the liver secretes insulin, stimulating the liver to convert excess glucose to glycogen to reduce blood glucose concentration • When blood glucose concentration is too low, the liver secretes glucagon, stimulating the liver to convert glycogen to glucose to raise the blood glucose concentration
Production of bile	• Bile is temporarily stored in the gallbladder and released via the bile duct into the small intestine

<table>
<tr><td rowspan="6">Deamination of amino acids</td><td>Deamination</td><td rowspan="2">Acid group remaining in the deaminated amino acid is converted into carbon residue</td></tr>
<tr><td>Amino group (-NH_2-) is removed from amino acids</td></tr>
<tr><td colspan="2">↓converted to</td></tr>
<tr><td>Ammonia</td><td>Glucose</td></tr>
<tr><td colspan="2">↓ converted to</td></tr>
<tr><td>Urea, to be excreted from the body in the urine</td><td>Glycogen, for storage in the liver</td></tr>
<tr><td>Protein synthesis</td><td colspan="2">• Synthesises prothrombin and fibrinogen</td></tr>
<tr><td>Detoxification</td><td colspan="2">• Process of converting harmful substances into harmless materials
Alcohol
↓
Alcohol dehydrogenase
↓
Acetaldehyde
• Acetaldehyde is a source of energy in cells</td></tr>
<tr><td>Storage of irons and vitamins</td><td colspan="2">Worn-out red blood cells broken down in the spleen
↓
Haemoglobin is released and broken down in the liver
↓ ↓
Iron removed and stored in the liver | Bile pigments produced</td></tr>
</table>

Harmful effects of excessive alcohol consumption		
Digestive system	Nervous system	Social effects
Cirrhosis, where liver cells are destroyed	Depressant	Violent behaviour

and replaced with fibrous tissue	Reduced self-control	
	Longer reaction time	Committing crimes under the influence of alcohol

Transport in Humans

- In a simple unicellular organism, the movement of materials into and from the cell occurs by diffusion as no part of the cell is far from the external environment
- In a complex multicellular organism, a transport system is needed to carry materials from one part of the body to another as cells are located deep in the body, far from the external environment
- Main functions of blood:
    1. Transport of oxygen from the lungs to body cells
    2. Protection of body against pathogens
    3. Coagulation at wounds to prevent excessive loss of blood and entry of pathogens into the bloodstream

<table>
<tr><td colspan="4">Components of blood</td></tr>
<tr><td rowspan="7">Plasma</td><td colspan="3">Pale yellowish liquid</td></tr>
<tr><td>90%</td><td colspan="2">10%</td></tr>
<tr><td rowspan="6">Water</td><td rowspan="3">Soluble proteins</td><td>Pro -thrombin</td></tr>
<tr><td>Fibrinogen</td></tr>
<tr><td>Antibodies</td></tr>
<tr><td>Dissolved mineral salts</td><td>Calcium phosphate</td></tr>
<tr><td rowspan="2">Digested food materials</td><td>Glucose</td></tr>
<tr><td>Amino acids</td></tr>
</table>

<table>
<tr><td></td><td></td><td>Excretory products</td><td>Urea</td></tr>
<tr><td></td><td></td><td>Hormones</td><td>Insulin</td></tr>
<tr><td rowspan="6">Red blood cells (erythrocytes)</td><td colspan="3">• Produced by bone marrow
• When worn-out, it is broken down in the spleen
• Iron in haemoglobin makes it red
• Lifespan of 3 months</td></tr>
<tr><td>Adaptation</td><td colspan="2">Function</td></tr>
<tr><td>Contains haemoglobin</td><td colspan="2">Transport of oxygen:
• As blood passes through the lungs, oxygen diffuses from the alveoli into the blood
• Haemoglobin combines reversibly with oxygen to form oxyhemoglobin
• As blood passes through oxygen-poor tissues, the oxyhaemoglobin releases oxygen</td></tr>
<tr><td>Absence of nucleus</td><td colspan="2">More space to carry more haemoglobin to bind to more oxygen, thus allowing rapid transport of oxygen</td></tr>
<tr><td>Biconcave, circular shape</td><td colspan="2">Increase surface area to volume ratio for rapid absorption and release of oxygen</td></tr>
<tr><td>Elastic</td><td colspan="2">Squeeze through blood capillaries</td></tr>
<tr><td rowspan="3">White blood cells (leucocytes)</td><td colspan="3">• Produced in the bone marrow
• Lifespan of a few days</td></tr>
<tr><td>Features</td><td colspan="2">Reason</td></tr>
<tr><td>Colourless</td><td colspan="2">Do not contain haemoglobin</td></tr>
</table>

