WJEC

Biology A2

Unit 5

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Index

1.1 Biological Molecules

Roles of Inorganic Ions in Animals and Plants

WJEC Specify: Mg^{2+}, Fe^{2+}, Ca^{2+}, PO_4^{3-}

Inorganic Ion	Role in Animals	Role in Plants
Mg^{2+}	- Component for teeth and bones	- Component for chlorophyll - *Deficiency cause chlorosis*
Fe^{2+}	- Component for haemoglobin - *Deficiency leads to anaemia*	- Component for chlorophyll
PO_4^{3-}	- Component for ATP, DNA, RNA (nucleic acid) and **phospholipids**	
Ca^{2+}	- Strengthening bones and teeths	- Strengthening cell wall

Water Properties

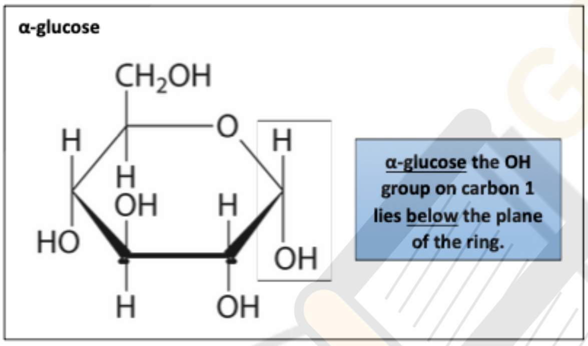
- Polar Molecules / Dipole
  - Uneven distribution of charge
  - Which form hydrogen bonds between molecules
- Dissolve ionic / polar substance
  - Which is used for transportation of molecules
- High latent heat of vaporisation
  - For cooling / lowering body temperature in animal
- **High Specific heat capacity**
  - Requires a lot of energy to cause water to heat up
  - Helps to maintain a thermal stable environment
- Transparent to allow light to pass through for aquatic plant photosynthesis
- **Polar: Cohesion and Adhesion of water molecules**
  - Cohesion: Forms hydrogen bond between water molecules – Allows insects to walk on water
  - Adhesion: Water transpiration through xylem
- Reactant in photosynthesis / hydrolysis of water
- **Ice is less dense than water**
  - Ice will floats on water surface providing insulation of pond life
- **Metabolite**
  - Chemical reaction occur in solution

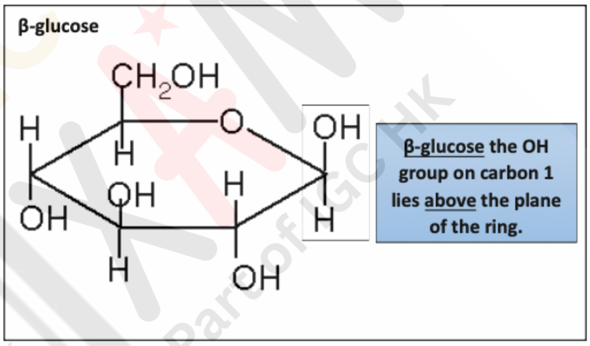
Carbohydrate

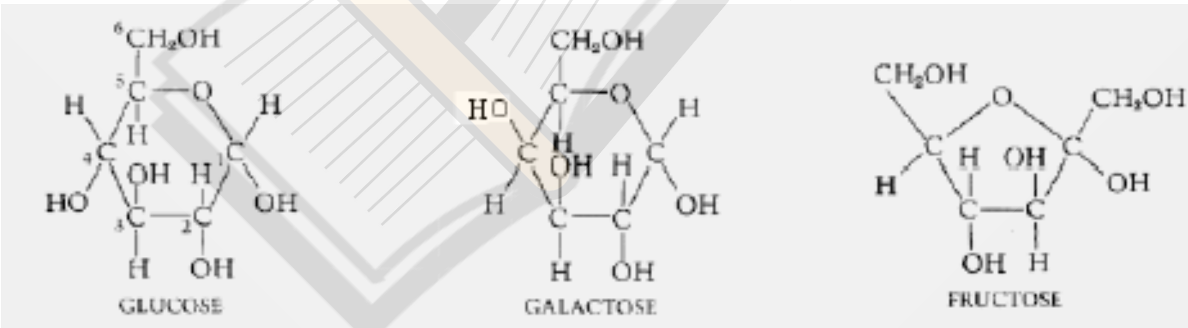
Monosachride

- Formula $C_nH_{2n}O_n$

Triose	Gluceraldehyde	Respiration intermediate
Pentose	Ribose Deoxyribose	Component of DNA Component of RNA
Hexose	α,β Glucose Fructose Galactose	Provides energy via respiration Sweetens fruit Milk sugar





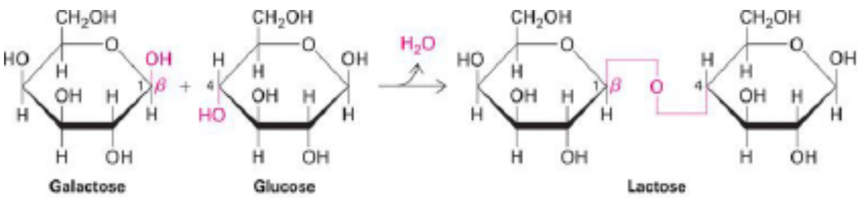


Disachride

- Formula $C_{12}H_{22}O_{11}$

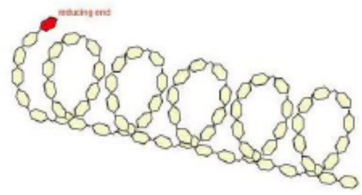
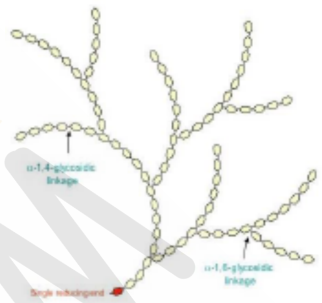
Sucrose	α Glucose – Fructose	Transported in phloem of flowering plants
Maltose	α Glucose – α Glucose	Used in seed germination
Lactose	Glucose – Galactose	Found in mammalian milk

Condensation Reaction

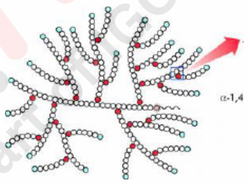


Polysachride

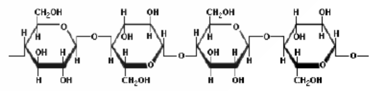
Starch

<u>Plants</u> Insoluble + Compact	Amylose - Polymer of alpha glucose - Straight chain - Coiled and Compacted - Alpha helix - α–1,4–glycosidic bond - <u>Store of carbohydrate</u>	
	Amylopectin - Polymer of alpha glucose - Branched chain - α–1,4–glycosidic bond and α–1,6–glycosidic bond - <u>Rapid Release terminal for ATP</u>	

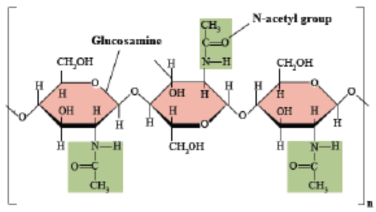
Glycogen

<u>Animals</u> Insoluble	- 1,4–glycosidic bond and 1,6–glycosidic bond - More branched chain so more terminal for <u>rapid release of ATP for respiration</u>	

Cellulose

<u>Plants</u> Strength and Support <u>Plant cell wall</u>	- β Glucose - β–1,4–glycosidic bond - Alternating glucose molecules must be rotted through 180° - Long and straight chains - Bundles of chains: <u>Microfibrils</u> - Hydrogen bond can be found between parallel chains	

Chitin

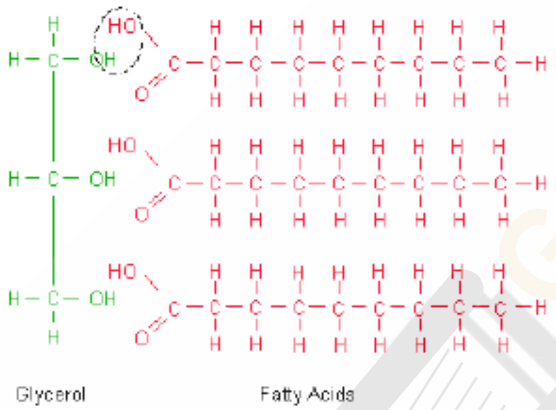
<u>Exoskeleton of insect</u> <u>Cell wall of fungi</u>	- Subunits: <u>glucosamine</u> - β Glucose - β–1,4–glycosidic bond - Alternating glucose molecules must be rotted through 180° - <u>Actylaminine group</u> at C2 - Hydrogen bond can be found between parallel chains forming <u>microfibrils</u>	

Lipid

- Long term energy storage
- Lipids yield twice as much energy than carbohydrates

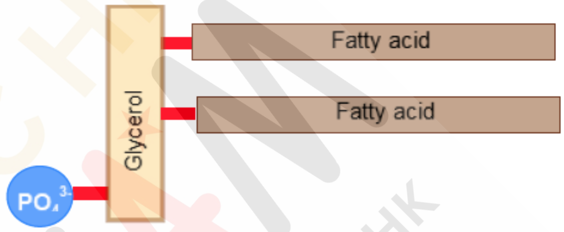
Triglyceride

- 1 Glycerol + 3 Fatty Acid
- Non-polar compounds
- Function; Thermal insulation, Energy Storage, Physical Protection + Buoyancy



Phospholipids

- Hydrophilic head
- Hydrophobic tail
- Function: Phospholipid bilayer



Saturated Fatty Acid

- Only single carbon to carbon bonds

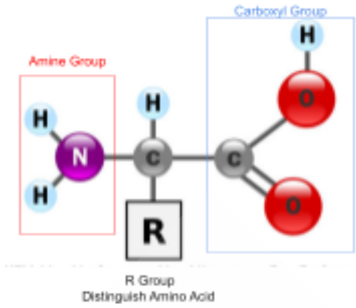
Human Health Problems:
- Contributor factor in heart disease
- Raises the LDL level
- Increases the incidence of atheromas in coronary arteries

Unsaturated Fatty Acid

- Two or more carbon to carbon double bonds
-

Protein

- C,H,O,N,(S)
- Polypeptide
- Peptide Bond



Level

- The primary structure is the sequence and number of amino acids in a polypeptide.
- The secondary structure of a protein is the coiling or folding of the polypeptide into an alpha helix and beta pleated with hydrogen bonds.
- The tertiary structure is the folding and coiling of the secondary structure to a complex 3D shape with ionic, disulfide, hydrophobic interaction and further hydrogen bond.
- The quaternary structure protein have 2 or more polypeptide chemically bonded together

Types

Essential amino acid

- Hyman: Diet
- Plant: Manufacture

Non-essential amino acid

- Human and Plant: Manufacture

Quaternary Structure

Globular Protein

- Water Soluble
- Functurnal Protein
- Congidated
  Have prosthetic group, eg: Haem Group
- Spherical
- Haemoglobin
- Dissolve in plasma

Fibrous Protein

- Insoluble in H_2O
- Structural Protein
- Collagen Fibre
  On skin and bone
  Strength as there is cross link in between

⭐ Food Test ⭐

Hazzard	Risk	Control measure
Biuret is an irritant	Could splash onto hands or into eyes when transferring biuret to test tube	Wear gloves/ eye protection
Ethanol is flammable	Could catch fire if used near a Bunsen burner	Ensure all Bunsen burners are turned off before ethanol is used

Reducing Sugar – Benedict's Test

1. Add equal volume of test solution and Benedict's reagent
2. Heat in a warm water bath
3. Positive Result: Blue → Orange / Red precipitate

Non Reducing Sugar

1. Add equal volume of test solution and Benedict's reagent
2. Heat in a warm water bath
3. Observe colour change. If not a reducing sugar → remains blue
4. Add 2 drops of HCl and heat
5. Add 2 drops of NaOH
6. Add Benedicts' reagent
7. Heat in warm water bath
8. Non reducing sugar: Blue → Orange / Red precipitate

Proteins – Biuret Test

1. Add equal volume of test solution and Biuret reagent
2. Cover the top and invert it once. Positive: Colour change from pale blue to purple

