Biology

Notes For Year 3 and Year 4

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Contents

Biological Molecules

Carbohydrates

- Made up of elements C, H, O
- 1g of carbohydrates yields 16kj of energy
- **3 types of carbohydrates**
    - Monosaccharides
    - Disaccharides
    - Polysaccharides

Monosaccharides:

- All with molecular formula $C_6H_{12}O_6$ (they are all isomers)
- Glucose
- Fructose (sweetest sugar)
- Galactose

Disaccharides:

- All with molecular formula $C_{12}H_{22}O_{11}$
- Two sugar units bonded together by dehydration synthesis (removal of water)
- Dehydration synthesis is also called **condensation reaction**.
- Formation of a complex molecule from the bonding of 2 simpler molecules with the **removal of a molecule of water.**
    - The bond between two monosaccharides is called a glycosidic bond
- Can be broken down by hydrolysis reaction/hydration (addition of water).
    - Sucrose – glucose + fructose
    - Lactose – glucose + galactose
    - Maltose – glucose + glucose

Polysaccharides

- Macromolecules of a few 100 or 1000 monosaccharides
- Formed by linking monomers in **enzyme mediated dehydration synthesis**
- Have 2 important functions
  - Energy Storage (starch and glycogen)
  - Structural Support (cellulose and chitin)

Storage Polysaccharides

Starch and glycogen are convenient storage molecules because :

- Large size makes them insoluble in water, exert no osmotic influence on cells

- Fold into compact shapes
- Easily converted to sugars by hydrolysis when required

Tests on Carbohydrates:

Test for reducing sugar (all mono and disaccharides except sucrose)

Benedict's Test

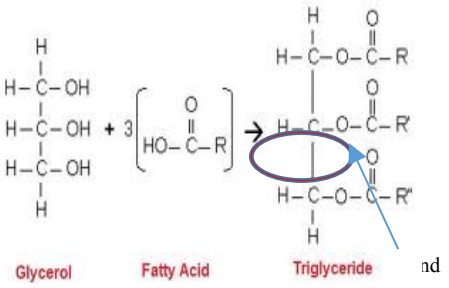
- To a test sample of unknown solution, add an equal amount of Benedict's solution. Shake. Heat in a boiling water bath.
- **Positive test:** a coloured precipitate is seen, with different colours indicating different concentrations of reducing sugars.
    - Green ppt → yellow ppt → orange ppt → red ppt → brick red ppt (increasing amounts of reducing sugar)
- **Negative test:** solution remains blue (colour of Benedict's solution)

Starch Test

- Add a few drops of iodine solution to unknown sample.
- Positive test: Blue black mixture is seen
- Negative test: Mixture remains yellowish brown (colour of iodine solution)

Lipids

- Made up of the elements C, H, O
- 1g of fat yields 38kj of energy
- No fixed molecular formula
- **Types of lipids**
  - Animal and vegetable fats (triglycerides)
  - Phospholipids
  - Steroids



Triglyceride molecule:

- Made up of glycerol and 3 fatty acids
- Formed by dehydration synthesis (condensation)
- Breakdown by hydrolysis

Lipids:

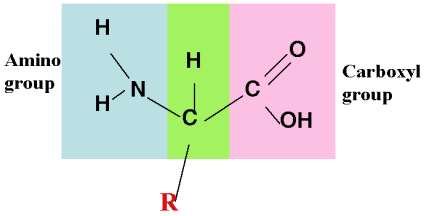
- Saturated fats: **no double bonds** present in fatty acid chain
- Monosaturated fats: presence of **1 double bond** in fatty acid chain
- Polyunsaturated fats: presence of **2 or more double bonds** in fatty acid chain

Ethanol Emulsion Test *(Test for fats)*

- Add 2 cm^3 of ethanol to a drop of oil in a test tube
- Shake mixture thoroughly (oil will be seen to dissolve in ethanol to form a clear solution)
- Add 2 cm^3 of water to the mixture and shake. A white emulsion is formed and heat is evolved (test tube feels warm)
- Negative test: No white emulsion is seen on shaking with water

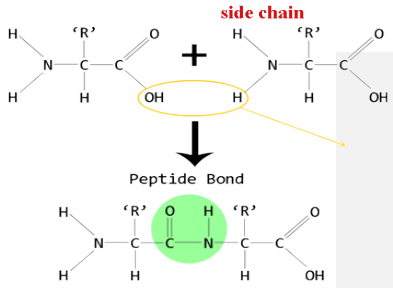
Proteins:

- Made up of the elements C, H, O, N and some contain S and P
- 1g of proteins yields 17kj of energy
- Basic unit of protein = **amino acid**
- By **dehydration synthesis**, amino acids can be joined to form dipeptides and polypeptides.
- Proteins/ peptides can be broken down to their respective amino acids by **hydrolysis**



Peptide bond:

- Formed when carboxyl group of one molecule reacts with amino group of another molecule



- **Dehydration synthesis** reaction (release of one H2O molecule)
- Usually occurs between 2 amino acids
- Amino acids vary in their side groups, which give them their unique properties

Biuret Test *(Test for proteins)*

- To 2 cm^3 of protein solution in a test tube, add 2cm3 of sodium hydroxide solution
- Shake mixture thoroughly
- Add copper sulphate solution to the mixture, drop by drop, shaking after each drop
- **Positive test** – a violet/ purple colouration is seen
- **Negative test** – solution remains blue (colour of copper sulphate solution)

Plant Nutrition (NS)

Role of Photosynthesis

- Plants are autotrophs - they produce their own food
- Most other animals are heterotrophs, they rely on autotrophs for nutrition
- Photosynthesis is effectively the source of all food on earth
- Maintains CO_2 in air, prevents accumulation of CO_2 which can cause harmful effects such as
    - Greenhouse effect / global warming
    - Health problems

Photosynthesis

Photosynthesis Equation							
Carbon dioxide	+	Water	SUNLIGHT →	Sugar	+	Oxygen	
$6CO_2$		$6H_2O$		$C_6H_{12}O_6$		$6O_2$	

- Photosynthesis is:

- Rate of photosynthesis is limited by
    - Light intensity → limits amount of energy available to carry out the reaction
    - Concentration of CO_2 → limiting reactant of reaction
    - Temperature → nonoptimal temperatures cause enzymes to function at a suboptimal rate → limits rate of reaction
- One of these factors is a limiting factor; it is the factor which is preventing the rate of reaction to increase any further
- Limiting factor of photosynthesis is usually CO_2 concentration
- Can be split into light dependent stage and Calvin cycle
    - Light dependent stage takes place in chlorophyll, uses H_2O to absorb light and produce ATP, NADP**H**
    - Calvin cycle uses energy from ATP and H from NADPH, combined with previously collected CO_2 to form glucose, sending ADP and $NADP^+$ back to the light dependent stage
- Magnesium is needed to synthesize chlorophyll
- Nitrogen is needed to produce RUBISCO, an enzyme which turns CO_2 into an organic molecule

Use of Glucose

- Used to produce cellulose and repair plant cells
- Converted to starch for storage, able to keep large amounts of energy without affecting osmotic pressure
- Converted to sucrose to be transported to rest of cell
- Used in cellular respiration

Cellular Respiration

Uses of Energy

- Muscle contraction
- Protein synthesis
- Cell division
- Active transport
- Growth
- Passage of nerve impulses
- Thermal homeostasis / thermoregulation

Aerobic Respiration	Anaerobic Respiration
Occurs in the presence of Oxygen (O_2)	Occurs in the absence of Oxygen (O_2)
Produces a lot of ene1rgy	Produces very little energy
2 reactants: ● Glucose (C6H12O6) ● Oxygen (O_2)	1 reactant: ● Glucose (C6H12O6)
Glucose + Oxygen → Carbon dioxide + water + large amounts of energy C6H12O6 (aq) + 6O2(g) → 6CO2 (g)+ 6H2O(l) + Large amounts of energy.	**In humans**: Glucose → Lactic Acid + Small amounts of energy C6H12O6 (aq) → 2C3H6O3 (aq) + Small amounts of energy. **In yeast (Alcoholic fermentation):** Glucose → Ethanol + Carbon dioxide + small amounts of energy C6H12O6 (aq) → 2C2H5OH (aq) + 2CO2(g) + Small amounts of energy.

Role of Adenosine Triphosphate (ATP)

- A temporary energy storage molecule
- Carries energy to cells that need it, then
- Breaks its ADP-P bond, releasing energy, becoming Adenosine Diphosphate (ADP).
- Will then regain its energy be re-bonding with P through the process of phosphorylation

Oxygen Debt

- Under strenuous physical activity, the body may need more energy than it is normally able to produce by aerobic respiration.
- It kicks into the secondary method of anaerobic respiration.
- Aerobic respiration CONTINUES, but anaerobic respiration assists to convert more glucose into energy
- Lactic acid accumulates in the muscles respiring heavily, causing cramps

Aerobic Respiration and Photosynthesis

- Aerobic Respiration = Glucose + Oxygen → Water + Carbon Dioxide + Energy

- Photosynthesis = Water + Carbon Dioxide - {Sunlight} > Glucose + Oxygen
- Polar opposites of each other

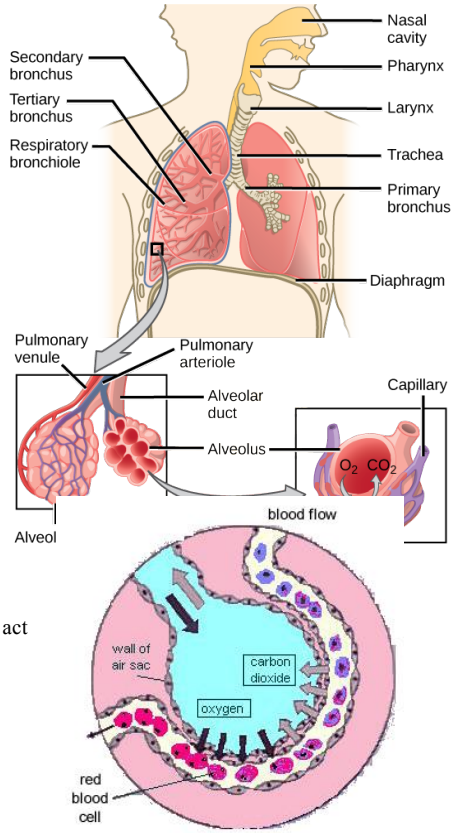
External Respiration

Principles of Gaseous Exchange

- Organisms need to take in O_2 while maintaining a relatively closed internal system
- Gas exchange would hence occur by diffusion through cells
- Rate of diffusion is directly proportionate to the surface area of the respiratory surface
- Due to Square-Cube rule, larger animals require specialised respiratory systems to increase the rate of gas exchange since natural diffusion is unable to sustain life.

The Human Respiratory System

- Nose and mouth allow for gas to enter the respiratory system
- Air enters pharynx, larynx, and finally trachea
- Air passes into bronchi and bronchioles before reaching the alveoli
- Gaseous exchange takes place between gas in alveoli and capillaries surrounding the alveoli
- Ribs protect the lungs from external injury
- Diaphragm triggers expansion and contraction of thoracic cavity, creates pressure systems fit for exhaling and inhaling
- Intercostal muscles act accordingly with diaphragm, external contracts when inhaling and internal contracts when exhaling
- Ribs, diaphragm and intercostal muscles all act together to breathe



Muscles and Bone Structures Involved; Pressure Gradient

Ribs

-12 pairs of ribs

-Front attached to sternum
-Back attached to vertebral column

Intercostal muscles
-External and internal
-When one contracts, other relaxes
-Moves ribs to change volume of thoracic cavity

Diaphragm
-Thin sheet of tissue that separates thorax from abdomen.
- Contract----→ Flattens downwards-----→ Thoracic cavity volume increases
- Relax------→ Arches upwards------→ Thoracic cavity volume decreases

Inspiration
- External intercostal muscles contract, internal intercostal muscles relax----→ Ribs swing upwards and outwards, sternum further from backbone------→ Dorso-ventral diameter increases-----→ **Thoracic cavity enlarges**
- Diaphragm contracts-----→ Flatten downwards--→ **Thoracic cavity expands**
- **Thoracic cavity expands**----→ Lungs expand to fill up space-------→ Air pressure in lungs lower than atmospheric pressure----------→ **Air fills lungs**

Relax **I**nternal, **C**ontract **E**xternal (RICE)

Expiration
-External intercostal muscles relax, internal intercostal muscles contract----→ Ribs lowered and inward------→ Returns to original position---------→ Dorso-ventral diameter returns to original----------→ **Thoracic cavity contracts**
- Diaphragm relaxes---------→ Arches upwards-------→ **Thoracic cavity contracts**
- **Thoracic cavity contracts**--------→ Lungs contract--------→Air pressure in lungs higher than atmospheric pressure----------→ **Air rushes out**

External **R**elax, **I**nternal **C**ontract (ERIC)

The Alveoli

- Smallest unit of the lungs, exact location of diffusion of CO_2 and O_2
- Cell wall of alveoli and capillary are one cell thick to allow diffusion to occur easily
- Lining of moisture of alveoli allows for gas to dissolve and speed up diffusion
- Alveoli wall has many capillaries to increase surface area of diffusion