<table>
<tr><td rowspan="7"></td><td>Mobile</td><td colspan="2">Able to move and change their shape to squeeze through walls of thin blood capillaries</td></tr>
<tr><td>Presence of nucleus</td><td colspan="2">-</td></tr>
<tr><td colspan="2">Lymphocytes</td><td>Phagocytes</td></tr>
<tr><td colspan="2">When pathogens enter the bloodstream, they stimulate lymphocytes to produce antibodies</td><td>Phagocytosis is the process of engulfing and ingesting foreign particles by phagocytes</td></tr>
<tr><td colspan="2">Antibodies protect our body from disease:
● Destroy bacteria
● Clump bacteria together for phagocytosis
● Neutralise toxins produced by bacteria</td><td>During phagocytosis, some phagocytes are killed together with bacteria, forming pus</td></tr>
<tr><td colspan="2">Immunisation</td><td>Tissue Rejection</td></tr>
<tr><td colspan="2">Exposes a person to weakened forms of a pathogen to induce lymphocytes to produce antibodies</td><td>Transplanted organs are treated as foreign bodies, stimulating the production of antibodies to destroy them</td></tr>
<tr><td>Platelets (thrombocytes)</td><td colspan="3">● Not true cell; it is a membrane-bound fragment of cytoplasm from bone marrow cells
● Plays a part in coagulation (blood clotting):
<table><tr><td>Damaged tissue and platelets
↓
Produce
↓
Thrombo</td><td>Prothrombin
↓
Thrombo -kinase* & calcium ions (from calcium phosphate)</td><td>Fibrinogen
↓
Thrombin
↓
Insoluble fibrin threads which trap</td></tr></table></td></tr>
</table>

	<table><tr><td>-kinase which neutralises heparin, an anti-clotting substance</td><td>↓ Thrombin</td><td>blood cells forming a clot</td></tr></table> ● Haemophilia occurs when the blood-clotting mechanism is greatly impaired, thus slight bleeding may cause death ● When blood clots, serum, which is plasma without the soluble proteins prothrombin and fibrinogen, is left behind

- Red blood cells have the protein antigen on their surface
- Plasma contains natural antibodies which recognise and bind to specific antigens on the red blood cells of another person, causing agglutination to occur, which block up blood vessels and prevent the flow of blood, leading to death
- Four types of blood groups:

Blood Group	Antigen	Antibody
A	A	b (binds to antigen B)
B	B	a (binds to antigen A)
O	Absent	a & b
AB	A & B	None

Feature	Arteries	Veins	Capillaries
Function	Carry blood away from the heart	Carry blood back to the heart	Link arteries to veins
Wall thickness	Thick to prevent rupture during influx of blood at high pressure	Thin as influx of blood is at low pressure	One-cell thick endothelium to provide a short distance for rapid diffusion of water and dissolved substances

Lumen	Small	Large	Large
Semilunar valves to prevent backflow	Absent	Present	Absent
Others	Elasticity	Movement of blood	Exchange of substances
	Walls are elastic so as to recoil and push the blood in spurts	Movement of blood is assisted by the pressure that the skeletal muscles exerts on the vein	Branches repeatedly to increase surface area for the exchange of substances
			Cross-sectional area is larger than that of artery, lowering blood pressure and slowing down flow of blood to give more time for the exchange of substances

Main arteries			Main veins		
Artery	From	To	Vein	From	To
Pulmonary artery	Heart	Lungs	Pulmonary vein	Lungs	Heart
Aortic arch		Dorsal aorta	Anterior / superior vena cava	Head	Heart
Dorsal aorta	Aortic arch	Regions below the heart		Neck	
Hepatic artery	Dorsal aorta	Liver		Forearms	

<table>
<tr><td rowspan="2">Artery to gut</td><td rowspan="3"></td><td>Stomach</td><td>Posterior / inferior vena cava</td><td>Regions below the heart</td><td></td></tr>
<tr><td>Intestine</td><td rowspan="2">Hepatic portal vein</td><td>Stomach</td><td rowspan="2">Liver</td></tr>
<tr><td>Renal artery</td><td>Kidneys</td><td>Intestine</td></tr>
<tr><td colspan="3" rowspan="2">-</td><td>Hepatic vein</td><td>Liver</td><td rowspan="2">Posterior / inferior vena cava</td></tr>
<tr><td>Renal vein</td><td>Kidneys</td></tr>
</table>

- Arterioles link the artery to capillaries, which is then linked to the vein by the venule
- Order of pressure in blood vessels:
  Arteries > arterioles > capillaries > venules > veins
- Tissue fluid carries substances in solution between the tissue cells and the blood capillaries:

<table>
<tr><td colspan="3">When blood flows from the arteriole into the capillaries, the blood pressure remains high</td></tr>
<tr><td>Dissolved food materials & oxygen in blood plasma</td><td>-</td><td>Excretory waste products</td></tr>
<tr><td colspan="3">Blood capillaries</td></tr>
<tr><td>↓</td><td>Diffusion through partially permeable endothelium</td><td>↑</td></tr>
<tr><td colspan="3">Tissue fluid</td></tr>
<tr><td>↓</td><td>Diffusion through partially permeable plasma membrane</td><td>↑</td></tr>
<tr><td colspan="3">Cells</td></tr>
</table>

1. White blood cells can change their shape and squeeze through the tiny pores of the endothelium

2. Larger substances such as red blood cells and proteins cannot pass through the endothelium

Double circulation				
• Blood enters the pulmonary circulation at lower pressure, ensuring sufficient time for oxygen to diffuse into the blood • Blood is pumped into the systemic circulation at high pressure, ensuring rapid transport of oxygenated blood to body tissues				
Circulation	Blood	From	To	Carried by
Pulmonary	Deoxygenated	Heart	Lungs	Pulmonary arteries
	Oxygenated	Lungs	Heart	Pulmonary veins
Systemic	Deoxygenated	All parts of body except lungs	Heart	Systemic veins
	Oxygenated	Heart	All parts of body except lungs	Systemic arteries

The cardiac cycle		
Parts	Events	
	Left side of heart	Right side of heart
	*Left/right of a person **facing you**	
Prerequisite		
Median septum	Muscular wall separating the left and right side of heart, preventing the mixing of deoxygenated blood in the right side and oxygenated blood in the left side which would reduce the amount of oxygen carried to tissue cells	
Atrium	Atria have comparatively thin muscular walls as they only force blood into the ventricles, which does not require high pressure	

<table>
<tr><td rowspan="2">Ventricle</td><td colspan="2">Ventricles have thicker walls to withstand high pressure than atria as they have to pump blood to other parts of the body, which requires high pressure</td></tr>
<tr><td>Left ventricle has thicker walls to withstand higher pressure as it pumps blood to body parts that are far away from the heart, which requires more pressure</td><td>Right ventricle has thinner walls as it only pumps blood to the lungs, which is close to the heart, which requires less pressure</td></tr>
<tr><td colspan="3">Event 1</td></tr>
<tr><td>Atrium</td><td colspan="2" rowspan="2">Both atria and ventricles are relaxed</td></tr>
<tr><td>Ventricle</td></tr>
<tr><td colspan="3">Event 2</td></tr>
<tr><td rowspan="2">Atrium</td><td rowspan="2">Oxygenated blood from the lungs is brought to the left atrium by the pulmonary veins</td><td>Deoxygenated blood from head, neck and arms is brought to the right atrium by the anterior or superior vena cava</td></tr>
<tr><td>Deoxygenated blood from body parts below the neck except the lungs is brought to the right atrium by the posterior or inferior vena cava</td></tr>
<tr><td colspan="3">Event 3</td></tr>
<tr><td rowspan="2">Atrium</td><td colspan="2">Both atria contract, increasing blood pressure in the atria</td></tr>
<tr><td colspan="2">$Pressure_{atria} > Pressure_{ventricle}$</td></tr>
<tr><td colspan="3">Event 4</td></tr>
<tr><td>Atrioventricula</td><td>The two flaps of the</td><td>The three flaps of</td></tr>
</table>

<table>
<tr><td rowspan="4">r valve</td><td rowspan="3">bicuspid or mitral valve open the valve</td><td>tricuspid valve open the valve</td></tr>
<tr><td>The flaps attached to the walls of the right ventricle by the chordae tendineae</td></tr>
<tr><td>The flaps point downwards to allow blood to flow easily</td></tr>
<tr><td colspan="2">Atrioventricular valve opens, allowing blood to flow from the atria to the ventricles</td></tr>
<tr><td colspan="3">Event 5</td></tr>
<tr><td>Atrium</td><td colspan="2" rowspan="2">Blood flows from the atria into the ventricles</td></tr>
<tr><td>Ventricle</td></tr>
<tr><td colspan="3">Event 6A</td></tr>
<tr><td rowspan="2">Ventricle</td><td colspan="2">Both ventricles contract (ventricular systole), increasing blood pressure in the ventricle</td></tr>
<tr><td colspan="2">$Pressure_{ventricles} > Pressure_{atria}$</td></tr>
<tr><td colspan="3">Event 7</td></tr>
<tr><td rowspan="3">Atrioventricular valve</td><td rowspan="2">The two flaps of the bicuspid or mitral valve closes the valve</td><td>The three flaps of the tricuspid valve closes the valve</td></tr>
<tr><td>The chordae tendineae prevent the flaps from being reverted into the right atrium</td></tr>
<tr><td colspan="2">Atrioventricular valves closes and produces a ‘lub’ sound, preventing the backflow of blood into the atria</td></tr>
<tr><td colspan="3">Event 8</td></tr>
<tr><td>Ventricle</td><td colspan="2">Blood pressure in ventricles increases until:</td></tr>
</table>