Starch – Iodine

1. Add $2cm^3$ of test solution and 2 drops of Idodine
2. If starch is present the solution will change colour from yellow brown to blue/ black

Fats and Oils

1. Add equal volume of test solution and alcohol in a boiling tube
2. Shake the tube
3. Pour the mixture into another boiling tube half full of cold water
4. If lipids are present a cloudy white emulsion will form

1.3 Cell membranes and Transport

Plasma Membrane

- Partially Permeable
- Controls what enter and leaves the cell

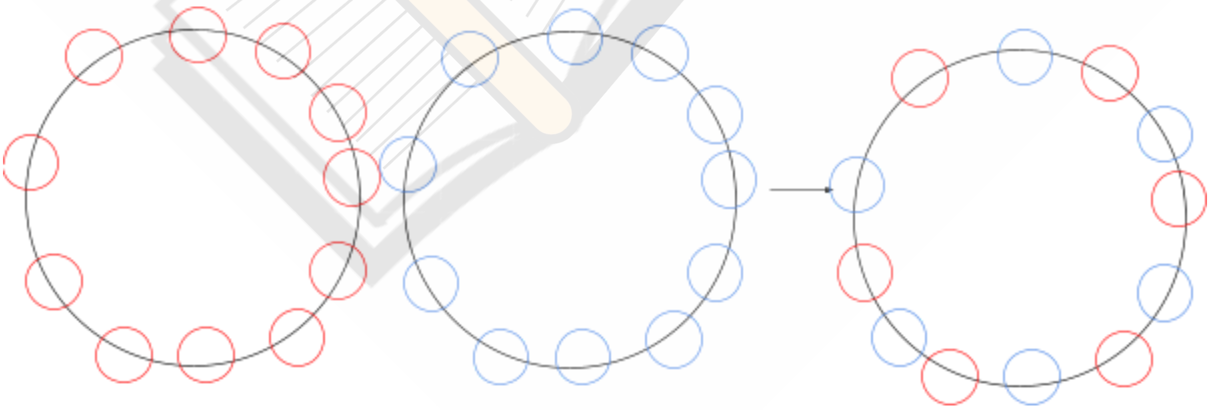
- Allow small and non-polar (lipid soluble) molecule to diffuse across the cell membrane
- Charged and polar molecules (water soluble) have to pass through proteins
- Vitamin A, D are lipid soluble (Dissolve + Simple Diffusion across bilayer)
- Vitamin B, C are water soluble (Facilitated Diffusion)
- Small molecule X Dissolve though bilayer, Lipid Soluble ✓ Dissolve

Fluid Mosaic Model

Explanation

Fluid - Individual phospholipid models can move within a layer of relative to one another.
Mosaic - The proteins embedded in the bilayer vary in shape and size in their distribution within their layer.

Proof Fluidity



Exocytosis, endocytosis
- Phospholipid molecule can form and break down easily

Cell Division
- Cell membrane forms during telophase
- Cell Membrane disintegrate during prophase

Substance inside the layer

Phospholipid Bilayer

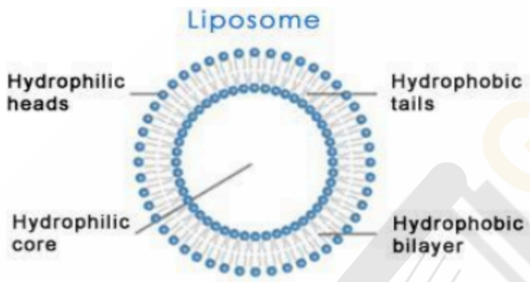
Hydrophilic Head

- Polar
- Water Loving

Hydrophobic Tail

- Non-polar
- Can be saturated or unsaturated

Liposome



Cholesterol

- Regular Fluidity

Protein

Extrinsic - Across single Layer
Intrinsic protein - Span the bilayer

Channel Protein

- Facilitated Diffusion
- Pores lined with polar group

Carrier Protein

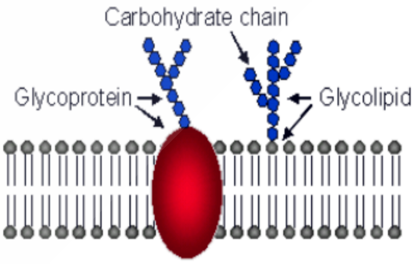
- Facilitated Diffusion
- Passive
- Changes shape
- No ATP required
- High Conc. to Low Conc.

- Active Transport
- Molecule binds to receptor
- ATP broken down into ADP
- Changes shape
- Molecule is released
- It returns to original shape
- Move the substance against the concentration gradient

Other Proteins

Glycoprotein

(Glycolipid)



- Stabilised the membrane
- Carbohydrate + Protein // Lipid

Receptor

- Allow substance such as hormones and neurotransmitter
- To bind with it

Antigen

- Immute System

Factors affecting Fluidity

Temperature

- Higher Temperature
- Higher Kinetic Energy
- More Fluid

Fatty Acid

- Unsaturated Fatty Acid
- More Kinks
- Fit together less closely

Pemaiblity $\propto$ Fluidity

Beetroot Cell Practical

- Proofs temperature after permeability
- Heating the cells cause gaps in the bilayer, more permeable
- The shape of protein molecule is broken, destroying tertiary structure
- Betalain (a red pigment in beetroot) could escape from vacuole if the plasma membrane is brocken

Higher the temperature, the more permeable it is. Because it gains more Kinetic Energy so it moves around, creating more gaps.

Diffusion

Simple Diffusion

- Net Movement
- Passive
- No ATP required
- Down a concentration gradient

- For non-polar and lipid soluble substance to diffuse through the membrane

Factors Affecting Diffusion

- Concentration gradient
  Steeper -> Higher Rate

- Temperature
  Higher Temperature, Higher KE, Higher Rate

- Size
  Smaller particle size -> Higher Rate of Diffusion

- Distance
  Shorter distance -> Higher Rate of diffusion

- Surface Area
  Larger the surface area, higher rate

Facilitated Diffusion

- For molecules or ions that are large or charged
- Passive
- No ATP required
- Down a concentration gradient
- By Protein Carrier Molecule

Comparison

Simple Diffusion is Faster than Facilitated Diffusion
Because the surface area for Simple Diffusion is bilayer which is more than facilitated diffusion which uses carrier protein

Facilitated Diffusion using Channel protein

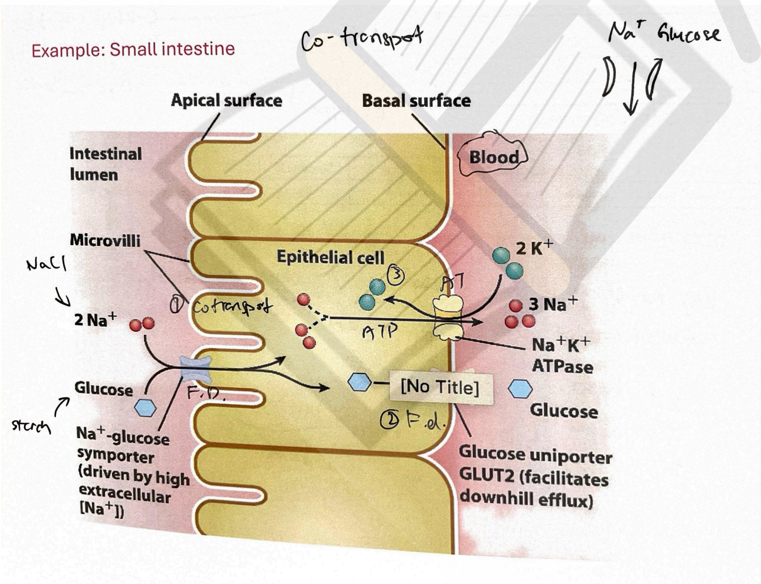
- Channel protein is for particular molecule / ion
- Pores are lines with polar group
- Gated Protein (Electrical signal)
- Aquaporines are channel proteins for H_2O molecules.

Facilitated Diffusion using Carrier protein

- For large pilar molecule
- Only specific molecule can fit as the shape is specific
- No ATP Required
- Protein changes shape to allow the molecule to pass through

Co-transport

- A type of facilitated diffusion
- Sodium-glucose co-transport
- 1 Glucose + 2 Sodium Ions are attached
- Carrier protein changes shape
- 2 molecule / ions must be present at the same time



- Intestinal lumen -> Epithelial Cell -> Blood
- From high concentration in interstitial lumen to low concentration in blood for co-transport to work

Osmosis

- Net movement of water molecule
- From higher water potential to lower water potential
- Through a selectively permeable membrane
- By osmosis

Only occurs in liquid

Water potential (ψ)

Water potential is the tendency of water molecules to move into / out of a cell or solution.
Ψ = 0 pure water

Solute potential ψ_s

- The reduction in water potential due to present of solute molecule
- Measures how easy water molecules can move out of a solution
- Ψ_s is always -ve

Pressure Potential ψ_p

- Always positive
- It is the pressure exerted on the cell contents by the cell wall

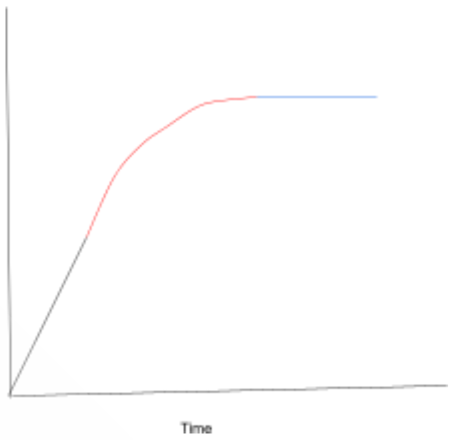
$$\Psi = \Psi_s + \Psi_p$$

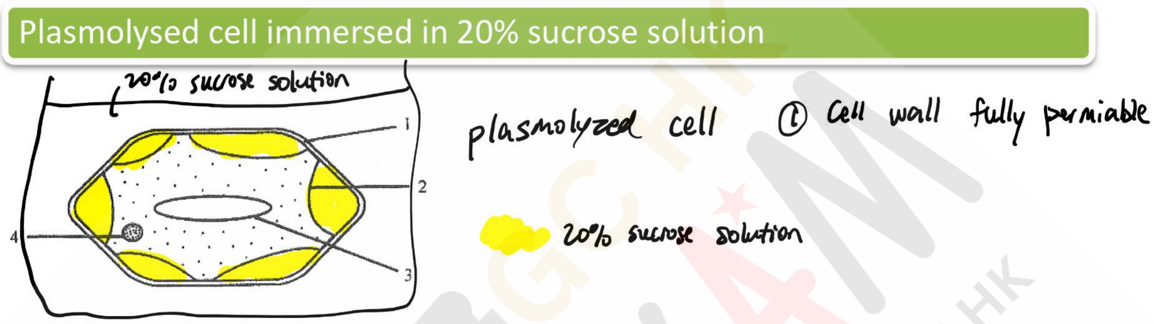
Potato Example

- Raw potato, ✓ Osmosis
  Differently permeable cell membrane present
- Boiled Potato, X Osmosis
  Damage cell membrane -> Fully Permable
- Peeled Potato
  High rate of Osmosis, because larger Surface Area for Osmosis
- Unpeeled Potato
  Impermeable in H_2O

If you want to increase the water level in the potato center, add some sucrose solution to reduce the water potential, so more water can move into the center.

