PERIOD 3 ELEMENTS

The period runs from sodium to Argon. The table below shows some physical parameters of the elements involved.

Elements	**Na**	**Mg**	**Al**	**Si**	**P**	**S**	**Cl**	**Ar**
Melting point	98	651	660	1410	44	114	-101	-189
Electronegativity	0.9	1.2	1.5	1.8	2.1	2.5	3.0	
Ionization energy	502	745	587	792	1020	1000	1260	1530
Atomic radius	1.57	1.36	1.28	1.17	1.10	1.04	0.99	
Electron Affinity	2.0	-6.7	3.0	13.5	6.0	20.0	36.4	
Oxidation states	+1	+2	+3	+4	+3, +5	-2, +4, +6,	+1, +3, -1, +5, +7	
Structure	Close packed	Close packed	Close packed	Giant molecular	←Discrete molecular structure →			

1. Melting point

This is a constant temperature at which an element in its solid state changes to liquid state under constant pressure.

The abrupt change in melting point is explained as:

- From sodium- aluminium, the strong metallic bonds have to be broken down. The strength of the metallic bond increases due to increase in the number of electrons used per atom and also due to decrease to metallic radius.
- From Aluminium- Silicon, the increase is due to the strong covalent bonds that have to be broken for a giant atomic structure of Silicon where each silicon atom contributes four electrons towards covalent bonding.
- From Silicon-phosphorous, the decrease is due to change from giant atomic structure to molecular discrete structure where the molecules are held by weak vanderwaals forces of attraction

- From phosphorous-Sulphur, these are discrete molecules which are as P_4 and S_8 held by weak Vanderwaals force whose magnitude increases with increase in molecular mass. Since the molar mass of S_8 is greater than that of P_4 therefore an increase in melting point.
- From Sulphur-chlorine, the diatomic molecule has a lower molar mass than sulphur there fore the magnitude of the vanderwaals forces are weaker hence low melting point.

Qn: *Explain the trend of the following parameters across period 3 of the periodic table*

(a) Ionization energy

(b) Electron affinity

(c) Electronegativity

NB. TO ALL STUDENTS. On the next page, start copying from chemical properties of elements of the third short period. Ignore the first part.

- Both form weak acids like H_3BO_3 and H_2SiO_3
- Both form binary compounds with several metals to give borides and silicide. These borides and silicide react with H_3PO_4 to give mixture of boranes and silanes.
- The carbides of both Boron and silicon (B_4C and SiC) are very hard and used as abrasives.
- Both the metals and their oxides are readily soluble in alkalis.
- Acids of both these elements form volatile esters on heating with alcohol in presence of concentrated sulphuric acid.

4.4 Chemical properties of elements of the 3rd short period

4.4.1 Introduction

In the third short period, metals tend to react as reducing agents by donating electrons

$$Ca(s) \longrightarrow Ca^{2+}(aq) + 2e$$

Relative reactivity of the metals can be measured in terms of ionisation energy, electropositivity or electrode potential. The lower the ionisation energy, the more reactive is the metal; the more negative the electrode potential, the more reactive is the metal. Since ionisation energy increases across the period, reactivity of the metals reduces across the period.

On the other hand, non-metals in this period react as oxidising agents by accepting electron

$$2Cl^-(aq) + 2e \longrightarrow Cl_2(g)$$

The relative tendency of non-metals to gain electrons (and thus reactivity) can be measured in terms of electron affinity and electronegativity; the higher the electron affinity and electronegatity, the more reactive is the non-metal. Since electron affinity increases across the period (*section 4.2.7*) reactivity of the non-metals also increases across the period.

4.4.2 Reaction with water

Sodium reacts vigorously with cold water to form sodium hydroxide and hydrogen gas.

$$2Na(s) + 2H_2O(l) \longrightarrow 2NaOH(aq) + H_2(g)$$

Magnesium hardly reacts with cold water but burns brilliantly in steam to form magnesium oxide and hydrogen gas.

$$Mg(s) + H_2O(g) \longrightarrow MgO(s) + H_2(g)$$

Despite its high negative electrode potential, aluminium is not very reactive owing to a thin oxide layer on its surface. When this layer is removed by rubbing with mercury, aluminium reacts with water to form aluminium hydroxide and hydrogen gas.
Silicon does not react with cold water but attacks steam when heated strongly to form silicon (IV) oxide and hydrogen gas.

$$Si(s) + 2H_2O(l) \longrightarrow SiO_2(s) + 2H_2(g)$$

Red phosphorous is insoluble in water while white phosphorous is soluble but does not react with water. Similarly, sulphur does not react with water.
Chlorine reacts with cold water to form chloric (I) acid and hydrochloric acid.

$$Cl_2(g) + H_2O(l) \rightleftharpoons HOCl(aq) + HCl(aq)$$

4.4.3 Reaction with alkalis

Sodium and magnesium do not react with alkalis.
Aluminium is amphoteric and reacts with sodium hydroxide to form sodium tetrahydroxo aluminate (III) and hydrogen gas.

$$2Al(s) + 2\bar{O}H(aq) + 6H_2O(l) \longrightarrow 2Al(OH)_4^-(aq) + 3H_2(g)$$

Silicon reacts with hot concentrated sodium hydroxide to form sodium silicate and hydrogen gas.

$$Si(s) + 2\bar{O}H(aq) + H_2O(l) \longrightarrow SiO_3^{2-}(aq) + 2H_2(g)$$

Sulphur reacts slowly with hot concentrated sodium hydroxide to form sodium sulphite, sodium sulphide and water.

$$3S(s) + 6\bar{O}H(aq) \longrightarrow SO_3^{2-}(aq) + 2S^{2-}(aq) + 3H_2O(l)$$

However, with excess sulphur, sodium thiosulphate is formed instead of sodium sulphite.

$$4S(s) + 6\bar{O}H(aq) \longrightarrow S_2O_3^{2-}(aq) + 2S^{2-}(aq) + 3H_2O(l)$$

The sodium sulphide formed from the above two reactions reacts with more sulphur to form sodium pentasulphide.

$$S^{2-}(aq) + 4S(s) \longrightarrow S_5^{2-}(aq)$$

Chlorine reacts with cold dilute sodium hydroxide to form sodium chloride, sodium chlorate (I) and water.

$$Cl_2(g) + 2\bar{O}H(aq) \longrightarrow Cl^-(aq) + \bar{O}Cl(aq) + H_2O(l)$$

However, with hot concentrated sodium hydroxide, sodium chloride, sodium chlorate (V) and water are formed.

$$3Cl_2(g) + 6\bar{O}H(aq) \longrightarrow ClO_3^-(aq) + 5Cl^-(aq) + 3H_2O(l)$$

4.4.4 Reaction with acids

With dilute non-oxidising acids

Magnesium and aluminium react with dilute non oxidising acids such as hydrochloric acid and sulphuric acid to form hydrogen gas and corresponding salts.
However, dilute sulphuric acid does not attack aluminium perhaps because of insolubility of the oxide layer in the acid.
Silicon is resistant to attack by most acids; it is only attacked by hydrofluoric acid.

$$Si(s) + 6HF(l) \longrightarrow H_2SiF_6(l) + 2H_2(g)$$

With oxidising acids

Nitric acid

With exception of magnesium, dilute nitric acid does not react with metals; it reacts with magnesium to form magnesium nitrate and hydrogen gas.

$$Mg(s) + 2HNO_3(aq) \longrightarrow Mg(NO_3)_2(aq) + H_2(g)$$

Hot concentrated nitric acid oxidises metals to nitrates while it is its self reduced to nitrogen monoxide (or to nitrogen dioxide if the acid is very highly concentrated).

$$3Mg(s) + 8HNO_3(aq) \longrightarrow 3Mg(NO_3)_2(aq) + 2NO(g) + 4H_2O(l)$$

However, aluminium is rendered passive (does not react) by concentrated nitric acid due to formation of an impenetrable layer of oxide on its surface.
Similarly, hot concentrated nitric acid oxides not metals. It oxidises to phosphoric(V) acid while it is reduced to nitrogen dioxide. It also oxidises sulphur to sulphuric acid.

$$P(s) + 5HNO_3(aq) \longrightarrow H_3PO_4(aq) + 5NO_2(g) + H_2O(l)$$

OR: $P_4(s) + 20HNO_3(aq) \longrightarrow 4H_3PO_4(aq) + 4H_2O(l) + 20NO_2(g)$

$S(s) + 6HNO_3(aq) \longrightarrow H_2SO_4(aq) + 2H_2O(l) + 6NO_2(g)$

Concentrated sulphuric acid

Concentrated sulphuric acid is a less effective reducing agent than concentrated nitric acid.

Hot concentrated sulphuric acid oxidises magnesium to magnesium sulphate while it gets reduced to sulphur dioxide. It also oxidises aluminium to aluminium sulphate.

$Mg(s) + 2H_2SO_4(l) \longrightarrow MgSO_4(aq) + 2H_2O(l) + SO_2(g)$

$2Al(s) + 6H_2SO_4(aq) \longrightarrow Al_2(SO_4)_3(aq) + 6H_2O(l) + 3SO_2(g)$

The acid has no reaction with silicon and phosphorous but oxidises sulphur to sulphur dioxide.

$S(s) + 2H_2SO_4(l) \longrightarrow 2H_2O(l) + 3SO_2(g)$

4.5 Compounds of elements of the 3rd short period

4.5.1 Introduction

Periodic three elements form several compounds including oxides, chlorides, hydroxides, hydrides etc. Properties of these compounds can be used to classify the elements into metals and non-metals. In this section, we look at properties of a few selected compounds including hydroxides, oxides, chlorides, and hydrides. Where appropriate, for all the compounds, we shall explore methods of preparation, type of bonding, reaction with water, alkalis and acids.

4.5.2 Hydroxides of the 3rd short period

Basing on the normal valency of the elements, we would expect the following hydroxides;

Element	Na	Mg	Al	Si	P	S	Cl
Valency	1	2	3	4	5	6	7
Expected hydroxide	$NaOH$	$Mg(OH)_2$	$Al(OH)_3$	$Si(OH)_4$	$P(OH)_5$	$S(OH)_6$	$Cl(OH)_7$
Hydroxide formed	$NaOH$	$Mg(OH)_2$	$Al(OH)_3$	H_2SiO_3	H_3PO_4	H_2SO_4	$HClO_4$

However, hydroxides of non-metals split off (lose) water molecules thus forming hydroxides shown below. The hydroxides of these non-metals are acidic.

Expected hydroxide	Water molecule(s) lost	Hydroxide formed
$Si(OH)_4$	$-H_2O$	H_2SiO_3
$P(OH)_5$	$-H_2O$	H_3PO_4
$S(OH)_6$	$-2H_2O$	H_2SO_4
$Cl(OH)_7$	$-3H_2O$	$HClO_4$

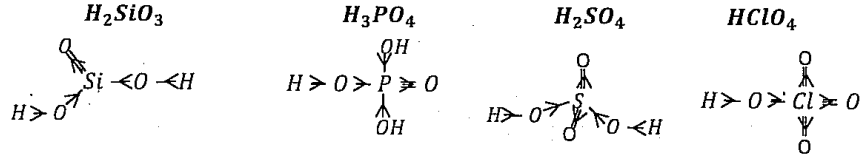
Acid-base character of the hydroxides

The hydroxides become more acidic across the period from left to right.

Hydroxide	$NaOH$	$Mg(OH)_2$	$Al(OH)_3$	H_2SiO_3	H_3PO_4	H_2SO_4	$HClO_4$
Character	Strong base	Weak base	Amphoteric	Weak acid	Weak acid	Strong acid	Strong acid

For metallic hydroxides, basic strength increases with increase in ease of loss of the hydroxyl group in form of $\bar{O}H$ ions. The less electronegative the metal, the weaker is the $M-OH$ bond and consequently the stronger is the base. Electronegativity of the metal atoms increases in the order Na < Mg < Al thus basic strength reduces in the order $NaOH > Mg(OH)_2 > Al(OH)_3$.

The non-metallic hydroxides (known as oxy-acids) are acidic. Their acidic strength increases with increase in the ease of loss of a proton. The acidic strength increases in the order $H_2SiO_3 < H_3PO_4 < H_2SO_4 < HClO_4$. This trend can be explained by considering the structures of the acids (*not drawn to scale*) below.



Oxygen atoms attached to the central atom withdraw electrons from the central atom which in turn withdraws electrons from hydroxyl groups bonded to it; this increases the partial positive charge on the hydrogen atom making it more easily lost. The greater the effect of withdrawing electrons, the stronger the acid. This effect increases with increase in number of oxygen atoms attached to the central atom and also with increase in electronegativity of the central atom. Electronegativity of the central atom increases in the order $Si < P < S < Cl$ thus acidic strength also increases in the same order.

4.5.3 Oxides of the 3rd short period

These include;

Element	Na	Mg	Al	Si	P	S	Cl
Oxide	Na_2O, Na_2O_2	MgO	Al_2O_3	SiO_2	P_2O_3, P_2O_5	SO_2, SO_3	Cl_2O_7, Cl_2O

Preparation

Sodium monoxide is formed by heating sodium in a limited supply of air. Sodium peroxide is a pale yellow solid manufactured by heating sodium metal in excess air at about 600K

$$4Na(s) + O_2(g) \longrightarrow 2Na_2O(s)\,; \qquad 2Na(s) + O_2(g) \longrightarrow Na_2O_2(s)$$

Magnesium oxide is a white solid prepared by heating a nitrate, carbonate or hydroxide of magnesium strongly.

$$MgCO_3(s) \xrightarrow{heat} MgO(s) + CO_2(g)$$

Acid-base character

Oxide	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_3, P_2O_5	SO_2, SO_3	Cl_2O_7, Cl_2O
Character	Basic	Basic	Amphoteric	Acidic	Acidic	Acidic	Acidic

Structure and bonding

Sodium, magnesium and aluminum oxides form giant ionic structures; ionic character of these oxides decreases with increasing charge density of the cation. Silicon(IV) oxide forms a giant covalent structure. The rest of the oxides form simple molecular structures.

Melting point of the oxides

Oxide	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_3	SO_3	Cl_2O_7
Melting point /^oC	1193	3075	2300	1728	563	30	-91

The melting point increases from sodium oxide to magnesium oxide then reduces up to dichlorine heptoxide.

Sodium oxide, magnesium oxide and aluminium oxide have giant ionic structures. The ions are held together by strong ionic bonds. The melting point increases from sodium

oxide to magnesium oxide due to increase in charge density of the cation; from magnesium oxide to aluminium oxide it decreases due to very high charge density of aluminium ion which makes aluminium oxide partly covalent (less ionic). Silicon dioxide has a giant covalent structure. Its atoms are held by strong covalent bonds, the rest of the oxides have simple molecular structures. Molecules are held by weak van der waals forces whose strength decreases with decrease in polarity of the molecules as a result of decrease in difference of electronegativity of bonding atoms.

