

Requirement	I: Cells and Chemistry of Life
Structure and function of: Cell Wall Cell Membrane Cytoplasm Nucleus Vacuole Chloroplasts	Cell wall (Made up of cellulose and FULLY permeable) - Gives plant cells a fixed shape - Provides structural support and protection Cell Membrane (Made up of lipids and proteins) - PARTIALLY permeable - Control movement of substance in and out of cell Cytoplasm (Jelly like fluid containing water, salt, and protein) - Contains organelles that perform specific jobs within a cell for a particular function Nucleus (Surrounded by nuclear membrane) - Controls cell activities like cell growth and repair of worn out parts - Essential for cell division as chromosomes contains DNA that has genetic information and instructions for cell activities Vacuole -> Store substances within the cell Plant -> Large and central, Contains cell sap (dissolved sugars, mineral salts, and amino acids) Animal -> Small and temporary, Contains water and food substances

	Chloroplast - Contains chlorophyll which is essential for photosynthesis
Structure and function of: Ribosomes Golgi Body RER SER	Ribosomes (Made of rRNA proteins) Attached to RER -> Synthesises protein that's transported out of cell Lies freely -> Synthesis proteins that are used within the cel RER (Continuous with nuclear membrane) - Modifies & packages protein made by ribosomes into vesicles to the Golgi Body for secretion out of the cell Golgi Body 1) Chemically modifies substances made by ER 2) Stores and packages substances in vesicles for secretion out of the cell SER (More tubular) 1) Synthesis of fats and steroids (sex hormones in mammals) 2) Detoxification
Compare structure of animal and plant cell	Large central vacuole vs Small temporary vacuole Chloroplast vs no chloroplast Cell wall vs no cell wall

How are <u>red blood cells</u> adapted to their functions?	1) Contains many haemoglobin -> Transports O₂ by temporarily binding to it to form oxyhaemoglobin 2) No nucleus -> More haemoglobin -> ↑↑ O₂- carrying capacity 3) Biconcave shape -> ↑↑ SA-V Ratio -> ↑↑ O₂ and CO₂ diffusion in and out of cell 4) Flexible -> Turns bell-shaped to pass through narrow capillaries -> Ensures O₂ can be delivered to every tissue in the body
How are <u>muscle cells</u> adapted to their functions?	1) Many mitochondria -> ↑↑ rate of aerobic respiration -> Release large amounts of energy for contraction of muscle cells 2) Many nuclei -> ↑↑ protein synthesis 3) Stores glycogen -> Converted to glucose for immediate energy supply
How are <u>root hair cells</u> adapted to their function?	1) Elongated shape -> ↑↑ SA-V ratio -> ↑↑ cell membrane surface -> ↑↑ Water and mineral salts uptake 2) Numerous mitochondria -> release energy for active transport of mineral salts and ions 3) Thin cell wall -> Allow substances to move across it quickly

Define diffusion and osmosis	Diffusion is the net movement of substances down a concentration gradient. Osmosis is the net movement of water molecules down a WP gradient through a partially permeable membrane. **** Continues until concentration / WP in both regions is the same
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What is the role of diffusion? (in nutrient uptake and gaseous exchange in both humans and animals)	Plant (gas exchange) Diffusion of carbon dioxide into cell through diffusion through the cell membrane and diffusion of oxygen out of the cell through diffusion in the cell membrane	Animals Nutrients, water and oxygen enter by diffusion through the cell membrane and metabolic waste substances like carbon dioxide are removed from the cell via diffusion in the cell membrane.
4 factors that affect rate of diffusion	1) Surface area-to-volume ratio 2) Diffusion distance (less time to move through shorter distances) 3) Concentration gradient 4) Temperature	

Investigate and describe the effect of osmosis on plants and animal tissues	Animal cells: Crenation -> Cell ↓ in size, membrane forms little spikes as the cell shrinks and dehydrates -> cell death Haemolysis -> Cell expands, bursts and dies (reason: no cell wall) Plant cells: Plasmolysis -> water molecules diffuse out of cell sap via osmosis -> decreases in size, becomes flaccid -> cytoplasm and cell membrane shrink away from the cell wall Turgor Pressure -> water molecules diffuse into cell sap via osmosis -> expands -> cell wall prevents overexpansion of cell membrane by exerting an opposing pressure -> fully turgid -> prevents further water entry
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Importance of turgor pressure	1) Supports the shape of soft tissues in plants 2) Keeps herbaceous plants firm and upright 3) Regulates opening and closing of stomata (turgid -> open)
Define WP	Measure of tendency of water to move from one place to another
Define active transport	It is the diffusion of substances against a concentration gradient. It uses energy released from aerobic respiration in the mitochondria.
2 examples of active transport	1) Uptake of mineral salts and ions in the root hair cells 2) Uptake of glucose by cells in the villi

Proportion of H and O in carbs and fats	Carbohydrates -> Hydrogen and oxygen in fixed ratio of 2 to 1 Fats -> NOT a fixed ratio -> Usually has much LESS OXYGEN than hydrogen
Main role of carbohydrates	1) Substrate of respiration -> Provides immediate source of energy for cell activities 2) Converted to amino acids and fats 3) Forms supporting structures (eg. cell walls)
Main role of proteins	1 mark answer: Growth and repair of cells - Synthesis of new cytoplasm for growth and repair of worn out cells - Synthesis of enzymes and some hormones - Formation of antibodies to combat disease

Main role of fats	1) Insulating material that prevents excessive heat loss 2) Source of long term energy storage due to higher energy value 3) Solvent for fat soluble vitamins and hormones 4) Reduces water loss from the skin surface
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Important notes for food tests	Reducing sugar -> equal volume, boiling water bath for 2-3 min Protein -> equal volume, shake, let it stand ** Ethanol emulsion Liquid food solution -> add it dropwise to ethanol solution Solid food -> Crush -> add ethanol -> decant -> add that to water
Why is glycogen and starch suitable for storage? (4m)	1) Insoluble in water -> Do not change WP of cells 2) Large molecules -> Cannot diffuse through cell membrane -> Not lost from cell 3) Easily broken down to glucose (eg. for tissue respiration) 4) Compact shape -> Occupy less space than individual glucose molecules
Explain the mode of action of an enzyme	1) Specific enzyme has specific three dimensional shape with a depression called the active site 2) Only substrate with 3-D shape complementary to active site can fit, forming an enzyme-substrate complex 3) Enzyme is the lock and substrate is like a key fitting into a lock.