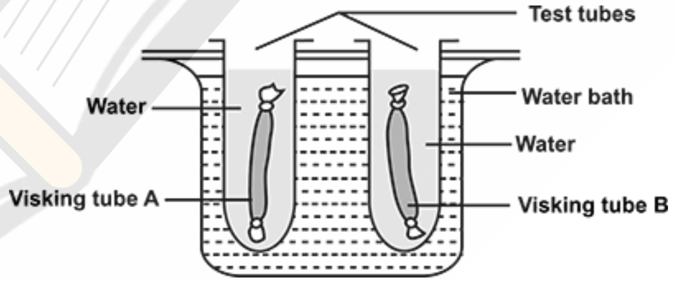
Black - Gradient Steepest, Highest Rate of Osmosis
Red - Gradient less steep, plateau
Blue - No net movement of water by osmosis
osmosis stoped
Same water potential



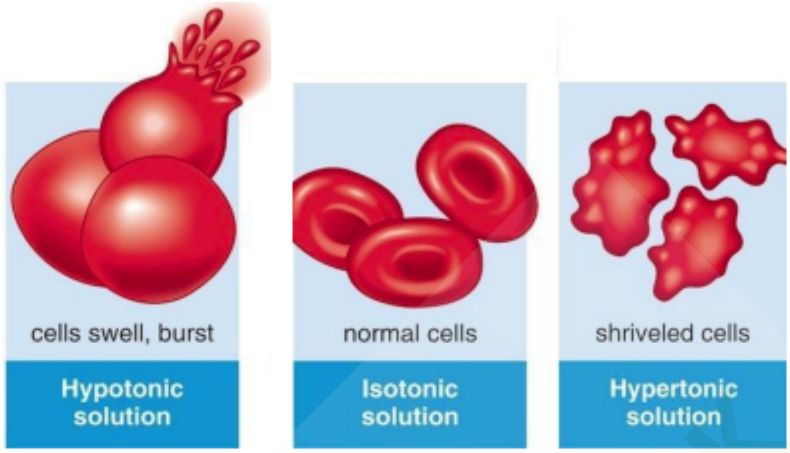


VIsking Tubing

If sucrose (originally) changes to glucose, it would affect water potential as glucose is small. Becomes diffusion instead of osmosis.



Osmosis in Animal



Hypotonic

- In Distilled Water, water moves into cell
- RBC swells and burst
- RBC is <u>haemolysed</u>

<u>Haemolysed:</u>
Cell burst
Haemoglobin released
Red pigment

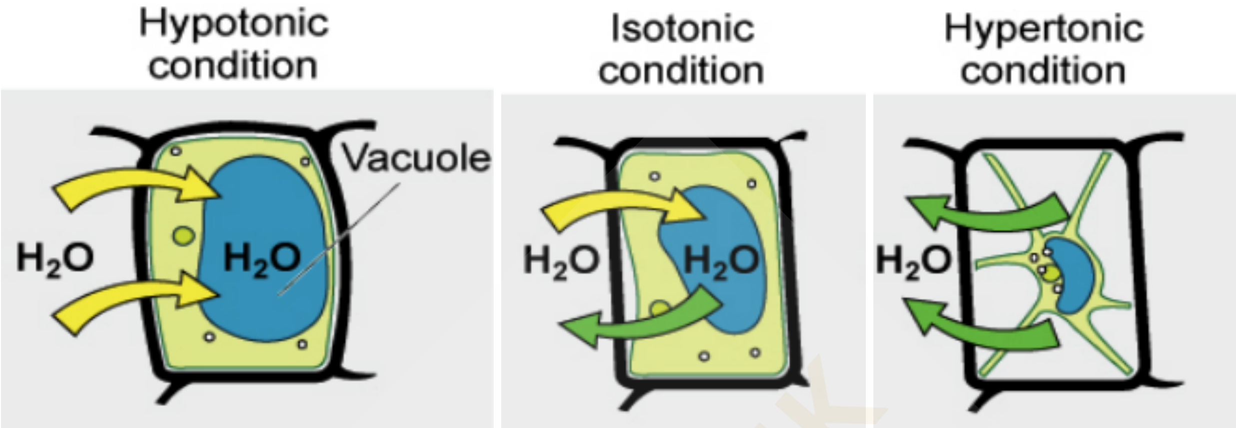
Isotonic

- Water potential inside cell is equal to the solution
- No net movement of water
- RBC remains in <u>biconcave</u> shape

Hypertonic

- Water moves out of cell
- Cell is <u>crenated</u>
- RBC <u>shrinks and wrinkles</u>

Osmosis in Plant



Hypotonic

- Water moves into cell
- Plant cell becomes turgid

Isotonic

- Cell is referred as incipient plasmolysis
- Cell membrane is beginning to pull away from cell wall
- $\Psi cell = \psi s$

Hypertonic

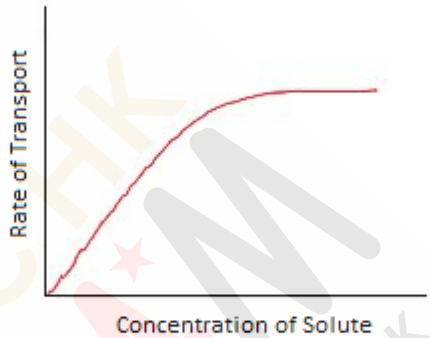
- Water pass out of cell
- Cell is described as plasmolysed
- Cell membrane is completely pulled away from cell wall

Active Transport

- Movement of molecule against a concentration gradient
- With the use of ATP

- (Intrinsic) carrier protein in plasma membrane
- Molecule binds to receptor
- Carrier protein changes shape
- Molecule is released
- Carrier protein returns to original shape

Graph plateau, Reason:
1. ATP Limiting
2. Number of protein limiting



Usage

1. Muscle contraction
2. Exocytosis
3. Neve impulse
4. Uptake of mineral ion

Cyanide

- Respiratory inhibitor
- Inhibits the enzyme
- Competitive inhibitor, blocks the active site for ATP
- Lower rate of respiration
- Less ATP produce

Bulk Transport

- Large quantity
- Require ATP
- Reduce surface area

Endocytosis

Phagocytosis

- Engulf into cell
- Solid material

- Example: Phagocyte (WBC) engulf bacteria

Pinocytosis

- Bulk uptake of fluid

Exocytosis

- Secrete substance out of cell
- Secretory vesicle fuse with cell membrane
- Increase surface area

Conclusion

Transport mechanism	Passive/Active?	Energy required? (Y/N)	Substance(s) moving?	Direction of movement	Protein needed? (Y/N)
Diffusion	Passive	No	Small/hydrophobic/ non-polar molecules	High to low conc.	No
Facilitated diffusion	Passive	No	Large/hydrophilic/polar Molecules/ions	High to low conc.	Yes
Osmosis	Passive	No	Water	High ψ to low ψ	No
Active Transport	Active	Yes	Any molecules/ions against a conc. gradient	Low to high conc.	Yes
Endocytosis	Active	Yes	Large volumes of any molecules/ions of large molecules	Into cell	No
Exocytosis	Active	Yes	Large volumes of any molecules/ions of large molecules	Out of cell	No

3.2 Photosynthesis

$$6CO_2 + 6H_2O \xrightarrow{\text{Sunlight}} C_6H_{12}O_6 + 6O_2$$

Carbon Dioxide Water Glucose (Energy) Oxygen

Photosynthetic pigments

Chlorophylls

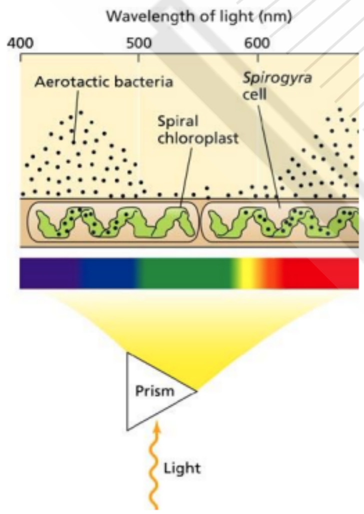
Chlorophyll a and Chlorophyll b

Carotenoids

Accessory pigments

β- carotene and Xanthophyll

Experiment for Photosynthetic Pigment (Engelmann's Experiment)



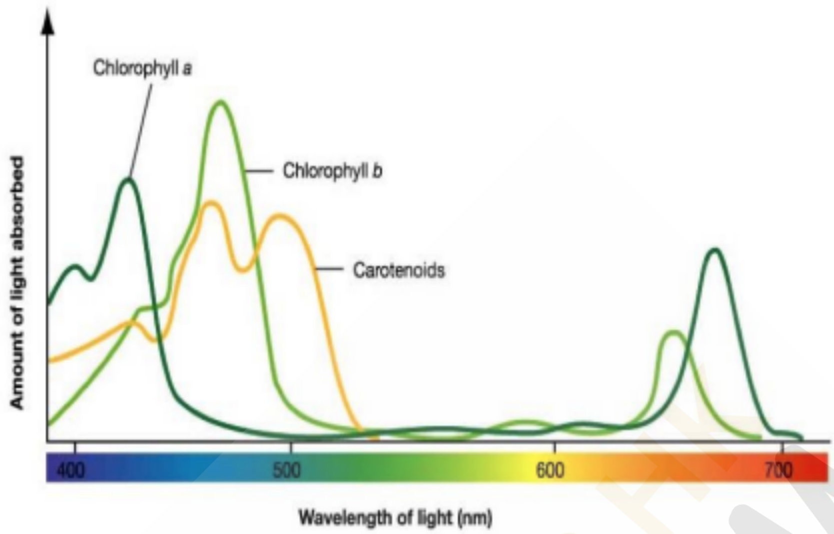
Results

- Bacteria are <u>clustered</u> around blue-violet and red light
- Only these wavelength of <u>algae photosynthesise</u>
- Forming <u>oxygen for the aerobic bacteria</u>

Conclusion

- Blue-violet and red are the most effective wavelength for photosynthesis
- <u>Because there is more O_2 produced in these regions to attract the bacteria</u>

Absorption and Action Spectrum

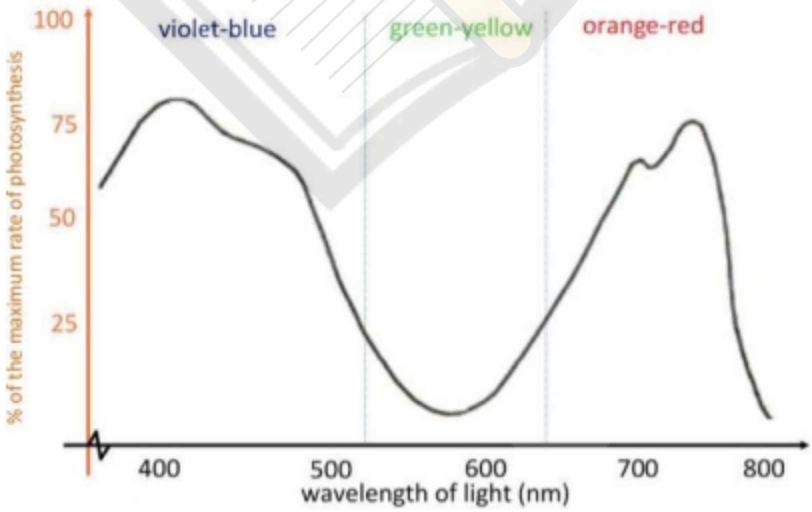


Absorption

- Shows <u>amount of light energy absorbed</u>
- Chlorophyll a and b absorb photon mainly in the blue-violet and red region
- Carotenoids absorb photon mainly in blue-violet region
- *They reflect wavelength in green region*

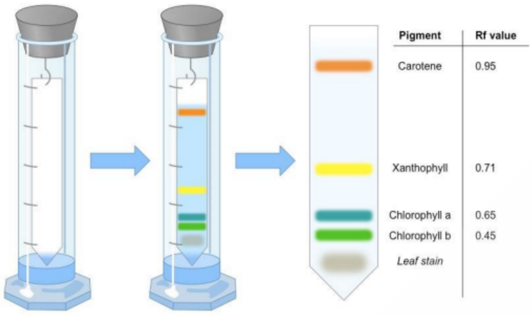
Action

- Shows <u>rate of photosynthesis</u>



Green light is mostly reflected so the action spectrum of green wavelength has a low P rate.