Reaction with water

Sodium oxide reacts violently with water to form sodium hydroxide solution.

$$Na_2O(s) + H_2O(l) \longrightarrow 2NaOH(aq)$$

Magnesium oxide reacts with water to form magnesium hydroxide.

$$MgO(s) + H_2O(l) \longrightarrow Mg(OH)_2(s)$$

Aluminium oxide does not dissolve in water and has no reaction with water.
Silicon(IV) oxide has no reaction with water up to its boiling point. It slightly reacts with water, when heated under pressure, to form silicic acid.

$$SiO_2(s) + H_2O(l) \longrightarrow H_2SO_3(aq)$$

The rest of the oxides dissolve in water to form acidic solutions.

$$P_2O_5(s) + 3H_2O(l) \rightleftharpoons 2H_3PO_4(aq)$$
$$P_4O_6(s) + 6H_2O(l) \longrightarrow 4H_3PO_3(aq)$$
$$SO_3(g) + H_2O(l) \rightleftharpoons H_2SO_4(aq)$$
$$SO_2(g) + H_2O(l) \rightleftharpoons H_2SO_3(aq)$$
$$Cl_2O_7(l) + H_2O(l) \longrightarrow 2HClO_4(aq)$$
$$Cl_2O(g) + H_2O(l) \longrightarrow 2HOCl(aq)$$

Reaction with alkalis

Sodium and magnesium oxides are basic and therefore do not react with alkalis.
Aluminium oxide is amphoteric and therefore reacts with concentrated alkalis to form complex salts.

$$Al_2O_3(s) + 2\bar{O}H(aq) + 3H_2O(l) \longrightarrow 2Al(OH)_4^-(aq)$$

Silicon(IV) oxide reacts with concentrated alkalis to form silicates.

$$SiO_2(s) + 2\bar{O}H(aq) \longrightarrow SiO_3^{2-}(aq) + H_2O(l)$$

The rest of the oxides are acidic and therefore react with alkalis to form salts and water.

$$P_2O_5(s) + 4NaOH(aq) \longrightarrow 2Na_2HPO_4(aq) + H_2O(l)$$

$$P_4O_6(s) + 8NaOH(aq) \longrightarrow 4Na_2HPO_3(aq) + 2H_2O(l)$$

$$SO_3(g) + 2NaOH(aq) \longrightarrow Na_2SO_4(aq) + H_2O(l)$$

$$Cl_2O_7(l) + 2NaOH(aq) \longrightarrow 2NaClO_4(aq) + H_2O(l)$$

Reaction with acids

Sodium, magnesium and aluminum oxides readily react with dilute mineral acids to form salts and water.

$$MgO(s) + 2H^+(aq) \longrightarrow Mg^{2+}(aq) + H_2O(l)$$

$$Al_2O_3(s) + 6H^+(aq) \longrightarrow 2Al^{3+}(aq) + 3H_2O(l)$$

Silicon(IV) oxide has no reaction with mineral acids except hydrofluoric acid.

$$SiO_2(s) + 4HF(l) \longrightarrow SiF_4(g) + 2H_2O(l)$$

The rest of the oxides are acidic and therefore do not react with acids.

4.5.4 Chlorides of the 3rd short period

The table below shows chlorides formed by period 3 elements

Element	Na	Mg	Al	Si	P	S
Chloride	$NaCl$	$MgCl_2$	$AlCl_3$	$SiCl_4$	PCl_3, PCl_5	S_2Cl_2, SCl_2

Preparation

Sodium chloride is prepared by neutralization method involving sodium hydroxide and hydrochloric acid; magnesium chloride is prepared by reacting its carbonate, oxide, or hydroxide with dilute hydrochloric acid.

$$NaOH(aq) + HCl(aq) \longrightarrow NaCl(aq) + H_2O(l)$$

$$MgO(s) + 2HCl(aq) \longrightarrow MgCl_2(aq) + H_2O(l)$$

However, anhydrous magnesium chloride is prepared by direct synthesis since any attempt to obtain it from the hydrated magnesium chloride or by evaporation of its aqueous solution yields a basic chloride due to hydrolysis.

$$Mg(s) + Cl_2(g) \longrightarrow MgCl_2(s)$$

$$MgCl_2.6H_2O(s) \xrightarrow{heat} MgCl(OH)(s) + 5H_2O(g) + HCl(g)$$

Aluminium chloride is a white solid prepared by passing dry chlorine (or dry hydrogen chloride) over the heated aluminium. It sublimes at 456K and at a temperature a little above 456K it exists as Al_2Cl_6.

$$2Al(s) + 3Cl_2(g) \longrightarrow Al_2Cl_6(s)$$

Silicon(IV) chloride may also be prepared by heating it with dry chlorine but a more convenient method is by heating a mixture of silcon(IV) oxide and carbon in a dry current of chlorine.

$$Si(s) + 2Cl_2(g) \longrightarrow SiCl_4(s)$$

$$SiO_2(s) + 2C(s) + 2Cl_2(g) \longrightarrow SiCl_4(g) + 2CO(g)$$

Phosphorous trichloride is a colourless liquid prepared by passing dry chlorine over heated white phosphorous.

$$P_4(s) + 6Cl_2(g) \longrightarrow 4PCl_3(l)$$

Phosphorous pentachloride is prepared by passing dry chlorine over heated phosphorous trichloride.

$$PCl_3(l) + Cl_2(g) \longrightarrow PCl_5(s)$$

Sulphur dichloride is a red liquid prepared by reacting chlorine with disulphur dichloride at $0°C$.

$$S_2Cl_2(l) + Cl_2(g) \rightleftharpoons 2SCl_2(l)$$

Disulphur dichloride is a red liquid prepared by passing dry chlorine over molten sulphur.

$$2S(s) + Cl_2(g) \longrightarrow S_2Cl_2(l)$$

Bond type and structure

Electropositive metals form mainly ionic compounds but the degree of ionic character reduces as electropositivity decreases across the period. Magnesium and aluminium chlorides are ionic with some considerable degree of covalent character. The rest of the chlorides on the right are covalent though the bonds possess some polarity. Bond type and structure have a very big consequence on melting point of the chlorides (see below)

Chloride	$NaCl$	$MgCl_2$	$AlCl_3$	$SiCl_4$	PCl_3	PCl_5	S_2Cl_2	SCl_2
Bond type	ionic	Partly ionic	covalent	Covalent	Covalent	Covalent	Covalent	covalent
Structure	Giant ionic	Giant ionic	Layered molecular	Layered molecular	Simple molecular	Simple molecular	Simple molecular	Simple molecular

Melting point of the chlorides

Chloride	$NaCl$	$MgCl_2$	$AlCl_3$	$SiCl_4$	PCl_3	PCl_5	S_2Cl_2	SCl_2
Melting point /^oC	808	714	192	-68	-92	160	-76	-80
Physical state	Solid	Solid	Solid	Liquid	Liquid	Solid	Liquid	Liquid

Melting point of the chlorides generally decreases as the period is traversed from left to right.

Sodium and magnesium chlorides form giant ionic lattices though the degree of ionic character decreases with increase in charge density in the same direction. Therefore magnesium chloride has a lower melting point than sodium chloride. Aluminium ions have a very high charge density which induces a very high covalent character in aluminium chloride thus a low melting point. Silicon tetrachloride is covalent consisting of molecules held by weak van der waals forces this a very low melting point. Phosphorous trichloride is also simple molecular thus the low melting point. Phosphorous pentachloride has an abnormally high melting point because at ordinary temperature it is known to consist of PCl_4^+ and PCl_6^- ions though in vapour state it consists of PCl_5 molecules. It is this ionic character that is responsible for its abnormally high melting point. The chlorides of sulphur are simple molecular held by weak van der waals forces. Magnitude of the van der waals forces decrease with decreasing molecular mass.

Reaction with water (hydrolysis)

Hydrolysis refers to chemical reactions of double decomposition brought about by water to form ions.

Cations of high charge density attract water molecules towards themselves. This attraction weakens the $O-H$ bond in the attracted water molecule making it to lose a proton. Consequently, solutions of such cations are acidic.

$$Al(H_2O)_6^{3+}(aq) + H_2O(l) \rightleftharpoons [Al(H_2O)_5OH]^{2+}(aq) + H_3O^+(aq)$$

Purely ionic chlorides do not hydrolyse in water thus sodium chloride does not undergo hydrolysis but dissolves in water to form sodium and chloride ions. Magnesium chloride undergoes partial hydrolysis in cold water to form a basic chloride.

$$MgCl_2(s) + H_2O(l) \longrightarrow MgCl(OH)(s) + HCl(g)$$

However, if heated, hydrolysis may go as far as magnesium oxide.

$$MgCl_2(s) + H_2O(l) \longrightarrow MgO(s) + 2HCl(g)$$

Aluminium chloride fumes in moist air by hydrolysis liberating hydrogen chloride gas. This explains why its solution is acidic.

$$AlCl_3(s) + 3H_2O(l) \longrightarrow Al(OH)_3(s) + 3HCl(g)$$

Silicon tetrachloride rapidly hydrolyses in cold water to form misty fumes of hydrogen chloride and silicic acid.

$$SiCl_4(l) + 3H_2O(l) \longrightarrow H_2SiO_3(s) + 4HCl(g)$$

It is not uncommon for this hydrolysis to proceed as far as silicon(IV) oxide.

$$SiCl_4(l) + 2H_2O(l) \longrightarrow SiO_2(s) + 4HCl(g)$$

Both phosphorous trichloride and phosphorous pentachloride hydrolyse in water to form phosphonic acid and tetraoxophosphoric(V) acid respectively, in addition to misty fumes of hydrogen chloride gas.

$$PCl_3(l) + 3H_2O(l) \longrightarrow H_3PO_3(s) + 3HCl(g)$$

$$PCl_5(s) + 4H_2O(l) \longrightarrow H_3PO_4(aq) + 5HCl(g)$$

Disulphur dichloride hydrolyses in water forming sulphurous acid, sulphur and hydrogen chloride gas.

$$2S_2Cl_2(l) + 3H_2O(l) \longrightarrow 4HCl(g) + H_2SO_3(aq) + 3S(s)$$

Reaction with acids

Sodium chloride reacts with concentrated sulphuric acid to yield hydrogen chloride gas.

$$NaCl(s) + H_2SO_4(l) \longrightarrow NaHSO_4(s) + HCl(g)$$

Chlorides of phosphorous react with carboxylic acids to yield corresponding acyl chlorides.

$$CH_3COOH(l) + PCl_5(s) \longrightarrow CH_3COCl(l) + POCl_3(l) + HCl(g)$$

$$3CH_3COOH(l) + PCl_3(l) \longrightarrow 3CH_3COCl(l) + H_3PO_3(s)$$

4.5.5 Hydrides of the 3rd short period

The table below shows hydrides formed by period 3 elements

Element	Na	Mg	Al	Si	P	S	Cl
Hydride	NaH	MgH_2	AlH_3	SiH_4	PH_3	H_2S	HCl

Preparation

Sodium hydride is a white crystalline solid prepared by heating sodium in a stream of dry hydrogen gas.

$$2Na(s) + H_2(g) \longrightarrow 2NaH(s)$$

Aluminium hydride is a white solid precipitated when lithium hydride is treated with excess aluminium chloride in a solution of ether.

$$3LiH(s) + AlCl_3(s) \longrightarrow AlH_3(s) + 3LiCl(s)$$

Silane is obtained by fractional distillation from a mixture of silicon hydrides formed when magnesium silicide is treated with 20 per cent hydrochloric acid.

$$Mg_2Si(s) + 4HCl(aq) \longrightarrow 2MgCl_2(aq) + SiH_4(g)$$

However, a more convenient way of preparing silane is by reduction of silicon tetrachloride with lithium aluminium hydride.

$$SiCl_4(l) + LiAlH_4(s) \longrightarrow SiH_4(g) + LiCl(s) + AlCl_3(s)$$

Phosphorous trihydride (phosphine) is prepared by heating concentrated sodium hydroxide solution with white phosphorous:

$$P_4(s) + 3\bar{O}H(aq) + 3H_2O(l) \longrightarrow PH_3(g) + 3H_2PO_2^-(aq)$$

Hydrogen sulphide is prepared by action of dilute hydrochloric acid on iron(II) sulphide.

$$FeS(s) + 2HCl(aq) \longrightarrow FeCl_2(aq) + H_2S(g)$$

Hydrogen chloride is prepared by action of concentrated sulphuric acid on sodium chloride.

$$NaCl(s) + H_2SO_4(l) \longrightarrow NaHSO_4(s) + HCl(g)$$

Structure and bonding

Sodium is highly electropositive sodium hydride is ionic (Na^+H^-). Sodium hydride has a sodium chloride-like crystal lattice.

Hydrides of magnesium and aluminium are predominantly covalent and polymeric. The covalent character can be attributed to the small ionic radius and high charge (charge density) of the cations.

The rest of the hydrides in this period are covalent and simple molecular held by weak van der waals forces.

Acidity of the hydrides increases across the period from left to right

Reaction with water

Sodium hydride reacts with cold water to form hydrogen gas and sodium hydroxide.

$$NaH(s) + H_2O(l) \longrightarrow NaOH(aq) + H_2(g)$$

Silane is hydrolysed by water but the hydrolysis is more rapid in presence of an alkali (see below).

Hydrogen sulphide does not hydrolyse in water but ionises to form an acidic solution.

$$H_2O(l) + H_2S(g) \rightleftharpoons H_3O^+(aq) + HS^-(aq)$$

Hydrogen chloride does not react with water but ionises to form hydrogen ions.

$$HCl(g) + aq \longrightarrow H^+(aq) + Cl^-(aq)$$

Reaction with alkalis

Silane is hydrolysed by water in presence of an alkali to form sodium silicate and hydrogen gas.

$$SiH_4(g) + 2\bar{O}H(aq) + H_2O(l) \longrightarrow SiO_3^{2-}(aq) + 4H_2(g)$$

Hydrogen sulphide reacts with sodium hydroxide to form sodium hydrogen sulphide.

$$H_2S(g) + NaOH(aq) \rightleftharpoons NaHS(aq) + H_2O(l)$$

Aqueous hydrogen chloride reacts with sodium hydroxide to form sodium chloride and water.

$$HCl(aq) + NaOH(aq) \longrightarrow NaCl(aq) + H_2O(l)$$

Reaction with acids

Hydrogen sulphide reduces concentrated sulphuric acid to sulphurdioxide.

$$H_2SO_4(l) + H_2S(g) \longrightarrow SO_2(g) + 2H_2O(l) + S(s)$$

It also reduces concentrated nitric acid to nitrogen monoxide.

$$2HNO_3(aq) + 3H_2S(g) \longrightarrow 4H_2O(l) + 2NO(g) + 3S(s)$$

4.6 Summary

Across the period from left to right, elements gradually change from purely metallic to non-metallic. There is also a gradual change in bond type, acidity of the compounds and many other properties.