Respiratory System and Other Systems

- Immune System
    - Nose hairs trap dust and pathogens

    - Cilia in bronchi and bronchioles secrete mucus to trap dust and pathogens, slow movement of cilia propels mucus out of lungs
    - Also warm the air
- Circulatory System
    - One half of heart dedicated to sending blood to lungs
    - Priorities half of blood collect gas, half of blood use gas
    - Faster heart rate causes faster gas exchange, more O_2 supply to rest of body

Rate of Respiration

- Determined by the pH of the blood
- CO_2 in blood lower the pH of the blood since HCO_3^- and H^+ are produced when dissociated
- Higher CO_2 concentration → pH → Breathing rate
- NOT dependent on O_2 concentration

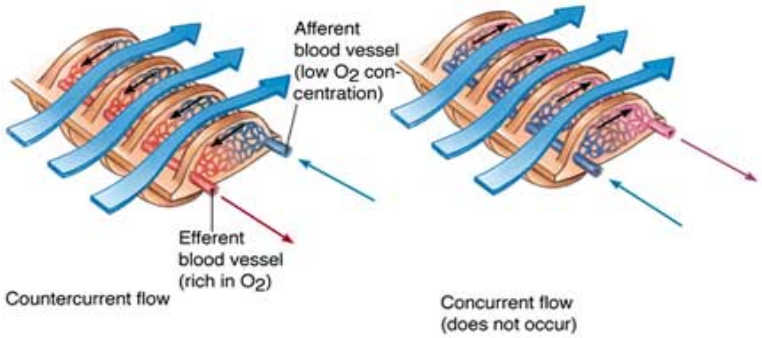
Inhaled and Exhaled Air

Compound	**Inhaled Air**	**Exhaled Air**
O_2	21	16
CO_2	0.04	4
N_2	79	79

Water as a Respiratory Medium

- **Advantages**
    - Pre-dissolved gases easier to diffuse
    - Countercurrent principle applied
- **Disadvantages**
    - Lower concentration of O_2
    - Inability to utilise pressure gradient

Countercurrent Gas Exchange in Fish



- Flow of water is against flow of blood
- Water always has a higher concentration of O_2
- Constant diffusion gradient is maintained throughout the blood
- More O_2 diffuses

Respiratory Disorders

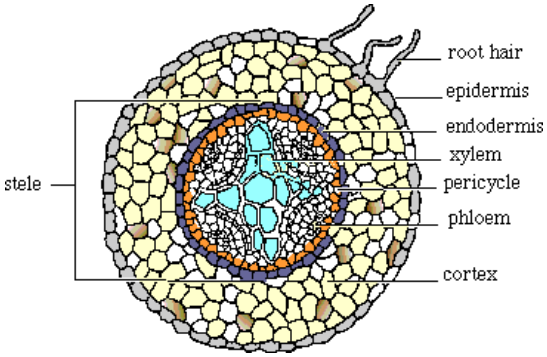
- Smoking can cause health problems
- Emphysema where alveoli walls are broken, less surface area for gas exchange
- Lung Cancer
- Bronchitis, smaller venue for gas to pass through into lungs
- Carbon monoxide binds with haemoglobin to form carboxyhemoglobin irreversibly
    - Less haemoglobin available to transport oxygen

Transport in Plants

Structure of a Plant

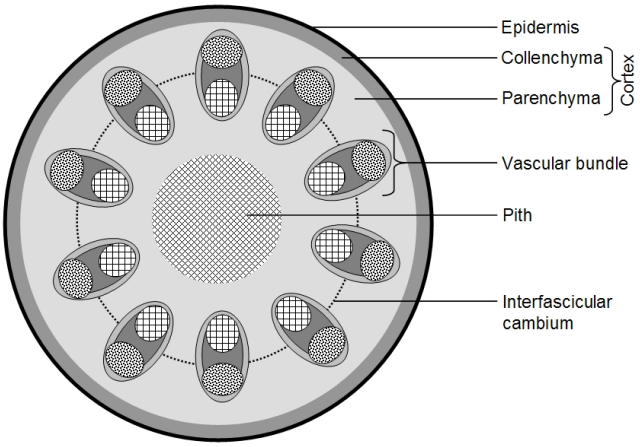
- Plants consist of 3 main parts
  - Water and mineral collecting **roots**
  - Transporting and supporting **stems**
  - Glucose-producing **leaves**

Structure of Roots



- Root hairs take in mineral salts via active transport.
- Due to higher concentration of mineral salts, water enters the root cell via osmosis.
- Epidermis protects cells from external environment
- Cortex is the bulk of the root mass, provides support for rest of root
  - Parenchyma cells store starch
- Endodermis separates cortex from stele which has a casparian strip
- Pericycle parenchyma cells are in between the phloem and endodermis, multiply to create lateral roots
- Xylem in root transports water up
- Phloem in roots receives food from rest of plant

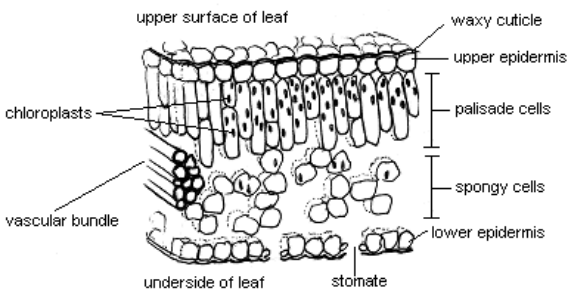
Structure of Stem



Cross-section through a young non-woody dicot stem

- Cuticle waterproofs the stem with cutin
- Epidermis protects stem from external environment
- Cortex is bulk of plant material, used to support plant and to store starch
- Vascular bundle contains various transport components
    - Xylem on the inner surface which transports water to leaves and supports plant through growth of sturdy lignin
    - Cambium which actively divides to maintain vascular bundle
    - Phloem on the outer surface which transports food to rest of leaves
- Pith contains storage parenchyma cells while supporting plant

Structure of Leaf



- Cuticle waterproofs leaf using a layer of cutin
- Upper epidermis protects leaf
- Palisade mesophyll cells are tightly packed and contain chlorophyll

- Spongy mesophyll cells are loosely packed with many air spaces and contain chlorophyll
- Lower epidermis protects lower surface of plant
- Stomatal guard cells in lower epidermis open and close stomata by absorbing and releasing water respectively

Structure of the Vascular Bundle

Xylem

- Found in center of root, inner side of vascular bundle in stem and top of vascular bundle in leaf
- Take part in lignification, where lignin is deposited on the surface of the xylem which then
    - Strengthen the xylem
    - Prevents breakages
    - Less hydrophilic, prevents osmosis of water to parenchyma cells
- Forms a continuous and hollow tube for water to flow without obstruction
- Xylem is the “hollow corpse” of previous cells

Phloem

- Found in outside of root, outer side of vascular bundle in stem and bottom of vascular bundle in leaf
- Consist of sieve tube elements and companion cells
- Companion cells maintain and nourish sieve tube elements
- Cell walls between sieve tubes are perforated to form sieve plates for nutrients to pass through
- Cells are living

Transpiration Cycle

Water entering the root

- Mineral salts absorbed by root cells via active transport
- Water osmoses into root cells
- Transfers from root hairs to xylem via
    - Apoplast pathway in cell wall
    - Symplast pathway in cytoplasm, especially due to plasmodesmata joining multiple cells via cytoplasm
    - Vacuolar pathway from vacuole to vacuole
- Minerals and water enter symplast of root hair cells
- Mineral solution transferred through apoplast
- Solution passes through casparian strip which controls flow of solution
- Solution reaches xylem

Water Exiting the Leaf

- Water in xylem enters mesophyll cells and travel from cell to cell via osmosis
- Water evaporates from mesophyll cells
- Water vapour diffuses out from intercellular spaces to out of stomata
- Water is transpired

Factors Affecting Transpiration

- Relative Humidity = Water vapour in air / Water vapour in leaf * 100%
- Temp ++ > RH -- & KE ++ > Diffusion gradient ++ > Rate ++
- Wind Speed ++ > RH -- > Diffusion gradient ++ > Rate ++
- Light ++ > Photosynthesis ++ > Water usage ++ > Water evaporation ++ > Rate ++
- Water availability

Transport of Water

- Root pressure forces water up
- Capillary action makes water climb up thin xylem due to surface tension (adhesion)
- Transpirational Pull applies a tension that pull water up the xylem vessel, due to H-bonds in between water molecules (cohesion)

Transport of Food

- Sucrose loaded into phloem from source cell via active transport
- Water from xylem osmoses into phloem
- Incoming pressure from water forces sap to move
- Pressure is relieved by unloading of sucrose to sink cell via active transport
- Water is returned to xylem

Reduction of Transpiration

- Guard cells which can close to limit the flow of water vapour
- Thick cuticle to reduce water loss by evaporation
- Multiple layered epidermis to reduce water loss further
- Sunken stomata with hairs to form saturated air outside of stomata, reducing internal diffusion gradient

Transport in Man

Need for a circulatory system

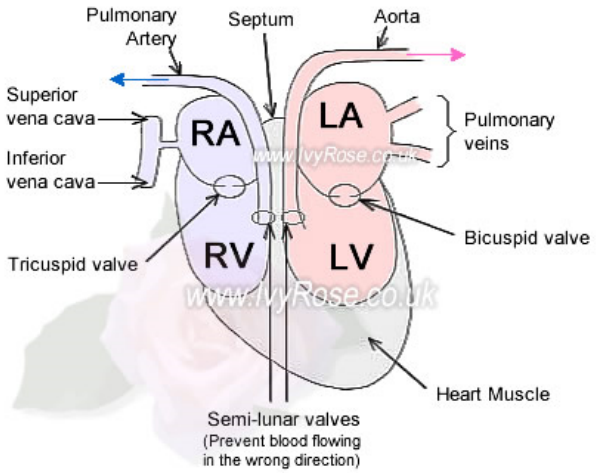
- materials and energy have to be exchanged with the environment, often on a cellular level
- simple organisms have cells in direct contact with the environment to exchange gases, nutrients or water through diffusion
- multicellular organisms are complex and there is a higher amount of materials and distance these materials have to travel
- direct exchange is not possible, and diffusion is inefficient due to the large surface area to volume ratio
- a circulatory system, with parts like a pump, vascular system and circulating fluid allow for diffusion, the constant exchange of fluids and a difference in pressure allowing for substances to be exchanged

	Closed Circulatory System	**Open Circulatory System**
Blood Flow	arteries to carry blood to capillaries, capillaries are site of exchange between blood and interstitial fluid, veins return blood to heart	circulatory fluid pumped through open ended vessels to cells, cells bathed directly in nutrient
Fluid	circulating fluid distinct from interstitial fluid, high blood pressure to allow effective delivery	circulating fluid is interstitial fluid

Double Circulatory System

- blood passes through heart twice
- high pressure maintained
- pulmonary circulation: heart to lungs to heart
- systemic circulation: heart to body to heart
    - blood from heart to rest of body, blood is rich in oxygen/nutrients or carries waste
    - arteries contain O_2, nutrient rich blood
    - veins contain CO_2, waste
- right side of heart pumps only deoxygenated blood, left side of heart pumps only oxygenated blood
- deoxy blood from body enters right side of heart → leaves heart to lungs for gas exchange → oxy blood from lungs enters left side of heart → leaves heart to proceed to rest of body → deoxy blood from body enters right side of heart

Structure of Heart



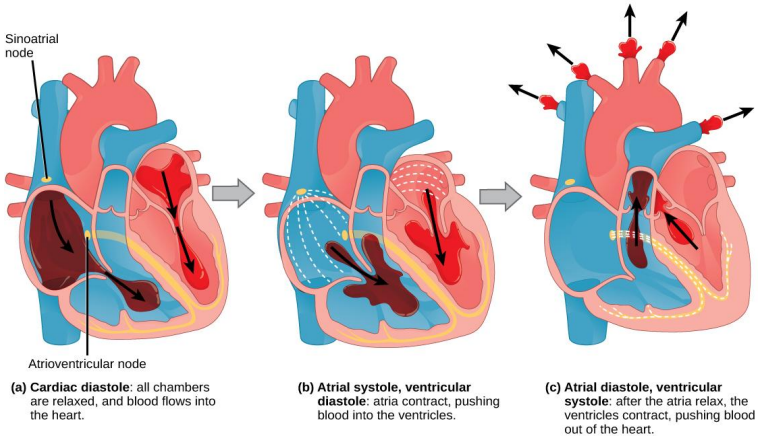
atria: thin walled as most blood that enters goes to ventricles
ventricles: thick and generates high pressure. left ventricle is 3x thicker than right ventricle (as it has to pump blood to the whole body).
atrioventricular valves: just a flap, opens with contractions of the heart. allows the blood to flow in one direction
tricuspid valve: between chambers of right side
bicuspid valve: between chambers of left side
semilunar valve: present in arteries leaving heart
pulmonary, aortic veins: prevents backflow
venae cavae: veins entering right atrium, carries deoxygenated blood from rest of body
pulmonary arteries: exits right ventricle of heart, carries deoxygenated blood to lungs and loads O_2.
pulmonary veins: enters left atrium of heart, carries oxygenated blood from lungs to heart
aorta: artery existing left ventricle, carries oxygenated blood to the rest of the body