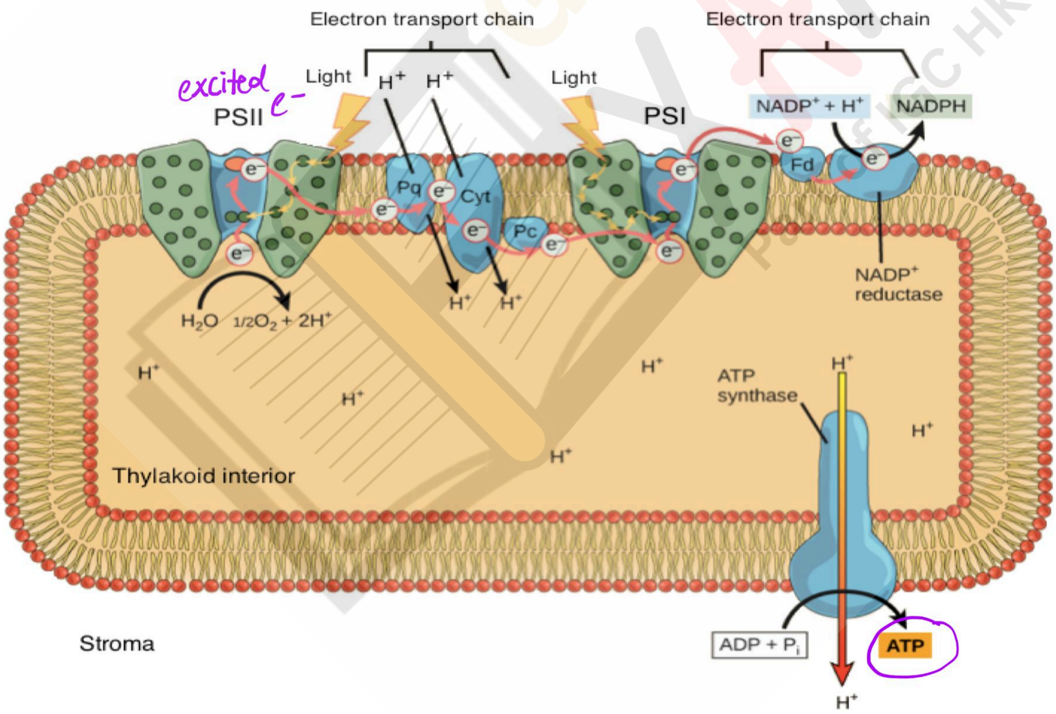
Chromatography



$$R_f = \frac{\text{distance travelled by pigment}}{\text{distance travelled by solvent front}}$$

Chemiosmosis

Protons (H^+) flow across these membranes down a concentration gradient

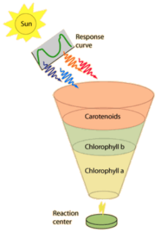


- Chemisosmosis is the process by which cells generate ATP using the energy stored in a proton gradient across a membrane
- Electrons are excited by light
- Excited e^- pass the ETC and release energy
- Energy is used to pump protons across the membrane creating electrochemical gradient
- Protons are passed through ATP synthetase
- Energy is released to combine ADP and Pi to form ATP

Photosynthesis - Light Dependent Reaction

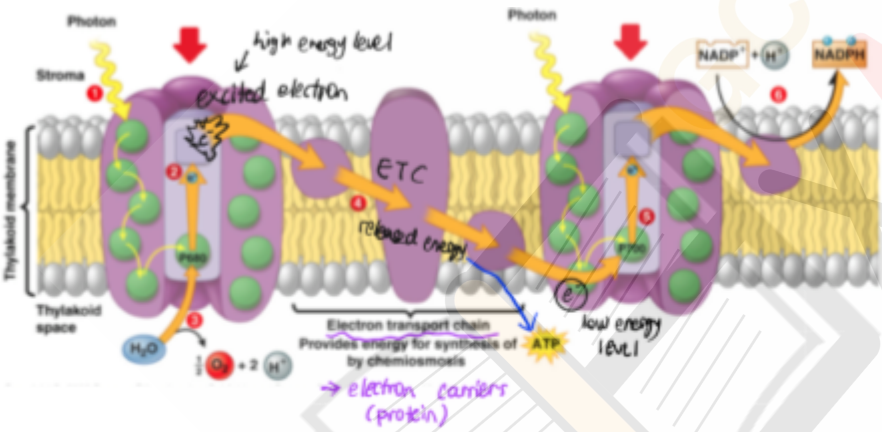
Overall

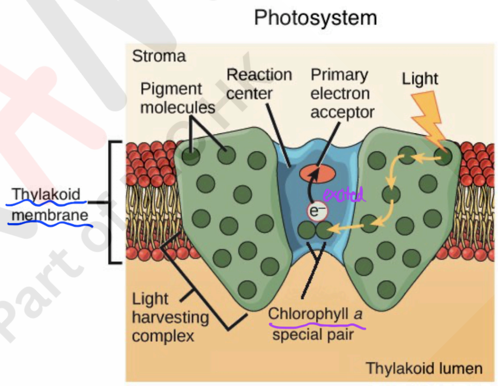
- Site: **Thylakoid Membrane**
- Required: Light energy + H_2O
- Product: ATP + Reduced NADP



Antenna Complex

- Light harvesting complex
- Accessory Pigments: Carotenoids + Chlorophyll b + Chlorophyll a
- **Reaction Center**: Chlorophyll a
- Electron is excited in reaction center





Photosystems

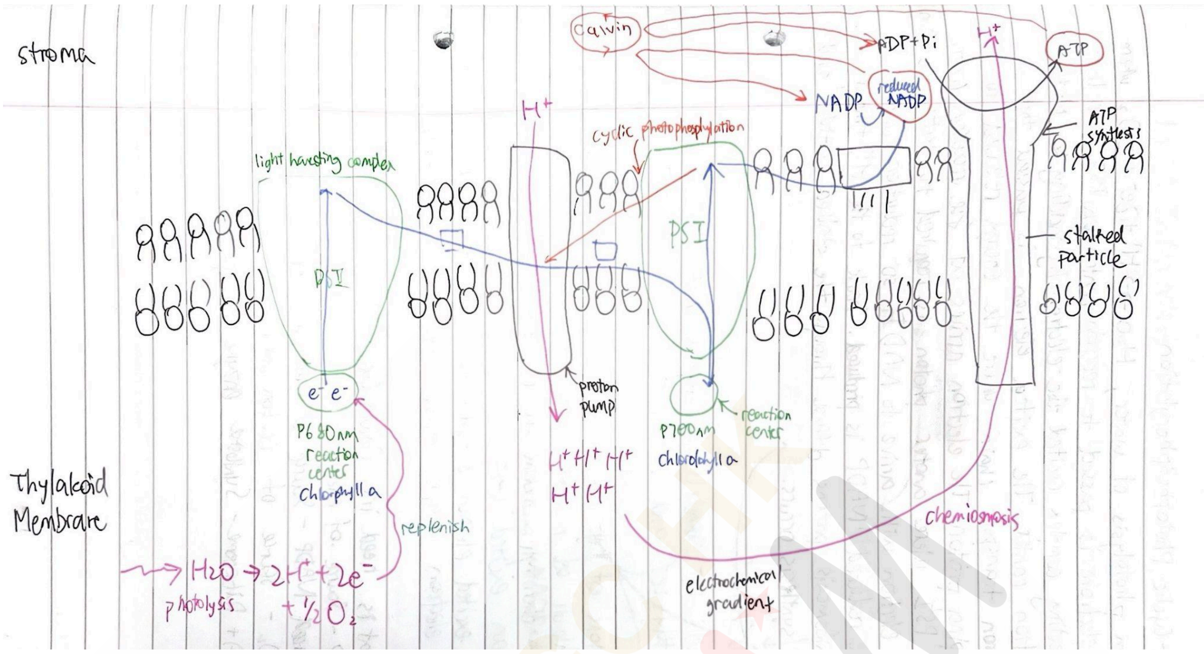
PSI

- 2 Chlorophyll a molecules
- Absorption peak of 700nm
- P700

PSII

- 2 Chlorophyll a molecules
- Absorption peak of 680nm
- P680

Photophospylation



Photolysis of Water

H_2O -> $2H^+ + 2e^- + ½ O_2$
- The electron provided for photophosphorylation
- Requires photon to activate

Photophosphorylation

Z Scheme (Non-Cyclic Photophosphrolation)

- Photon is incident on light harvesting complex (Antenna Complex) of PSII
- Which excites the electron from PSII reaction center
- The electron is passed down the electron transport chain (ETC) which release energy
- The released energy is used to pump the proton in the proton pump
- The electron in ETC would reach the reaction center of PSI
- Another photon will incident on PSI and excites the electron
- The NADP accepts the excited electron and H^+ and NADP -> Reduced NADP
  This process is The Reduction of NADP
- The reduced NADP is used in Calvin Cycle

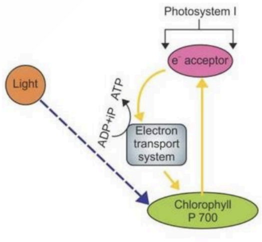
- Back to the proton pump, energy is used to pump the electron across from stroma to thylakoid membrane
- Creating an electrochemical gradient, where the H^+ moves by chemiosmosis to the stalked particles
- The H^+ passes through stalked particle, at the end of stalked particle phosphorylation occurs where ADP + Pi -> ATP, ATP is used in Calvin Cycle

Mark Scheme for Flow of electrons from PSII to NADP (Z Scheme)

- Photons of light are absorbed by accessory pigments and passed to 2 chlorophyll a molecules at the reaction centre of PSII.
- Each chlorophyll a molecule has one electron boosted from ground state to an excited state.
- The excited electrons are lost from chlorophyll a (oxidised) and passed to an electron acceptor molecule with the reaction centre of PSII.
- The electron acceptor becomes reduced.
- The electrons pass along a series of electron carriers embedded within the thylakoid membrane, which form the electron transport chain.
- The electrons lose energy along the chain, as their energy is being used to power the single proton pump within the ETC.
- The electrons pass the reaction centre of PSI where they are at ground state.
- The accessory pigments of PSI absorb photons of light and transfer them to the 2 chlorophyll a molecules at the reaction centre.
- Each chlorophyll a molecule has one electron boosted from ground state to an excited state.
- The excited electrons are lost from chlorophyll a (oxidised) and passed to an electron acceptor molecule with the reaction centre of PSI.
- The electron acceptor becomes reduced.
- The electron acceptor then transfers the electrons to NADP via a second electron transport chain.
- NADP + 2e- + 2H+ = Reduced NADP
- Reduced NADP is formed in the stroma ready to be used as a hydrogen donor in the light-independent reaction.
- The electrons at PSII are replaced by the photolysis of water which generates 2e-

Cyclic Photophosphrolation

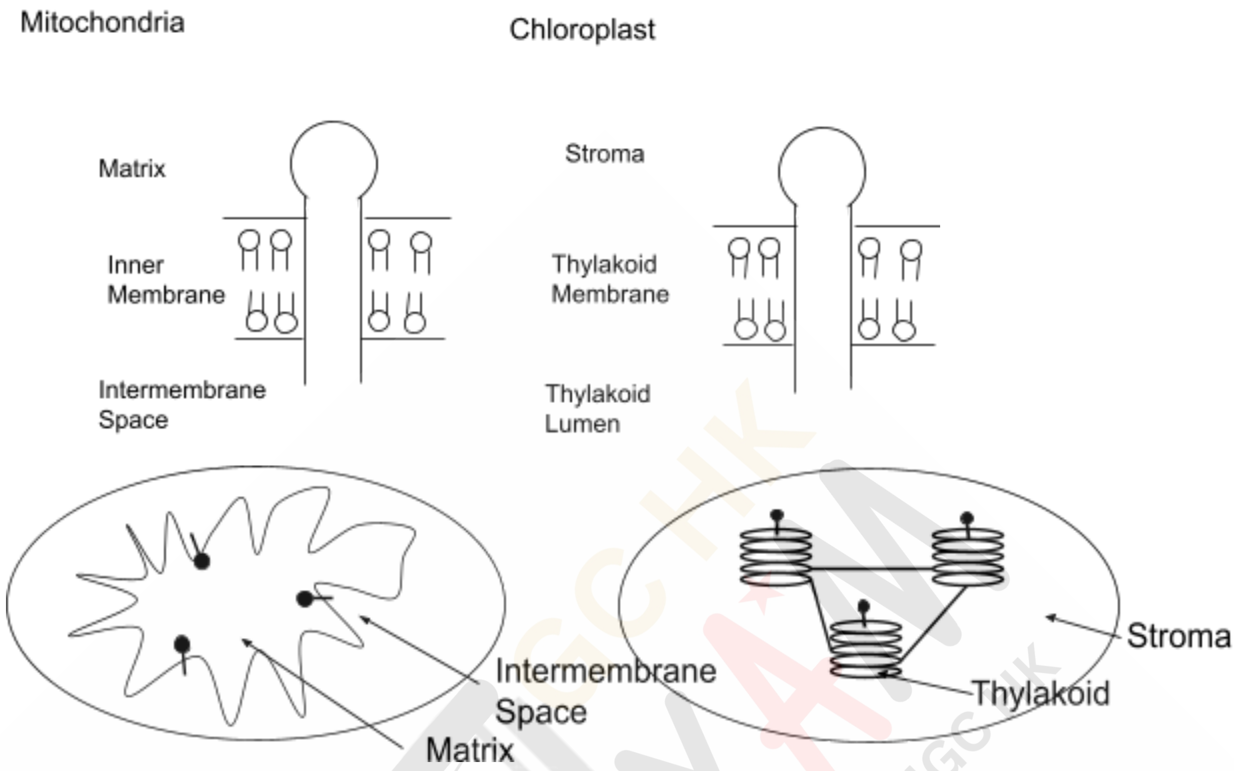
- Only occurs in PSI, Reduced NADP is not produced
- Occurs when plant needs extra ATP
- Photons excite 2 electrons from the chlorophyll a molecules at the reaction centre of PS I
- The electron is passed to the reaction centre
- The electrons are then passed along the first electron transport chain
- The energy of the electrons is used to drive the proton pump
- Chemiosmosis and ATP synthesis occurs