	(lock and key hypothesis) 4) While substrate is attached, a chemical reaction occurs where the substrate is converted to products 5) Products eventually leave the active site, while the enzyme remains unchanged and catalyses other reactions
Explain the effects of temp and pH on enzyme catalysed reactions	Temp: Change in KE -> change in rate of effective collisions -> increase rate of enzyme-substrate complex formation Above optimum -> Enzymes loses original shape -> no longer complementary -> RAPIDLY decreases rate of enzyme action pH: Begin denaturation when pH conditions vary from optimum (Range is about 2)

II: Human Body (Nutrition, Transport, Respiration, Excretion, Homeostasis, Nervous, Infectious Disease)

Requirement	Answer
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Describe the functions of the various parts of the digestive system. Mouth, Salivary gland, oesophagus, stomach, duodenum, ileum, colon, rectum, anus ... in terms of ingestion, digestion, absorption, assimilation, egestion	Mouth: Teeth mechanically breaks down food into smaller pieces, increasing its surface area of efficient enzyme action. Tongue helps mix the food with saliva and roll it into a bolus for swallowing. Salivary glands: Secrete saliva which contains amylase that breaks down starch to maltose. Also softens food, making it easier to chew and form into a bolus for swallowing. Oesophagus: Carries out peristalsis which allows food to be mixed and propels food to the stomach. Stomach: a) Has numerous gastric pits, the walls of which are lined with gastric glands that secrete gastric juice that contains pepsin. b) Peristalsis churns and breaks up food and mixes it with gastric juice. c) **Mucus layer prevents stomach wall from being digested and also moistens food for easy movement. Duodenum: a) Entering of chyme stimulates pancreas to secrete pancreatic juice via the pancreatic duct into the duodenum (protease, lipase, pancreatic amylase) b) Gall bladder releases bile via the bile duct c) Epithelial cells in small intestine produces enzymes like maltase, protease, and lipase
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	Ileum: Absorption of digested food substances via the villi Colon: Absorb 90% of remaining water and mineral salts from undigested food material Rectum: Temporarily stores faeces until it is expelled Anus: Fecal continence and defecation
Adaptations of the small intestine for absorption (5m)	1) 1-cell thick epithelial wall 2) Microvilli that further increase surface area 3) Villus has many blood capillaries (maintain steep conc grad) 4) Contains lacteal to transport absorbed fats away (steep conc) 5) Many mitochondria -> Provide energy for active transport of nutrients into villi
Functions of the liver (5m)	1) Bile production 2) Deamination (removal of amino group of amino acids to be converted to urea) 3) Carbohydrate metabolism (converts excess glucose to glycogen for storage, vice versa) 4) Hormone breakdown (after they served their purpose) 5) Detoxification (Eg. alcohol, food preservatives)

Function of hepatic portal vein	It transports blood rich in absorbed nutrients from the small intestine to the liver
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Effect of alcohol consumption on the brain	1) Depressant: Slows down brain functions 2) Reduced self-control: May do things one later regrets 3) Increased reaction time (eg; slurred speech, blurred vision, muscular discoordination, deterioration of judgement)
LONG TERM EFFECT of alcohol consumption	1) Wet brain -> Type of dementia caused by brain damage (interferes with the absorption of vitamin B1) 2) Shrinkage in brain volume (esp regions associated with memory and reasoning) 3) Liver cirrhosis -> when liver cells are destroyed and replaced with fibrous tissue. -> May haemorrhage in the liver, leading to liver failure 4) Affects development of fetus' brain, resulting in lifelong physical, mental and behavioural problems
SOCIAL implications of alcohol consumption	1) Neglect work and family 2) Exhibit violence, esp towards family members 3) May commit crime under the influence of alcohol

Relate the structure of arteries, veins and capillaries to their functions	1) Arteries Structure: Thick, muscular, elastic walls. Reason: - Need to withstand high pressure of blood forced out of the heart. Blood is also fast-moving - Elasticity enables the walls to stretch and recoil, helping push the blood in spurts along the artery. (produces a pulse!) 2) Veins
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	Structure: Thin wall with less elastic tissue. Has values Reason: - Transports blood of low pressure that moves slowly and smoothly - Valves prevent backflow of blood 3) Capillaries Walls are partially permeable and made up only of a single layer of flattened cells. They are very thin. - Enables substances to quickly diffuse through them - Large SA for exchange of substances *** Higher total cross-sectional area -> Lower blood pressure -> slower flow of blood -> more time for exchange of substances
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Describe the transfer of materials between the capillaries and the tissue fluid	Blood capillary -> Tissue fluid -> cells of tissue - Dissolved food substances and oxygen Cells of tissue -> Tissue fluid -> blood capillary - Metabolic or excretory waste products
Role of RBC	Contains haemoglobin that binds reversibly with oxygen to form oxyhaemoglobin in the lung. It then releases oxygen to the tissue cells where O ₂ concentration is low.
Role of WBC	Phagocytes: Perform phagocytosis, a process where the WBC engulfs and destroys foreign particles like bacteria

	Lymphocytes: a) Recognises foreign particles b) Destroy disease causing organisms like bacteria and viruses c) Cause bacteria to clump together for easy ingestion by phagocytosis d) Neutralise toxins made by the bacteria
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Role of Plasma	Transport... a) Blood cells around the body b) Nutrients from small intestine to other parts of the body c) Excretory products from where it's produced to excretory organs for removal d) Hormones from endocrine glands to target organs
Role of Platelets	Contains the thrombin enzyme that catalyses conversion of fibrinogen to fibrin threads that form a network that entangles RBC to form a clot. Prevents excessive blood loss and entry of harmful organisms into the bloodstream.
Blood group	A -> antigen A and antibody b B -> antigen B and antibody a AB -> antigen A and B only O -> antibodies a and b only
Describe the function of the heart in terms of muscular contraction and working of valves	The heart is a pump that circulates blood throughout the body. Atrial contraction -> Forces blood into ventricles Ventricular contraction -> Pumps blood out of heart to lungs and the