Cardiac Cycle

	state of muscles	**blood flow**	**state of**	**state of tricuspid,**

			semilunar valves	**bicuspid valves**
ventricular diastole (0.4s)	all heart muscles relax	blood flows into atria then into ventricles	semilunar valves close	tricuspid and bicuspid valves open
atrial systole (0.1s)	atria contracts	blood flows from atria into ventricles	semilunar valves closed	tricuspid and bicuspid valves open
ventricular systole (0.3s)	ventricles contract	blood forces out from ventricles into arteries	semilunar valves open	tricuspid and bicuspid valves close

- Contraction → systole
- Relaxation → diastole



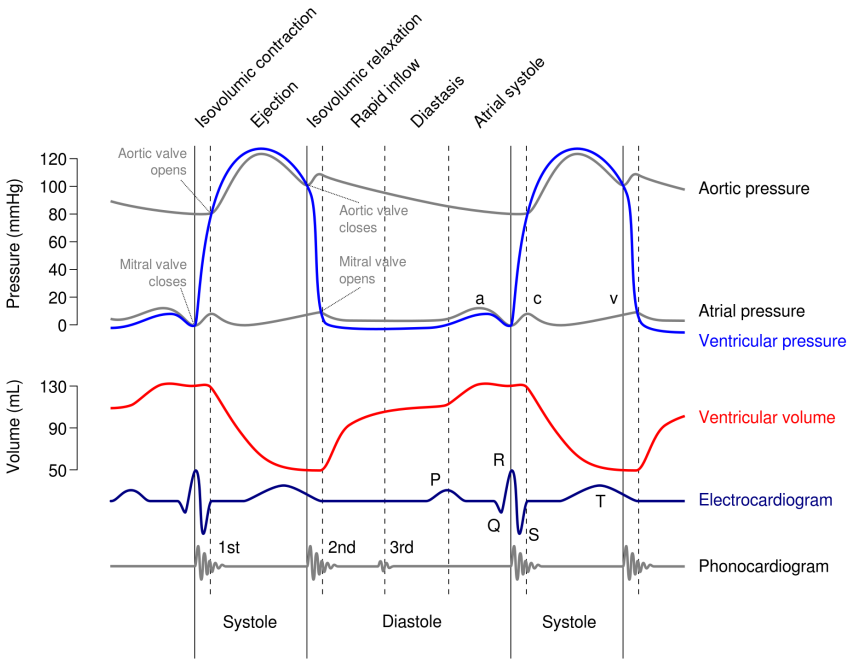
(a) Cardiac diastole: all chambers are relaxed, and blood flows into the heart.

(b) Atrial systole, ventricular diastole: atria contract, pushing blood into the ventricles.

(c) Atrial diastole, ventricular systole: after the atria relax, the ventricles contract, pushing blood out of the heart.

- Heart rate = number of cardiac cycles per min.

- Cardiac cycles are kept in rhythm by the sinoatrial (SA) node or pacemaker, atria contract
- Impulses from SA node travel to atrioventricular (AV) node
- Impulses delayed at AV node
- Impulses travel to Bundle of His and Purkinje fibres, ventricles contract
- Impulses can be measured using an electrocardiogram/ECG



- Pressure is exerted onto the walls of the four heart chambers during systole
- Low pressure is exerted in mitral valves/ right ventricle as blood flow is only required to go to the pulmonary circulatory system (to the lungs)
- High pressure is exerted on aortic valve/left ventricle as blood flow is to the aorta and to the rest of the body
- Thickness of left ventricle is about 3x more than right ventricle due the different pressures they need to exert onto blood

Blood Vessels

	arteries	**veins**	**capillaries**
function	carry oxygenated blood away from heart	carry deoxygenated blood towards heart	connect arterioles and venules, allow for exchange between blood and cell
structure	branch and narrow into arterioles, arterioles further branch and narrow into capillaries	widened from venules	branch and widen into venules
endothelium	thicker, muscular and more elastic walls than veins	thinner walled vessels	thin, one celled thick walls
smooth muscle, connective tissue and elastic fibre	accommodates and maintains high pressure of blood pumped from the heart	extremely low blood pressure	not present
valves	no valves	valves present to prevent backflow of blood	no valves
structural features	-	skeletal muscles contract during movement, pressure exerted on veins by the surrounding contracting muscles. blood pushed through one way valves, and muscular contractions help to move blood along	branches repeatedly: large surface area for exchange of materials between blood and tissue cells, rapid diffusion can occur. exchange driven by osmotic and hydrostatic gradients (difference in water potential).

Blood Pressure

Blood pressure is the hydrostatic pressure that blood exerts against the walls of a vessel.

- systolic pressure is pressure in the arteries during ventricular systole, is the highest pressure in arteries
- diastolic pressure is the pressure in arteries during diastole, is lower than systolic pressure

It is determined by cardiac output (volume of blood pumped by each ventricle per minute) and peripheral resistance (variable constriction of arterioles to generate resistance to flow)

Exchange of Materials

There is a critical exchange of substances between the blood and interstitial (tissue) fluid, which occurs across the thin endothelial walls of the capillaries. The difference between the hydrostatic (blood) pressure and osmotic pressure drives fluids out the capillaries at the arteriole end and draws fluids into the capillaries at the venule end. Protein, plasma and other macromolecules are not forced out. Fluid reenters the circulation directly at the venule end of the capillary bed, and indirectly via the lymphatic system.

Components of Blood

Plasma 55%	**Platelets** <1%	**Red Blood Cells** 45%
Pale yellowish substance about 90% water, and contains salts, dissolved ions and proteins and antibodies	irregular in shape, colorless (white blood cells). platelets are not true cells and are fragments of cytoplasm from bone marrow cells.	Circular, flattened, flexible biconcave discs without nuclei and containing haemoglobin
Transports dissolved nutrients and removes waste products like carbon dioxide, lactic acid and urea		Lifespan of 3-4 months, produced in bone marrow and destroyed in spleen and liver
Three ways plasma transports carbon dioxide: ● dissolved CO_2, where about 5% of CO_2 is transported unchanged and dissolved ● binding reversibly to haemoglobin , where about 15% of CO_2 binds to amino groups on polypeptide chains ● bicarbonate ions: about 80% forms carbonic acid with water, then dissociates to form bicarbonate ions and hydrogen ions	Platelets reduce blood loss, help in clotting when endothelium of blood vessel is damaged. white blood cells protect body from microorganisms	Haemoglobin contains a protein chain, and an iron-containing haem group. haem group can bind to an oxygen molecule forming oxyhaemoglobin, which is needed as a transport as oxygen otherwise has low solubility in water. $\mathbf{Hb(aq) + 4O_2(aq) \Leftrightarrow HbO_8(aq)}$

$H_2O(l) + CO_2(aq) \Leftrightarrow H_2CO_3(aq) \Leftrightarrow H^+(aq) + HCO_3^-(aq)$		

Reflex Action, Eye, Muscles and Movement

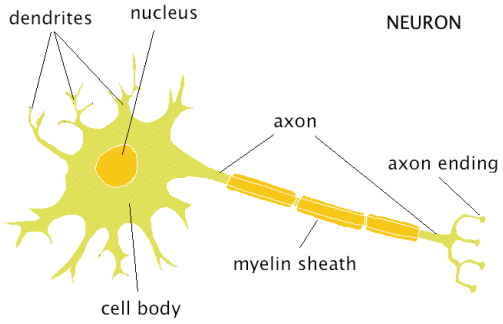
The Nervous System

The central nervous system consists of the brain and spinal cord, while the peripheral nervous system consists of the cranial nerves from brain, spinal nerves and receptors like nerve endings and specialized cells in sensory organs.

When a stimulus is detected by receptors, information is sent via sensory nerves to the central nervous system, and the central nervous system receives information and processes it, decides a response and sends a response via motor nerves to effectors.

Sensory/Receptor	Carries impulses from receptors to central nervous system. There is a single long dendron and short axons, and it begins at a sensory organ and transmits impulses to a relay neuron or straight to a motor neuron
Motor	Carries impulses from central nervous system to effectors. There is a single long axon and several short dendrons.
Relay	Carries impulses from central nervous system to effectors and transmit impulses from upwards or downwards of brain.

A neuron is a specialized cell for carrying information in the form of electrical impulses from receptors to the central nervous system and from the central nervous system to effectors.



Cell body	Contains nucleus, cytoplasm, membrane
Axon	Transmits impulses away, may be covered with myelin sheath

Dendron	Conducts impulses to cell body
Dendrites	Numerous highly branched extensions that receive impulses from other neurons
Myelin Sheath	Thin membrane that provides nourishment
Node of Ranvier	Unmyelinated part of axon/dendron where impulses are faster
Synapse	Junction between 2 neurons
Neurotransmitter	Chemical substance released at synapse to help with transmission

Central Nervous System

White matter	Axons, myelin. Mainly nerve fibres
Grey matter	Mainly cell bodies
Spinal cord	Collection of neurons which passes through and is protected by vertebral column 31 pairs of spinal nerves which emerge at regular intervals Central canal runs through middle of spinal cord, with cerebrospinal fluid to nourish neurons and to cushion CNS Front/ventral spinal nerve has motor neurons cell bodies found within grey matter Rear/dorsal spinal nerve contains sensory neurons, cell bodies found in dorsal root ganglion
Spinal Nerves	Bifurcates into ventral roots (only motor neurons, found in grey matter) and dorsal roots (only sensory neurons that aggravate a swelling called dorsal root ganglion)
Central canal	Narrow canal running through middle of spinal cord, carries cerebrospinal fluid that brings nutrients to spinal cord and cushions central nervous system.

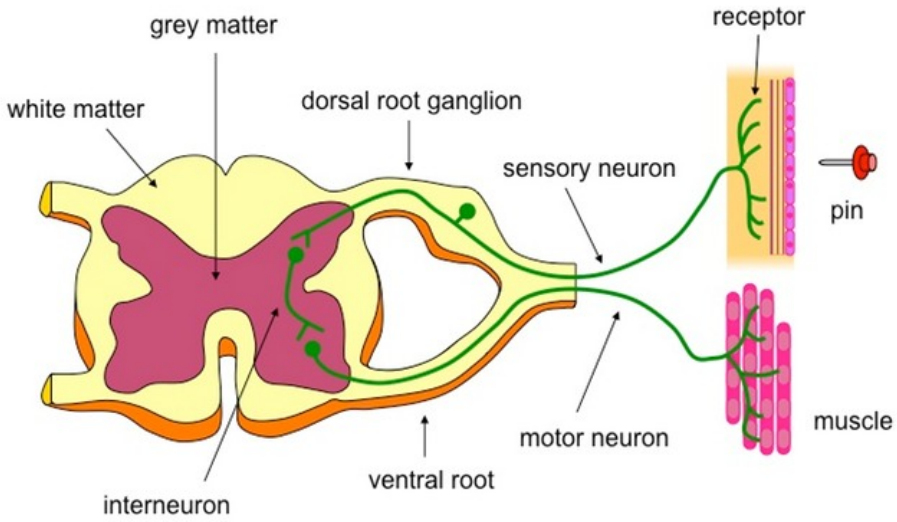
Reflex Action

A reflex action is an automatic/spontaneous/immediate/rapid response to stimuli without conscious control, and often protects the body from physical injury. Impulses go through the reflex arc, which is the shortest pathway impulses can travel from receptor to effector.

When hand touches hot object,

1. Stimulates nerve endings in skin
2. Nervous impulses are initiated by receptors
3. Impulses travel along dendron of sensory neuron to spinal cord
4. In spinal cord, impulses travel across synapse to the relay neuron
5. Impulses transmitted across another synapse to motor neuron
6. Impulses leave spinal cord and travel along axon of motor neuron to effector
7. Effectors are bicep muscles, and they contract, bringing about a sudden withdrawal of hand (response)

Axon of sensory neuron has many branches in spinal cord. One branch may form a synapse with a relay neuron → transmitting impulses up to the brain. Another may form a synapse with a motor neuron → voice box. Spinal cord acts as a coordinator for simple reflex action.



Conditioned Reflex Action

- Reflex action acquired from past experience
- Previously unrelated / ineffective stimulus is conditioned, future responses achieved due to stimulus after conditioning

Eye

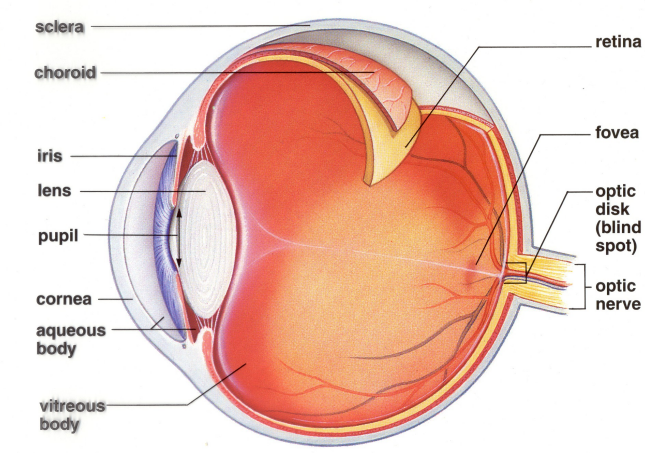


Fig. 32.30 Structure of the human eye.