Cyclic photo-phosphorylation

Cyclic Photophosphorylation	Non-Cyclic Photophosphorylation
Only PS I is involved	PS I and PS II are both involved
Water is not required	Photolysis of water is required
Oxygen is not evolved	Oxygen is evolved
NADPH is not synthesized	NADPH is synthesized
Used to produce additional ATP in order to meet cell energy demands	Products can be used for the light independent reactions

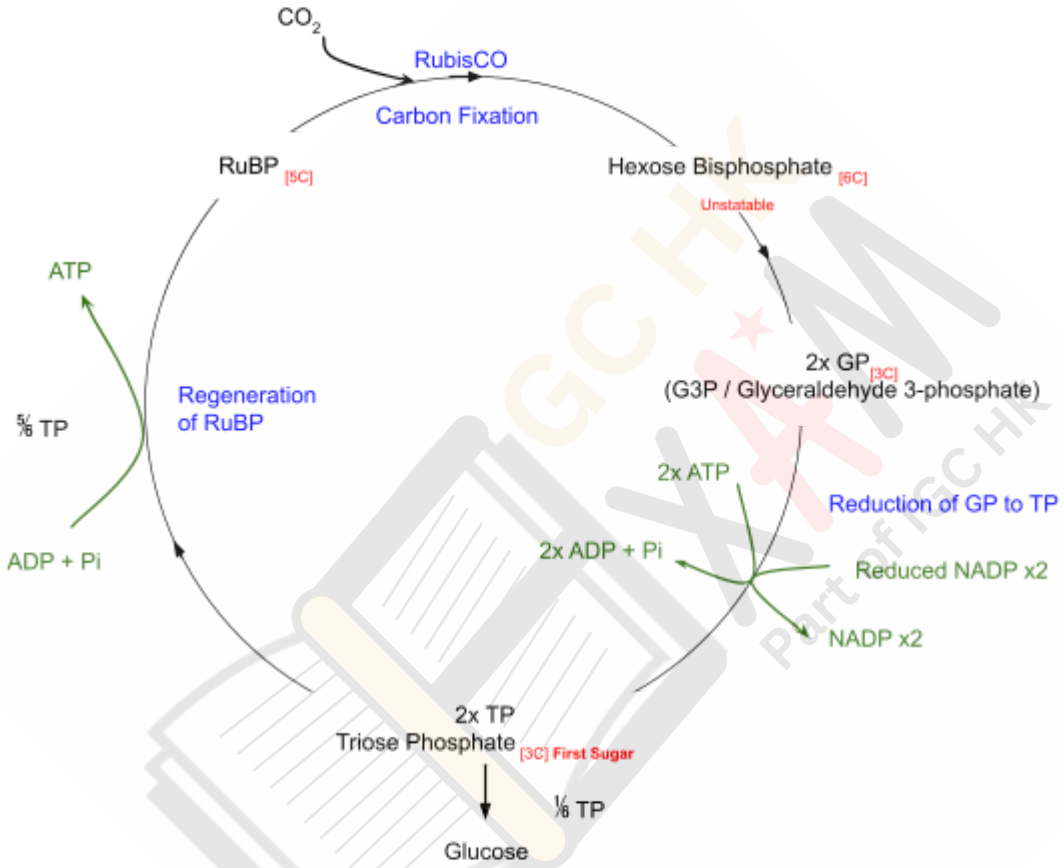
Location of Chemiosmosis Occurs



Light Independent Stage

Calvin Cycle

- Occurs in stroma
- Can happen in dark as long as there is a supply of ATP and reduced NADP
- Carbon fixation let CO_2 to be in the biomass
- TP is the first true sugar



Carbon Fixation

- One carbon dioxide molecule combined with RuBP (5C)
- Reaction is catalysed by RuBisCO
- An unstable Hexose Bisphosphonate (6C) is formed
- It breaks down into 2 GP (5C)

Reduction of GP to TP

- 2x Reduced NADP are oxidised to 2x NADP by giving up its H^+ ions
- 2x ATP are used to provide a source of energy
- 2 molecules of Triose Phosphate are formed

Regeneration of RuBP

- ⅚ TP molecules are recycled into 3 more molecules of RuBP (5C)

Application Questions

What happens to the relative concentrations of GP to RuBP in the dark?

- There is no reduced NADP or ATP generated
- The relative concentration of RuBP could decrease and GP would increase
- As carbon fixation still occurs but not the reduction of GP to TP

What happens to the relative concentrations of GP to RuBP if CO_2 is removed or if RuBiSO is denatured?

- GP concentration decrease RuBP concentration increase
- Reduction of GP to TP and Regeneration of RuBP still occurs

Evidence of Calvin Cycle

- Carbon 14 isotopes are used as tracers
- Algae is used in solution
- Chlorella (algae) are put into hot methanol to be killed
- A 2-way chromatography is extracted

Result

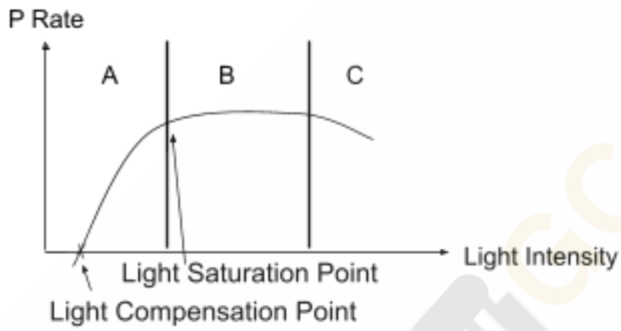
Time (s)	Relative Substance
0	–
5	GP
10	GP + TP
15	GP + TP + Glucose
20	GP + TP + Glucose + RuBP

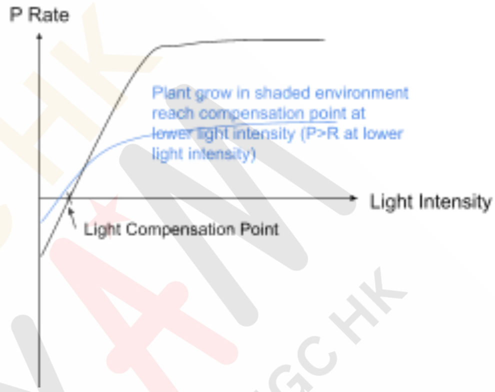
RuBP is formed later than Glucose as there are more reaction steps in Regeneration of RuBP

Limiting Factors

- CO_2 Concentration
- Light Intensity
- Temperature
- Water Availability

Light Intensity





A

- As light intensity increase, P rate increase
- Light intensity is a limiting factor

B

- As light intensity increase, P rate constant
- Light intensity is a limiting factor
  Limiting factor: CO_2 concentration, temperature, water availability

C

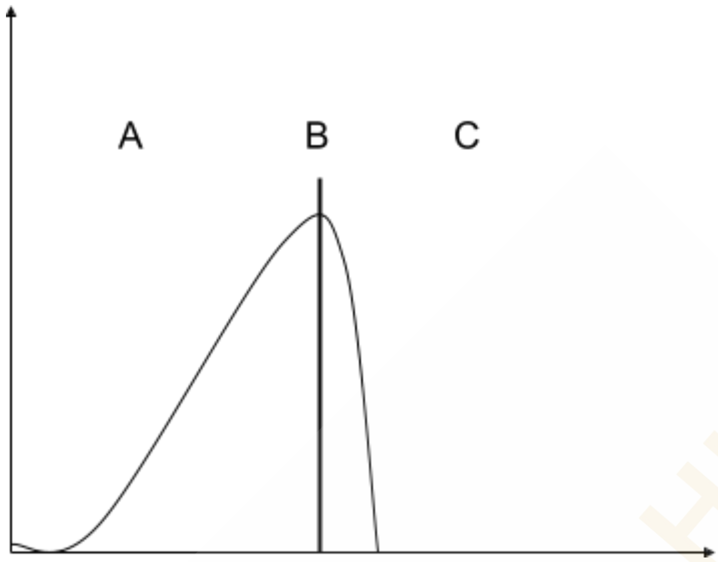
- Photobleaching of chlorophyll

Light Compensation Point: No net gas exchange,

- <u>Rate of Photosynthesis = Rate of Respiration</u>
- **<u>Uptake of CO_2 by the plant through Calvin cycle is equal to the release of CO_2 through link and Krebs cycle</u>**
- *No change in CO_2 concentration*

Light Saturation Point: Maximum rate of photosynthesis

Temperature



A

- Higher Kinetic Energy
- More successful collision
- More enzyme substrate complex
- Faster rate

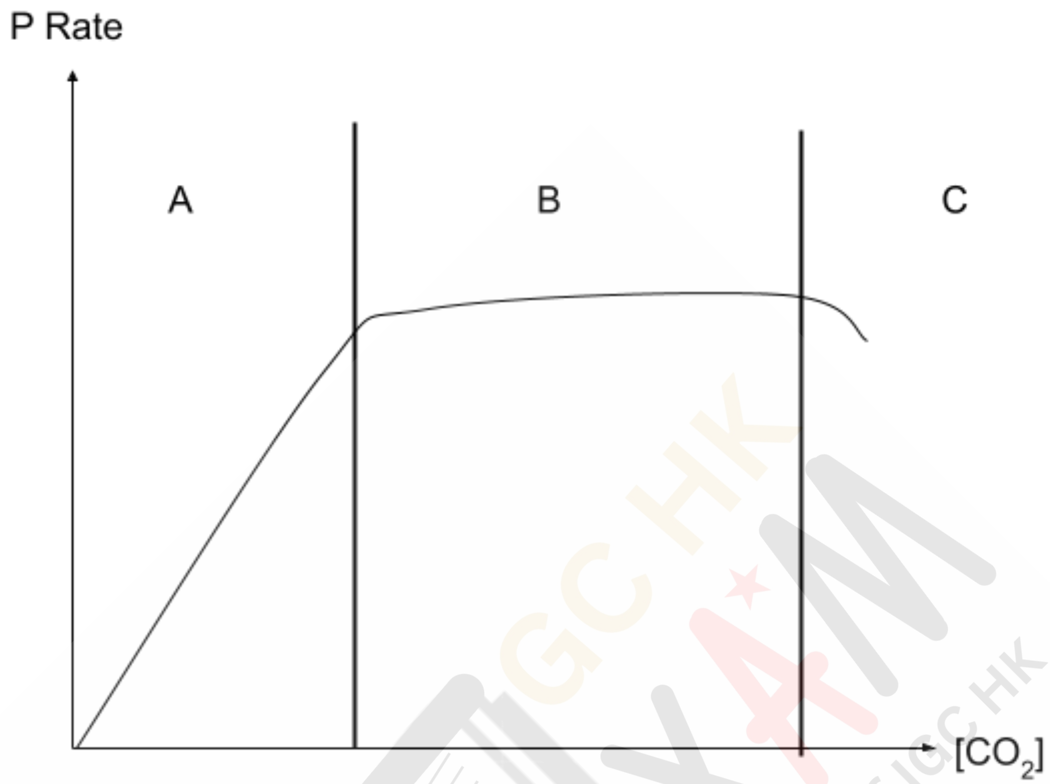
B

- Optimum temp
- Max Enzyme Substrate Complex

C

- Denature
- No ESC
- Active site shape changes

CO_2 Concentration Graph



A

- As $[CO_2]$ increase, P rate increase
- CO_2 is required for Carbon Fixation
- $[CO_2]$ is a limiting factor