	rest of the body Atrioventricular valve -> Prevents backflow of blood from ventricle to atria Semi-lunar valve -> Prevent backflow from arteries to the ventricles
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Outline the cardiac cycle in terms of what happens during systole and diastole	1: Atrial systole -> blood forced into ventricles 2: Ventricular systole -> rise in ventricular pressure -> bicuspid and tricuspid valves close (causes loud 'lub' sound) -> semi-lunar valves open -> blood flows from RV and LV to pulmonary artery and aorta. 3: Atrial diastole -> RA and LA receive blood from vena cavae and pulmonary vein respectively 4: Ventricular diastole -> Fall in ventricular pressure -> semi-lunar valves close (causes soft 'dub' sound) -> bicuspid and tricuspid valves open and blood flows from atria to ventricles. 5: Atrial systole occurs again. The whole cycle repeats.
What is coronary heart disease and what are its possible causes?	Coronary heart disease is the occlusion of the coronary arteries that can cause a heart attack. Unhealthy diet (high in cholesterol, saturated fat, and salt), smoking, sedentary lifestyle, genetic factors, age (65+)
State the functions of _____ in gaseous exchange	Larynx: A hollow tube that connects the pharynx (throat) to the trachea allowing air to flow into the lungs. It also contains the epiglottis, a valve that closes during swallowing, preventing food

Larynx, Trachea, Bronchi, Bronchioles, alveoli and associated capillaries	and water from entering the trachea and lungs Trachea: The inner walls of the cartilage contains gland cells that secrete mucus to trap dust particles and bacteria and ciliated cells that contain cilia which sweeps the dust-trapped mucus up the trachea. Bronchi: Carries air from the trachea into the lung Bronchioles: Carries air from the bronchi into the alveoli Alveoli: Perform gas exchange between alveoli and blood. O₂ diffuses to blood and CO₂ diffuses to alveoli.
Describe the process of inhalation and exhalation	Inhalation: External intercostal muscles contract, internal intercostal muscles relax, diaphragm contracts and flattens downwards. Ribcage moves upwards and outwards, sternum moves upwards and forwards. Thoracic cavity increases -> air pressure decrease -> air flow into lungs Exhalation: opposite of inhalation (e.g. ribs downwards and inwards)
How is conc gradient maintained for gas exchange?	1) Continuous breathing 2) Continuous flow of blood in capillaries
Adaptation of alveolus for gaseous exchange	1) Small & numerous -> ↑ SA-V ratio -> ↑ rate of O₂ absorption 2) Thin film of moisture -> Allow O₂ to dissolve in it 3) 1-cell thick alveolar wall -> ↑↑ rate of diffusion 4) Wall richly supplied with blood capillaries -> Constant flow of blood maintains concentration gradient of gases

Effect of nicotine on health	- Increases heart rate and blood pressure - Build up of plaque -> increases chance of blood clot in arteries -> coronary heart disease - Narrowing of arteries -> Reduces amount of O₂ and food substances reaching fetus -> affect development, may cause miscarriage
Effect of carbon monoxide on health	Binds irreversibly with haemoglobin -> less haemoglobin for oxygen transport -> inadequate O₂ delivery -> Fatigue, dizziness, headaches, confusion Increases risk of coronary heart disease
Effect of tar on health	Paralyses cilia lining of air passages -> reduced efficiency of gas exchange Carcinogenic -> Cause DNA damage and mutation
Define aerobic respiration	Release of energy by the breakdown of glucose in the presence of oxygen. Carbon dioxide and water are released as waste products. Large energy release.
Define anaerobic respiration	Release of energy by the breakdown of glucose in the absence of oxygen. Produces lactic acid. Smaller energy release.
Why do cells respire anaerobically during exercise?	Rate of aerobic respiration is insufficient to meet energy demands for the vigorous muscular contractions -> Anaerobic respiration occurs to meet this demand

How is oxygen debt removed?	Oxygen debt -> Amount of O ₂ needed to remove lactic acid
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	Rapid and deep breathing + Fast Heart rate
Define excretion.	Removal of metabolic waste substances, toxic substances, and excess substances so they don't accumulate and become harmful for the body.
Effect of urea, excess CO ₂ or water on the body	High urea conc -> abdominal pain, nausea, vomiting High conc of CO₂-> Hypercarbia -> Headache, confusion, rapid breathing, premature heartbeats Excess water -> ↑↑ WP of blood plasma -> cells swell and burst
State the functions of _____ in excretion Kidneys, Ureter, Bladder, urethra	Kidney: Filter blood and remove waste and excess products via the urine. Carries out ultrafiltration and selective reabsorption. Ureter: Brings urine from kidneys to the bladder Bladder: Temporarily stores urine Urethra: Expel the urine
Outline nephron function in reference to ultrafiltration and selective reabsorption	Note: For selective reabsorption Most water -> Osmosis, Some salts -> Active transport, all glucose and amino acids -> Active transport Mostly in proximal convoluted

How is glomerulus adapted for ultrafiltration	1) Large SA for filtration 2) 1 cell thick blood capillaries with tiny pores in capillary wall 3) Capillaries covered by partially permeable membrane
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Outline the mechanism for dialysis in the case of kidney failure	Dialysis Process: 1) Blood drawn from vein in the arm and is pumped through a tubing 2) Tubing bathed in dialysis fluid. Walls of tubing partially permeable 3) Small molecules like urea and other metabolic waste products diffuse out of tubing into the dialysis fluid. Blood cells, platelets, and large molecules remain in the fluid. 4) Filtered blood returned to a vein in patient's arm Features of Dialysis Machine 1) same conc of essential substances of a healthy blood 2) Dialysis Fluid does not contain metabolic waste products. Sets up a concentration gradient 3) Tubing is narrow, long and coiled -> increases SA-V ratio, increase rate of exchange of substances 4) Direction of blood flow is opposite
Homeostasis	Maintenance of a constant internal environment

Explain the basic principles of homeostasis	Works as a negative feedback loop. Set point -> Stimulus -> Receptors -> Corrective mechanisms -> Condition decreases -> Return to set point
Describe how a constant body temperature is maintained.	(Thermoreceptors, Sweating, Shivering, Altering blood flow through blood vessels near skin surface, coordinating role of hypothalamus) Ans: Through thermoregulation, controlled by the hypothalamus. When body temperature rises / falls below a set point, thermoreceptors in skin and hypothalamus detect the change and

	trigger corrective mechanisms Increase in body temp: - Vasodilation, Sweating Decrease in body temp: - Vasoconstriction, less sweating, shivering (rapid contraction of skeletal muscles that generates heat via ↑ respiration)
Hormone	- Chemical substance produced in minute quantities by the gland - Carried by the blood - Alters the activity of one or more specific target organs.