4.7 Suggested further reading on chapter 4

G. F. Liptrot, *Mordern Inorganic Chemistry*, Scotprint Ltd, Fourth Edition, 1983.

A. Holderness, Advanced Level Inorganic Chemistry, Thomson Press, Third Edition, 1979

H. L. Heys, Physical Chemistry, Chapter 8.

W. R. Kneen, *Chemistry, Facts, Patterns and Principles*, Addison-Wesley Pub (Sd), 1972

4.8 Questions on chapter 4

1. (a) Draw a graph of first ionisation energies of period 3 elements against atomic number.
   (See table 4.3 for the values of the ionisation energies)
   (b) Explain the general shape of the graph in (a) above.
   (c) Explain any abnormalities in the graph in (a) above.
2. Arrange the following elements/compounds in order of increasing melting point and explain your answer in each case.
   (a) Sodium, aluminium, magnesium.
   (b) sodium oxide, magnesium oxide, aluminium oxide
3. Discuss the trend in atomic radii of period 3 elements across the Periodic Table.
4. (a) Complete the following table about oxides of elements of the 3rd short period.

Element	*Na*	*Mg*	*Al*	*Si*	*P*	*S*	*Cl*
Formula of oxide							
Nature of bonding							

(b) Describe the variation of the structures of the oxides across the period.

(c) From the table above, select one oxide which is basic, one which is amphoteric and one which is acid, then write equations for reactions to illustrate each property.

(d) Give and explain the shapes of the molecules formed by;
(i) Silane (ii) aluminium chloride (iii) hydrogen sulphide

(e) Write an equation for the reaction between sodium hydroxide and;
(a) sodium hydride (ii) silane

5. (a) Write equations to show how you would prepare the following chlorides;
(i) Magnesium chloride (ii) silicon tetrachloride (iii) hydrogen chloride

(b) Give the type of bonding in each of the chlorides in (a) above and state the structure formed.

(c) Write an equation (if any) for the chlorides above with water.

UMSSN A LEVEL INTERACTIVE BIOLOGY SEMINAR 2019
DISCUSSION QUESTIONS

1. (a) Describe the;
(i) role of the pancreas in the digestion of food and metabolism of the absorbed products.
(ii) control of digestive juice secretion along the alimentary canal in humans.
(b) The table below summarises the mechanisms of control of release of digestive secretions along different parts of the human alimentary canal.

Part of Alimentary canal	**Control mechanism**
Mouth	Nervous only
Stomach	Both nervous and hormonal control
Duodenum	Hormonal control only

(i) Discuss the significance of the trend of control of release of digestive secretions shown in the table.
(ii) Give reasons why release of digestive secretions should be controlled.

UGANDA MARTYRS' S.S. NAMUGONGO

2. (a) Describe the structure of a plant cell wall.
(b) State the functions of the cell wall in plants.
(c) State the differences between the cell wall and the plasma membrane.
(d) Describe how the cell wall is strengthened in various forms of life.

LUWEERO S.S.

3. Discuss the significance of the chemical composition, arrangement and distribution of mammalian photoreceptors in the eye.

HILTON HIGH SCHOOL

4. (a) Differentiate between growth and development.
(b) Explain how each of the following takes place.
(i) Increase in girth of a flowering plant stem. (ii) Increase in size of a mammal after birth.
(c) How is old cuticle in insects replaced by new cuticle?
(d) What is the significance of larva forms in the life cycle of some organisms?

RINES INTERNATIONAL S.S.

5. (a) What are the principle effects of each of the following plant hormones on plant tissue?
(i) auxin (ii) gibberellin (iii) cytokinin (iv) abscisic acid
(b) Explain how the balance between two or more of the hormones listed in (a) above controls
(i) seed dormancy and germination (ii) leaf senescence and abscission

KIIRA COLLEGE BUTIKI

6. (a) Describe the structure of each of the following tissues, indicating in each case how structure is related to function.
(i) Parenchyma (ii) Collenchyma (iii) Sclerenchyma
(b) Compare the distribution of tissues in a dicotyledonous stem and root in relation to the mechanical functions of the stem and root.

ST. MARK'S COLLEGE NAMAGOMA

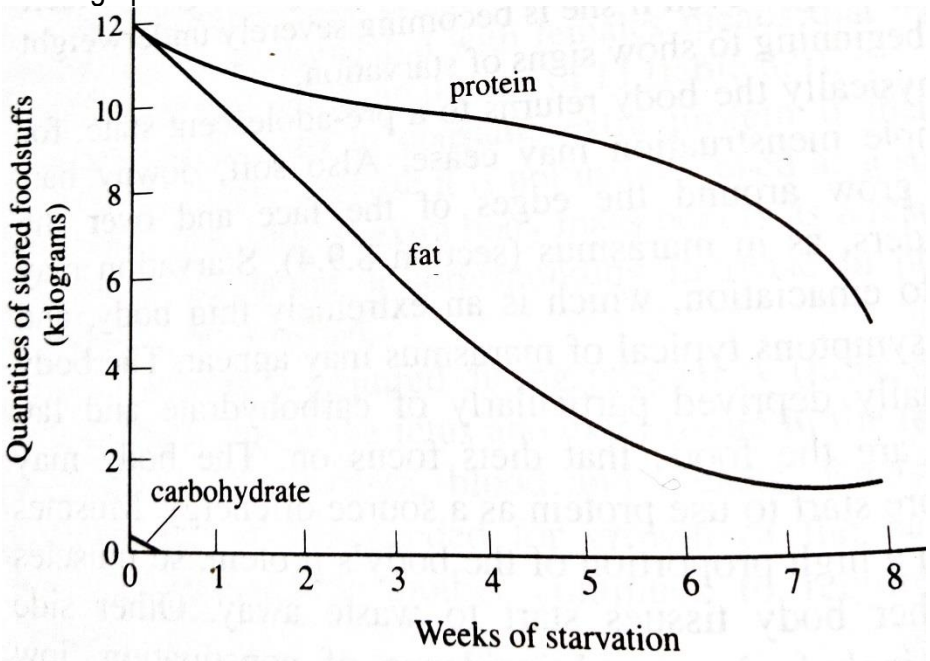
7. (a) Explain why an Amoeba does not need a specialized surface for gaseous exchange.
(b) Describe the roles of membranes in an Amoeba.
(c) Most of the organelles of eukaryotic cells are bound by membrane. State the significance of this observation.
(d) Explain what would happen to an Amoeba if it had no contractile vacuole.
(e) A student investigated the activity of the contractile vacuole when an Amoeba was placed in solutions of different water potential. The student placed the Amoeba in each solution and counted the number of times the contractile vacuole filled and emptied in the first minute. The results are shown in Table.

Water potential surrounding Amoeba (kPa)	Number of times the contractile vacuole filled and emptied in the first minute.
0	19
-100	14
-200	9
-300	5
-400	2
-500	0

(i) What conclusions can be drawn from the table above.
(ii) Explain why the contractile vacuole emptied more frequently when the water potential surrounding the Amoeba was –100 kPa compared to when the water potential was –400 kPa.

EXODUS COLLEGE WAKISO

8. The graph below shows the effect of starvation on the food stores of the human body.



(a) Compare the effect of starvation on the quantities of fat and protein stored in the body.
(b) (i) Define the term starvation.
(ii) Explain the trend of each of the foodstuffs with increasing weeks of starvation.
(c) Account for each of the following.
(i) Lipids have a higher energy value than carbohydrates of comparably the same mass.
(ii) Cells of poikilothermic animals have a higher proportion of unsaturated fatty acids than homoeothermic animals.
(d) What is meant by obesity and state its effects.

TURKISH LIGHT ACADEMY

9. In maize the genes for coloured seed and full seed are dominant to genes for colourless and shrunken seed respectively. Pure breeds of double dominant variety were crossed with double recessive variety; and a test cross of the resultant F_1 offspring produced the following.

Phenotype	Number of offspring
Coloured full seed	382
Colourless shrunken seed	394
Coloured shrunken seed	15
Colourless full seed	13

(a) Suggest explanation for the phenotypic ratio obtained as shown by the results in the table.
(b) Using suitable genetic symbols; show how you have come to conclude as in (a) above.

(c) Calculate the distance in Morgan units between the genes for seed colour and seed shape on a chromosome.
(d) Outline the importance of Cross Over Values in genetics.

MT. ST. HENRY'S HIGH SCHOOL MUKONO

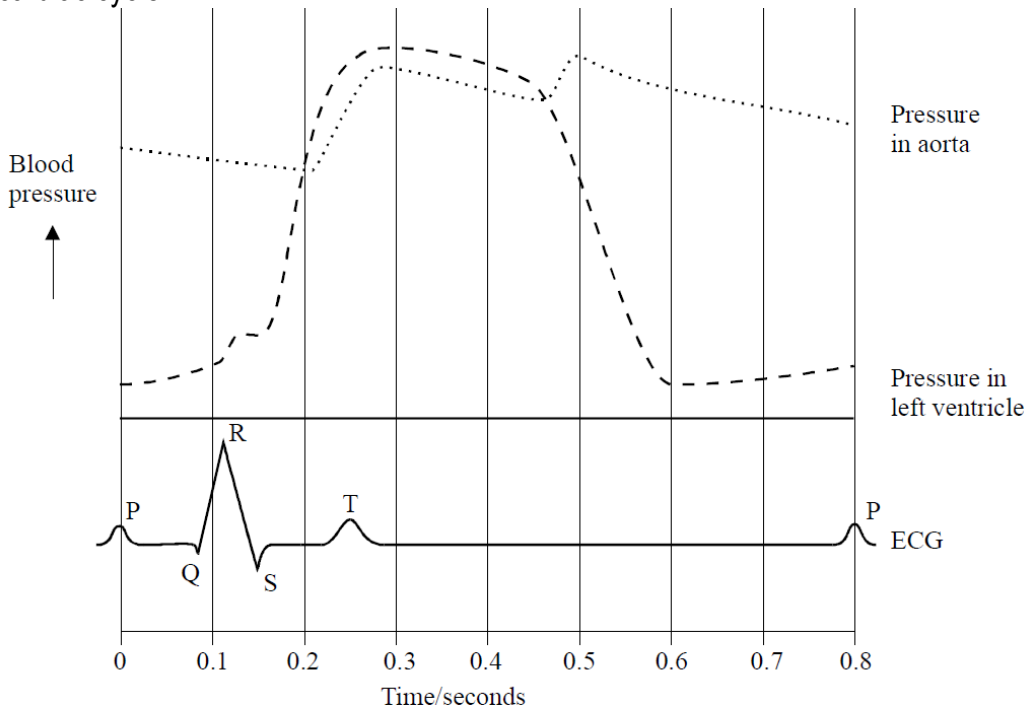
10.(a) With examples, state the type of behavioral stimuli.
(b) Distinguish between hormone and pheromone.
(c) State the importance of pheromones in insects.
(d) Discuss the biological application of pheromones.

BULOBA HIGH SCHOOL

11. (a) Compare myoglobin and haemoglobin molecules.
(b) Explain each of the following observations;
(i) the oxygen dissociation curve for haemoglobin is sigmoid in shape.
(ii) fetal haemoglobin is gradually replaced with adult haemoglobin after birth.
(iii) Individuals with sickle cell trait do not suffer from malaria.
(iv) Earthworms run out of their hideouts on a rainy day.
(c) Explain the significance of red blood cells being impermeable to cations.
(d) How are blood capillaries adapted for their function?

KAJJANSI PROGRESSIVE S.S.

12. The diagram shows an electro-cardiogram (ECG) and the pressure changes during a human cardiac cycle.



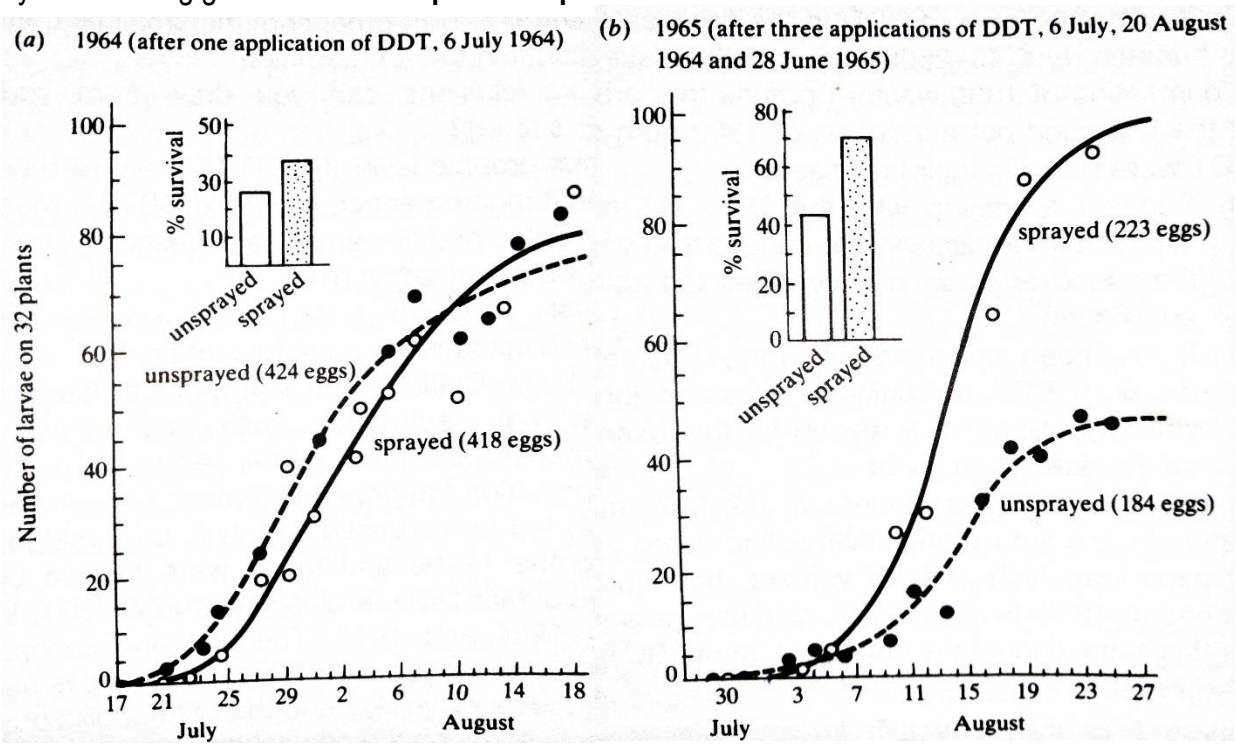
(a) (i) Define the term electrocardiogram.
(ii) What does each of the waves shown on the ECG represent and state their significance.
(iii) Explain why there is no change in the electrical activity between 0.31s and 0.77s.
(b) Use the graph to calculate the heart rate of humans.
(c) (i) Compare the pressure changes in the left ventricle and aorta.
(ii) State the significance of the differences stated in (c) (i) above.
(d) The pressure changes shown in the diagram are on the left side of the heart. Sketch a curve on the graph to show the pressure changes in the right ventricle.
(e) Outline the functional properties of heart muscles.