<table>
<tr><td></td><td>$Pressure_{aorta} > Pressure_{left\ ventricle}$</td><td>$Pressure_{pulmonary\ artery} > Pressure_{right\ ventricle}$</td></tr>
<tr><td colspan="3">Event 9</td></tr>
<tr><td>Semilunar valve</td><td>Aortic valve opens, allowing blood to flow into the aortic arch</td><td>Pulmonary valve opens, allowing blood to flow into the pulmonary arch</td></tr>
<tr><td colspan="3">Event 10</td></tr>
<tr><td>Ventricles</td><td rowspan="2">Blood flows from the right ventricle into the aortic arch, entering the systemic circulation</td><td rowspan="2">Blood flows from the right ventricle into the pulmonary arch, entering the pulmonary circulation</td></tr>
<tr><td>Arteries (Pulmonary or systemic)</td></tr>
<tr><td colspan="3">Event 6B</td></tr>
<tr><td rowspan="3">Atrium</td><td colspan="2">As the ventricles contract, the atria relax</td></tr>
<tr><td rowspan="2">Oxygenated blood from the lungs is brought to the left atrium by the pulmonary veins</td><td>Deoxygenated blood from head, neck and arms is brought to the right atrium by the anterior or superior vena cava</td></tr>
<tr><td>Deoxygenated blood from body parts below the neck except the lungs is brought to the right atrium by the posterior or inferior vena cava</td></tr>
<tr><td colspan="3">Event 11A</td></tr>
<tr><td rowspan="3">Ventricle</td><td colspan="2">Both ventricles relax (ventricular diastole), decreasing blood pressure in the ventricle</td></tr>
<tr><td colspan="2">$Pressure_{aorta} > Pressure_{ventricle}$</td></tr>
<tr><td colspan="2">$Pressure_{pulmonary\ vein} > Pressure_{ventricle}$</td></tr>
<tr><td colspan="3">Event 12</td></tr>
</table>

<table>
<tr><td rowspan="2">Semilunar valve</td><td>Aortic valve closes, preventing the backflow of blood into the left ventricle</td><td>Pulmonary valve closes, preventing the backflow of blood into the right ventricle</td></tr>
<tr><td colspan="2">The closure of both semilunar valves produces a ‘dub’ sound</td></tr>
<tr><td colspan="3">Event 11B</td></tr>
<tr><td rowspan="2">Atrium</td><td colspan="2">As the ventricles relax, the atrium contracts</td></tr>
<tr><td colspan="2">$Pressure_{atria} > Pressure_{ventricle}$</td></tr>
<tr><td colspan="3">Event 13</td></tr>
<tr><td rowspan="2">Atrioventricular valve</td><td>The two flaps of the bicuspid or mitral valve open the valve</td><td>The three flaps of the tricuspid valve open the valve</td></tr>
<tr><td colspan="2">Atrioventricular valve opens, allowing blood to flow from the atria to the ventricles</td></tr>
<tr><td colspan="3">The whole cycle repeats itself again</td></tr>
</table>

- A ventricular systole and ventricular diastole make up one heartbeat
- The average normal heartbeat is 72 times per minute
- The sphygmomanometer is used to measure blood pressure
- Increase in pressure in the right ventricle is lower than that in the left ventricle
- Coronary heart disease: atherosclerosis ➜ thrombosis
  Coronary artery carry blood to heart muscle

Atherosclerosis: build up of fatty deposits in coronary arteries		
↓	• Narrows the lumen of coronary arteries • Increases blood pressure	↓
↓	• Inner surface of coronary arteries becomes rougher	↓
↓	• Increases risk of blood clot being trapped in coronary arteries	↓

Thrombosis: formation of blood clot in an artery		
↓	• Blood flow to heart is reduced	↓
↓	• Heart tissues are starved of oxygen	↓
Heart attack: death of heart tissues		

- Prevention of coronary heart disease:
    1. Proper diet by cutting down on animal fats which stick to the inner walls of coronary arteries
    2. Not smoking to avoid inhalation of nicotine and carbon dioxide
    3. Regular physical exercise to strengthen the heart and maintain elasticity of arterial walls