Endocrine gland	Ductless gland that secretes hormones directly into the bloodstream (Eg. insulin and glucagon released in the islets of langerhans)
Explain how blood gc is regulated by insulin and glucagon	A: Blood glucose concentration RISES - Detected by beta cells in the Islets of langerhans of pancreas - Secretes insulin into bloodstream travels to liver and muscle - Causes cell membrane of liver and muscle cells to be more permeable to glucose -> ↑↑ glucose uptake - Excess glucose converted to glycogen in liver for storage - Glucose used for respiration to release energy - Blood gc returns to set point - Insulin secretion decreases

	B: Blood glucose concentration FALLS - Detected by alpha cells in Islets of Langerhans of pancreas - Secrete glucagon into bloodstream - Glycogen converted back to glucose in liver and is released into blood - Blood gc returns to set point - Glucagon secretion decreases (negative feedback)
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Describe Type 2 diabetes and its risk factors	Persistently higher than normal blood glucose concentration due to the body's resistance to insulin or insufficient insulin production. Obesity, Old age, sedentary lifestyle, Family, ↑ HDL and ↓ LDL cholesterol
Ways to manage T2	Eat healthier (low cal, high fibre) , more exercise (use of glucose + makes muscle and liver insulin sensitive) , healthy body weight
Outline role of ADH in osmoregulation	When water potential of blood falls below normal, ↑ in ADH makes the collecting duct more permeable to water.
Function of the nervous system?	It serves to coordinate and regulate bodily functions
Outline what happens during a reflex action (neurones)	1) Stimulus (e.g. heat, sharp object) stimulates receptors, produces nerve impulses. 2) Sensory neurone transmits the nerve impulse to the spinal cord by synapsing with the relay neurone.

	3) Relay neurone synapses with motor neurone, thus transmitting the nerve impulse to the effector. 4) Effector (e.g. muscles) contracts and causes hand to withdraw
Reflex action	Immediate reaction to a specific stimulus without conscious control

What are the principal functions of eye parts in forming a focused image of near and distant objects?	Near: Ciliary muscles contract -> suspensory ligaments slacken, lens becomes thicker and more convex -> More bending of light Far: Ciliary muscle relax -> suspensory become taut and pull on lens-> Lens become thinner and less convex -> less bending of light Light rays are sharply focused on the retina, stimulating photoreceptors, producing nerve impulses that travel via the optic nerve to the brain. The brain interprets nerve impulses, allowing the person to see.
Pupil reflex in bright light	Circular muscles contract while radial muscles relax in iris muscles Pupil constricts -> less light can enter (Vice versa for dim light)
Key diff between infectious and non-infectious disease + examples	Infectious disease can be spread from person to person while non-infectious disease cannot. Infectious: Influenza, Pneumococcal Non-infectious: Liver Cirrhosis, Diabetes, Coronary heart disease
Describe what causes infectious disease and how it's spread	Cause: Pathogens like bacteria and viruses Spread by: 1) Direct contact (Eg. body fluids, breastfeeding, infected blood

	with mucous membrane) 2) Food and water (clean hygiene, water supply, proper sewage) 3) Respiratory droplets
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Describe a typical virus	- Has a protein coat enclosing its genetic material. - No cellular structures. - Does not move, grow, feed, respire, or excrete. Only reproduces in living host cells - Either DNA OR RNA as genetic material
Describe a typical bacteria	- Has a cell wall, cytoplasm, ribosomes, DNA without a nucleus. - Some are pathogenic, some are not - May have one or more flagellum
Signs and symptoms of Influenza (Viral)	- Fever, headache, cough (same as pneumococcal) - Stuffy nose, sore throat - Muscle aches
Describe transmission and method to reduce transmission of Influenza	Transmission: Via respiratory droplets, touching contaminated surface then face Reduce: Vaccine, wash hands, don't touch eyes, nose and mouth If infected: Take antivirals, cover mouth when sneezing, don't come into close contact with uninfected

Signs and symptoms of Pneumococcal disease (bacteria)	- Fever, Headache, cough - Vomiting - Chest pain - Rapid breathing
Describe transmission and reducing pneumococcal	Transmission: Respiratory droplets Reduce: Vaccination, daily preventive actions, taking antibiotics if sick
What can pneumococcal disease cause?	1) Middle ear infection 2) Lung infection 3) Inflammation of the kidneys
How do antibiotics work?	- Kill and inhibits bacteria growth by interfering with growth and metabolic activities i.e. inhibiting cell wall synthesis, cell membrane function, protein synthesis in ribosomes, and enzyme action in the cytoplasm
What do vaccines contain?	They contain an agent resembling the pathogen. They stimulate WBCs to quickly produce antibodies when pathogens invade. How they work 1) Agent that resembling a pathogen enters the body 2) WBC binds to the agent, stimulated to divide

	3) The pathogen (antigen) stimulates WBC to produce antibodies
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	4) Antibodies destroy the agent in vaccine 5) Some of these WBC remain in the bloodstream, so if live pathogens enter the bloodstream, the WBC will recognise them and quickly produce antibodies to destroy the pathogens before it can infect our cells
Discuss how the misuse and overuse of antibiotics may accelerate the emergence of antibiotic-resistant bacteria	Misuse and overuse -> sensitive bacterial cells killed but less sensitive ones not easily killed -> Less sensitive bacterial cells will survive and multiply, increasing in number -> Less sensitive to antibiotics and becomes antibiotic-resistant

III: Living Together (Nutrition and Transport in Flowering Plants, Organism and their environment)

Requirement	Answer
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Describe and explain the distribution of chloroplasts for photosynthesis in leaves	1) Chloroplast most abundant in the palisade mesophyll cell near the upper epidermis -> Positioned to receive maximum light for photosynthesis 2) Fewer chloroplasts found in spongy mesophyll -> Aiding in photosynthesis while allowing space for gas exchange 3) Few chloroplasts found in guard cells -> Need to perform photosynthesis to generate energy to regulate the opening and closing of the stomata
Describe the significance of the stomata and mesophyll cells for gaseous exchange	Stomata is an opening that allows for CO₂ from the surrounding air to diffuse into the leaf and O₂ out of the leaf via diffusion. Spongy mesophyll cells have large intercellular spaces to facilitate rapid gaseous exchange between the cell and the stomata.