Component	Description	Function
Cornea	Bulge at front of sclera, convex and transparent	Protects front of eye and refracts light, bent most here
Conjunctiva	Membrane covering exposed front of the eye	Protects exposed part of eyeball
Sclera	Opaque and white outer coat of the eye, tough and fibrous outer layer covering whole eyeball, eventually forming cornea	Protection of entire eyeball
Choroid	Middle covering of eyeball which is black, eventually forming ciliary body and iris	Contains capillaries which nourish eyeball, black pigment prevents TIR and hence prevents multiple images
Iris	Pigmented part of eyeball which light cannot pass through, disc shaped structure with pupil in middle. Contains radial and circular muscles to control size	Controls diameter of pupil by adjusting circular and radial muscles Prevents damage from too much light
Pupil	Hole in center of iris, formed by lack of choroid	
Lens	Transparent biconvex and elastic disc	Refracts light to focus image on retina

	behind iris which is attached to suspensory ligament	
Ciliary Body	Ring of muscle fibres around lens	Contracts and relaxes to control lens thickness and curvature
Suspensory Ligament	Ligament between lens and ciliary body	Connects lens to ciliary body
Retina	Innermost layer of eye, contains photoreceptive cells which are connected to optic nerve	Images are formed on retina which excite cone cells (color) and rod cells (b&w). Fovea centralis is area with largest density of photoreceptive cells
Aqueous Humour	Clear watery fluid between iris and cornea	Refract light onto lens, maintain shape
Vitreous Humour	Jelly-like fluid inside of eyeball	Refract light onto lens, maintain shape
Blind Spot	Point where optic nerve meets the eyeball, has no photoreceptors	No images will be seen when light falls on it
Optic Nerve	Bundle of nerves at back of eye	Transmits signals from photoreceptors to brain

Eye Reflexes

Focus Reflex

Near Vision	Far Vision
Ciliary muscles contract	Ciliary muscles relax
Suspensory ligaments relax	Suspensory ligaments tighten
Less pull on lens	More pull on lens
Lens thicker, more convex	Lens
Light rays from near objects focused on retina	Light rays from far objects focused on retina

Accommodation Reflex

Bright Light	Dim Light
Circular muscles contract	Circular muscles relax
Radial muscles relax	Radial muscles contract
Iris expands, pupil becomes smaller	Iris contracts, pupil becomes bigger

Less light enters the eye	More light enters the eye

Binocular Vision

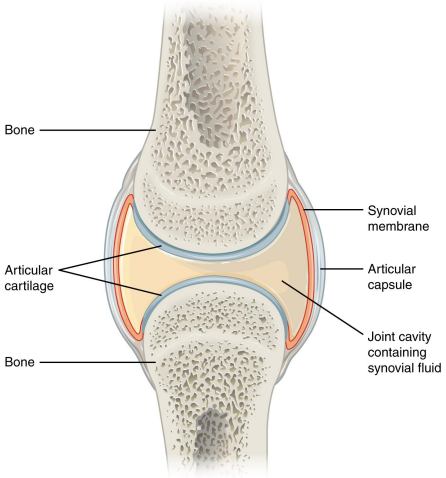
- Humans have two eyes
- Images from eyes are slightly displaced
- Differences in images allow perception of depth

Muscles and Movement

Bones are used to provide framework to hold up body, protect internal organs, produce blood cells, and allow for movement. Bones are a point of attachment for skeletal muscles that pull on bones when they move to produce movement.

- Skeleton serves many functions
    - Support to provide rigid shape of body
    - Protection of internal organs from injury
    - Movement by providing attachment for skeletal muscles
    - Production of blood cells in bone marrow
- Skeleton acts as lever while muscles act as force
- Most common lever in the body is a 3rd class lever

Joints



- Joints are where 2 bones meet
    - Immovable joints e.g. skull
    - Partially movable joints e.g. spinal column
    - Freely moving joints or Synovial joints
        - Ball and socket joints move 360 degrees in all planes e.g. shoulder
        - Hinge joints move 180 degrees in one plane e.g. elbow
- Synovial joints consist of
    - Joint capsule or ligament which joins 2 bones together, comprised to be able to withstand mechanical stress, made of elastic collagen.
    - Synovial membrane secretes synovial fluid or lubricant
    - Joint cavity containing synovial fluid cushions movement between bones
    - Articular cartilage prevents damage to bone surfaces caused by friction, grows back very slowly

Skeletal Muscle

- Voluntary muscle function
- Muscle is attached to bone in at least 2 places, one is fixed (origin) while one is mobile (insertion)
- Attachment of muscles to bone is through tendons

Human Elbow Joint

- Biceps and Triceps involved

- Antagonistic action between two muscles allow for bi-directional movement
- Flexion occurs when biceps contract and triceps relax
- Extension occurs when triceps contract and biceps relax

Types of Muscles

Property	**Skeletal**	**Cardiac**	**Smooth**
Striations / Stringy or Stripy structure	Present	Present	Absent
Control	Voluntary and Involuntary	Involuntary	Involuntary
Location	Attached to bone	Forms bulk of heart wall	Walls of internal structures e.g intestines
Number of Nuclei	Multiple	One	One

Homeostasis

Definitions

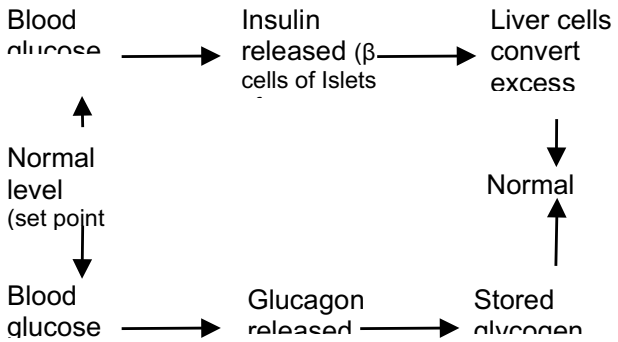
Homeostasis is the maintenance of a constant internal environment despite changes in the external environment (e.g. human maintains constant body temp. of 37℃, pH of blood and interstitial fluid with 0.1 pH unit of 7.4, and concentration of glucose at 90mg/100ml of blood).

A **regulator** controls its internal condition in the face of fluctuating external conditions (e.g. warm-blooded animals), while a **conformer** allows its internal condition to vary with external changes (e.g. cold-blooded animals).

Homeostasis involves 3 factors: 1) **Receptors**, to detect **stimulus** (fluctuations in the variable above/below set point); 2) **Messengers**, to coordinate a corrective mechanism via negative feedback; and 3) **Effectors**, to carry our **response** (physiological activity that helps to return the variable to set point).

Homeostasis relies on **negative feedback** (control mechanism which reduces the stimulus), and regulatory responses are effected through the nervous and endocrine systems respectively. The 3 main types of regulatory processes are: 1) Blood glucose level regulation; 2) Thermoregulation; and 3) Osmoregulation.

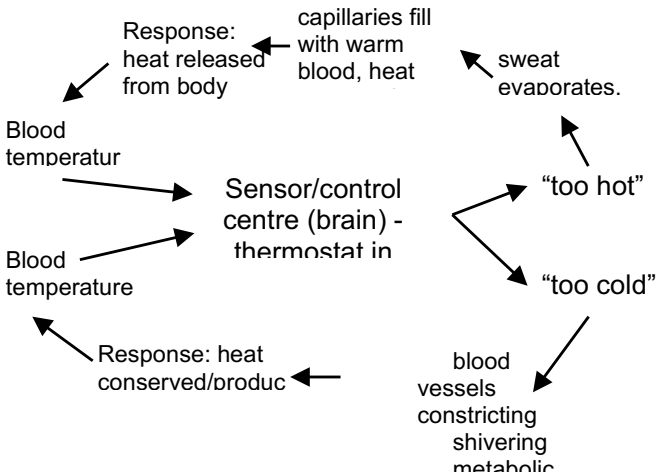
Blood glucose level regulation



Thermoregulation

The process by which animals maintain an internal temperature within a tolerable range.

Receptors for temperature change: thermoreceptors in hypothalamus
Messengers for temperature change: nerve impulses from brain to effector organs
Effectors to affect response to stimulus change: sweat glands, arterioles (blood vessels), hair erector muscles, skeletal muscles



When body temperature rises
Factors causing rise: 1) increased muscular activities; 2) hot external environment; 3) infection(s). These factors cause an increase in blood temperature.

1. Thermoreceptors in hypothalamus (heat regulating centre) in brain detects this increase.
2. Sends nerve impulses to bring about following changes:
    a. Sweat glands in skin stimulated → greater sweat production. As more sweat evaporates from skin surface, more latent heat (of vapourisation) is removed from body.
    b. Arterioles in skin dilate (vasodilation). Allows more blood to flow through the skin. More heat is lost by radiation, convection and conduction.
    c. Hair erector muscles relax, hairs lie close to skin surface.
    d. Metabolic rate decreases.
3. Body temperature falls to normal levels.

When body temperature falls
Factors causing drop: 1) cold external environment. This factor causes a drop in blood temperatures.

1. Thermoreceptors in hypothalamus (heat regulating centre) in brain detects this decrease.
2. Sends nerve impulses to bring about following changes:

    a. Sweat glands in skin not stimulated → decreased sweat production. As less sweat evaporates from skin surface, less latent heat is removed from body.
    b. Arterioles in skin constrict (vasoconstriction). Allows less blood to flow through the skin. Less heat is lost by radiation, convection and conduction.
    c. Hair erector muscles contract, hairs stand on end, forms insulating layer of air between hair (important for small animals like rabbits)
    d. Involuntary muscle contractions (shivering)
    e. Metabolic rate increases.
3. Body temperature rises to normal levels.

Exchanges with the external environment

Organisms must continuously exchange chemicals and energy with their surroundings. All living cells must be bathed in a watery solution (interstitial fluid) so that exchange of materials can occur. Complex animals have extensively folded or branched internal surfaces to maximise surface area for exchange.

Osmoconformers are organisms whose internal and external environments have similar solute concentrations (e.g. most marine invertebrates), while osmoregulators are organisms who actively regulate their water gain or loss (e.g. freshwater animals; most marine vertebrates; all land animals).

Excretion

The process by which metabolic waste products are removed from the body. (The body requires chemical energy for growth, repair, activity and reproduction.)

Egestion is the process by which undigested food materials are removed from the body. These substances have never been absorbed into the cells and hence are not produced as a result of metabolic changes.

Excretory products include:

1. Carbon dioxide - excreted by lungs as a gas in expired air
2. Excess water - excreted by kidney, skin and lungs. a constituent of urine, sweat and expired air
3. Urea - excreted by kidney and skin. constituent of urine and sweat. formed during deamination of proteins (removal of amino acid group from amino acids, converted to ammonia). type of nitrogenous waste. found in mammals, sharks and adult amphibians.
4. Uric acid - excreted by kidney and skin. constituent of urine and sweat. breakdown of nuclear materials. found in insects, reptiles and birds.
5. Bile pigments - excreted by liver, through intestines. breakdown of haemoglobin.
6. Mineral salts - excreted by kidney and skin. constituent of urine and salt.

Lungs (as excretory organs)

Carbon dioxide produced by cellular respiration diffuses into blood (carried as hydrogen carbonate ions) in red blood cells and blood plasma). The ions are carried to the lungs. Hydrogen carbonate is converted back into carbon dioxide in the lungs, and the carbon dioxide diffuses into the alveoli. During exhalation, carbon dioxide is expelled from the lungs, Water evaporates from alveoli walls (excretion of excess water).

Kidneys
Processes: 1) Excretion; 2) Osmoregulation

Functions of kidneys:

1. Elimination of waste substances (water, nitrogenous waste (urea), mineral salts (NaCl))
2. Salvage of essential ions (Na^+, K^+, Cl^-)
3. Regulation of blood pH by removing/reabsorbing H^+, HCO_3^-
4. Regulation of plasma volume/blood pressure
5. Regulation of blood osmotic concentration
6. Hormone production - erythropoietin, renin
7. Removal of toxic substances (e.g. metabolites of drugs)

Excretion by kidneys
A very large volume of extracellular fluid is separated from plasma per day - of which 99% (~ 1.5 litres) is reabsorbed back to the plasma. Leaves behind excess water, salts and urea.

Renal Artery	Brings waste in blood to kidneys
Renal Vein	Outputs blood (without waste) from kidneys
Ureter	Carries blood to urinary bladder, urethra
Urinary Bladder	Stores urine before discharge
Urethra	Transports urine to exterior
Nephron	System of tubes that act as a filter within kidney Comprises: 1. Bowman's capsule + glomerulus 2. Proximal convoluted tubule 3. Loop of Henle 4. Distal convoluted tubule 5. Collecting duct
Bowman's Capsule + Glomerulus	Ultrafiltration occurs here
Loop of Henle/Proximal Convoluted Tubule	Selective reabsorption occurs here

Ultrafiltration	Renal artery divides into a mass of blood capillaries (glomerulus) located in

	the Bowman's capsule. 1. Diameter of afferent arteriole is larger than diameter of efferent arteriole. 2. Hydrostatic pressure created forces fluid out of artery into Bowman's capsule. 3. Small particles like water, glucose molecules, amino acid molecules, urea and salts are filtered into Bowman's capsule. 4. Large molecules like red blood cells remain in renal artery. 5. The resultant fluid is glomerular filtrate.
Selective Reabsorption	1. In the proximal convoluted tubule, the filtrate passes through the tubule, and selective reabsorption of useful molecules would occur. 2. Most of water is reabsorbed. 3. Glucose, amino acids, and some minerals are reabsorbed into the capillaries (through tubule walls, via active/passive transport) 4. Excess water, mineral salts and nitrogenous waste are left and can pass to ureter and urinary bladder as urine.