B

- As $[CO_2]$ increase, P rate constant
- $[CO_2]$ is no longer limiting factor
  Limiting factor: Temperature, Water, Light Intensity

C

- Carbonic acid could form due to high $[CO_2]$ when dissolving in water
- pH would be lowered and enzyme denatured
- Closing stomata act as a precaution
- So $[CO_2]$ increase → Decrease in P rate

Minerals

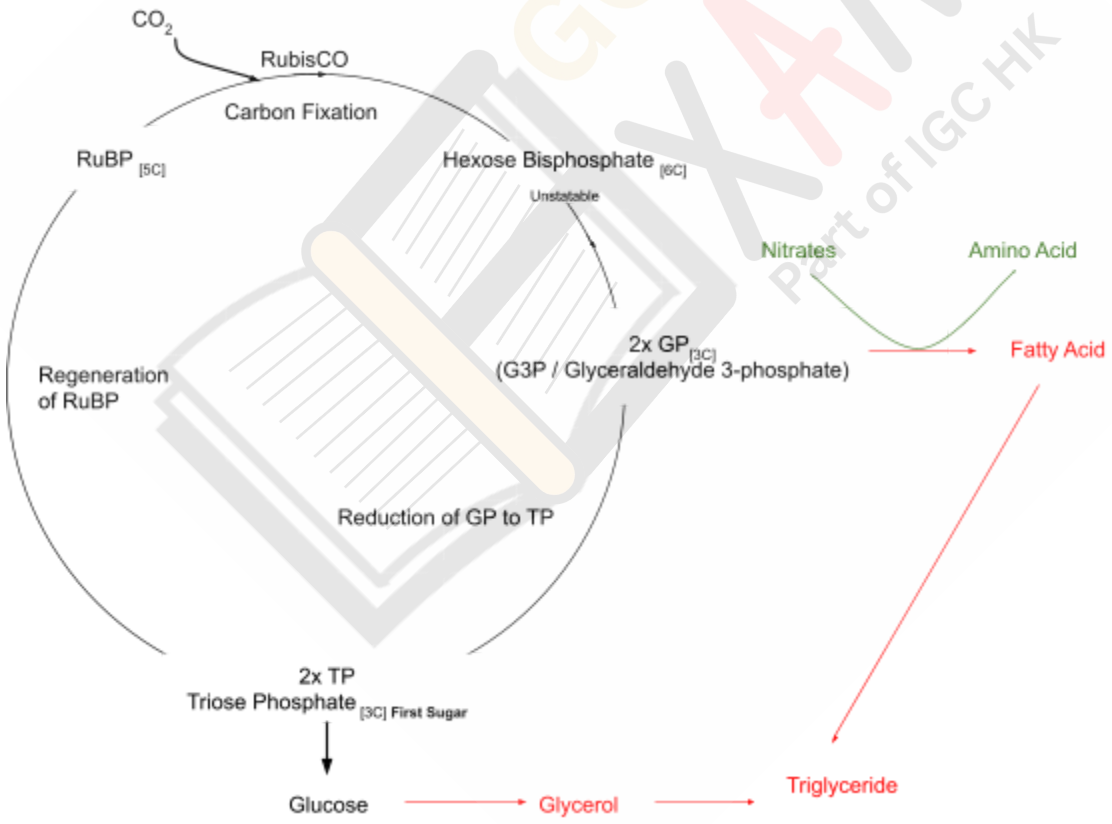
Magnesium

- Mg^{2+} is absorbed
- It is required for the synthesis of chlorophyll
- Chlorosis (deficiency) – such as yellowing of leaves
- Also used to activate the enzymes DNA polymerase and ATP synthetase

Nitrogen

- Component of amino acids, nucleic acids and chlorophyll
- Plant obtain their nitrogen in the form of Nitrates (NO_3^-)
- Stunted growth and chlorosis (deficiency)

Organic Products of Calvin Cycle



Glycerate-3-Phosphate → Acetyl CoA → Fatty acids

Triose Phosphate (3C) → Glycerol (3C)

Glycerol + 3 Fatty acids → **Triglyceride**

Glycerate-3-phosphate → Amino acids + Nitrates → Proteins

3.7 Homeostasis and the kidney

Homeostasis

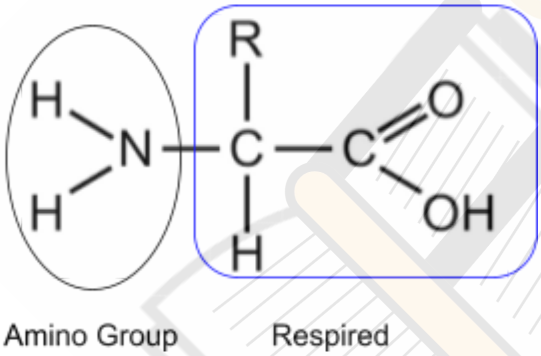
Definition: Maintenance of constant **internal** condition despite external changes
Examples: Thermoregulation, Osmoregulation

Excretion

Excretion is the removal of metabolic waste made by the body. Metabolic waste products are produced inside cells during metabolic reactions.
(Different from egestion which is the removal of undigested food from the body (faeces))

Nitrogenous waste

Nitrogenous waste comes from the breakdown of excess amino acids and nucleic acids.



Amino Group is toxic → **Deamination**: Removal of amine group from a molecule

Deamination

- Removal of amino group by deamination
- Combining amino group with CO_2 forming urea
- In liver

Forms of N-waste

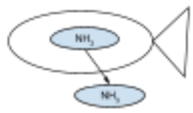
Excess amino acid + nucleic acid

↓

Aquatic Animals — **Ammonia**

Lots of water available required to remove it from the body
TOXIC!
Easy to make

Freshwater Fish



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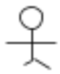


Mammals — **Urea**

Less water needed from the body
toxic
More energy

↓

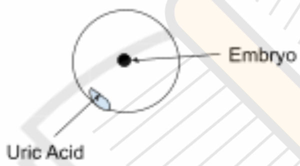
Birds / Reptile — **Uric Acid**

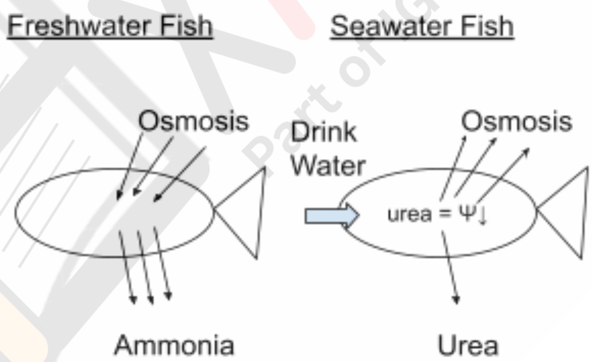
Insoluble (virtually no water)
non toxic
Most Difficult but light

Terrestrial: Less access to water
Urea is a sensible option

Uric acid is best if developing embryo inside of an egg on land

Terrestrial Eggs





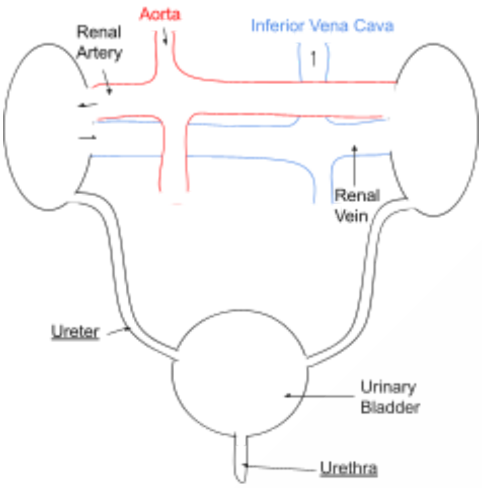
Amphibians

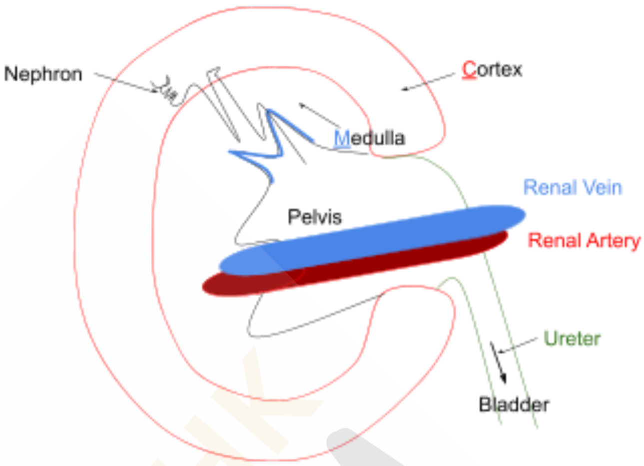
Tadpoles – Ammonia (water)
Frog – Urea (land)

Insects

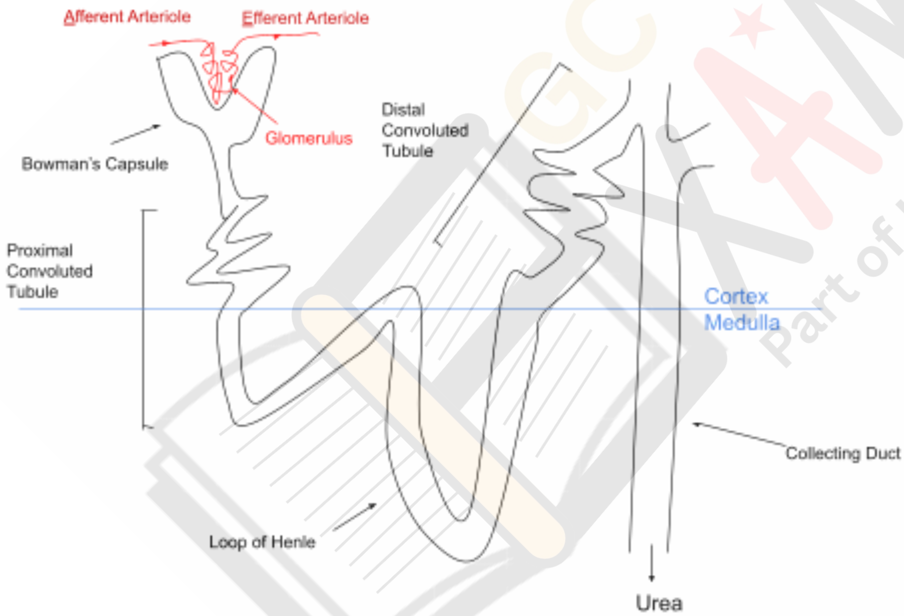
Depends on where they live
Land (uric acid)

Kidney Diagram



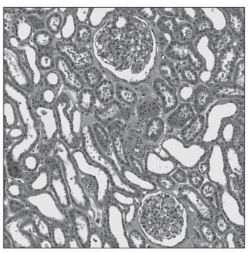
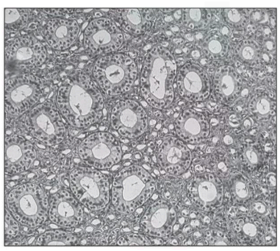


Kidney Tubule / Nephrons



Identify Cortex & Medulla in Microscope Slide

Cortex – Presence of Bowsman's Capsule / Glomerulus
Medulla – Sections of Collecting Duct / Loop of Henle