SEETA HIGH MUKONO

13. (a) What is meant by each of the following as applied in pest control.
(i) Lethal dose 50. (ii) Persistence

(iii) Pest resurgence. (iv) Biological control

(b) The figure below illustrates the differential effects of DDT application on crop and soil fauna in the USA. **Pieris rapae** is a cabbage crop pest that feeds on its leaves. Spraying with DDT to control it is effective only for a short period in the first year. The larvae of the Cabbage crop pest are eaten by soil-dwelling ground beetle **Harpalus rufipes**.

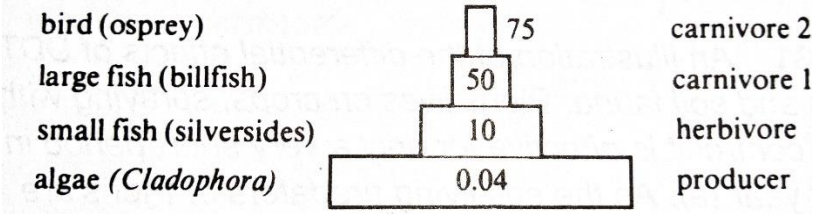


(i) Explain the effect of one application of DDT on **Pieris rapae** population.

(ii) Account for the differences in the number of eggs of **Pieris rapae** at the sprayed and unsprayed farm yards due to three successive applications of DDT.

(c) What advice would you give to the farmer before making the choice of the pesticide?

(d) The figure shows the biomass and amount of DDT in ppm at different trophic levels in a food chain collected during a certain study in the USA.



(i) Account for the trend of change in DDT concentration showed by the figure.

(ii) Suggest ways in which birds such as penguins and hawks in the Antarctic Ocean might have come to contain DDT.

(e) Disturbance of natural ecosystem of originally clear Lake California by eutrophication lead to increased population of midges (mosquitoes/flies) during the 1940s and these were treated by spraying with DDD, a close relative of DDT. The first and second application killed about 99% of the midges but they recovered so quickly that the third application had little effect on their population.

(i) Suggest the observation made following the different DDD applications.

(ii) Animal death due to DDT poisoning is rampant in times of starvation. Explain why this is so.

NAALYA S.S. BWEYOGERERE

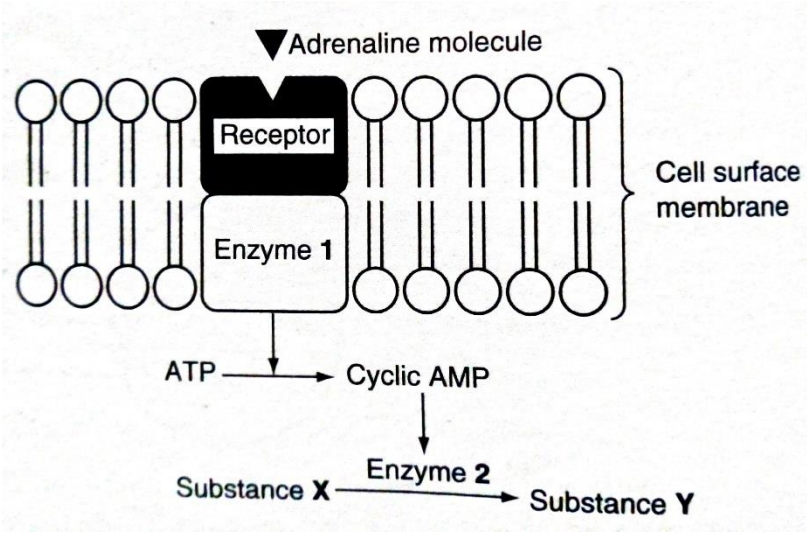
14. (a) The human kidneys process 1200 cm^3 of blood every minute. This 1200 cm^3 of blood contains 700 cm^3 of plasma. As this blood passes through the glomeruli of the kidneys, 125 cm^3 of fluid passes into the renal capsules (Bowman's capsules). This fluid is called the glomerular filtrate and is produced by a process is called ultrafiltration.

(i) Calculate the percentage of plasma that passes into the renal capsules. Show your working.

(ii) Explain how the structure of the glomerular capillaries is adapted for ultrafiltration.
(iii) Explain why the epithelial cells of the proximal convoluted tubule have many mitochondria in them.
(iii) Describe the role of the hypothalamus and kidney nephrons in the control of the osmotic pressure of blood.
(b) Kidney failure may result in a buildup of urea in the blood, protein in the urine and retention of tissue fluid. Patients with kidney failure may need a transplant. Recipients of transplanted kidneys are treated with drugs that suppress their immune system.
(i) Explain how ultrafiltration and reabsorption remove urea from the blood without losing essential nutrients such as protein and glucose.
(ii) Explain the part played by the loop of Henle and the collecting duct in concentrating urine in a healthy individual.
(iii) Explain the link between protein in the urine and retention of tissue fluid in patients with kidney failure.
(iv) If not treated with drugs, explain how the recipient's immune system would reject a transplanted kidney.

ST. JOSEPH OF NAZARETH

15. (a) What is meant by **cascade effect** of hormonal action?.
(b) The diagram summarises the way in which adrenaline can control a chemical reaction in a liver cell.



(a) Describe the function of cyclic AMP in this process.
(b) Give an example of a chemical reaction in a liver cell which is controlled by adrenaline by naming substance X, Substance Y, and enzyme 2.
(c) Use the diagram to explain:
(i) why adrenaline may affect some cells and not others.
(ii) how a single molecule of adrenaline may cause this cell to produce a large amount of substance Y.
(d) Differentiate between peptide and steroid hormones.

MT. ST. MARY'S COLLEGE NAMAGUNGA

16. (a) Describe the modification of Munch's theory of translocation.
(b) Describe stomatal movement basing on mineral ion change theory.
(c) What are the evidences to reflect that active movement of sugars within the sieve tube is based on the activity of the companion cells?
(d) Suggest a mechanism by which rise in abscisic acid concentration leads to closure of stomata.

ST LUCIA S.S. NAMAGOMA

17. Describe how each of the following affect distribution and abundance of plants.
(a) Temperature (b) Sunlight (c) Altitude

ST. BALIKUDDEMBE S.S. KISOGA

18. (a) Explain
(i) the origin of genetic diversity in a population (ii) the effect of cross-breeding in agriculture.
(b) Describe mechanisms in plants to increase genetic variability. **AGHA KHAN HIGH SCHOOL**

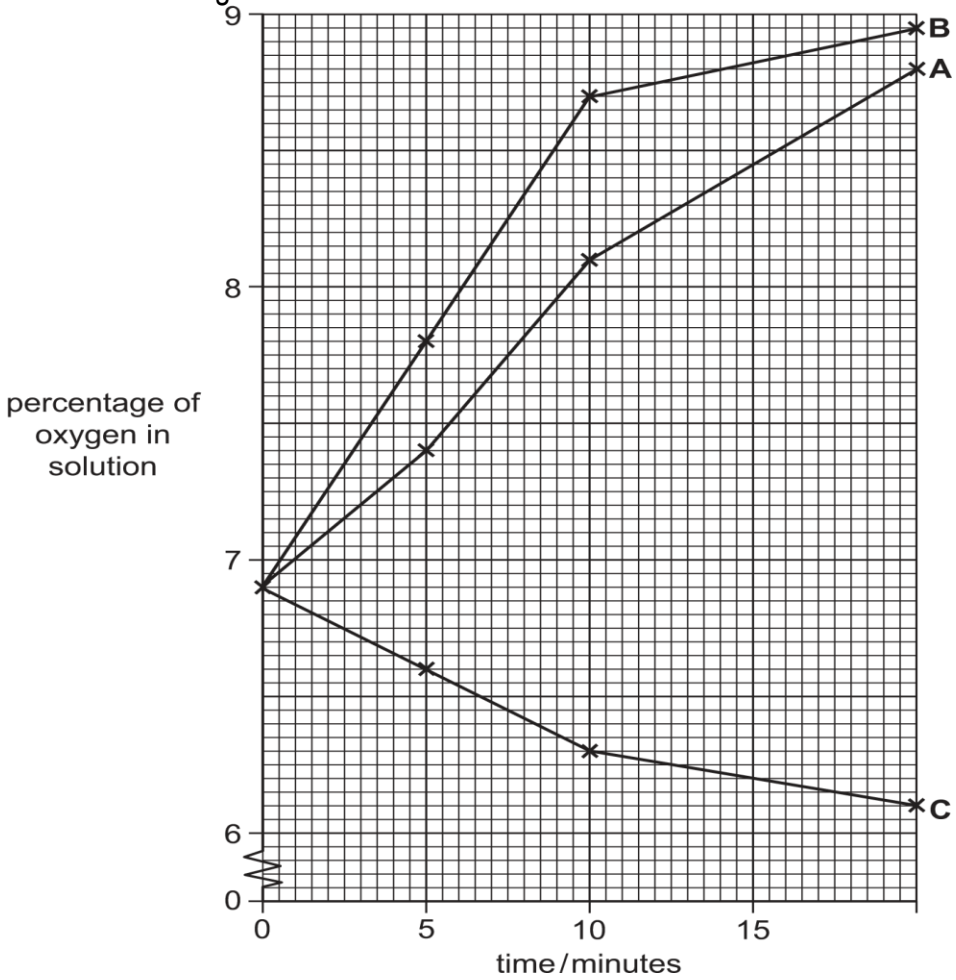
19. (a) Describe mechanisms in the human body by which it;
(i) carries out osmoregulation. (ii) regulates pH of blood.
(b) Using suitable examples; state circumstances under which body homeostasis may be under positive feedback.

ST. CYPRIAN HIGH SCHOOL KYABAKADDE

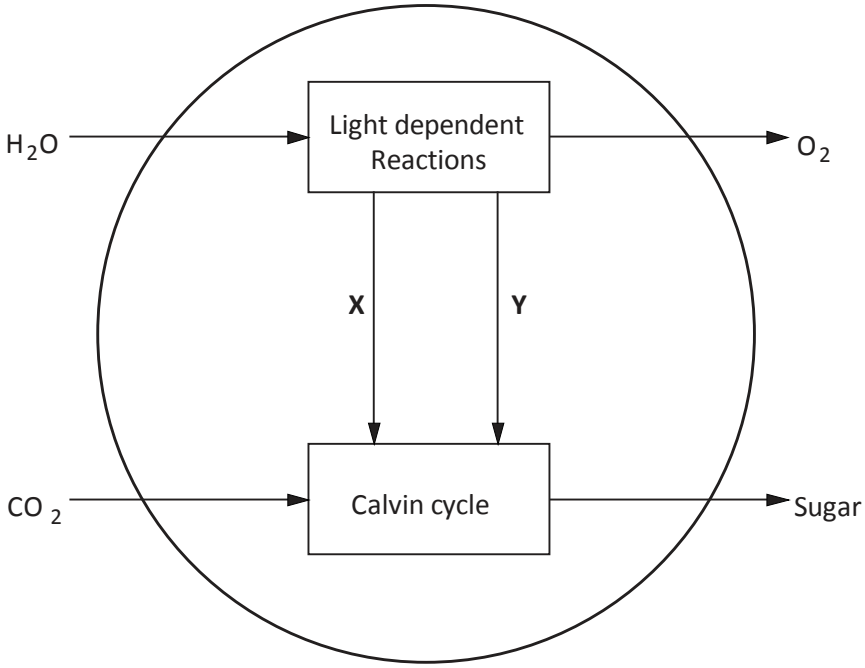
20. (a) The following experiment was carried out to investigate the effect of light intensity on the rate of photosynthesis of a water plant, Elodea.

- Elodea was cut into three pieces, each 10 cm long.
- Each piece of Elodea was placed in a glass tube, containing 0.5% sodium hydrogen carbonate solution, which was then sealed with a stopper.
- Tube **A** was placed 10 cm away from a lamp.
- Tube **B** was placed 5 cm away from a lamp.
- Tube **C** was placed in a dark room.
- An oxygen sensor was used to measure the percentage of oxygen in the solutions at the start of the experiment and again at 5, 10 and 20 minutes.

The results are shown in Figure below.



(i) Describe the changes in the percentage of oxygen in solution for tubes A and C.
(ii) State why sodium hydrogen carbonate solution was used.
(iii) Calculate the mean rate of oxygen production for tube **A** for the 20 minutes of the experiment.
(iv) Compare the results for tubes **B** and **C**.
(v) Explain the results for tube **C**.
(vi Suggest what factor, which may have an effect on the rate of photosynthesis, was **not** taken into account in this experiment.
(b) Figure below shows the relationship between the light dependent and light independent reactions in a chloroplast.



(i) Name substances **X** and **Y** in Figure above.
(ii) Describe the steps involved in the formation of the products in the above reactions.
(iii) Explain what makes C_4 plants more photosynthetically efficient than C_3 plants.