Osmoregulation

Osmoregulation is the regulation of blood osmolarity/osmotic pressure (in mOsm/l). This controls amount of blood available for epithelial cells to absorb. Osmoreceptors are able to detect osmotic pressure situated on hypothalamus. Hypothalamus sends chemical messages to pituitary gland next to it. (ADH is produced in the hypothalamus and stored in the gland posterior.)
When hormone reaches kidneys, it alters the tubules of kidney to become either more or less permeable to waste.

If more water is required in the bloodstream, high concentrations of ADH is released. Tubules become more permeable, and more water is reabsorbed by the kidneys, and less urine is produced.

Conversely, if less water is required in the bloodstream, low concentrations of ADH is released. Tubules become less permeable, and less water is absorbed by the kidneys, and more urine is produced.

Haemodialysis

When both kidneys fail, patient will be treated with a dialysis machine. Blood is drawn from a radial artery (fistula) in patient's arm, and the blood flows through a tubing in the machine, bathed in a specially-controlled dialysis fluid (dialysate - an isotonic solution). Fluid contains essential salts for body (e.g. NaCl, $NaHCO_3$, $CaCl_2$, KCl, $MgCl_2$) - these do not diffuse out of the blood.

The walls of the tubing are partially-permeable, and urea and other waste products diffuse through the partially-permeable membrane. Proteins and blood cells stay in the tubing. Tubing is coiled to increase surface area and thus speed up exchange of substances.

Filtered blood returns to the vein. The process is repeated thrice a week, several hours each time.

Human Endocrine System

Functions of Hormones

- Alternate messengers in the body, sends chemical signals through bloodstream instead of nervous system
- Come in the form of
    - Protein Hormones, water soluble and stay on surface of a cell
    - Lipid hormones, water insoluble and enter cell to take effect
- Used to send signals to entire body instead of localised areas near neurons
- Alters activity of target organs
- Destroyed by liver or excreted through urine
- Acts as the endocrine system (glands etc)

Common Hormones

- Antidiuretic Hormone (ADH)
    - Monitored in osmoreceptors in Hypothalamus
    - Triggered by low volume or high osmolarity of plasma
    - Released from posterior pituitary gland
    - Increases permeability of distal convoluted tubule and collecting duct in kidney
    - Reabsorbs more water via osmosis in said areas
    - More water retained in body
- Adrenaline
    - Triggered by fight or flight reflex, fear and excitement
    - Stimulated by motor nerve cells
    - Secreted by the adrenal medulla above the kidneys
    - Affects entire body
        - Increases heart rate
        - Increases breathing rate
        - Vasoconstriction (e.g. digestive system) and vasodilation (e.g. muscles)
        - Glycogenolysis in liver
        - Stimulates lysolipids
    - Increased body function
- Insulin
    - Antagonistic to Glucagon
    - Monitored by Islets of Langerhans in Pancreas (beta cells)
    - Triggered when blood glucose levels are high
    - Affects cells and muscles, especially liver
        - Increase intake of glucose into cells
        - Increase production of glycogen in liver and muscles
        - Increases metabolic rate
    - Decreases blood sugar level
- Glucagon
    - Antagonistic to Insulin

    - Monitored by Islets of Langerhans in Pancreas (alpha cells)
    - Triggered when blood glucose levels are low
    - Affects cells and muscles, especially liver
        - Stimulates breakdown of glycogen stores
        - Breakdown of fats and proteins into glucose
    - Increases blood sugar level

- Thyroxine and Triiodothyronine (Not Tested)
    - regulates metabolic behavior, ensuring normal growth and mental development
    - secreted by thyroid gland
    - under secretion results in goitre, and weight gain
    - over secretion results in overly high bodily temperatures and metabolism, sweating and irritability

Thyroid	Produces thyroxine and triiodothyronine which regulates metabolic behavior, ensuring normal growth and mental development. An under secretion results in goitre, and weight gain while over secretion results in overly high bodily temperatures and metabolism, sweating and irritability.
Anterior Lobe (Pituitary Gland)	Secretes growth hormone, and an under secretion results in dwarfism and over secretion results in gigantism and in adults overgrowth of extremities is called acromegaly.
Posterior Lobe (Pituitary Gland)	Secretes antidiuretic hormone which controls urine by affecting water retention. Also secretes oxytocin which regulates milk release during childbirth and nursing.
Gonads	Produces hormones that control development of male or female sexual characteristics (testosterone, or estrogen and progesterone respectively)
Adrenal Gland	Adrenal medulla: located on kidneys. Adrenaline is produced, which increases metabolic rate, heartbeat, blood pressure and induces vasoconstriction and dilation of pupils (fight or flight reaction)
Islets of Langerhans (Pancreas)	Glucagon: Binds to receptors in livers, and stimulates breakdown of glycogen to glucose in liver, and inhibits the synthesis of glycogen from glucose in liver and skeletal muscle cells. Glucose is produced from outer sources like amino acids and overall blood glucose concentration is increased. Insulin: Binds to receptors on tissue cells, and inhibits breakdown of glycogen to glucose in liver, and stimulates the synthesis of glycogen from glucose in liver and skeletal muscle cells. Excess glucose is converted to glycogen to be stored and overall blood glucose concentration is decreased.

Diabetes Mellitus

- Present when blood sugar levels are abnormally high / hyperglycemia
- Caused by
    - Pancreas not producing sufficient Insulin
    - Body cells insensitive towards Insulin
- Effects include
    - Polyuria, due to high osmolarity of blood
    - Polydipsia, due to polyuria
    - Glycosuria, sugar present in urine
    - Weakness, due to lack of glucose intake
    - Damage to blood vessels and organs

Mitosis and Meiosis

Comment [1]: y4 topics start here

Mitosis and Meiosis refer to the process of cell replacement and growth via cell division. It can involve asexual reproduction (mitosis) or sexual reproduction (meiosis). The terms diploid and haploid will be used, where diploid refers to most cells having 46 chromosomes with 23 homologous pairs, and haploid refers to gametes (sex cells) having 23 chromosomes.

Cell Cycle - Mitosis

Interphase: is 90% of the cell cycle, threadlike genetic material in nucleus that cannot be seen clearly

G1 Phase	S Phase	G2 Phase
After cytokinesis, cell builds up a store of energy and manufacture proteins and synthesizes organelles	DNA replication, where the DNA material doubles and DNA is in loosely packed chromatin.	Cell builds up energy, manufactures proteins and synthesizes organelles

Mitosis

Prophase	Metaphase	Anaphase	Telophase
❖ Nucleolus disappears ❖ Nuclear membrane breaks down ❖ Two identical sister chromatids are formed ❖ Spindle fibres created ❖ Centrioles move to opposite ends of the cell	❖ Spindle fibres are fully formed ❖ Chromosomes line up at equator	❖ Sister chromatids pulled apart by spindle, move to opposite ends of the spindle	❖ Nucleolus reappears ❖ Nuclear membrane forms ❖ Chromosomes uncoil to become chromatin threads ❖ Spindle fibres disintegrate: leads to cytokinesis (division of cytoplasm) which forms new cells

Cell cycle- Meiosis

One cycle of chromosome replication occurs, then successive cycles of nuclear division leading the formation of 4 hybrid daughter cells. 4 male gametes are formed, or 1 ovum and 3 polar bodies

Interphase: same process as mitosis

G1 Phase	S Phase	G2 Phase
After cytokinesis, cell builds up a store of energy and manufacture proteins and	DNA replication, where the DNA material doubles and DNA is in loosely packed chromatin.	Cell builds up energy, manufactures proteins and synthesizes organelles

synthesizes organelles		

Meiosis 1 - homologous chromosomes separate (2n → n)

Prophase I	Metaphase I	Anaphase I	Telophase I
❖ Chromatin threads shorter, thicker ❖ 2 sister chromatids formed ❖ Each pair of homologous chromosomes form a bivalent (2 homologous chromosomes, 2 sister chromatids) ❖ Chiasmata between non-sister chromatids (crossing over of genes occurs) ❖ Nuclear membrane disintegrates	❖ Bivalents arrange themselves at equator ❖ Independent of /unaffected by position of other bivalents	❖ Homologous chromosomes separate ❖ Pulled to opposite poles	❖ Chromosomes reach opposite poles ❖ Spindle fibres disintegrate ❖ Nuclear membrane, nucleolus forms ❖ Two haploid daughter cells form

Meiosis 2 - starts with haploid cell (n) that has not undergone chromosome replication during preceding interphase, and pairs of sister chromatids are separated

Prophase II	Metaphase II	Anaphase II	Telophase II
❖ Nucleolus disappears ❖ Nuclear membrane breaks down ❖ Two identical sister chromatids are formed ❖ Spindle fibres created ❖ Centrioles move to opposite ends of the cell	❖ Spindle fibres are fully formed ❖ Chromosomes line up at equator	❖ Sister chromatids pulled apart by spindle, move to opposite ends of the spindle	❖ Nucleolus reappears ❖ Nuclear membrane forms ❖ Chromosomes uncoil to become chromatin threads ❖ Spindle fibres disintegrate: leads to cytokinesis (division of cytoplasm) which forms new cells

Genetic Variation Occurs During:

- Formation of chiasmata in meiosis (prophase I) between non-sister chromatids of homologous chromosomes results in new combination of alleles
- Independent arrangement and separation of homologous chromosomes during metaphase I/anaphase I
- Random fertilization: 64 trillion combinations of chromosomes
- Independent arrangement of chromosomes of equator of spindle during metaphase II, separation of chromatids during anaphase 2

Patterns of Inheritance

Gene	Unit of inheritance: a heritable sequence of nucleotides along a DNA molecule which codes for polypeptide
Locus	The position on a chromosome a gene resides
Allele	An allele is an alternative form of a gene, and alleles occupy the same locus on a pair of homologous chromosomes
Phenotype	The expressed or observable characteristics of an individual
Genotype	The genetic constitution of an organism with respect to its alleles (e.g Aa, aa)
Dominant Allele	Allele that shows its phenotype in a homozygote or heterozygote
Recessive Allele	Allele that shows its phenotype in a homozygote only
Co-dominant	Two alleles are codominant when both alleles are equally expressed (e.g black + white = black and white spots)
Incomplete Dominance	Expression of phenotype is intermediate (e.g black + white = grey)
Homozygous	Diploid condition where alleles at a given locus are identical (i.e AA, aa)
Heterozygous	Diploid condition where alleles at a given locus are different (i.e Aa)

Phenotype and Genotype

- The genotype of an organism is its genetic makeup or the specific sequence of DNA
- The phenotype is the organisms expressed traits and/or characteristics
- Genotype → Amino Acids → Proteins → Expressed Quality → Phenotype
- Genes are given to gametes, where gametes express same genotype as parents

Gene Diagrams

- Monohybrid Cross
    - Cross between purebred plants that differ in only one character
    - Crossing of this nature is called hybridization
    - Pure-breeding parents are the P generation
    - Hybrid offspring are first filial F_1 generation
    - Offspring of F_1 produces second filial F_2 generation
    - Mendel's first law: Law of Segregation: A single factor from each parent is present in the gamete, where gametes only have one copy of every allele
- Dihybrid Cross

- Mendel's second law: Law of Independent Assortment: Genes for different traits assort independently of one another in the formation of gametes in equal proportions
- Any one of a pair of characteristics may combine with either one of another pair

Observed and expected ratios

- Expected ratio of a dihybrid cross is 9:3:3:1
- Observed ratio does not agree with expected ratio
- Observed tends to expected when
  - Fertilisation is random
  - Offspring have equal chances of survival (bad gene combinations may not survive, observations skewed due to survivors' bias
  - Large numbers of offspring are produced and observed

Multiple Alleles and Codominance

- Some genes have alleles of more than 2 states, called multiple alleles
- ABO blood in humans is an example of multiple alleles
- Written as I^A, I^B and I^O
- I^A and I^B are codominant, which equally express themselves in the phenotype in a heterozygous situation
- I^A and I^B are dominant to I^O

Genotype	**Phenotype**	**Donor**	**Antibodies in plasma**
I^OI^O	O	O	A, B
I^AI^O	A	A	B
I^BI^O	B	B	A
I^AI^A	A	A	B
I^BI^B	B	B	A
I^AI^B	AB	All types	None

Sex Determination and Linkage

- Humans have 22 pairs of autosomes and 1 pair of sex chromosomes
- XX produce female, XY produce male
- Y is significantly shorter than X, meaning that males have less genetic data than females
- Sex linkage refers to the carrying of genes on the sex chromosomes, where genes will follow the X or Y chromosome to the offspring
- Sex-linked characteristics are non-sexual characteristics controlled by genes found on the sex chromosomes, such as haemophilia and ocular albinism
- Some alleles are expressed in the X chromosome but are absent in the Y chromosome, meaning that recessive alleles on the X chromosome will be expressed

Considering Haemophilia: X^H for healthy and X^h for haemophiliac

Genotype	**Phenotype**
X^HX^H	Normal Female
X^HX^h	Carrier Female
X^hX^h	Haemophiliac Female
X^HY	Healthy Male
X^hY	Haemophiliac Male

Crossing Over

- During Prophase 1, chiasma formed and chromatids swap places at the same loci
- New phenotypes are called recombinants
- The further away two genes are, the greater the chance of crossing over