Functions of the xylem	1) Conducts water and mineral salts from the roots to the stems and the leaves -> Occurs as xylem vessels are made up of dead cells with <u>no cytoplasm or cross walls</u> -> reduces resistance to water flowing through xylem 2) Provides mechanical support for the plant as inner xylem vessels contain deposits of <u>lignin</u> that strengthens it.
Functions of the phloem	Conducting manufactured food (sucrose + amino acids) substances from the green parts of the plant, especially the leaves, to other parts of the plant.

Adaptations of the phloem	1) Each sieve tube has sieve tube elements. Sieve plates are cross walls with minute pores that separate the cells . 2) Each sieve tube cell has a companion cell that provides nutrients and helps transport manufactured food (Contains many mitochondria-> Provide energy for active transport of sugar from mesophyll cells to the sieve tube)
How are the root hair cells structured for water and ion uptake? (3m)	1 -> Root hairs are long and narrow extensions growing out of the epidermal cell, which increases its SA-V ratio, increasing the rate of absorption of water and mineral salts. 2 -> Cell sap is highly concentrated with sugar and salts -> Sets up steep water potential gradient for osmosis 3-> Contain many mitochondria that carry out aerobic respiration to release energy for active transport of ions into the cell.
Role of the chlorophyll	Chlorophyll in chloroplasts absorb light energy and convert it to chemical energy for the formation of carbohydrates and their subsequent uses.
Why are most forms of life dependent on	Photosynthesis makes chemical energy available to animals and

photosynthesis?	other organisms. Sunlight is the ultimate source of energy for all living organisms, and carbohydrates, fats and protein formed from it directly or indirectly become the food for all organisms as plants are the producer in food chains.
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Eqn for photosynthesis (Words + symbols)	Carbon dioxide + Water → Glucose + Oxygen (in presence of light & chlorophyll) $6\text{CO}_2 + 6\text{H}_2\text{O} \rightarrow \text{C}_6\text{H}_{12}\text{O}_6 + 6\text{O}_2$
Describe how carbon dioxide reaches mesophyll cells in the leaf	CO_2 enters through open stomata , diffuses through intercellular air spaces, then dissolves in the thin film of moisture on mesophyll cells before diffusing into cells.
Discuss the effect of light intensity, CO_2 , and temperature on rate of photosynthesis	Low light → limits rate (light-dependent stage slow). Low CO_2 → Necessary substrate for photosynthesis. Temperature affects enzyme activity: too low = slow, optimum = fastest, too high = enzyme denaturation.
Define transpiration	Transpiration is the loss of water vapour from the aerial parts of the plant (eg. leaves, stems) mainly through the stomata of the leaves. It is a consequence of gaseous exchange in plants.
3 reasons why transpiration is important (3m)	1) Transpirational pull draws water and mineral salts from the roots to the stems and leaves 2) Evaporation of water from the leaf cell surface cools the plant,

	preventing overheating. 3) Water transported to the leaves can be used in photosynthesis to keep the cells turgid, and replace water lost by the cells. Turgidity keeps the leaves spread out widely to trap light for photosynthesis.
Explain movement of water molecules between plant cells and between the environment in terms of water potential.	1) Water evaporates from the thin film of moisture surrounding the mesophyll cells to form water vapour in the intercellular air spaces 2) Water vapor then diffuses through the stomata to the drier air outside the leaf. 3) As water evaporates from the thin film of moisture, more water moves out from mesophyll cells to replenish it. As water is lost from the mesophyll cells, the WP of the cell sap decreases and becomes lower than its neighbouring mesophyll cells 4) The mesophyll cells draw water from cells deeper inside the leaf via osmosis. 5) The cells deeper inside the leaf then draw water from the xylem via osmosis, creating a suction force which pulls the whole column of water up the xylem vessels.
Outline the pathway by which water is transported into the roots and through the xylem vessels to the leaves via transpirational pull.	1) Each root hair is an extension of the epidermal cell, growing between the soil particles, coming into close contact with the soil solution surrounding it. The thin film of liquid surrounding each soil particle is a dilute solution of mineral salts. 2) The cell sap in the root hair cell has a high concentration of sugar and salts, meaning it has a lower WP than the soil. Since the cell sap and soil solution is separated by a partially permeable cell membrane, water enters the root hair via osmosis. 3) Entry of water dilutes the cell sap, so the cell sap now has a higher WP than the next cell. Hence, water passes by osmosis from the root hair cell into the inner cells. 4) Water is continually passed from one cell to the next inner cell. This continues until water enters the xylem and moves up the plant.

	(pulled up due to suction force from transpirational pull)
Explain how variations in air movement, temperature, humidity and light intensity affects transpiration rate.	Air movement $\uparrow \rightarrow$ faster removal of water vapour $\rightarrow \uparrow$ rate. Temperature $\uparrow \rightarrow$ faster evaporation $\rightarrow \uparrow$ rate. Humidity $\uparrow \rightarrow$ smaller water potential gradient $\rightarrow \downarrow$ rate. Light intensity $\uparrow \rightarrow$ more stomata open $\rightarrow \uparrow$ rate.
Trajectory of glucose after photosynthesis (5m)	1 -> Glucose immediately used for cellular respiration and synthesis of cellulose cell walls 2 -> Excess glucose, esp in high light intensity, converted to starch 3-> Converted to sucrose -> Transported to other parts of the plant via the phloem 4-> Converted to amino acids to form protein for synthesis of new protoplasm 5-> Forms fat for storage, cellular resp., and synthesis of new protoplasm
Explain how wilting occurs	Rate of transpiration exceeds the rate of water gained by roots $\rightarrow$ loss of turgor in mesophyll cells $\rightarrow$ leaves become flaccid and wilt.

Define translocation	Transport of manufactured food substances (mainly sucrose) in the phloem tissue.
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**Describe the non-cyclical nature of energy flow ** Energy lost as heat cannot be recycled Energy has to be constantly supplied to the ecosystem	Energy flow in nature is non-cyclical because the Sun provides the initial energy, which is converted by producers into chemical energy during photosynthesis. This energy passes through trophic levels via feeding, but much is lost to the environment as heat through respiration, excretion, egestion, and uneaten body parts at each stage. Decomposers release trapped energy from egested and excreted material and dead organisms, using some for themselves and losing the rest as heat via respiration. Since heat energy cannot be recycled back into the ecosystem, the flow of energy is one-way.
What is a food chain?	It is a series of organisms, beginning with the producer, through which energy and nutrients are transferred.
What is a food web?	A network of interconnected food chains
Describe the role of producers in a food chain	Producers convert light energy from the sun to chemical stores of energy in the form of glucose via photosynthesis.
Describe the role of consumers in a food chain	Consumers obtain energy and nutrients by feeding on other organisms. This process transfers energy from one trophic level to the next.