ROYAL COLLEGE BULOBA

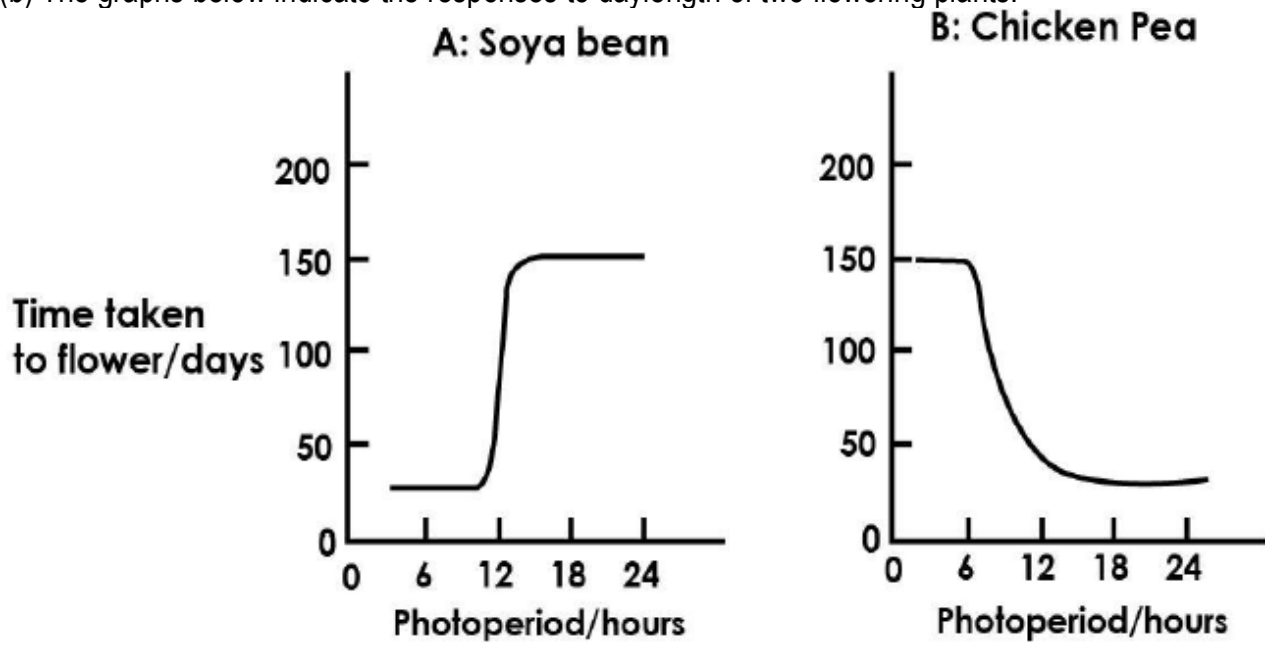
21. (a) Outline the properties of receptors.
(b) Describe the role played by the organ of corti in the mammalian ear.
(c) An individual who has been spinning for quite long feels dizzy when one suddenly stops. Explain why this is so.

ST. PETER'S S.S. NAALYA

22. (a) Explain the mechanism of organic evolution.
(b) Describe the factors that lead to the deviation from Mendel's laws of inheritance.

KISUBI MAPEERA S.S

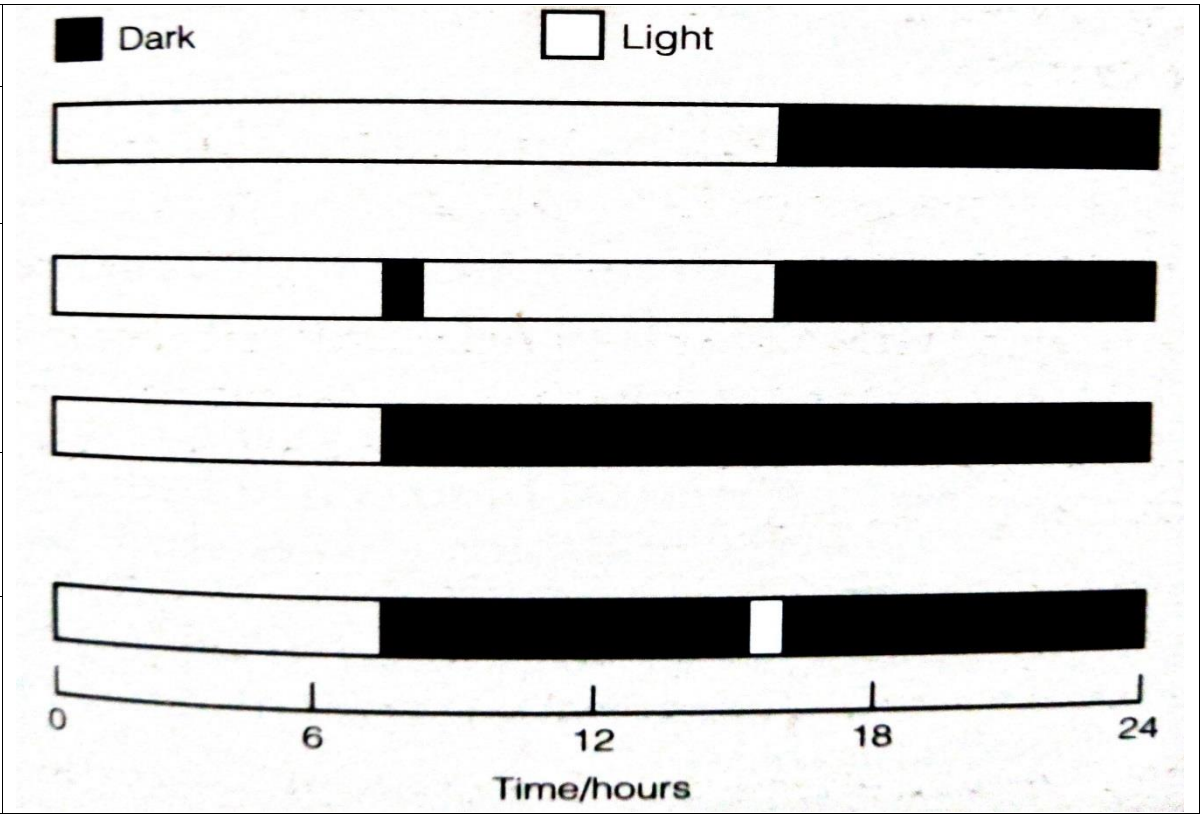
23. (a) What is meant by:
(i) Photoperiodism (ii) Phytochrome
(b) The graphs below indicate the responses to daylength of two flowering plants.



(i) Which one of the plants will flower under long-day conditions? Give a reason.
(ii) Describe the role of phytochrome in the flowering process.

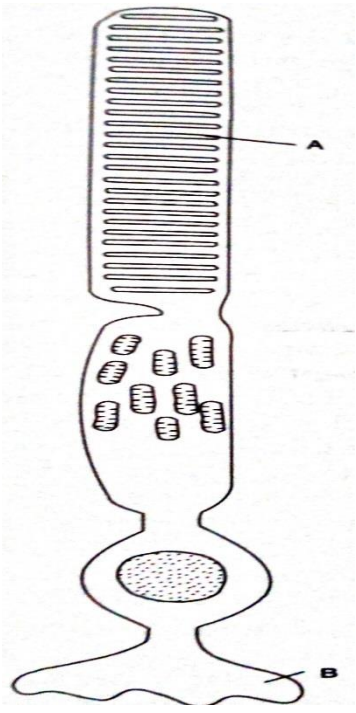
(c) The figure below shows an investigation of the different light and dark periods on flowering of short day and long day plants.

Light Regime	
1	
2	
3	
4	



Explain the effect the different light and dark regimes on the flowering of both short day and long day plants.
(i) Regime 1 (ii) Regime 2 (iii) Regime 3 (iv) Regime 4
(d) Chrysanthemum plant flowers are produced commercially under glass throughout the year. At certain times of the year growers cover the greenhouse with black polythene for part of the day. Account for this in terms of photoperiodism.

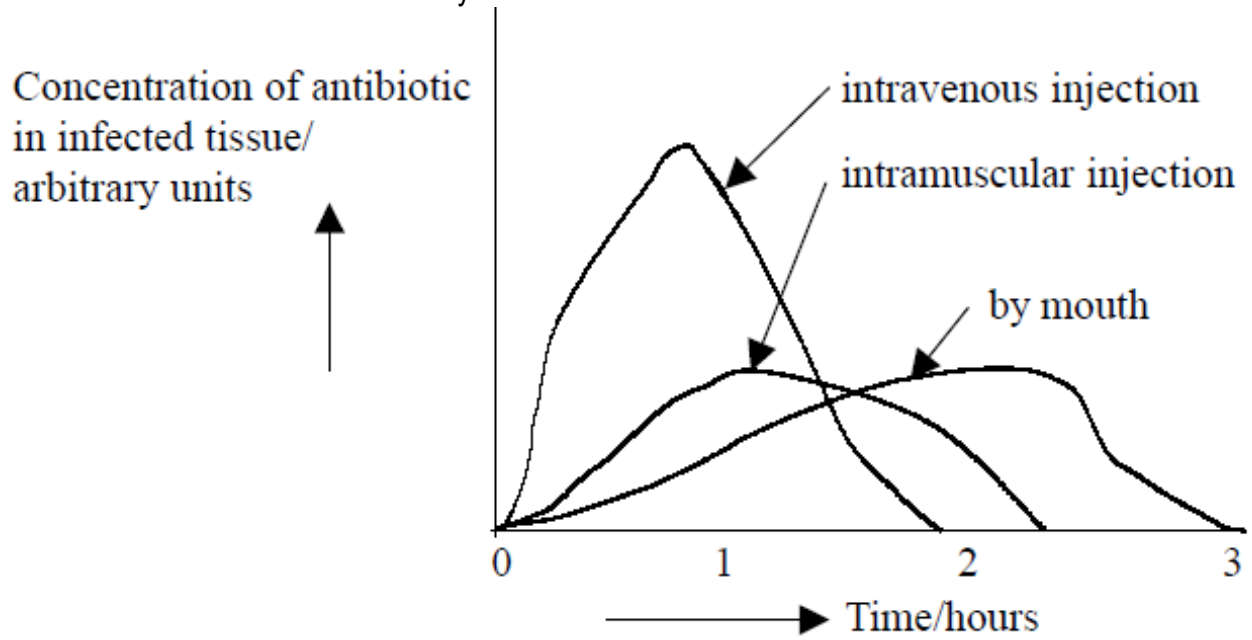
JJINJA COLLEGE SCHOOL



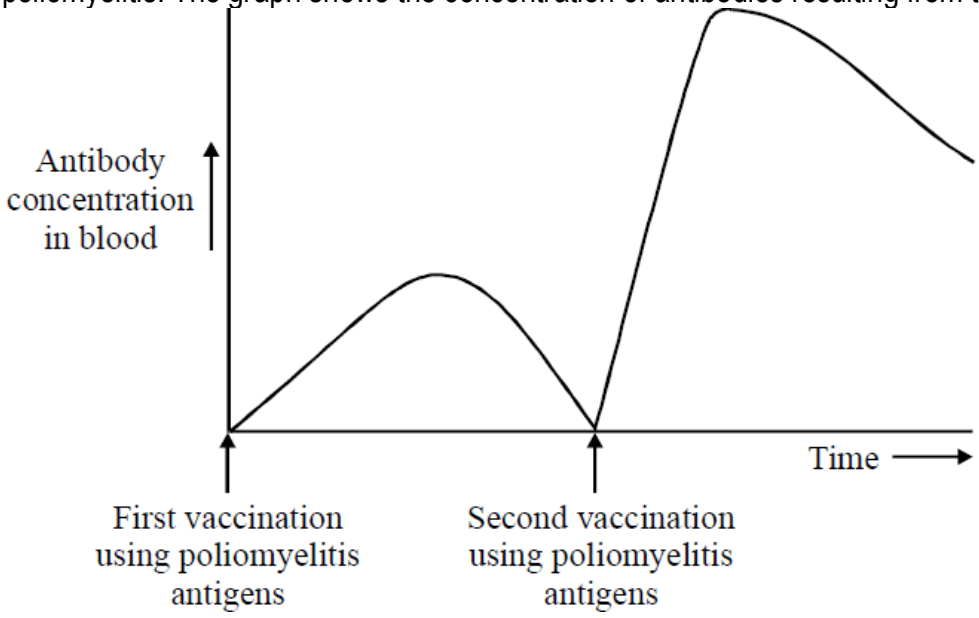
24. The diagram besides is of a rod cell.
(a) Name the parts labelled A and B and give one function of each.
(b) Describe other features of rod cells that enable them perform their function in the mammalian eye.
(b) Draw an arrow next to the diagram to indicate the direction in which light passes through this cell.
(c) State two ways in which vision using cones differs from vision using rods.
(d) Explain how light energy falling on a rod cell in the retina of the eye is converted to electrical energy.
(e) Explain why an individual is temporarily blinded when one moves from bright light into a dimly light room.
(f) Explain how the possession of different types of cone cell helps us to see:
(i) blue light; (ii) white light.

BUGEMA ADVENTIST HIGH SCHOOL

25. The graph below shows the time taken for an antibiotic to reach certain concentrations in infected tissues after administration by different routes.



(a) Differentiate between the terms 'antibiotic' and 'antibody'.
(b) What conclusions can be drawn from the graph about the three methods of antibiotic administration?
(c) Suggest reasons for the different concentrations in infected tissue achieved by the different methods of administration.
(d) Antibodies may sometimes be injected into people. Explain why this is so.
(e) Suggest explanations for the following facts;
(i) The female Anopheles mosquito can transmit the malarial parasite (Plasmodium) from human to human but does not act as a vector for the HIV virus.
(ii) HIV positive individuals are more prone to infection by organisms causing diseases such as tuberculosis and pneumonia.
(f) A child was given two vaccinations consisting of antigens from the virus which causes poliomyelitis. The graph shows the concentration of antibodies resulting from these vaccinations.