Family Pedigree

- Inheritance of a trait in a family can be studied by constructing a family tree called a pedigree
- Squares represent males, circles represent females
- White shapes represent healthy individuals, colored shapes indicate an affected individual
- Oldest generation at the top, youngest at the bottom
- Individuals are identified according to [Generation Number] - [Child Number}
- Generation number counted in roman numerals from top being I, child number counted in arabic numerals starting from left being 1
- Can be used to identify the nature of a trait
    - Autosomal Dominant
        - If a child has the trait, at least one of the parents has the trait
        - If two individuals have trait, their offspring may not necessarily have the trait
    - Autosomal Recessive
        - If both parents are affected, all children are affected
        - If a child is affected, both parents have the trait

        - Recessive traits can skip generations
    - X-linked Recessive
        - If the mother carries a recessive trait, the male children may or may not have the trait
        - If the mother is affected, all male children will be affected
        - If the father is affected, the female children will be carriers or affected
        - If both parents are affected, all children will be affected

Mutation

- Mutation is a change of the structure of a gene independent of genetic variation through normal meiosis
- Cases include
    - Instantaneous change of a base and hence the structure of a gene in a chromosome e.g. Sickle cell anemia
    - Chromosome aberration e.g. Aneuploidy / Down's syndrome
    - Single chromosome mutations:
        - **Deletion** - removal of a string of DNA
        - **Duplication** - replication and insertion of a string of DNA
        - **Inversion** - inverted insertion of a string of DNA
    - Dual chromosome mutations:
        - **Insertion** - DNA from one chromosome is inserted into another
        - **Translocation** - DNA between two chromosomes are swapped
    - Radiation and chemicals increase the rate of mutation

Sickle Cell Anemia

- Is a point mutation
- Healthy adults have healthy haemoglobin (Hb A)comprised of two alpha-globin and two beta-globin chains, coded by two different genes on two different chromosomes
- Affected adults have one base changed in the beta-globin chain (CTT→CAT), replacing a glutamate (polar) amino acid with a valine (non-polar, hydrophobic) amino acid
- Affected adults produce affected haemoglobin (Hb S) which forms a hydrophobic patch in low O_2 conditions which causes affected hemoglobin to bind to each other, polymerising into rod-like fibres and crystals which distorts the cell and creates a sickle-shaped erythrocyte
- Hb S result in
    - Poor oxygen transport
        - Anemia, breathlessness and physical weakness
        - Heart failure
    - Clogging of capillaries
        - Depriving organs of O_2 e.g. Stroke
        - Severe pain due to localised blockages resulting in cell death
        - Damage to organs with numerous capillaries e.g. Lungs, Spleen
- Sickle-cell anamia is a homozygous recessive disorder, where sufferers need one copy of the recessive gene from each parent
- Individuals with one recessive allele are said to have the Sickle-cell trait

- Mutations usually result in recessive conditions since they usually cause in a loss of function through miscoding of a protein, where mutant proteins have no function and the proteins made by the other healthy allele are able to mask the defective gene

Variations in chromosomal number

- Aneuploidy is the condition where the nucleus has an abnormal number of chromosomes
- Caused by nondisjunction
    - The failure of chromosome pairs or sister chromatids to seperate properly during cell division
    - Homologous chromosomes do not move apart properly during Prophase 1
    - Sister chromatids fail to separate properly during Mitotic Prophase or Prophase 2
    - Results in an aneuploid cell with an imbalance of chromosomes
    - Extra chromosome (2n+1) is Trisomy
    - Missing chromosome (2n-1) is Monosomy
- Nondisjunction in mitosis is called post zygotic nondisjunction and can result in mosaicism
- Mosaicism where multiple cell lines are developed in an individual due to mutations (new mutation or chromosomal abnormality) e.g. Some cells have 46 chromosomes while some have 47
- Common diseases include
    - Trisomy 21 or Down's Syndrome, usually due to non-disjunction during Meiosis 1, where individuals have abnormal facial features, short stature, heart defects, vulnerability to respiratory infection and mental retardation. May result in lack of sexual development and sterility.
    - XXY or Klinefelter Syndrome where individuals have male gonads but testes are abnormally small and sterile. Extra X chromosome is inactivated but female body characteristics are common. Individuals' intelligence is unaffected
    - Monosomy X or Turner Syndrome is the only viable monosomy in humans, where individuals are phenotypically female but are sterile and gonads do not mature. Estrogen therapy can allow individuals to display secondary sex characteristics

Continuous, Discontinuous Variation and Environment

- Some traits display discontinuous variation- they are displayed in clear-cut, binary traits
- Other characteristics are not as distinct e.g. Skin colour, height
- Traits of continuous variation or of polygenic inheritance are expressed along a gradient, which is the result of the additive effects of two or more genes (polygenic inheritance) / a displayed characteristic is controlled by numerous genes
- Polygenic inheritance can be identified by a wide range of phenotypes in the filial generation of two pure-bred parents
- Environment (nutrition, exercise) also affects phenotypes, but these modifications are not inherited to the next generation
- Distinct different groups in a parental generation suggest that variation in phenotype is genetic
- Variation in a phenotype in pure-bred parental groups suggest that variation in phenotype is due to environment even though genotype is the same

Structure of DNA and RNA

- A chain of nucleotides form DNA strands
- A gene is the specific sequence of nucleotides in a coding strand of DNA which codes for a specific sequence of amino acids in a polypeptide chain which has a fixed locus on the chromosome which specifies a biological function
- Strands of DNA are coiled to form chromosomes contained within the nucleus
- Basic unit of RNA molecule is the ribonucleotide
- RNA are single stranded molecules (except for some RNA viruses)
- mRNA is derived from the transcription (across-writing) of DNA
- rRNA is the ribosome
- tRNA is the molecule which recognises a triplet of base pairs on the mRNA and delivers the specific amino acid to the protein chain on the protein strand on the rRNA
- DNA → Sequence of Amino Acids → 3D Conformation of a Protein → Function → Phenotype
- Complementary base pairing ensures that one base can only bind to another base
    - A binds to T/U
    - C binds to G

Genetic Engineering

A genetically-modified organism is one that has artificially acquired one or more genes from a species. genetic engineering is therefore the transfer of genetic material from one cell to another, and gene cloning is the isolation of individual genes (target DNA) and the subsequent generation of recombinant DNA molecules, which is then propagated in a host cell to produce multiple copies of recombinant DNA.

DNA Cloning

4 parts are needed: the **restriction enzyme**, **DNA ligase**, **plasmid vector** and a **gene of interest**

Plasmid vector	❖ A plasmid is a piece of DNA exchanged within bacteria ❖ Can self-replicate ❖ Plasmid vector is the 'host' of the gene of interest, and the target DNA is inserted into this vector so the gene can be replicated and passed on to descendants of this bacterium
Gene of interest	DNA fragment to be cloned
Restriction Enzyme	❖ Recognizes a specific DNA sequence that is palindromic ❖ Often an enzyme found naturally in bacteria digesting foreign DNA ❖ Will cut both strands of DNA helix at precise points in the restriction site ❖ Cleaves the sugar phosphate backbone of DNA molecule ❖ Some enzymes make a cut in the middle of the recognition sequence, resulting in blunt ends ❖ Most enzymes cleave sugar phosphate backbone of both DNA strands in a staggered manner, resulting in short single-stranded overhangs at the end which produces sticky ends ❖ Two molecules of DNA digested with the same restriction enzyme that produces sticky ends will have complementary sticky ends ❖ This exposes nucleotides that can undergo complementary base pairing (via hydrogen bonding) ❖ Can also cut bacterial plasmid so foreign target DNA can be inserted ❖ Can als isolate target DNA from genome ❖ Restriction enzyme used to isolate target DNA must not have restriction sites within the target DNA sequence ❖ Digestion of both the plasmid vector and target DNA performed at 37 deg C
DNA ligase	❖ Joins DNA fragments by repairing the sugar phosphate backbone during ligation ❖ Ligation is performed at 16 deg C ❖ Once foreign DNA has been inserted into a cloning vector, the

	Resulting recombinant vector is replicated by introducing it to an appropriate host cell
Multiple Cloning Site (MCS)	❖ Short segments of DNA which contain restriction sites for numerous restriction enzymes to be implanted into the bacterial plasmid, giving scientists a larger choice of restriction enzymes to be used to cut the plasmid ❖ MCS also contain promoter sequence before MCS to encourage transcription of the DNA inserted into the MCS

Heat Shock Transformation

- The bacteria and plasmid are exposed to a Ca^{2+} rich environment under cold conditions for 30 mins.
- The calcium rich environment neutralizes the negative charge on the bacterial cell wall and the sugar-phosphate backbone of plasmid DNA, and weakens the electrostatic repulsion between bacteria and plasmid.
- Bacteria is thus more competent to take up foreign DNA, and heat shock treatment can begin. The mixture is exposed to 42 deg C of heat briefly, then is incubated on ice.
- It is then added to a nutrient dish to incubate at 37 deg C, and then it is exposed to antibiotics overnight.

Selection of Transformed Bacteria

- Transformation is not completely effective, bacteria might not have took up plasmid
    - Plasmid is cut to have sticky ends where some plasmids may have recombined with each other by complementary base pairing
- Plasmids have a selectable marker used to differentiate between bacteria which are transformed and those which are not transformed
- Antibiotic resistance gene is commonly used, culture is done on a plate with an antibiotic such that only transformed bacteria which express resistance to the antibiotic is able to survive

Bacteria Culturing

- A bacteria colony is the visible cluster of bacteria growing on a culture surface, which has supposedly originated from a single cell and are thus genetically identical
- Streak method involves repeatedly streaking bacteria culture onto an agar plate
- With each streak, only a small number of bacteria from the previous phase is picked up for streaking, resulting in continuous dilution of the inoculum
- Individual cells become spaced further from each other and create colonies when cultured
- Utilise aseptic technique to avoid contamination of bacteria samples and cultures
    - Disinfecting table surface with 70% ethanol before and after work
        - Prevent introduction of bacteria from table surface
    - Wear gloves and long sleeves, disinfect gloves with 70% ethanol
        - Prevent introduction of bacteria from hands and arms

    - Keep working area sterile and work close to with lit bunsen flame
        - Create convection current of air to prevent bacteria-containing particulate on the air from settling on working area and tools
    - Use sterile supplies and tools
        - Prevent introduction of bacteria from tool surfaces
    - Flame mouth of test tubes after removing and before replacing covers
        - Create high pressure zone when removing covers to prevent contaminated airborne contaminants from entering
        - Create negative pressure in test tube before replacing covers?

Applications of Genetic Engineering

- Genetically Modified Organisms
    - Desired gene introduced into Ti plasmid and inserted into bacteria
    - Bacterium is used to insert T-DNA into chromosome of the plant cell, giving plant cells a desired quality
    - Plant cells (explants) are cultured and grown into plantlets which express the foreign trait
    - Genetically Modified Plants
        - Pest resistance
        - Herbicide resistance
        - Improved Quality and Yield
        - Production of vaccines using bananas
        - Production of chemicals e.g. silk and fuel
- Production of Recombinant Proteins
    - Human genes for protein production are introduced into plasmids and then bacteria
    - Bacteria are cultured in a fermentation tank with overproduction of human protein
    - Proteins are then purified and used
    - Human Insulin production using insertion of human genes into bacteria to produce insulin for diabetes treatment
    - Growth Hormone production using insertion of human genes into bacteria to produce hormone for treatment
    - Hepatitis B vaccine using insertion of virus coat protein gene to produce virus coat to trigger immune response and gain immunity
- Gene Therapy
    - Introduce gene of interest into a vector e.g. virus
    - Infect human with the recombinant vector, change the genetic makeup of cells within the body via healing viral infection
    - Used in treatment of genetic disorders e.g. Cystic Fibrosis
- Biomedical Research

Risks and Ethics of Genetic Engineering

- Externalities due to harmful nature of GM crops towards external ecosystem
    - Bt Corn killing monarch butterflies
- Superweeds and superbugs arise due to proliferation of antibiotic resistance genes
- Reduce effectiveness of pesticides

- GM crops may pollinate non-GM crops of other farmers
- Lack of genetic variance implies fragile nature of GM crops, where a single disease can wipe out massive harvests
- Allergy to transgenic food
- Small-scale farmers go out of jobs due to inability to compete with production of GM crops, increase in inequality
- Bioterrorism and biological warfare imminent
- Inhumane treatment of animals in GM testing
- Livestock grow too fast to survive in humane conditions
- Interruption of natural order of environment

Immunology

Disease and the immune system

- Disease and unfavourable environmental conditions threaten health
    - Immune system sets out to prevent disease with the use of cells
    - Environmental conditions are managed with use of homeostasis and other biological processes
- Combats inorganic toxins, genetic organisms and microorganisms (pathogens)
- Pathogens include
    - Extracellular bacteria, parasites and fungi
    - Intracellular bacteria, parasites and fungi
    - Intracellular viruses
    - Extracellular parasitic worms
- All pathogens have antigens on the surface of their cells which are recognised by the human immune system
- Human immune system comprises 2 branches with 3 lines of defence
    - Innate immunity
        - Nonspecific immunity which responds to anything classified as a pathogen
        - First line involves physical barriers and secretions
        - Second line involves nonspecific biological response and inflammatory response
    - Acquired/adaptive immunity
        - Specific immunity which responds to a previously recognised pathogen
        - Humoral response to pathogens in body humor (out of/between cells)
        - Cell-mediated response to pathogens inside of body cells