Describe the role of decomposer in a food chain	Decomposers break down dead organisms, faeces, and excretory products and get energy from them. This returns nutrients like mineral salts back into the environment.
Discuss the efficiency of	(about 90%) -> Heat during respiration, Uneaten body parts, faeces,

energy transfer between trophic levels	excretory products The shorter the chain, the greater the energy available for the next consumer
Describe how carbon is cycled in an ecosystem	1) Photosynthesis: Plants absorb CO_2 and use it to synthesise carbs, and some is converted to proteins and fats. 2) Feeding: Animals obtain carbon compounds by feeding on plants or other animals 3) As plants and animals respire, CO_2 is released into the atm 4) Decomposers like bacteria and fungi break down dead organic matter and release carbon dioxide. 5) Dead bodies of plants and animals buried deep underneath the earth are subjected to high pressure and temperature, where they are converted to fossil fuels. 6) Combustion of these fuels releases CO_2 into the environment.

Describe the role of forests and oceans as carbon sinks	They store carbon from the atmosphere for a long period of time. It stores more carbon than it releases Ocean -> Fossil fuel in seabed, photosynthesis for aquatic plants Forest -> Storage by trees, coal, Photosynthesis by plants
Describe how human activities increase	Burning fossil fuels, deforestation, industrial processes → more

atmospheric CO ₂ and lead to global warming.	greenhouse gases → trap heat → raise global temperatures.
Discuss how human actions can reduce the effects of global warming.	Use renewable energy, reforestation, improve energy efficiency, reduce emissions
Describe the effect of pollution caused by sewage in water	1) Increase risk of diseases -> Untreated sewage contains cholera and typhoid bacteria (water borne diseases) 2) Eutrophication Sewage washed by rain to lakes and rivers -> Nitrates and phosphates in sewage enhance and multiply algae growth -> Algae overgrowth prevents sunlight reaching submerged plants -> They die due to lack of sunlight -> Decomposed by decomposers -> Bacteria and fungi multiply rapidly -> uses up oxygen in water -> other organisms like fish die due to lack of oxygen

Describe the effect of pollution caused by plastic wastes in the marine environment	1 -> Harmful chemicals in plastics poison wildlife 2 -> Ingestion of microplastics can lead to biomagnification of microplastics down the food chain 3-> Animals may ingest bulky plastics like straws or cutleries
Describe the effects of insecticides and their biomagnification up food chains, impacting top carnivores.	Insecticides are non-biodegradable -> Accumulates in the body of organisms -> Small amounts enter bodies of producers or primary consumers -> These organisms are eaten in large quantities by predators -> Concentration of insecticides increases at each trophic level as predators consume many prey over time -> Top carnivores accumulate the highest concentration in their tissues as they are at the end of the food chain -> Toxic effects like reproductive failure and death

**Discuss how the conservation of species contribute to the maintenance of biodiversity and a balanced ecosystem	Conservation: Protection and preservation of natural resources in the environment Biodiversity: Range of species present in a particular ecosystem Reason: - By protecting and preserving natural resources, we ensure genetic diversity and a large gene pool that makes changes in environmental conditions less likely to wipe out the whole species - By protecting and preserving natural resources, we maintain a stable and balanced ecosystem, prevent disruptions of natural cycles like the carbon cycle and prevent global warming.
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Discuss how the sustainable use of natural resources contribute to the maintenance of biodiversity and a balanced ecosystem	Sustainable use of natural resources like forests, mangrove swamps, and coral reefs lead to preserved habitats for organisms to survive
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IV: Continuity of Life (Genetics, Reproduction, Inheritance)

Requirement	Answer
Outline relationship among DNA, genes, and chromosomes	- DNA is a molecule that carries genetic information. Each DNA molecule is made up of <u>2 strands of polynucleotides</u> twisted around each other. - A gene is a <u>specific segment</u> of the DNA which contains a sequence of nucleotides that codes for a single polypeptide - A chromosome is made up of protein molecules tightly coiled around DNA molecules.

	- A single chromosome carries many genes along the chromosomes
Outline structure of DNA (3m)	- Double helix structure comprising 2 strands of polynucleotides, with each nucleotide formed of a sugar, phosphate group, and one of four different bases
State the rule of complementary base pairing	Complementary base pairing dictates that - Adenine always pairs with thymine and cytosine with guanine - These bases are held together by hydrogen bonds.

Define a gene. (3 points)	- Unit of inheritance in a living organism - Is a sequence of DNA nucleotides that controls the formation of a single polypeptide.
What is a genetic code?	Message that determines how a specific polypeptide should be synthesised. It is stored in DNA molecules.
Explain how a gene controlling human insulin can be inserted into bacterial DNA to produce human insulin in medical biotech.	1) Obtain a DNA fragment in the body containing the insulin gene. Cut out the gene using a restriction enzyme, which cuts the restriction site at 2 ends to produce sticky ends. 2) Obtain a plasmid from a bacterium. Cut the plasmid with the same restriction enzyme. This produces complementary sticky ends to the insulin gene. 3) Mix the plasmid with the DNA fragment with the insulin gene. The insulin gene will bind to the plasmid along its sticky ends via complementary base pairing. 4) DNA ligase is added to seal the insulin gene to the plasmid, thus forming a recombinant plasmid. 5) Mix the recombinant plasmid with E.Coli bacterium. Apply

	temporary heat/electric shock to open up pores in the cell membrane for the plasmid to enter the bacterium. 6) The now transgenic bacterium can now produce insulin hormones due to the insulin gene. Such bacteria are isolated and grown in fermenters for mass production of human insulin. Note: Insulin protein must be extracted and purified before human use.
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State 4 benefits of genetic engineering and briefly state its impacts	1) Low cost production of medicine -> Increased accessibility -> More patients can be treated 2) Crops that can grow in extreme conditions -> Give farmers financial stability and more food supply 3) Pesticide-resistant/Pesticide killing crops -> Reduced use of pesticides that cause damage to environment + is costly 4) Foods designed to meet specific nutritional goals -> Improve nutritional quality of foods -> Improve human health
State 6 key ethical considerations of genetic engineering	1) Inequality -> GE is expensive, so gene technologies may only be accessible to those with financial means to afford it. 2) Animal Welfare (Eg. Transgenic mice used for cancer research) 3) Long term Harm (Eg. Accidental use of genes that code for antibiotic resistance, making antibiotics ineffective against disease)