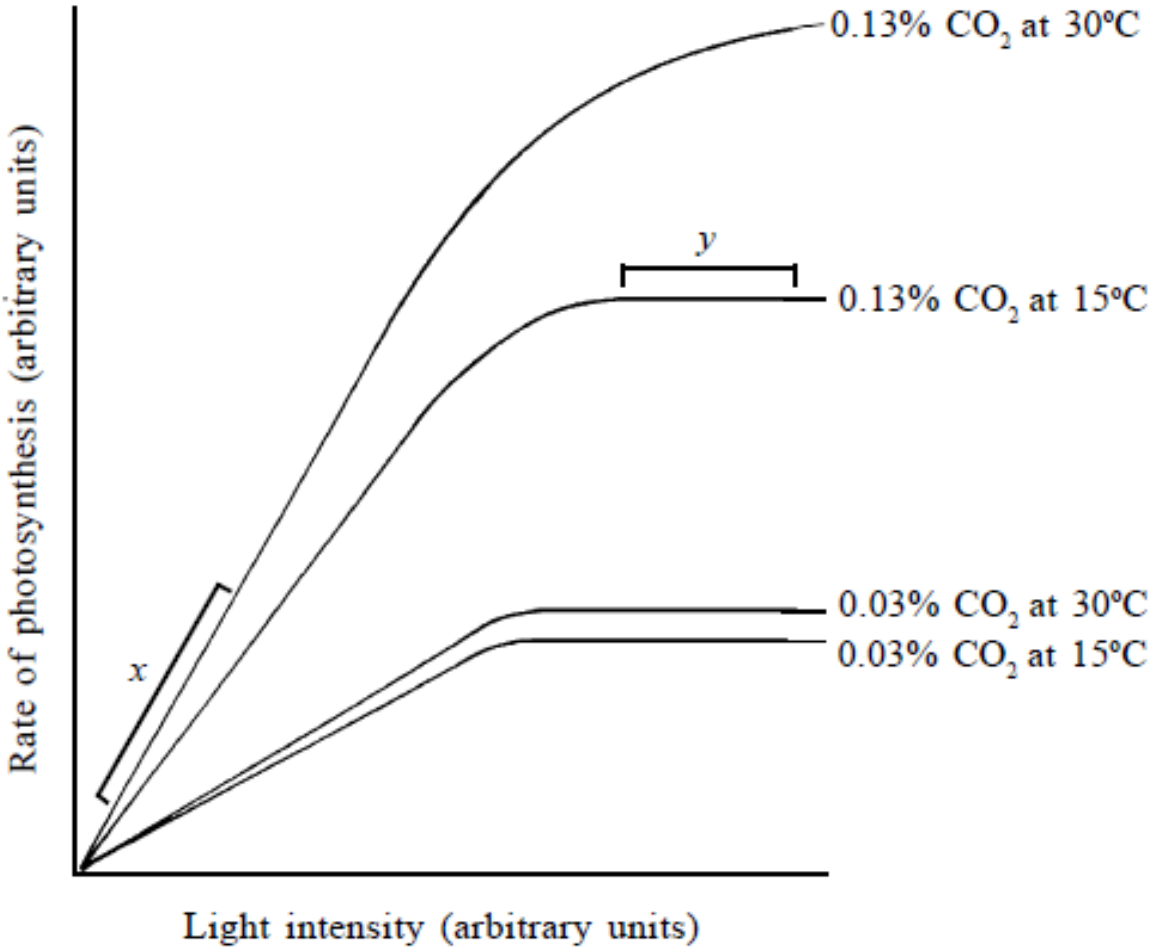


(i) What is a poliomyelitis antigen?
(ii) Describe and explain the difference in the child's response to the two vaccinations shown in the graph.

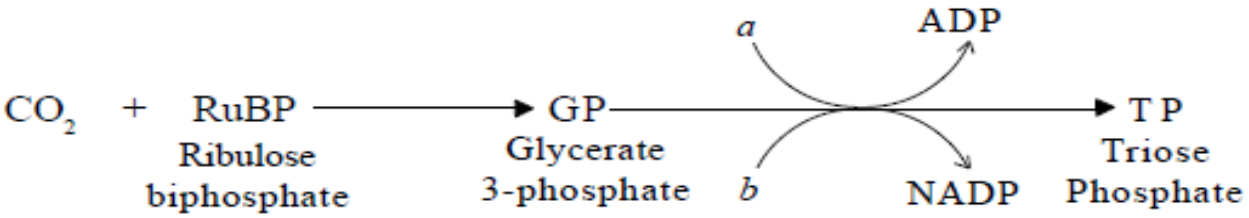
(iii) Immunisation programmes may use either attenuated or dead microorganisms. Suggest why there might be problems for the patient when using these vaccines.

KIBULI S.S.

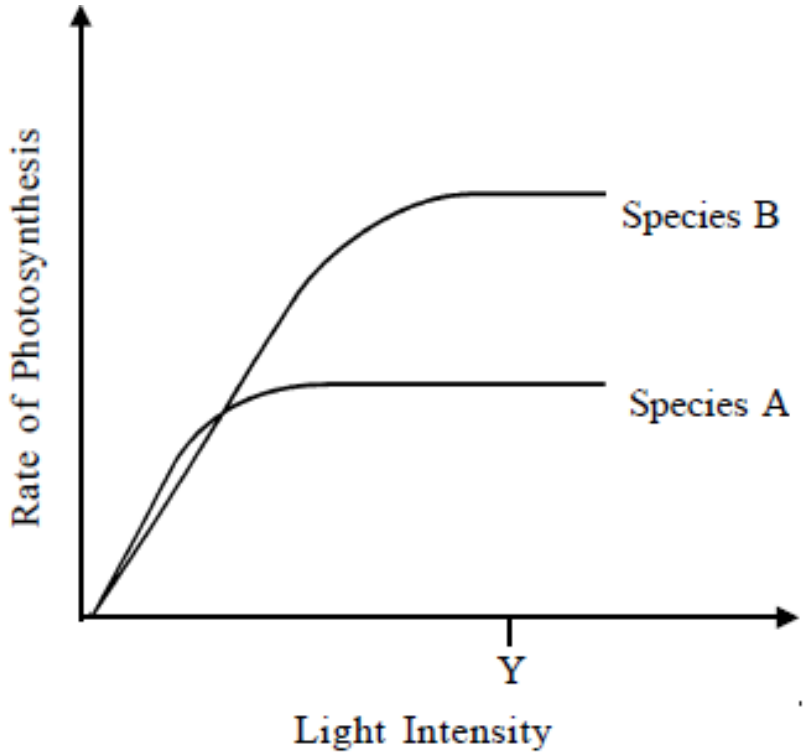
26. (a) The graph below shows some of the effects of light intensity, carbon dioxide, and temperature on the rate of photosynthesis.



(i) Use the graph to explain the term 'limiting factor'.
(ii) Suggest why, on hot bright summer days, commercial greenhouses may use fans to cool the greenhouses.
(b) The diagram below shows some of the steps in the light independent stage of photosynthesis.



Identify substances a and b produced in the light dependent stage of photosynthesis.
(c) Suggest explanations for the following observations:
(i) At sunset, the concentration of glycerate-3-phosphate in chloroplast stroma begins to increase rapidly.
(ii) During the night, the level of glycerate-3-phosphate eventually levels off.
(d) The graph shows the effect of light intensity on the rates of photosynthesis of plant saplings growing in a woodland. One species normally grows in direct sunlight, the other species normally grows in shaded conditions.



(i) Suggest which species normally grows in shaded conditions. Explain your answer.
(ii) How are shade plants adapted to ensure that they are photosynthetically efficient?

(iii) Suggest which factor is limiting the rate of photosynthesis of species A at light intensity Y.

(e) The light compensation point for three woodland species is shown in the table below. The average light compensation point for plants in this woodland is 1150 lux.

Species	Light compensation point (lux)
A	2000
B	350
C	900

(i) Define Light compensation point.
State and explain which of these three species:
(ii) normally grows in bright sunlight
(iii) has leaves with the highest chlorophyll content. **ENTEBBE S.S.**

27. (a) Discuss how each of the following overcome the major challenge in their environment.
(i) hydrophytes (ii) halophytes (iii) Camel
(iv) Salmon fish (v) Marine elasmobranchii
(b) Differentiate between osmocoformers and osmoregulators.

BISHOPS S.S. MUKONO

28.(a) Explain saltatory conduction in myelinated nerve fibres.
(b) Compare the structure and suitability of slow twitch and fast twitch muscles to their function.
(c) Skeletal muscles of an individual who has died eventually stiffen. Explain the physiological changes that result into this observation.
(d) During exercise, the rate of respiration of muscle cells increases. Explain what causes human haemoglobin to unload more oxygen to these cells.

LIGHT ACADEMY S.S.

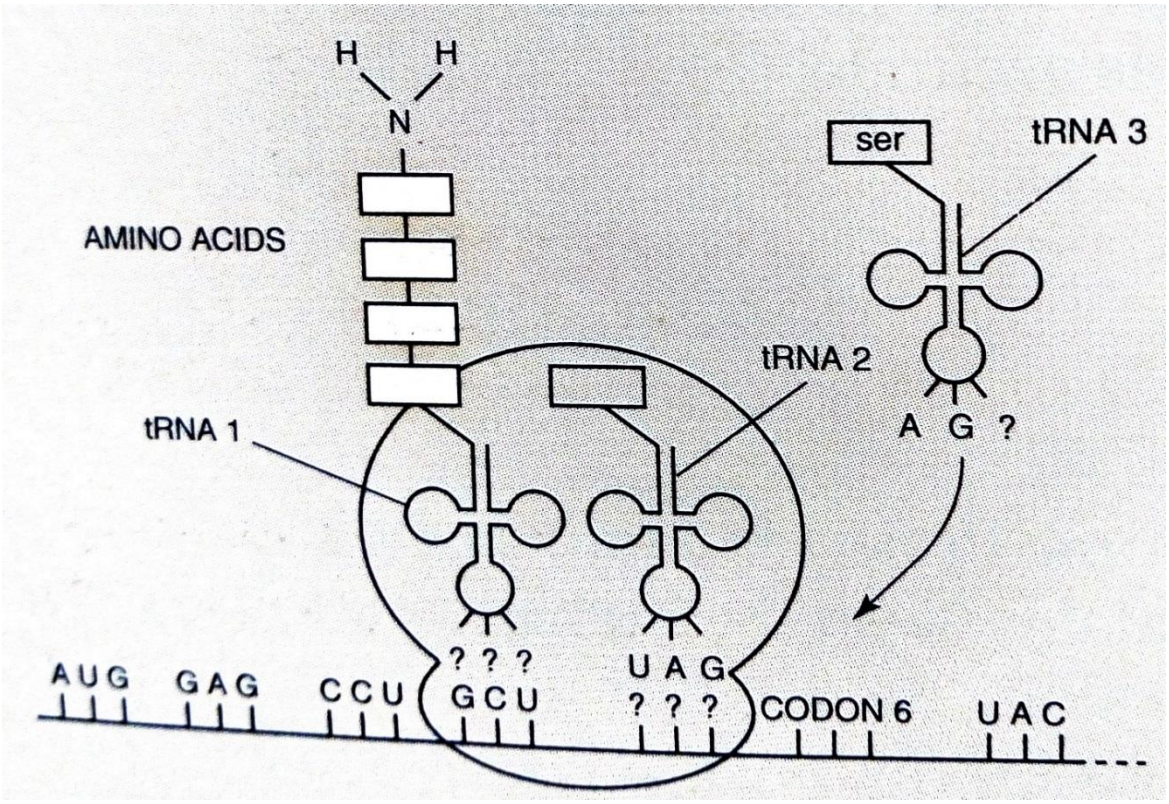
29. (a) Describe the mechanism by which the respiratory surfaces of an insect are ventilated.
(b) In many of the lugworm gills, the blood flows in the opposite direction to the current of water passing over them. Explain the advantage of this arrangement.
(c) Differentiate between the breathing system of mammals and that of insects.
(d) Explain why the rate of water loss during gaseous exchange in insects is very low a s compared to that in mammals.
(e) Air is a better respiratory medium than water. Explain why this is so.

NAMUGONGO SECONDARY AND VOC SCH

30. (a) Describe, with aid of annotated diagrams the essential features of the process of meiosis in a cell whose diploid number of chromosomes is 4.
(b) Give an account of how meiosis leads to evolution in a species.

ST. HENRY'S COLLEGE MBALWA

31. The diagram below summarises the processes of protein synthesis. Use it to answer the questions that follow.



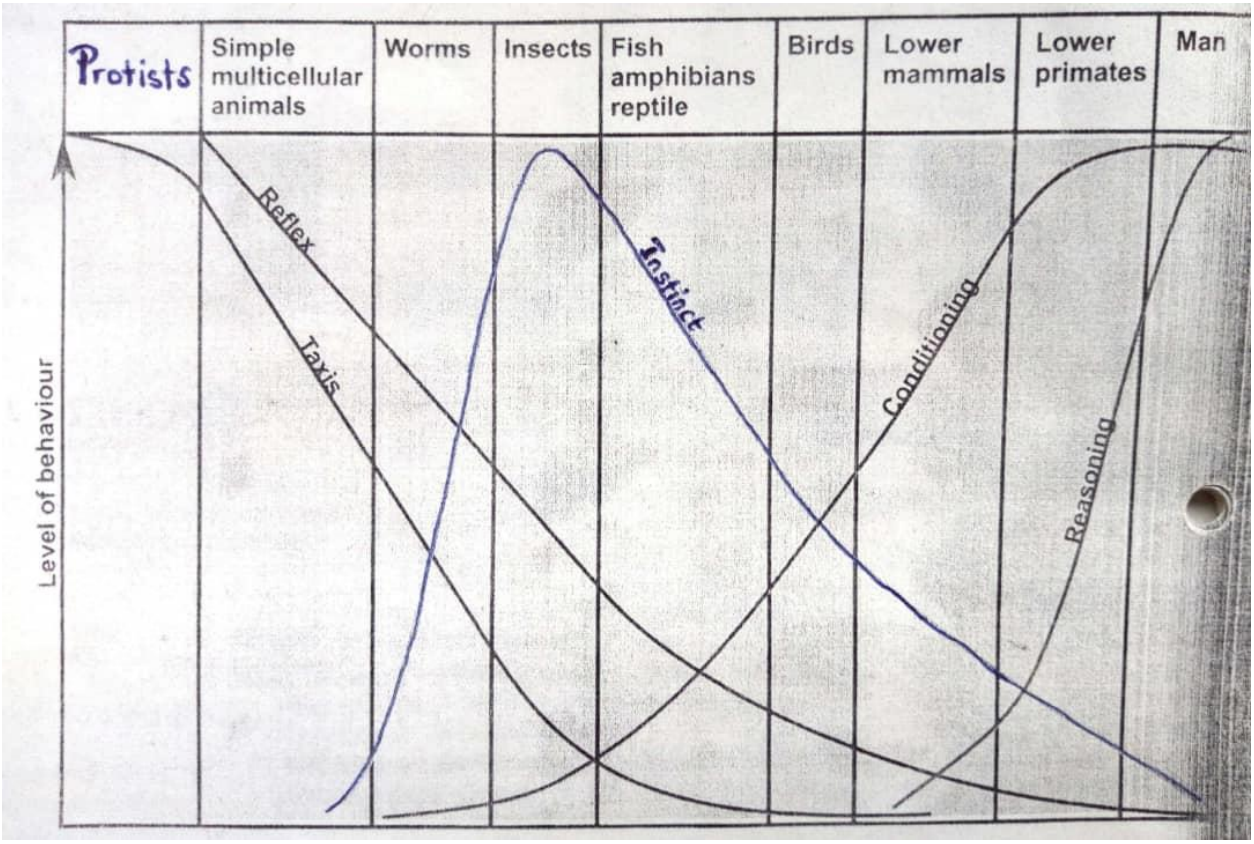
(a) (i) Which is the first tRNA anticodon used in protein synthesis from this mRNA?
(ii) What is the anticodon sequence in tRNA 1?
(iii) Give the DNA triplet code which is recognised by tRNA 2.
(b) (i) Explain what changes will occur in the translation apparatus to allow codon 6 to be translated.
(ii) What are the possible codon sequences for codon 6?
(c) Explain why mutations involving the deletion of a base may have greater effects than those involving substitution of one base for another.
(d) (i) Precisely describe how errors are minimized during DNA replication.
(ii) Describe how errors that occur during DNA can lead to sympatric speciation.
(e) What is the significance of DNA duplication prior to mitosis?
(f) Describe how DNA controls the behavior and physical appearance of an organism.