First Line of Defense - Mechanical and Chemical Barriers

	Mechanical	**Chemical**
Skin	Epithelial cells joined at tight junctions	Fatty acids- lysozymes attack bacterial cell walls
Respiratory Tract	Movement of mucus via cilia	Nasal Secretions
Gastro-intestinal Tract	Mucus Lining	Lysozymes in saliva pepsins, defensins and low pH of stomach
Eyes	Eyelids	Lysozymes in tears
Microbiological flora	-	Antibacterial secretions

Second Line of Defense - Internal, and recognizes and destroying pathogens

Inflammatory Response

Vasodilation	Phagocyte Migration	Release of Histamines
❖ Blood flow increased ❖ Faster accumulation of phagocytes, antimicrobial proteins at infection site ❖ Capillary permeability leads to immune cells better being able to gain entry	❖ Phagocytosis can occur ❖ Phagocytic vacuole and vesicles carrying lysosomal enzymes break down and kill bacteria	❖ Redness (erythema) ❖ Swelling (edema) ❖ Heat (fever) ❖ More porous capillary results in plasma flowing out ❖ Water retention

Phagocytosis

- Internal nonspecific defence largely managed by Phagocytes which eliminate pathogens
- Undergo Phagocytosis
    - Phagocytes' Pattern Recognition Receptors (PRR) recognise patterns on pathogens
    - Phagocytes attracted to pathogens
    - Engulfs pathogens
    - Vacuole formed with pathogen bond with lysosome
    - Lysosomal enzymes and other toxic compounds destroy microbes
    - Microbial debris is ejected by exocytosis

Types of Phagocytes

Neutrophil	Macrophage	Eosinophil	Dendritic Cells	Natural Killer Cells	Basophil
-60%-70% of phagocytes -self destruct in process -release soluble antimicrobials -circulate in blood -first to migrate to infection site	-developed from monocytes -less mobile -migrate through body or reside in organs, tissue	-engulf multicellular parasites, specialized cells	-use destructive cells -ingest pathogens to stimulate acquired immunity -activates T-lymphocytes	-invoke major histocompatibility complex -attack tumor/virus-infected and transplanted cells that display class I MHC -bind to specific receptors -cells undergo lysis or apoptosis	-release histamines for inflammatory response
-Multilobed -Fine granules	-Regular nucleus -Granules	-Release cytotoxic granules		Release cytotoxic granules	

Tissue repair also occurs, where platelets form a plug to seal off injury and clotting elements trigger coagulation cascade, strengthening the platelet plug.

NK Cells

- Natural Killer cells
- Check all human cells (except RBC) for presence of MHC-1/Class 1 MHC (major histocompatibility) protein on surface of cytoplasm
    - Abnormal cells do not present the MHC-1 protein
        - Tumors
        - Pathogen/Virus-infected cells
        - Transplanted cells
- Bind to receptors of abnormal cells
- Release chemicals (granzymes/perforin)
- Cells undergo apoptosis/necrosis

Antibacterial Proteins

- Proteins outside of cells which help in the protection against pathogens
- Interferons
    - Proteins secreted by virus-infected cells which inhibit viral replication and hence limit spread
    - White blood cells excrete proteins which activate macrophages and enhance phagocytic ability
- Complement system
    - Proteins loosely flowing in blood which react to membranes of microbes
    - Cascade to cause lysis of microbe

Third Line of Defense - Targeting and Destroying Specific Pathogens

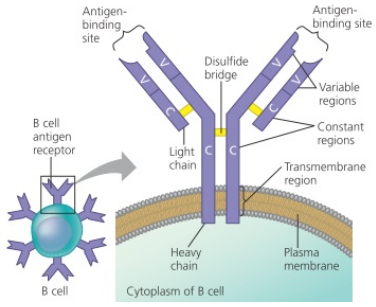
Adaptive Immunity

- Internal immunity which develops in response to previous infection
- Recognises traits of specific pathogens using an exhaustive array of receptors
- Generally slower response
- Involve the operation of lymphocytes
    - White blood cells unique to adaptive immunity
    - All originate from bone marrow but travel to different areas of body to mature
    - Maturation in thymus produces T-cells
    - Maturation in bone marrow produces B-cells
    - Some go on to become NK cells
    - B and T lymphocytes all are specific to one certain kind of antigen,have receptors for one kind of antigen, around 100k receptors per cell
- Utilises various properties for effective immunity
    - Specificity forces one lymphocyte to react to only one type of antigen

- Diversity of receptors ensures that any and every antigen has a complement lymphocyte that can respond to it, due to the differentiation of antibody genes to determine different composition of variable ends on receptors
- Clonal Selection of activated lymphocytes allows lymphocytes which detect antigens to replicate rapidly from a small epitope of lymphocytes merely detecting antigens to one that can elicit an effective immune response
- Memory allows lymphocytes to respond to previously encountered antigens on subsequent exposures to last a lifetime, also prevents resource wastage on replicating lymphocytes with unneeded antigen specificity
- Self-unreactivity prevents lymphocytes from identifying body cells as pathogens and subsequent implications of autoimmunity

Antigen Recognition

- Lymphocytes need a mechanism to identify antigens and do so by producing antigen receptors
- B cell receptors
  - Y shaped molecules with 2 identical light and heavy protein chains linked by disulfide bridge at the angled sections
  - Heavy chains anchor molecule to cell membrane, small portion extends into cytoplasm
  - All 4 chains consist of a C constant protein chain and V variable protein chain
  - Composition of V chain is determined by random selection when lymphocyte was made
  - Pair of light chain and heavy chain creates the antigen binding site
  - Lock and key complex is made between the free-flowing antigen and binding site, antigens can then be recognised
    - Note: antigens can have multiple reactive sites and react to multiple different antigen receptors



- B cell receptors are also expelled from the B cell to create antibodies or Immunoglobulins (Ig), able to freely flow in body humors to bind to antigens
- T cell receptors
  - Consist of only one pair chains, specific title is α-chain and β-chain
  - Both chains protrude into cytoplasm
  - Disulfide bridge is near to the cell membrane
  - Reacts to antigen (fragments) presented within a MHC-2/Class 2 MHC molecule on a host cell

Activation of Lymphocytes

- Requirements must be met before lymphocytes can respond to an infection

- Second barrier defences, especially antigen-presenting cells such as macrophages and dendritic cells need to attack the pathogen and express an antigen on the MHC-2 molecule
- Helper T-Cells then recognise the antigen and receive cytokines from antigen-presenting cell and itself to activate it
- Helper T-Cell then proliferates and moves around the body activating other B and T cells specific to the antigen by releasing cytokines to activate them
- B and T cell population is now activated and ready to react to infection

Cell-mediated Response

- T-Cells are responsible for the destruction of infected cells
- Cytotoxic T-Cells activated by cytokines from antigen-presenting cells recognise antibodies presented in MHC-1 of infected cells
- Release granzymes and perforin, former enters by endocytosis
- Cause apoptosis in infected cell, deprives pathogens of opportunity to multiply and exposes antigens to antibodies in body humors
- Memory T-Cells linger after infection at higher numbers to allow for faster response on subsequent infection

Humoral Response

- B-Cells are responsible for the management of body humor-suspended antigens
- B cells take in portions of antigen molecules and expresses it on the MHC-2 molecule
- Previously activated helper T-Cell binds to antigen on MHC-2 and releases cytokines to activate B-Cell
- B-Cell differentiates into memory B-cells and Plasma cells
- Plasma cells produce antibodies rapidly over 5 day lifespan
- Memory B-cells linger after infection at higher numbers to allow for faster response on subsequent infection
- Antibodies in body humor are used in immune response
    - Neutralisation/opsonization by having antibodies bind exhaustively to antigens, preventing antigens from bonding to other cells
    - Agglutination where antibodies polymerise and bond multiple antigens into a single molecule, where the large size of the molecule prevents infection
    - Precipitation of soluble antigens to prevent reactions
    - Promotes phagocytosis of antigens bonded to antibodies
    - Activates complement protein system where an antibody bonding to the surface of a antigen cell causes a reaction cascade resulting in the formation of pores in cells and ultimately cell lysis

Immunological Memory

- Memory B and T cells linger after first infection and first activation, henceforth called primary infection/response
- Antibodies also linger after infection

- A second exposure to the antigen induces a faster and stronger secondary response due to the existing population of B and T memory cells which cause a faster response

Immunization

- **Active:** Defenses which arise when infection triggers a primary or secondary immune response. Acquired and lasts a lifetime and can be acquired via vaccination
- **Passive :** Antibody exposure which does not involve the B or T lymphocytes of the organism e.g. IgA antibodies in breast milk transferred from mother to child. Typically persists for a few weeks but effective immediately
- **Natural**: Acquired in response to infection
- **Artificial:** Man-made insertion
- Early observations found that humans which were exposed to cowpox were immune to deadlier smallpox. Intentional exposure to cowpox would be used to acquire adaptive immunity
- Modern immunization involves the exposure of humans to prepared antigens of many sources which include inactivated toxins, weakened virus coatings and weakened pathogens such that immunity can be acquired without having to suffer the full force of a disease
- **Vaccine:** Deactivated or weakened antigen
- **Antiserum:** Suspension of antibodies
- **Virulence:** Harmful potential of a pathogen
- **Attenuation:** action to reduce the virulence of a pathogen but still allow for immune response

Immune Disorders

- Immune disorders cause the immune system to function sub-par or even in a harmful manner
- Autoimmunity
    - Immune system mounts response against own body
    - Caused by faulty lymphocyte production, abnormal development of antigens and incorrect cytokine production
    - Treatments include controlling inflammation, suppressing immune system and introduction of antibodies to combat autoimmune cells
- Blood group
    - Initially a mechanism to prevent mixing of foreign blood
    - Blood group causes certain antibodies to appear in the bloodstream
    - Antigens and antibodies specific to blood group are produced and can cause immune response when reaction occurs
- Allergies
    - Production of histamine from mast cells, eosinophils and basophils cause harmful response and inflammation
    - Can be remedied with antihistamines to prevent production or detection of histamine

OVERVIEW OF IMMUNITY

1) Innate immunity (immediate: 0-4h): Infection → recognition by pre-formed, non-specific effectors → removal of infectious agent
2) Early-induced response (early: 4-96h): Infection → recruitment of effector cells → recognition activation of effector cells → removal of infectious agent
3) Adaptive immune response (late: >96h): Infection → transport of antigen to lymphoid organs → recognition by naive B and T cells → clonal expansion and differentiation to effector cells → removal of infectious agent

Reproduction in Flowering Plants

Asexual vs Sexual Reproduction

Asexual reproduction: rapid method of fertilisation; occurs in simple organisms (like binary fission, pore formation, budding, fragmentation); in flowering plants: vegetative propagation

Asexual Reproduction	**Sexual Reproduction**
One parent involved, no fertilisation	Two parent involved; fertilisation of egg and sperm
Daughter cell has identical genetic makeup to parent	Daughter cell has different genetic makeup as parent
Mitosis	Meiosis
Allows plant to pass on all genetic materials to progeny	Plant passes only ½ of its alleles down
Offsprings genetically well-adapted to same environmental conditions as parent	Generates genetic variation
e.g. hydra (budding), planarians (fragmentation)	e.g. humans, most animals

Vegetative Propagation

The process by which new individuals arise without seed production. Part of parent is used to form new plant. Underground storage organs (e.g. rhizomes, bulbs, tubers, corns) can be used. The buds produce shoots, and the nutrients for growth is obtained from the storage organs itself. Runners and leaves can also be used.

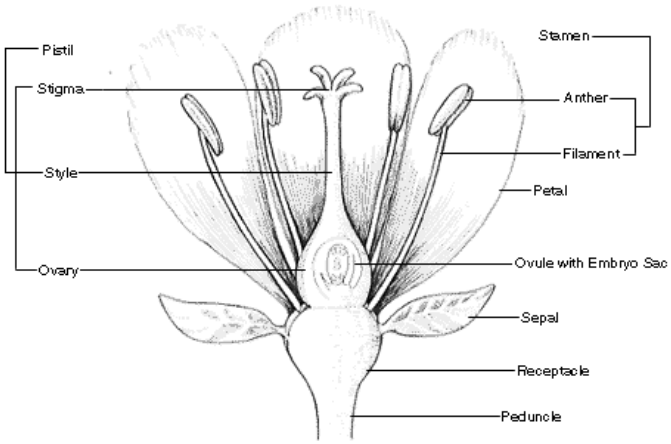
Underground storage organs act as perennating organs (i.e. organs used by plant to survive harsh, adverse conditions). During unfavourable conditions, storage organs lie dormant in ground while above-ground plants may die. When favourable organs return, new shoots regenerate from storage organ to form new plant. Leaves formed photosynthesize to produce more food (stored in new storage organs) - this allows plants to survive from one growing season to the next.

Advantages: 1) Offspring genetically identical - favourable traits kept; 2) One parent required - eliminates need for pollination and fertilisation; 3) Much faster than sexual reproduction; and 4) With perennating organs, plants can tide over unfavourable conditions.

Disadvantages: 1) Plants lose vigour due to no genetic variation - prone to diseases that can wipe out whole crop; and 2) Plants produced in short time - if growth is not controlled, overcrowding and competition for resources may ensue.