A  B 

A	Cortex	Presence of Bowman's capsule / Glomerulus / renal capsule;
B	Medulla	(Sections of) collecting ducts / (Only sections of) loops of Henle / collecting ducts;

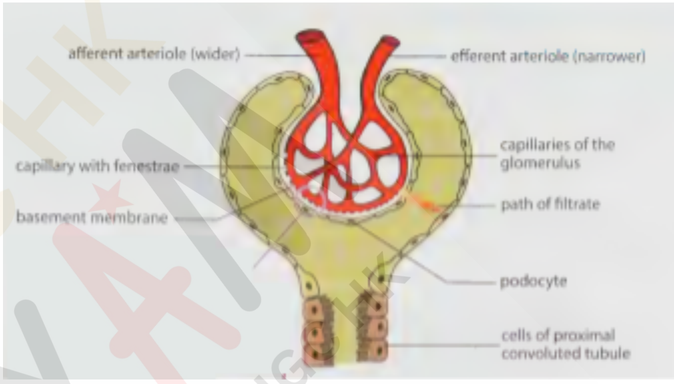
Ultrafiltration

Ultrafiltration is filtration under high pressure at a molecular level

Adaptation

- Glomerulus has a high hydrostatic pressure as afferent arteriole has wider diameter
- Glomerulus capillaries contains fenestrations which are leaky
- Basement membrane acting as a molecular sieve allowing small molecules to squeeze through
- Podocyte contain filtration slit

Glomerulus

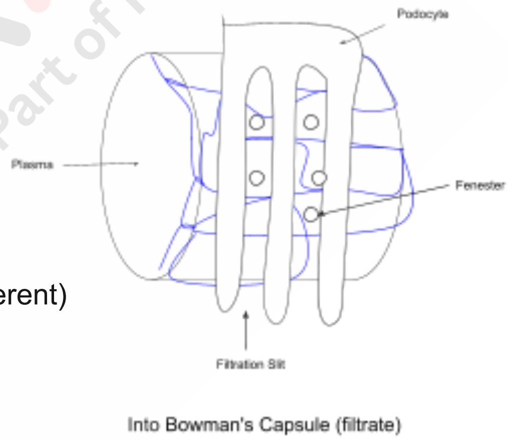


- Capillary Knot
- High hydrostatic pressure in glomerulus
- Single layer of epithelium
- Form fluid → Glomerular filtrate
- Afferent arteriole – wide, more pass
- Efferent arteriole – narrow, less pass

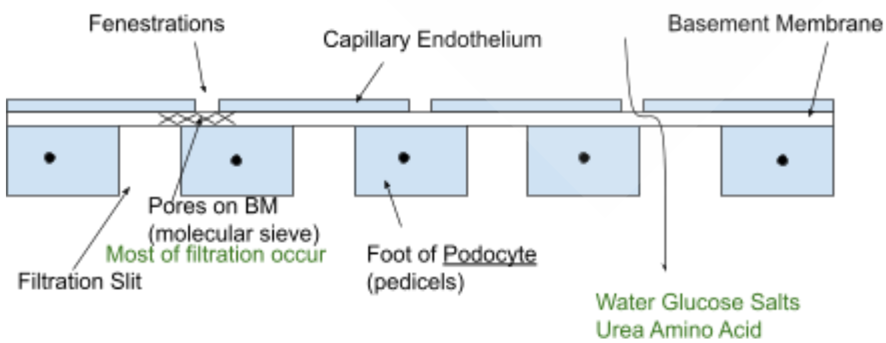
Bowsman Capsule

- Podocyte – Specialised Squamous Epithelial cell
- Other epithelial cell – Surface of blood capillary

Image Below:
- High Pressure in glomerulus is due to
    - Diameter of arteriole (afferent greater than efferent)



Filtration Membrane



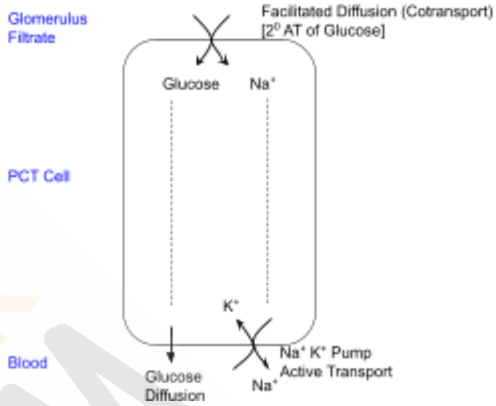
- Filtration slit is really where the filtration occur

Proximal Convoluted Tubule (PCT)

Selective reabsorption – Uptake of specific molecules and ions from the glomerular filtration in the nephron back into the blood stream

Reabsorption of Na^+ (2^0 AT)

1. Na^+ actively transport out of PCT into blood capillary *and K^+ is transported into cell*
2. This lowers the concentration in cell and creates concentration gradient
3. As Na^+ concentration is high co transport (facilitated diffusion occurs) and at the same time glucose is also co transported
4. As glucose is going against concentration gradient, this is secondary active transport

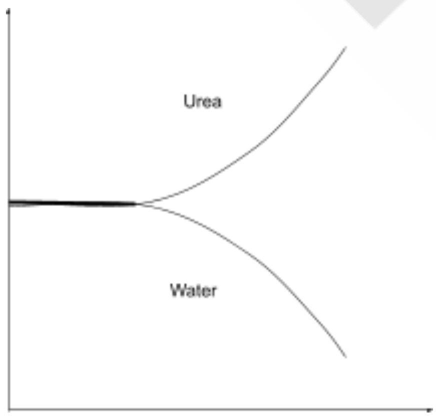


Adaptation of PCT

- Epithelial cell → Single layer → Provide short diffusion distance
- Many mitochondria → More ATP for AT
- Microvilli on epithelial cell → Increase Surface Area
- Dense capillary network around tubule → Maintain steep conc gradient

Others Reabsorb

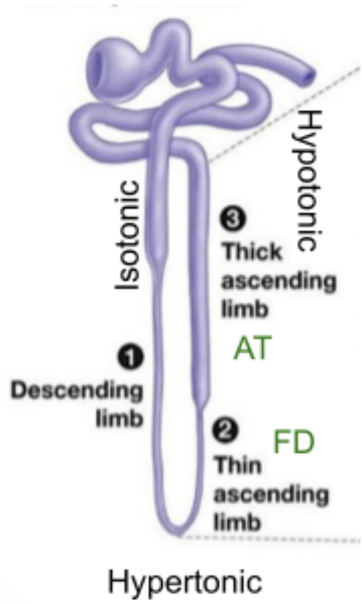
- 70% of salt is reabsorbed by active transport in PCT (most of salt)
- 90% of water is reabsorbed passively (osmosis)
  Other place of water reabsorbed occurs in collecting duct
- 50% of urea and small proteins are reabsorbed by diffusion → so water can be lost
- Other minerals and vitamin are reabsorbed by AT
- At terminal end of PCT, higher concentration gradient for these non-polar molecules as more water has been absorbed



As urea is reabsorbed more slowly than other molecules and water, the relative concentration increase

Eduqas Mark Scheme:
Glucose & Amino Acid – They are reabsorbed by secondary active transport
Urea – Water reabsorbed so volume decrease but urea stays in the filtrate

Loop of Henle



- Inside medulla
- Hair pin counter current multiplier
  Hair pin – shape
  Counter current – filtrate moving in opposite directions in the ascending compared to the descending limb
  Multiplier – Change of concentration of filtrate

Descending Limb

- Permeable to water, impermeable to ions
- Water diffused out of descending limb by osmosis (as there is ↓Ψ)
- As the filtrate reaches the bottom of the hairpin, it contains more ions and less water (hypertonic). It becomes more concentrated and its water potential decrease / more negative

Assending Limb

- Imperable to water, permeable to ions
- *Ions diffuse out by <u>facilitated diffusion</u> into interstitial fluid in thin ascending limb*
- The higher the ascending limb, more ions move out
- Ions are <u>actively transported</u> out in thick section of ascending limb to medullary interstitial fluid (← most mark scheme talk about this, the 2nd place for ion to be reabsorbed after the secondary active transport in PCT)

Vesa Recta (Blood Vessel)

- Hair pin shape
- Thin epithelial layer which is one cell thick → many microvilli
- Heart beat renews blood in vasa cava → maintain conc gradient
- Counter current multiplier (filtrate flows in opposite direction)
- Multiplier effect

Relationship of Length of Loop of Henle to Environment

Longer loop
- Desert / Dry environment → Low water availability
- Water retention is important
- Produce less volume of urine
- Stay in underground → cool + less water loss by evaporation

Moderate length
- Mammals / humans
- Moderate water availability
- Produce moderate volume of urine

Short Loop
- Animals living in around water → Beaver
- More water availability
- Water retention is not important
- Produce large volume of urine

Conclusion
- Longer loop of Henule
- Longer loop increase concentration difference between filtrate and tissue fluid
- More water reabsorbed

Distal Convoluted Tubule & Collecting Duct

DCT:

- Fine tuning of filtrate composition → water and salt that are reabsorbed
- Control blood pH
- More water potential in lumen of DCT compared to medulla
- Epithelial cells in DCT and collecting duct are slightly impermeable to water – unless there is ADH around

Na^+ Reabsorb & Water Reabsorb in LoH (Osmoregulation)

- Ions actively transport out of ascending limb of LoH into interstitial fluid
- Lower water potential of tissue fluid and create a water potential gradient in medulla
- As ascending limb is impermeable to water, water moves out of descending limb + *collecting duct* by osmosis
- This reduce volume of urine
- Fewer ions into medulla reduces water potential gradient so less water reabsorbed from descending limb + collecting duct

ADH in Urine ↑	Negative Feedback ADH ↓
- ADH increase permeability of collecting duct to water - More aquaporin added to cell membrane - More water reabsorbed and lower urine produced	- Water enters blood and water potential of blood increase - Less ADH released - Less permeable to water - Less water reabsorbed into blood - Therefore larger volume of urine are produced - NEGATIVE FEEDBACK

ADH Mechanism (High Solute Intake / Sweating / Low Ψ)

- Low water potential of blood detected by osmoreceptors in hypothalamus
- Posterior lobe pituitary gland release more ADH
- *Travels in blood to collecting duct*
- Makes collecting duct walls **more permeable** to water
- As more aquaporin are added to cell membrane
- Water moves into medulla by osmosis
- Low volume of concentrated urine produced

Kidney Failure

- Diabetes
- High blood pressure
- Infection
- Physical damage

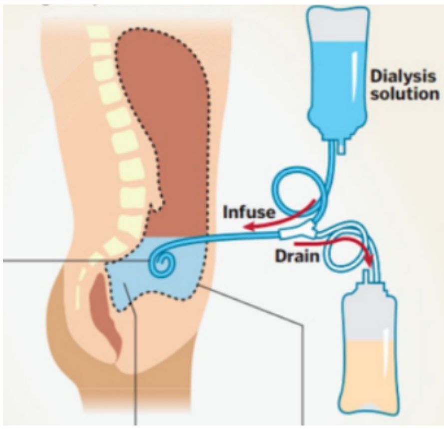
Problems

- Toxin not effectively removed – build up in high concentration → affect metabolic reaction
- Molecules that should be selectively reabsorbed excrete in urine
- Excess water not removed → high water potential of blood

Treatment

Treatments to regulate the concentrations of K^+ and Ca^{2+} ions:

1. Kidney Transplant
   Problem:
   - Incompatible blood type
   - Cause rejection → patient has immune response
   - Lack of donors
2. Continuous ambulatory peritoneal dialysis
   Problem: Risk of infection of pathogen
3. Haemodialysis – 6-8 hours per 48 hours
   - Dialysis tubing → selectively permeable → allow small molecules diffuse out of dialysis tubing (eg: urea) → retain large molecule (RBC, plasma protein)
   - Counter current flow → maintain conc gradient → urea diffuse out along whole dialysis tubing → effective
   - Dialysis fluid at 37°C → similar to body temp → maintain body temp
   - Composition of dialysis fluid – no urea, similar conc substance + Ψ to blood
4. CAPD
   - Continuous
   - Ambulatory (mobile)
   - Peritoneum
     Peritoneum is the membrane lining the body cavity and it has a rich supply of capillaries. It acts as the dialysis membrane
   - Dialysis