ST. MICHAEL INTERNATIONAL SCHOOL WAKISO

32. (a) Describe the asynchronous and synchronous contractions of muscles in insects.
(b) Describe the bird's wing as an aerofoil.
(c) Discuss the properties of skeletal muscles.
(d) Describe the process of; (i) muscle contraction. (ii) muscle relaxation

GAYAZA CAMBRIDGE COLLEGE

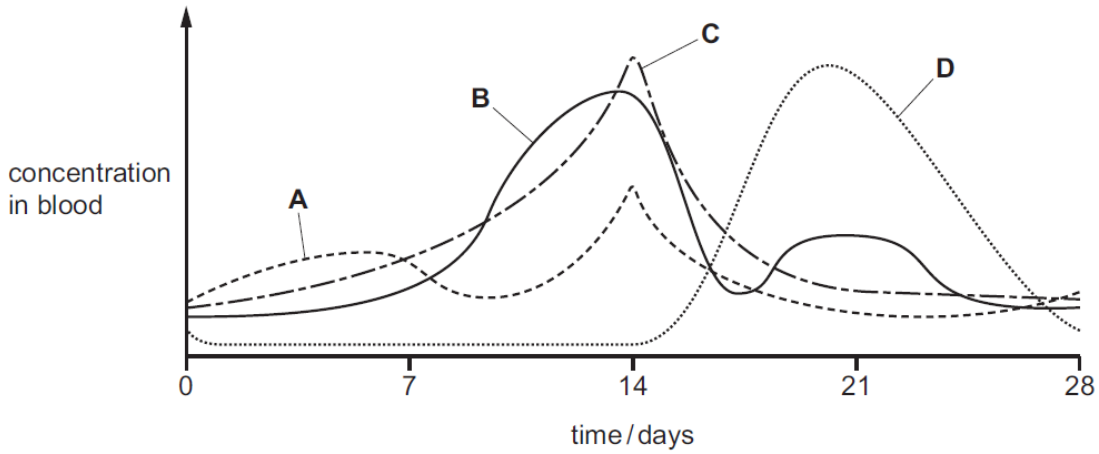
33. The graphs in the figure below show the dominant behaviour patterns studied in invertebrates and vertebrates. Carefully study them and answer the questions that follow.



(a) Describe the behaviours which are a result of taxis and reasoning in the experimental animals specified above.
(b) Comment on the behaviour patterns illustrated in the graphs above.
(c) Categorise the above behaviours in to the two major types of behaviour.
(d) From your knowledge of the organisms above what conclusion(s) can you draw from the graphs?
(e) What explanation can suit your conclusion(s) in (d) above?

MERRYLAND HIGH SCHOOL

34. The graph shows the rise and fall of pituitary and ovarian hormones during the human ovarian cycle.



(b) Outline the role of hormones; (i) B (ii) C
(c) Was the lady pregnant at the end of the cycle or not? Give reason for your answer.
(d) Some animals like rotifers and aphids are able to alternate between sexual and asexual reproduction. Under what conditions might it be advantageous to reproduce;
(i) sexually? (ii) sexually?
(e) Explain what might cause the variation in length of human menstrual cycle.
(f) Explain why oral contraceptives (pills) are rich in hormone D.

(g) The embryos of reptiles, birds and mammals have systems of extra embryonic membranes. What are the functions of these membranes, and how do fish and frog membranes survive without them? **BUDDO S.S.**

35. In an experiment to investigate the respiratory metabolism of yeast, the latter was mixed with 1% glucose solution. The carbon dioxide evolved was passed through oil and the volume of oil displaced by carbon dioxide (cm^3) was recorded in the table 1 below.

Time/minutes	Volume of oil displaced/cm^3
0	0
4	5
8	10
12	15
16	21
20	30
28	40
32	41

In another experiment, the ability of the yeast to metabolise a range of different carbohydrates, all at the same conditions was estimated by measuring the volume of oil displaced by the carbon dioxide evolved after 20 minutes of running each experiment. The results are shown in the table II

Carbohydrates	Volume of oil displaced/cm^3
Glucose	8.7
Sucrose	5.9
Lactose	0.0
Maltose	6.1
Starch	0.8
Fructose	8.9
No carbohydrate	0.9

(a) Comment on the results obtained in table I and II.
(b) Suggest the type of curve that would be obtained if the results in table I were plotted on a suitable graph and give reasons for your answer.
(c) Explain your reasons in (b) above.
(d) Predict what would happen to the volume of oil displaced if the experiment were continued for more hour.
(e) What was the aim of the experiment in table (II)?
(g) (i) Suggest with reasons the food substance that yielded high carbon dioxide concentration.
(ii) Explain why the volume of oil displaced from metabolism of starch and lactose were the least.

NANSANA ST. JOSEPH'S S.S.

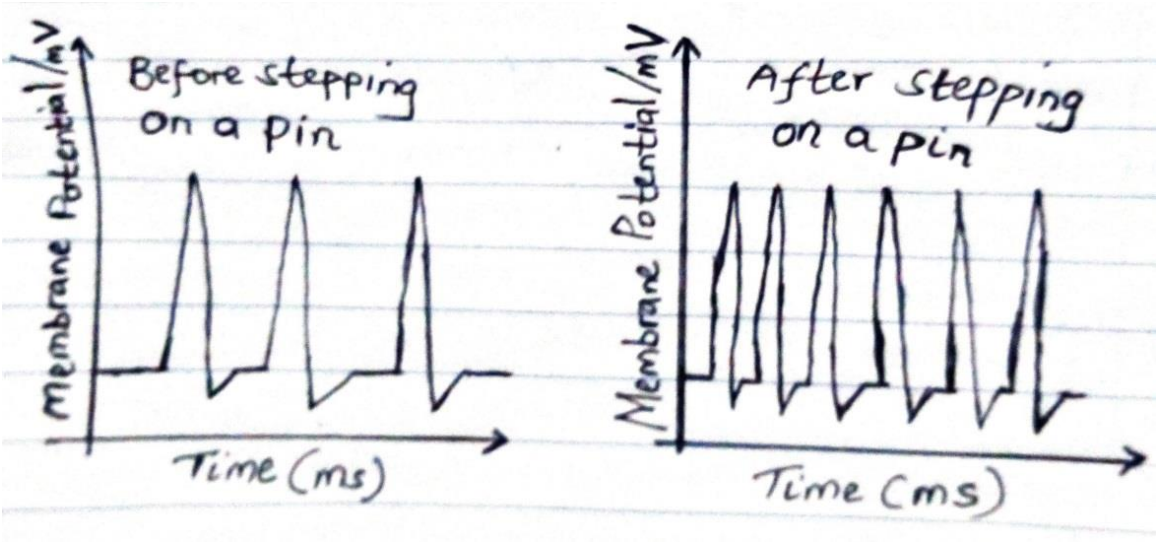
36. (a) Describe how abnormal haemoglobin arises in a human population.
(b) Explain the effect of the gene for abnormal haemoglobin in humans.
(c) Describe the life cycle of Plasmodium.
(d) What are the adaptations of plasmodia to its parasitic mode of life?
(e) Why is malaria severe in sub Saharan Africa?

ST. LAWRENCE HORIZON MAYA

38. (a) Describe with the aid of diagrams how each of the following types of movement occur.
(i) Cilliary movement (ii) Amoeboid movement
(b) What is the importance of ciliary and amoeboid movements in humans?

KIIRA COLLEGE BUTIKI

38. The graphs in the figure below show the rate at which the sensory neuron triggers action potentials when an s.6 student steps on a pin and before stepping on it.



(a) Explain the changes in the membrane voltage of the sensory neuron:
(i) before the student steps on a pin (ii) after the student steps on a pin
(b) State and explain what will happen if the student swallows some pain killers.
(c) Explain why an odour at first is strong but seems to fade with time even when the substance producing it is still there.
(d) (i) What enables a receptor in a taste bud to key on just a certain type of chemical in food?
(ii) what determines the "taste" that is perceived in response to that particular chemical?
(e) Account for the different types of receptors found in human skin.

UGANDA MARTYRS' HIGH SCHOOL RUBAGA

39. (a) Describe the physiological behavior of the rods during;
(i) darkness (ii) low light intensity (iii) exceedingly high light intensity
(b) Explain the significance of the compactness of cones at the fovea.

FAITH HIGH SCHOOL

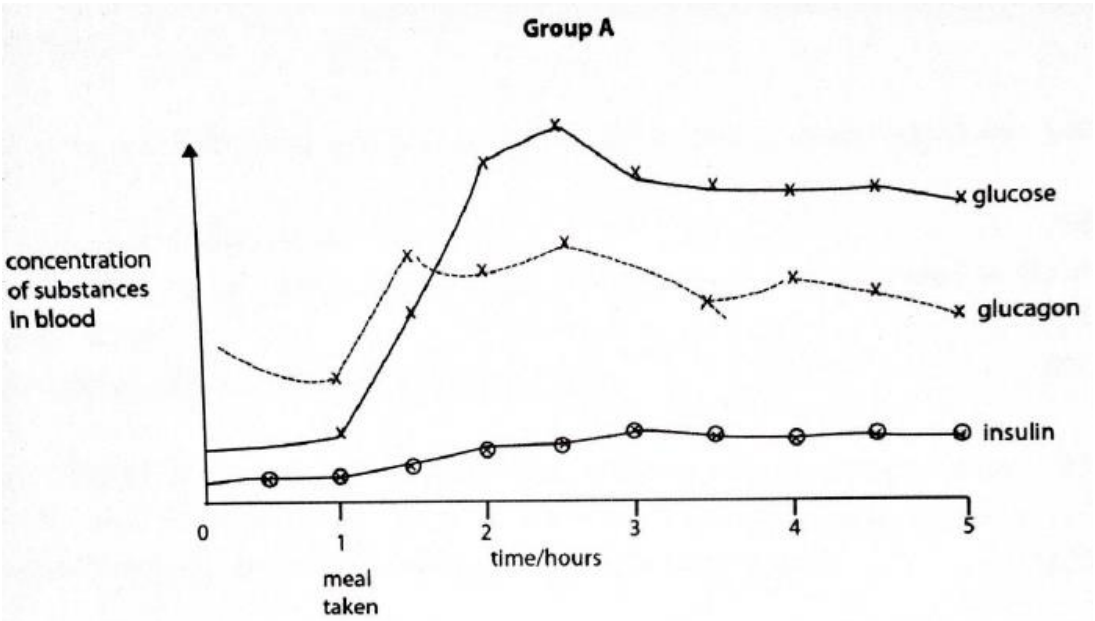
40.(a) Explain how Amino acids are able to regulate the PH of blood.
(b) How does the lock and key theory explain how enzymes function?
(c) Explain how allosteric inhibitors regulate cell metabolism.

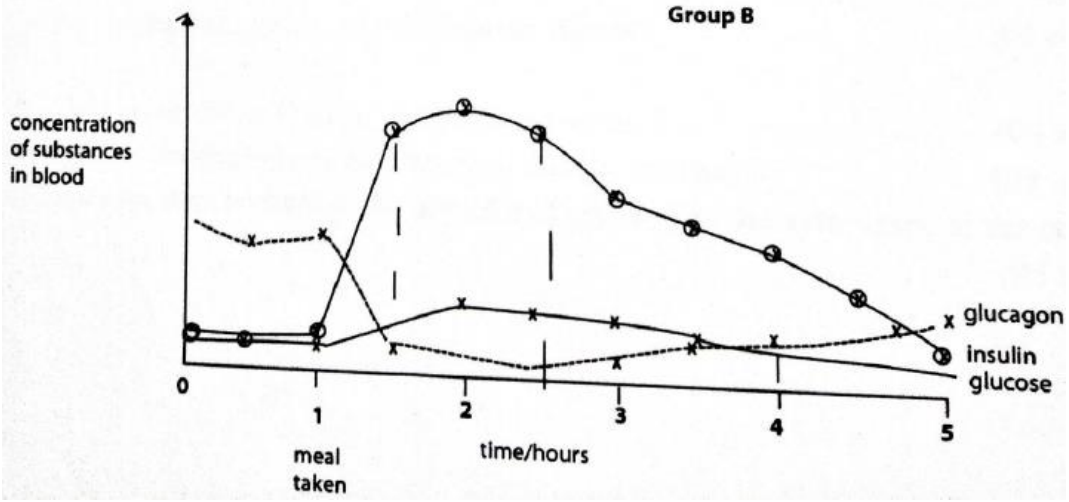
ST. MICHAEL HIGH SCHOOL SSONDE

41. Describe the effects of light on:
(i) abundance (ii) morphology of plants **BUSOGA S.S.**

42. (a) Describe the changes in the;
i) pressure potential,
ii) water potential of the plasmolysed plant cell when inserted in a hypotonic solution.
(b) Account for the negative water potential of any solutions. **JJINJA PROGRESSIVE S.**

43. In one form of diabetes, the pancreas is unable to make sufficient insulin. In an investigation, twenty people were divided into two groups.
Group A contained ten people with this form of diabetes, while group B contained ten people without diabetes (control).
Blood samples were taken from each person at 30 minutes' intervals and the amount of glucose, insulin and glucagon measured. After one hour, each person ate a meal containing large amount of carbohydrate. Mean concentrations were calculated for each substance at each sampling time. The results were shown in the graphs below.





(a) Explain the relationship between glucose concentration and insulin in
(i) Group A. (ii) Group B.
b) Explain the variation of glucagon hormone in group A and B.
(c)Predict what would happen to the glucose concentration of people of group A if they ate carbohydrate for another 24 hours. Explain your answer.
(d) Other than the concentration of glucose in blood, what other factors must be regulated in the internal environment (tissue fluid).