	4) Intentional malice (Eg. Deliberately creating gene combinations used in chemical or biological warfare) 5) Impact on Human Health (Eg. New proteins in GM foods may cause allergies in some) 6) Corporate exploitation (Eg. Dependence of farmers on biotech companies as some genetically engineered crops produce seeds that cannot germinate)
Define Asexual Reproduction	It is a process resulting in genetically identical offspring from one parent without the fusion of gametes .
Define Sexual Reproduction	It is a process resulting in genetically dissimilar offspring from 2 parents. It involves the fusion of male and female gametes to form a zygote.
Define Haploid	It refers to cells with only one set of chromosomes. In humans, this is 23 chromosomes.
Define Diploid	It refers to cells with 2 sets of chromosomes. In humans, this is 46 chromosomes.
Why do we need a reduction division process before fertilisation in sexual reproduction?	It halves the number of chromosomes in gametes. Hence when fertilisation occurs, the 2 gametes must combine to restore the normal diploid number in the zygote. (46 chromosomes) Thus important in maintaining the diploid chromosome number.

What is mitosis ?	It is a type of cell division giving rise to genetically identical cells. Chromosome number is maintained.
Why is mitosis important in growth, repair and asexual reproduction?	It's important in its ability to form genetically identical cells. Growth -> New cells must be produced by mitosis Repair -> Replaces damaged cells with genetically identical ones Asexual reproduction -> Produces genetically identical offspring from a single parent.
What is meiosis?	It is a type of cell division giving rise to genetically dissimilar cells. Chromosome number is halved due to the separation of homologous chromosomes.
What is meant by homologous pairs of chromosomes?	They are pairs of chromosomes with the same <u>shape, size, and sequence of genes</u>, but may carry <u>different alleles</u>. *One comes from the mother and one comes from the father.
Function of a sepal?	Sepals <u>enclose and protect</u> the flower in the bud stage.
What is the function of a petal? (3m)	In insect pollinated flowers, they, a) <u>Attract insects</u> for pollination through its brightly colored petals b) Provide a <u>platform for insects to land</u> c) Guide insects to the base of the petal to obtain nectar using the <u>nectar guide</u>.

What is the function of an	Anthers <u>produce pollen grains</u> , releasing them by splitting open
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anther?	when mature. (Note: Pollen grains are haploid male gametes)
What is the function of a carpel (pistil) ?	The carpel or pistil (stigma, style, ovary) is the female part of the flower responsible for sexual reproduction. The stigma receives the pollen grains, the style connects the stigma to the ovary, and the ovule contains an ovum (female gamete).
Outline the process of pollination.	Pollination is the transfer of pollen grains from the anther to the stigma.
How are self and cross pollination different?	Self-pollination is the transfer of pollen grains from the anther to the stigma of the same or different flower of the same plant , while cross pollination is the transfer of pollen grains from one plant to the stigma of a flower in another plant of the same species.
State 3 features of a plant that favors X-poll. (Not in syllabus list)	1) The plant bears either male or female flowers only. 2) The plant has a bisexual flower where the anther and stigma mature at different times 3) The stigma is situated some distance away from the anthers, making self-poll unlikely.

What are the advantages and disadvantages of X-poll? (Not in syllabus list)	Advantage: Beneficial qualities passed down, greater genetic variation which increases chance of survival, more viable seeds -> survive for longer before germination. Disadvantage: 2 parents, dependence on external factors, lower probability of pollination, more energy and pollen wasted
In what ways are insect and wind pollinated plants	1) Presence of nectar and nectar guides

different? (6m)	2) Large brightly colored petals to attract insects vs No petals 3) Wind poll has more pollen grains than insect poll plants 4) Wind: <u>Smooth, tiny, light</u> pollen grains easily blown away by the wind Insect: <u>Large</u> pollen grain with <u>rough</u> surfaces that cling to insect body 5) Wind: <u>Large, feathery stigma</u> protruding out of flower -> Large SA to trap pollen Insect: <u>Small compact stigma</u> that doesn't protrude out of the flower. 6) Wind: <u>Long and pendulous</u> filament with protruding anthers -> pollen grain easily shaken out of anthers Insect: <u>Non-pendulous</u> filament that doesn't protrude out of flower
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Outline the growth of the pollen tube, its entry into the ovule, and fertilisation.	1) After pollination, the pollen grain germinates after coming in contact with the stigma in response to sugary fluid secreted by the mature stigma. 2) A pollen tube grows out from each pollen grain. Male gametes enter the pollen tube. 3) As the pollen tube grows, it secretes enzymes to digest the surrounding tissues of the stigma and style, causing it to grow down the style to the ovary. 4) Pollen tube enters ovary via the micropyle (opening in the ovule) 5) In the ovule, the tip of the pollen tube absorbs sap and bursts, releasing the male gamete.
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	6) The nucleus of the male gamete fuses with the nucleus of the ovum, forming a zygote. (Fertilisation) 7) Ovary develops into a fruit while ovule develops into a seed.
Function of the testes	- Produces sperm and male sex hormones like testosterone. (Male hormones responsible for development and maintenance of secondary sexual characteristics in males)
Function of the scrotum	- Pouch like sac that encloses the testis - Has a slightly lower temperature than the main body cavity, which is essential for proper sperm development.
Function of sperm duct	- Transports sperm released in the testis to the urethra for ejaculation

Function of the prostate gland	Produces a fluid which contains nutrients and enzymes to nourish the sperm and stimulate it to swim actively. It combines with sperm to produce semen.
Function of the urethra	Allow semen and urine to be passed out of the body via the urethra
Function of the penis	As it is an erectile organ, it becomes rigid and upright when it enters the vagina of the woman during sexual intercourse to deposit semen containing sperms .
Function of ovaries (females)	1) Produces female sex hormones like progesterone and oestrogen responsible for the development and maintenance of secondary sexual characteristics. 2) Eggs released from the ovaries when matured