4.4 Variation and Evolution

Variation

The differences between organisms of the same species

Variation could be due to
- Genetic differences – different alles
- Epigenetic modification – control gene expression
- Environmental differences

Heritable Variation

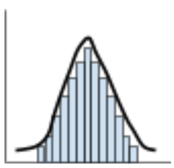
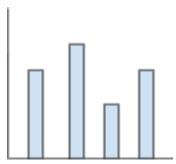
Asexual Reproduction
- Random mutation

Sexual Reproduction
- Crossing over during prophase I of meiosis
- Independent assortment of chromosomes during metaphase I
- Independent assortment of chromatids during metaphase II
- Random fertilisation

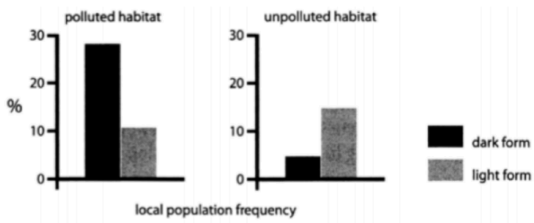
Non heritable Variation

- Due to environmental changes
- Cannot be inherited by the offspring

Categories of Variation

	Continuous Variation	**Discontinuous Variation**
Properties	- No distinct categories - Shows a graduation from one extreme to another	- Discrete categories - Have a clear cut - Qualitative
Examples	Sea snail shell size	Blood Type
Graph	 Bell Shape + Symmetrical	
Controlled by	Polygenic (controlled by multiple genes for phenotype) + Environmental	One gene

Peppered Moth – Discontinuous Variation



- Peppered moth can only be light or dark
- At polluted habitat, dark coloured are harder to spot → more common

Competition

Same	Difference
Intarspecific	Interspecific

- Limited resources availability (eg: food) → limit population growth around carrying capacity

Selection Pressure

An environmental factor that can alter the frequency of alleles in a population, when it is limiting.

Alleles and the Environment

- If phenotype is advantageous, it is more likely to be selected for
- Allele frequency increase over time

Gene Pool

- All of the alles present in a population at a given time

Hardy–Weinberg Principle

In a population where there are 2 possible alles, the frequency of dominant and recessive alles will be 100% (All are either BB, Bb, bb)

$$p + q = 1$$

$$p^2 + 2pq + q^2 = 1$$

p = frequency of dominant allele (A)
q = frequency of recessive allele (a)

p^2 = frequency of homozygous dominant (AA)
2pq = frequency of heterozygous (Aa)
q^2 = frequency of homozygous recessive (aa)

Conditions

- A large population
- No selection for or against phenotype
- Random mating throughout the population
- No mutations
- The population is isolated ie: No immigration or emigration

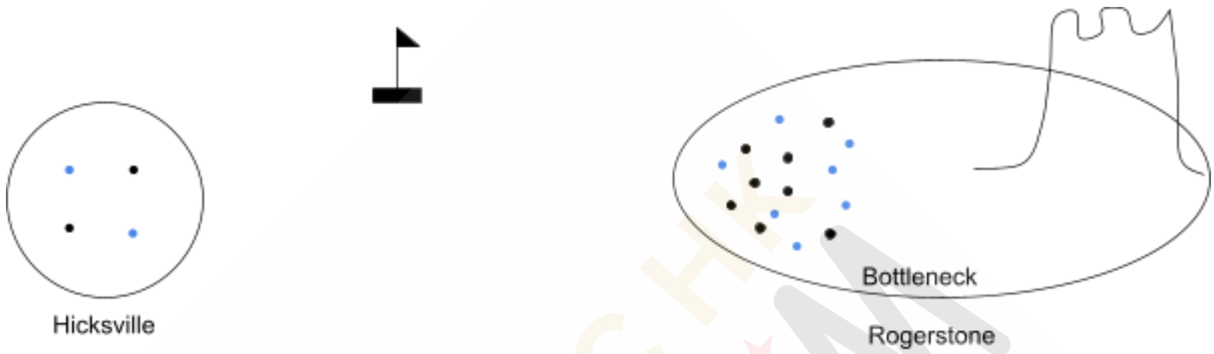
Important to remember!
This is a common question after H-W.

Evolution

Change in frequency of allele over time // Change on the average phenotype of a population

Genetic Drift

- RANDOM
- Chance variation in allele frequency in a population



Founder Effect

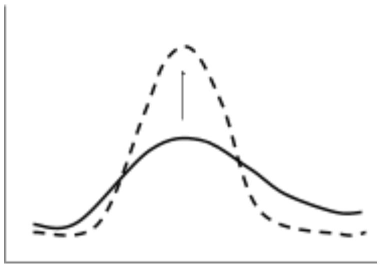
- A few individuals from a population start a new population with a different allele frequency than the original population
- Small number of individual become isolated and start a new population
- Founder members are a small sample of the original population → different allele frequency from original population
- Founder population has a small gene pool and lower diversity

Bottleneck Effect

- Sharp reduction in a population and a sharp reduction in gene pool due to earthquake / fire
- An outside forces destroy most of a population
- Increase inbreeding due to reduced gene pool → Little genetic diversity left in gene pool
- Increase expression of recessive trait
- Eventually there will be a large genetically similar population of organisms

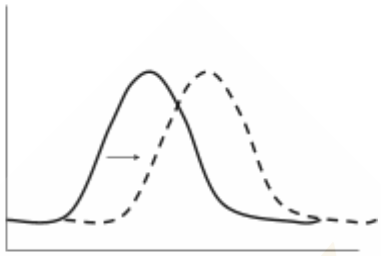
Natural Selection

Stabilising Selection



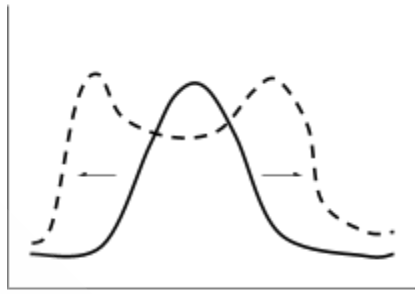
- Natural selection that favours the proportion of the average phenotype in a population
- It selected against the extreme population → reduce variability

Directional



- Selection of one extreme of a phenotype
- It slows evolution!
- Example: Peppered moth change colour from light to dark colour

Dispersive



- Average phenotype is selected against
- Slows evolution at the beginning of speciation
- Eventually it will become two species
- Bimodal peak

T Test

* Significance * Mean
H_0: There is no statistically significance between the mean values of the shell size of population a and population b.

Example: Sea Snail Shell Size
We collected 15 samples from habitat a and 15 from b
Our calculated t value was 2.55
DoF = 15 + 15 – 2 = 28
Confidence Limit = 0.05
Critical Value = 1.701

Reject H_0 ∵ As out calculated value of 2.55 is above the critical value of 1.701 (with 28 dof and a confidence level of p=0.05) we must reject null hypothesis, and accept that there is a significant difference between the mean shell size in the exposed and sheltered shore line.

T-Test compares means of two samples for and significant difference, Chi^2 compares expected and observed results

Isolation and Speciation

Reasons to tell whether organism can interbreed and produce fertile offspring:

- Organisms have not reached sexual maturity
- Organism will not mate
- Very long reproductive cycles
- Organisms reproduce a sexually

Speciation

- Pre-zygotic: Gametes are prevented from fertilising each other, so a zygote does not form
- Post-zygotic: Gametes can fertilise each other to form a **zygote**. However the organism formed is a hybrid and is sterile **(chromosomes cannot pair up to in meiosis to form games)**
- **Deme**: A subgroup within a population that may breed more often with each other than with the rest of the population.
- Reproductive Isolation: The prevention of reproduction and gene flow between breeding groups within a species.

Pre-zygotic

⭐Geographical Isolation – Allopathic Speciation (Different Geological Location) *Most Common*

- Isolated groups are geographically isolated / allopathic speciation / physical barrier
- Each group have different selection pressure
- Those with selective advantageous breed and reproduce pass on allele to offspring

Behavioral Isolation – Sympatric Speciation (Same Geological Location)

- Different courtship display or mating call
- Males will not attract females
- This is a reproductive barrier

Morphological Isolation – Sympatric Speciation

- Different body form
- Crudely "their bits" may not fit together to breed
- 2 population may be compactable
- Prevent alleles from 2 group mixing

Genetic Isolation – Sympatric Speciation

- Gamete from different population are prevented from coming into contact with each other

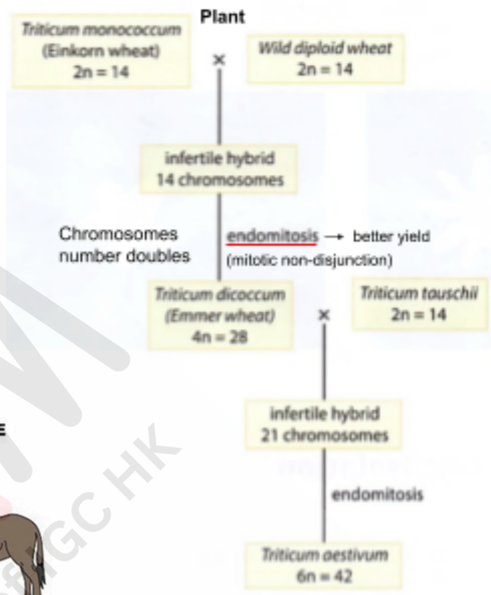
Seasonal / Temporal Isolation (Plant)

- Reproduce organs mature in different time of year → Prevent breeding

Post Zygotic

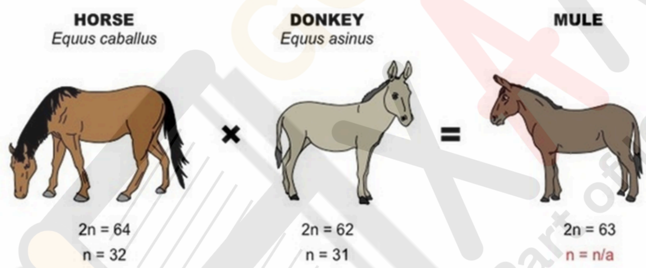
Hybrid Inviability (Embryo development failed to occur)

- Inviability: **Cannot survive**
- Gametes can fertilise other to form zygote
- Embryo failed to form



Hybrid Sterility (Polyploidy)

- Gametes can fertilise together to form offspring
- Fertile offspring is sterile
- Chromosomes from different species are not homologous
- Chromosomes cannot pair up in prophase I of meiosis
- Meiosis cannot continue and gametes cannot form



Hybrid Breakdown (Plants [less common])

- F1 is fertile but F2 is sterile
- Example: Nuclear genes vs Mitochondria / Chloroplast genes

Summary Table

	Type of isolation	Sympatric or allopatric	Example
Pre-zygotic	Geographical	Allopatric	Sticky cinquefoil
	Behavioural	Sympatric	Grasshopper
	Morphological	Sympatric	Insects
	Gametic	Sympatric	Sea urchin
	Seasonal	Sympatric	Buttercup and lesser celandine
Post-zygotic	Hybrid inviability	Sympatric	Northern leopard frog and wood frog
	Hybrid sterility	Sympatric	Mule
	Hybrid breakdown	Sympatric	Cotton

Darwin Evolution

☆ – Gene Flow
☆ – Alleles passing over

Darwin Deduced

- Survival of fittest
- Survive and reproduce to pass on allele
- New species forms when many changes
- Environmental changes, natural selection is a continuous process

Natural Selection (A Level Version)

- Mutations + Variation
- Competition of resource
- Advantageous alleles are selected for
- Survive to adulthood and reproduce
- Alleles passed onto offspring for many generations
- Alleles increase in frequency in a gene pool
- Organism with alleles which have lower tolerance will die and cannot pass on gene
- New species formed

Tips:

In A Level, use the word Gene Flow and Allele Frequency in terms of natural selection to gain more mark important!

Additional Notes:

WJEC

Biology A2

Unit 5

IGC HK Exam – WJEC Condense Notes

Written by experienced author, teacher and examiner, this book's engaging visual style and comprehensive detail will support you through the A2 course and help you prepare for your exams.

- This book offers high quality support
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