The Flower

The flower contains reproductive structures. May be either bisexual (hermaphrodite) flowers - monoecious flowers, or unisexual flowers - dioecious flowers.



Flower parts	**Function(s); other comments**
Stamen	❖ male reproductive organ; ❖ filament with anther at the end; ❖ all stamen make the androecium; ❖ each anther is made of 2 lobes, each lobe has 2 pollen sacs, each sac contains pollen grains; ❖ each pollen grain contains 2 male gametes. ❖ pollen grains released when anther matures lobes split; ❖ filaments hold up anther in suitable position to release pollen grain.
Carpel	❖ female reproductive organ; ❖ made up of ovary, style, stigma; ❖ stigma receives pollen grain; style holds stigma out and connects it to ovary; ❖ flower can have more than 1 carpel, all carpels make up gynoecium/pistil; ❖ ovary can contain more than 1 ovule - ovule contains female gametes (ovum); ❖ ovule becomes seed, ovary becomes fruit;

	❖ ovule is attached to the ovary at the placenta.
Petals	❖ brightly-coloured, sometimes scented; ❖ arranged in cylinder/circle - corolla; ❖ attract insects (in insect-pollinated flowers).
Sepal	❖ modified petals - often green; ❖ protects flower when in bud stage; ❖ all sepals make the calyx.
Pedicle	❖ flower stalk; ❖ plants without pedicles known as sessile flowers.
Receptacle	❖ enlarged end of pedicle - flower structures attached here.

Pollination

The transfer of pollen grains from the anther to the stigma. Anthers split open, exposing pollen grains, and grains are carried by either wind or insect bodies. Flowers are adapted to different modes of pollination, namely self-pollination and cross-pollination.

	Self-pollination	**Cross-pollination**
Definitions	Transfer of pollen grain from anther to stigma of same flower OR Transfer of pollen grain from anther to stigma of another flower in same plant.	Transfer of pollen grains from anther to stigma of flowers from different plants, but of same species.
Advantages	One parent plant needed; Beneficial qualities inherited by offspring; No dependence on external factors; Less pollen required - less energy wasted; Ensures that every ovule develops into a seed.	Offspring inherits beneficial qualities from both parents; Greater genetic variation - better adapted to environmental changes; More viable seeds, thus longer dormancy possible.
Disadvantages	Offspring has less genetic variation - less adapted to environmental changes; Weaker, smaller, less resistant	Two parent plants needed; Dependant on external factors; More pollen required, thus more energy needed to improve

	offspring (e.g. to diseases).	chance of pollination.
Features favouring	Bisexual (monoecious) flowers; Same maturation times of anthers and stigmas; Anthers situated just above stigmas on same flower; Cleistogamous (closed) flowers → self pollination unavoidable.	Unisexual (dioecious) plants - male (staminate) flowers on 1 plant, female (carpellate) flowers on another; Different maturation times of anthers and stigmas; Anthers and stigmas on same flowers situated far apart; Self-incompatibility - ability to reject own pollen.

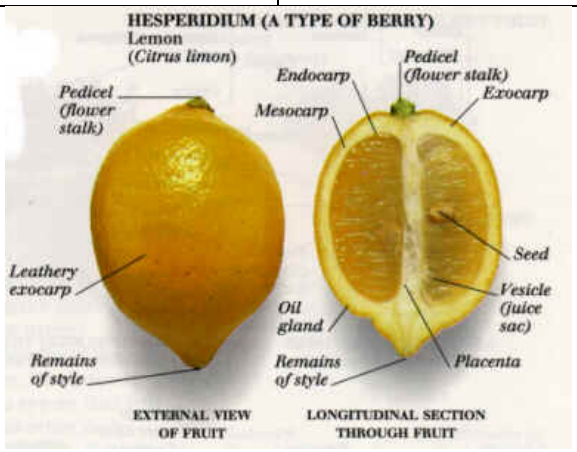
	Wind Pollination	**Insect Pollination**
Petals	Small and dull or absent	Large, brightly colored
Nectar	Absent	Present
Scent	Absent	Present
Stigma	Large, feathery, protruding out of flower	Small, compact, does not protrude out of flower
Stamen	Long and pendulous, protruding anthers	Not pendulous, does not protrude out of flower
Pollen	More abundant, tiny and light with smooth surfaces to prevent clumping	Fairly abundant, larger with rough surfaces

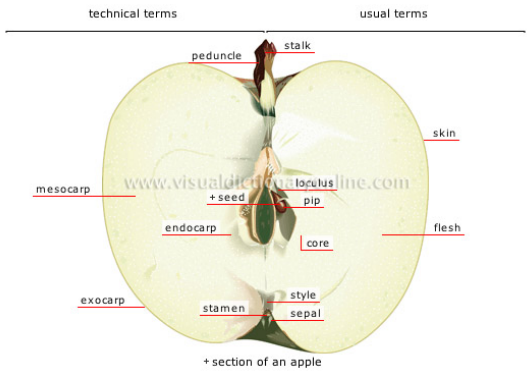
Fertilization

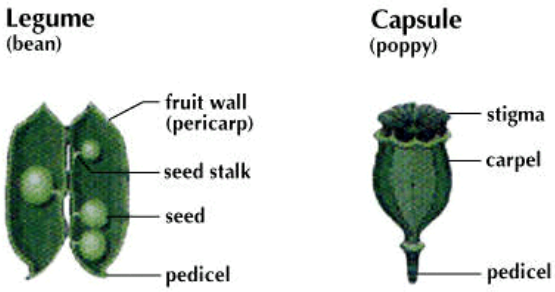
1. Pollen grain lands on stigma, and the pollen grain germinates in response to fluid secreted by stigma to form a pollen tube;
2. 2 nuclei are present in the pollen grain: the pollen nucleus and the generative nucleus;
3. Pollen nucleus moves in front, and secretes enzymes to digest tissue of stigma and stole. The pollen tube then grows, and the tip of the pollen tube grows towards the micropyle;
4. The pollen tube grows and generative nucleus divides by mitosis to form 2 male gametes. At the micropyle, the tip of the pollen tube absorbs sap and bursts, releasing 2 male gametes.
5. One male gamete fuses with the ovum to form zygote which develops into a new plant. The other male gamete (n) fuses with definitive nucleus (2n) to form endosperm nucleus (3n).

Self Fertilization	**Cross Fertilization**

Transfer of pollen grain from anther to stigma of same flower or another flower in same plant	Transfer of pollen grain from anther to stigma from different plants.
Only one parent plant needed	Two parent plants needed
Beneficial qualities likely to be inherited	Beneficial qualities from either parent may be inherited
Does not depend on external factors as much	Dependent on external factors (i.e wind, insects)
Less pollen needed, less energy needed	More pollen needed, and energy needed to create pollen
May have weaker, smaller, less resistant offspring	Greater genetic variation possible so better offspring
Flowers often bisexual	Flowers often dioecious
Anther and stigma have same maturation time	Anther and stigma have different maturation times
Anthers situated right above stigma	Self incompatibility: plant rejects its own pollen
Flowers are enclosed	Flowers open



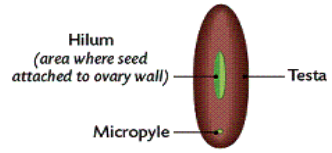


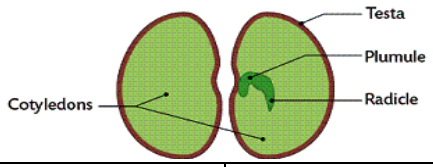


Pre Fertilization	**Post Fertilization**
Ovule	Seeds
Zygote	Embryo (plumule + radicle + cotyledons)
Endosperm Nucleus	Endosperm for food or absorbed by embryo
Integuments	Testa (seed coat)
Ovary	Fruit
Ovule Stalk	Funicle
Ovary Wall	Fruit Wall
Stigma and Style	Wither/modified for dispersal
Stamen	Wither

Petal	Wither
Sepals	Sepals

The Seed





Part of Seed	**Function/Facts**
Testa; Seed coat	-Outer coat of the seed; it protects the embryo from environmental influences as well as fungi, bacteria and insects. -Furthermore, the testa needs to be wet before germination can take place, so it ensures germination only occurs in right conditions.
Micropyle	-Area which pollen tube entered during fertilisation. Water and air enters the seed through the micropyle so that it can germinate.
Plumule	-Developing shoot (Part of embryo)
Radicle	-Developing root, this part comes out before the plumule. Eventually develops into root system of plant. (Part of embryo)
Cotyledon(s)	-Dicotyledonous- 2 cotyledons -Most dicotyledonous seeds have little to no endosperm as food reserves are just stored in the cotyledons -They contain the embryo and food reserves -Monocotyledonous- Single cotyledon -Most monocotyledonous seeds' food reserves are in the endosperm.
Endosperm(Only present in some seeds)	-Food reserves
Hilum	Scar. The Hilum indicates the original position of funicle(the site from which it was attached to the fruit)

Fruit/Seed Dispersal

Explosive Force	Pericarp of fruit is dry. When drying, the pericarp contracts, twists and opens with force to throw out seeds.
Wind	Wings and hairs develop from style of fruit. Fruit or seed is dry to reduce weight and has enlarged surface area so the the fruit and seed can stay afloat longer.
Water	Surface of fruit and seeds are waterproof, and there are light and spongy parts filled with air in seeds and fruit wall.
Animals I	Fruits are edible and often sweet smelling or scented animals. Seeds have tough seed coats so seeds can pass out in droppings or are too large to consume and are discarded by animals after eating flesh
Animals II	Attachments like hooks or hairs are present on the seed coat or wall of fruit, so that they can cling onto animal bodies to be transported further.

Germination

Artificial Selection

- Process where humans breed organisms for desired traits by selecting plants with better genes
- Natural population occurs in the wild
- Plants with desired traits are chosen for the next generation of plants by humans and are farmed
- Desired traits are passed on to offspring
- Parent plants with desired traits are also hybridised, strains are crossed to produce plants with more desired genes by manually fertilising flowers
- Over multiple generations, desired traits are concentrated and eventually increases the quality of crop
- Provides advantages of higher yield, shorter maturation times, pest and drought resistance

Biodiversity and Food Security

- Plants provide many advantages
    - Rubber trees provide latex and its derivatives
    - Coconut husks used for ropes
    - Cotton fibres used for cloth
    - 25% of medicinal drugs originate from plants in rainforest
    - Rice, pineapple and banana originated from rainforest environments
    - Plants provide habitat for wildlife
- Genetic homogenisation may result in vulnerability of human environments to disease and harm security
    - Irish potato famine

Evolution and Natural Selection

Definition

Species evolve over time, and non-random selected breeding processes may be present today. Changes in allelic and genotypic frequency can be determined by humans. Natural selection refers to the process where environment of nature selects for well-adapted individuals with inherited traits best suited to local environments. With selective advantages, they reproduce more and can leave more offspring.

Theory of Natural Selection

1. Organisms have great potential to reproduce (observation I)	Organisms produce large numbers of offspring, which assuming they survive, leads to an increase in size of population.
2. Constancy of numbers (observation II)	Populations often maintain relatively constant numbers. Limited resources also mean the majority of offspring die before reproducing.
3. Struggle for existence (inference I)	More individuals than environment can support leads to competition for survival (tests for survival). Factors like climate, disease and predators affect the chances of survival of an organism.
4. Variation among offspring (observation III)	Individuals are not identical in physiology, body, and behavior. Variations from genes can be inherited by the next generation. Variations occurs spontaneous before change in environment and not formed by environment, which causes adaptation. Sexual reproduction reshuffles genes, and mutations can also produce new genes.
*5. Survival of the fittest by NATURAL SELECTION (inference II)	Among offspring, some can better survive conditions due to genes. Better adaptation makes them more suited to survive in the struggle for existence. These advantageous genes allow them to better survive long enough to breed. Selective advantage present: even a small advantage tends to survive and multiply; small changes add up to big differences.
6. Like produces like (observation IV)	Those that survive to breed are likely to produce offspring similar to them. Advantageous traits that give them the edge in the struggle for existence are likely to be passed down to the next generation. The result would be an evolutionary modification that improves the chances of survival and reproductive success in a given environment.

Formation of new species
Over time, the proportion of individuals with advantageous genetic traits may increase, and the accumulation of new modifications can lead to a new species created over many generations.

Speciation
If a barrier splits a population in 2 different environments, the populations could become different due to differences in selection pressures (one environment could require a certain trait due to presence of predators, while the other may not).

Evolution occurs when the inherited characteristics of a population of species changes over a period of time. Differences in form or behaviour may prevent further interbreeding (e.g. reproductive isolation: allows each population to collect unique changes to their DNA as they evolved independently). When these changes lead to a formation of more than 1 new species, speciation has taken place.

Explaining Natural Selection

- Natural Selection occurs
- Environment acts on [favourable phenotype] by selecting species more likely to [selection pressure]
- Favours [species] because [favourable phenotype] causes [action favourable to selection pressure]
- Most likely to [survive/reproduce/colonise]
- Individuals leave more offspring which display similar phenotype
- Results in propagation of allelic frequency

Variation in Species

- Species is said to come from same ancestor when a common phenotype is observed across different subspecies
- Isolation of different species which allow natural selection to take place over a long period of time in varied environments and selection pressures, produces varied offspring with vastly different phenotypes