Function of oviducts	Area where mature eggs are released and fertilised Physical Feature: 1) Funnel like opening makes it easier for egg to enter 2) Inner surface lined with cilia to help move the egg along the oviduct 3) Contains smooth muscles which propels the egg and embryo via peristaltic contraction and relaxation.
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Function of uterus	Area where the fetus develops during pregnancy. Embryo is implanted in the soft and smooth uterine lining Physical Feature: Has elastic muscular walls. Smooth muscular tissue contracts and pushes the fetus out during birth.
Function of cervix	Ring of muscles that allow menstrual blood to flow out of the vagina during menstruation.
Function of vagina	Area where semen is deposited during sexual intercourse.
Outline menstrual cycle (natural variation, fertile and infertile phases, effect of progesterone and oestrogen)	Natural variation: 28 day cycle, Egg released in ovulation on Day 14 - Fertile period is Day 10-15 as an egg can survive for 24h while sperm can survive for 3-5 days in the female body. Oestrogen (After menstruation): <u>Repairs and thickens</u> uterine lining, High oestrogen leads to ovulation. Progesterone (After ovulation):

	a) <u>Prevents ovulation and further development of eggs</u> b) Causes uterine lining to <u>thicken further</u>, preparing it for implantation and growth of embryo.
Define fertilisation (in humans)	Process where the nucleus of the male gamete fuses with the nucleus of the female gamete to produce a zygote (fertilised egg cell).

Describe fertilisation and early development of zygote (in terms of the formation of a ball of cells)	1) Cilia lining on the inner surface of the oviduct sweep the zygote along the oviduct. Peristaltic movement of the oviduct wall also helps move zygote to the uterus. 2) Zygote divides by mitosis to form a ball of cells called the embryo (Energy for this cell division provided by nutrients in the egg) 3) Embryo eventually gets embedded in the uterine lining. This implantation usually occurs 7 days after fertilisation.
Describe how the placenta is developed (Not in syllabus list)	1) After implantation, villi begins to grow from the embryo into the uterine lining. It contains blood capillaries of the embryo 2) Villi and uterine lining make up the placenta 3) Umbilical cord attaches embryo to the placenta
Function of amniotic fluid and/or sac	1) Shock absorber that supports and cushions fetus before birth. 2) Protects fetus from physical injury as fluid is incompressible 3) Allows fetus a degree of movement, promoting muscular development 4) Lubricates and reduces friction in vagina and birth canal before birth.

Function of placenta	1) Allow O₂ and dissolved food substances to diffuse from maternal to fetal blood 2) Allow metabolic waste and excretory products to diffuse from fetal to maternal blood 3) Allow productive antibodies to diffuse from maternal to fetal blood to protect fetus against certain diseases 4) Produces oestrogen and progesterone which maintains the uterine lining.
Function of umbilical cord	1) 2 umbilical arteries transport deoxygenated blood and metabolic waste substances from fetus to placenta 2) 1 umbilical vein transport oxygenated blood and food substances from placenta to uterus.
How is HIV transmitted?	1) Sexual intercourse with the infected person 2) Sharing hypodermic needles with an infected person 3) Blood transfusion with blood from infected person 4) Via pregnancy from infected mother to fetus
What are some methods to reduce transmission of HIV?	1) Keep to one sexual partner / Abstinence 2) Wearing condoms to reduce risk of infection 3) Not sharing instruments likely to break the skin / contaminated with blood 4) Using sterilised needles for acupuncture, tattoo, ear piercing, etc.
Distinguish between genes and alleles	Genes are units of inheritance that are made up of a sequence of nucleotides that control the formation of a single polypeptide.

	Alleles are different forms of the same gene, giving rise to variations of the specific trait or characteristic of the gene. They occupy the same relative position of a pair of homologous chromosomes.
Explain what dominant, recessive, and codominant mean.	Dominant: Allele that expresses itself even when paired with a different allele Recessive: Allele that expresses itself only when paired with another identical allele. Codominant: Both alleles express themselves in the heterozygote, which has a phenotype intermediate between its pure bred parents.
Explain the term homozygous and heterozygous	Homozygous: Having 2 identical alleles of a particular gene Heterozygous: Having 2 different alleles of a particular gene.
Explain the terms genotype and phenotype	Genotype: Combinations of alleles for a particular gene Phenotype: Expressed trait or outward experience

Why do observed ratios differ from expected ratios, esp when there's a small number of progeny	Due to the random nature of fertilization, when sample number is too small, the ratio will be statistically inaccurate due to the random nature of fertilisation. (Eg. expected ratio of dominant to recessive is 3:1 in theory)
What factors increase the rate of mutation?	Exposure to ionising radiation (Eg. X-Ray) Exposure to chemical mutagens (Eg, tar, formaldehyde, LSD drugs)

What is a mutation	Change in the sequence of a gene (Sickle cell anemia) or number of chromosomes (47 chromosomes in Down Syndrome)
Describe how continuous and discontinuous variations differ.	Discontinuous: Involves a few clear cut phenotypes, controlled by fewer genes, No additive effect in genes, Relatively unaffected by environmental conditions Continuous: Involves a range of phenotypes, controlled by more genes, additive effect in genes, Greatly affected by environmental conditions
Give an example of continuous and discontinuous variation.	Discontinuous: Eye color, Blood type, ability to roll tongue, attached earlobes Continuous: Height, Weight, Skin pigmentation in humans, (Number of seeds)
What does variation and competition lead to?	It leads to differential survival and reproduction by organisms best fitted to the environment.

What are some environmental factors that act as forces of natural selection?	Climate -> Determines which organism survive and reproduce under certain temperature, rainfalls, or seasonal conditions Habitat type -> Favors trait suited to physical environment (Eg. camouflage, burrowing ability, climbing) Available food -> Selects for organisms with traits that efficiently obtain / digest / complete for food source Habitat's predators -> Drives evolution of defensive traits like
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	speed, camouflage, toxins, or protective behaviours.
Explain the role of natural selection as a mechanism for evolution. Key Words: Spontaneous mutation, competition, survival of the fittest, favorable genes and characteristics best fitted to the environment, pass on favorable genes to offspring, predominant variety	Evolution by Natural Selection: 1) Competition due to food, diseases, or predators and Variation (differences in genes and characteristics) caused by mutagens lead to differentiated survival and reproduction by organisms best fitted to the environment. 2) Organisms with favourable genes or characteristics make them better adapted to environmental conditions and most likely to survival (Survival of the fittest) 3) Organisms that survive pass down their favourable genes to their offspring. Over time, more beneficial qualities (genes or alleles) accumulate in a species, leading to evolutionary change.