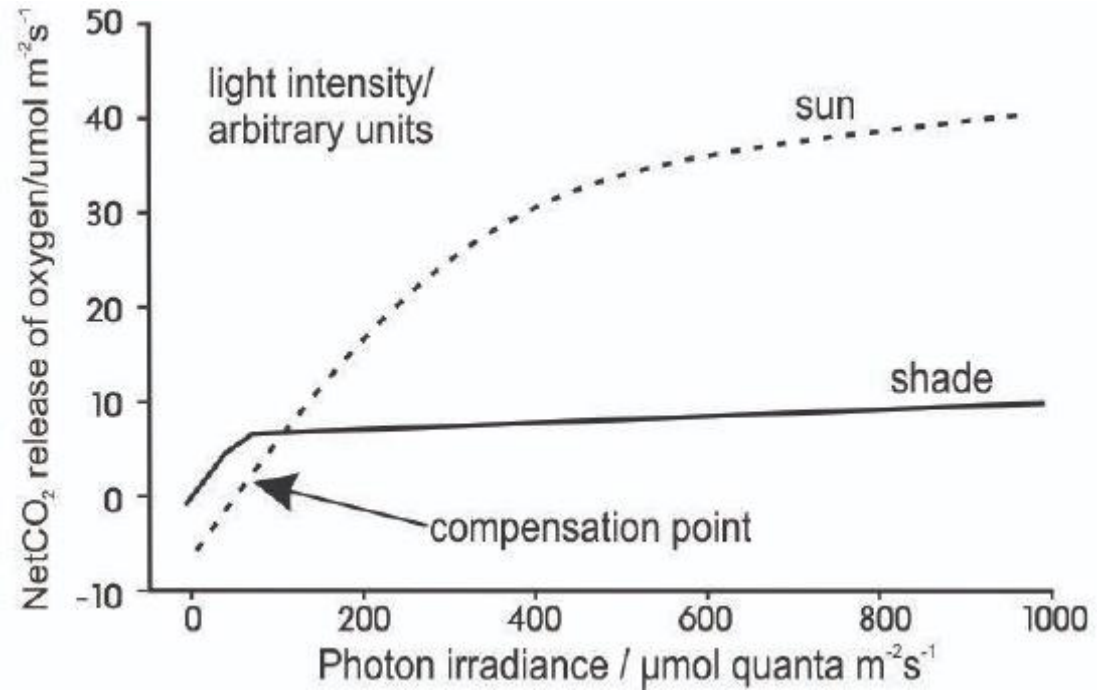
ST. HENRY'S COLLEGE KITOVU

44. (a) Describe how the stratosphere is destroyed
(b) Outline the indicators to support the destruction of the stratosphere
(b) What is meant by an indicator species? **SAITAH HIGH SCHOOL**

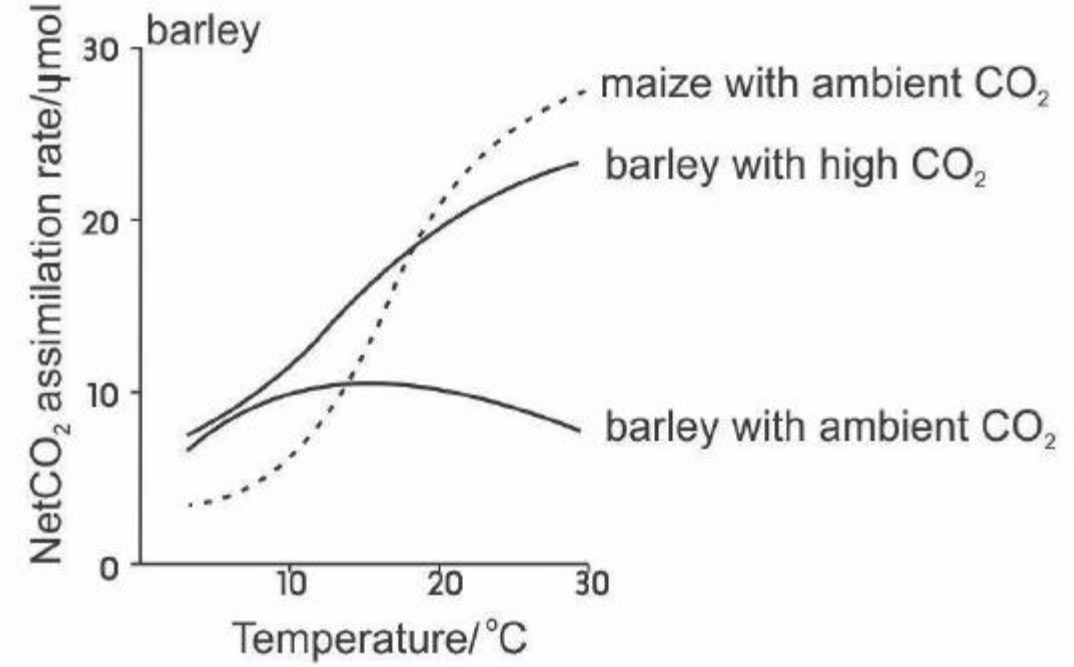
45. (a) Explain how the following are determined:
(i) ABO blood groups (ii) Sex in Man
b) Explain Charles Darwin's finches in terms of evolution

STANDARD HIGH SCHOOL ZZANA

46. The figure 1 below shows the effect of increasing light intensity on the rate of release of oxygen of two wood plants, a sun plant and a shade plant .The sun plant is a tall tree while the "shade plant "grows on the woodland floor.



(a) (i) Compare the effect of increasing light intensity on the two plant types
(ii) Explain the effect of increasing the light intensity on the sun plant
(iii) Suggest and explain the reason for the difference in the effect of increasing light intensity on the two plants
(b) The figure 2 below shows the effect of increasing temperature on the net assimilation rate of carbon dioxide of barley and maize plants. Barley was grown at different temperatures in ambient (normal atmospheric) and high levels of carbon dioxide. Maize were grown at different temperatures in ambient carbon dioxide.



(i) Explain the effect of increasing carbon dioxide concentration and temperature on the net carbon dioxide assimilation rate of barley.
(ii) Explain the difference in the effect of increasing temperature on the uptake of carbon dioxide in maize at ambient carbon dioxide concentration compared with the effect of Barley
(iii) Use Figure 2 to suggest and explain why C4 plants tend to be found in hotter, more arid regions than C3 plants.

47. (a) What is meant by each of the following?

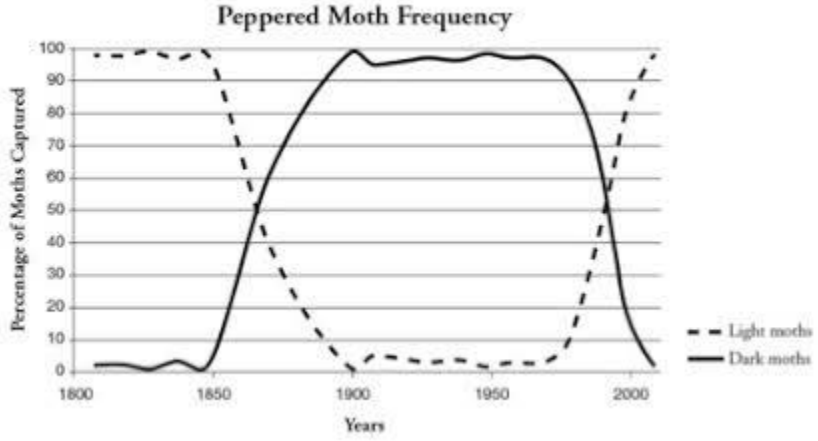
(i) Polymorphism. (ii) Industrial melanism.

(b) Differentiate between transient and balanced polymorphism.

(c) Outline the causes of polymorphism in a population.

(d) What is the importance of polymorphism in a population?

(e) The figure shows the changes in the frequency of Peppered Moths in the U.K. recorded over a period of 200 years.



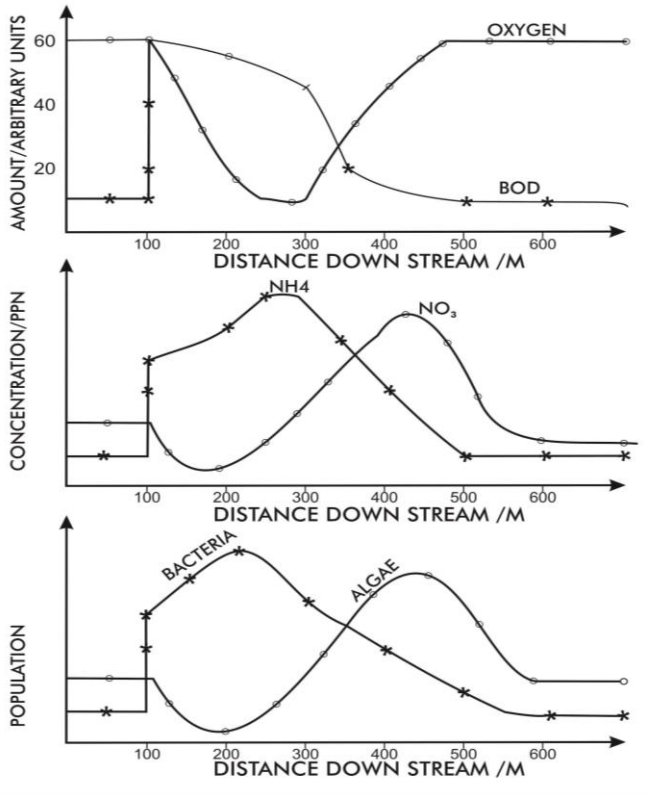
(i) What evolutionary phenomenon is under study as shown by the graph?

(ii) Explain the changes in frequency of peppered moth varieties over the course of study.

(iii) Suggest possible ways how the dark form of moth came into existence.

KABOWA HIGH SCHOOL

48. The graphs below indicate the effect of sewage discharge at 100 meters of the river towards its biotic and abiotic environments. Study them carefully and answer the questions that follow.



(a) Define the term B.O.D.

(b) Explain the effect of sewage discharge towards;

(i) Oxygen (ii) BOD, downstream

(c) Account for the changes in the concentration of;

(i) Ammonium ions,

(ii) Nitrate ions, downstream

(d) Account for the changes in the population of;

(i) Bacteria,

(ii) Algae, downstream

(e) Suggest the likely effects of the population changes of algae to the river between 200m – 450m, when it occurs for a long period of time, downstream.

SSAKU HIGH SCHOOL

END **HEARTFELT SUCCESS!**

ADVANCED LEVEL: EXTRACTION OF METALS

General principles of extraction of metals

Metals are extracted from substances called ores; an ore is a naturally occurring substance from which a metal can be extracted

General steps involved in extraction of metals

The method of extraction differs from metal to metal, some general steps include

- Crushing and grinding the ore
- Concentration of the ore
- Roasting the ore
- Reduction/electrolysis of the ore to metal

Crushing the ore

This involves breakdown of the ore into small particle sizes depending on the concentration process to be followed

The particles are then separating according to sizes; this is termed as sorting/sizing. It is usually done by using screens with a given pore size to allow certain sizes to pass through

Concentration

In this process, the proportions of the required metal is increased in the ore, this can be done in a number of ways such as; froth flotation, electrostatic separation, gravity concentration, magnetic separation and leaching.

Roasting the ore

This aims at converting the ore into more desired products (ores) and driving out water of crystallization

1. EXTRACTION OF ALUMINIUM

The chief ore of Aluminium is Bauxite

Bauxite ($Al_2O_3.2H_2O$)

Other ores include

Cryolite (Na_3AlF_6)

Diaspore ($AlO(OH)$)

Gibbsite ($Al(OH)_3$)

Purification of the ore (Bauxite)

During extraction, the ore is first roasted in air to convert iron(ii) oxide to iron(iii) oxide, the roasted ore is then crushed to powder (pulverized)

The crushed ore is then dissolved in hot concentrated sodium hydroxide solution where the Amphoteric aluminium oxide and acidic silicon dioxide dissolve, the basic iron(iii) oxide remains undissolved

Equations

$$Al_2O_{3(s)} + 2OH^-_{(aq)} + 3H_2O_{(l)} \longrightarrow 2Al(OH)^-_{4(aq)}$$

OR

$$Al_2O_3 + 2OH^-_{(aq)} \longrightarrow 2AlO^-_{2(aq)} + H_2O_{(l)}$$

$$SiO_{2(s)} + 2OH^-_{(aq)} \longrightarrow SiO^{2-}_{3(aq)} + H_2O_{(l)}$$

The undissolved impurities (iron (iii) oxide) are filtered off leaving the Aluminate and Silicate in the filtrate.

Freshly prepared Aluminium hydroxide is added to the filtrate to precipitate Aluminium hydroxide, a process called Seeding

$$Al(OH)^-_{4(aq)} \longrightarrow Al(OH)_{3(s)} + OH^-_{(aq)}$$

Alternatively

Aluminium hydroxide is precipitated by bubbling carbon dioxide gas through the filtrate

$2Al(OH)^{-}_{4(aq)} + CO_{2(g)} \longrightarrow 2Al(OH)_{3(s)} + H_2O_{(l)} + CO^{2-}_{3(aq)}$

Either way, Aluminium hydroxide is filtered off leaving any silicates present in the filtrate

The hydroxide (precipitate) is washed, dried and heated strongly to form Aluminium oxide

$2Al(OH)_{3(s)} \longrightarrow Al_2O_{3(s)} + 3H_2O_{(l)}$

Electrolysis of Aluminium oxide

Pure aluminium oxide (alumina) is added to hot molten Cryolite to lower its melting point and increase its electrical conductivity

It is electrolyzed between carbon electrodes to form molten aluminium which collects at the bottom of the electrolytic cell since it is denser than the mixture of molten Cryolite and molten oxide

At the cathode

$Al^{3+}_{(aq)} + 3e^{-} \longrightarrow Al_{(s)}$

At the anode

$2O^{2-}_{(aq)} \longrightarrow O_{2(g)} + 4e^{-}$

<u>Uses of aluminium</u>

- ✓ Used in making bodies of air craft because it is light
- ✓ Used in making alloys which are light with high tensile strength e.g Duralumin and Magnalumin
- ✓ Used in making windows and door frames since it is resistant to corrosion
- ✓ Used in making aluminium paint
- ✓ Used in the thermite process to extract metals from their ores
- ✓ It is used for packaging (aluminium foils)

2. EXTRACTION OF ZINC

The chief ores are;
Zinc blende (ZnS)
Calamine ($ZnCO_3$)

Concentration of the ore
The ore is first crushed into powder and then concebtrated by froth flotation
During floth froth flotation, the pulverised ore is mixed with water and the frothing agent
The earthly impurities are wetted and hence sink leaving the ore containing particles on the surfaceas froth which is skimmed off, filtered and dried

Roasting
The dried concentrated ore is then roasted in air
Calamine decomposes

$$ZnCO_{3(s)} \longrightarrow ZnO_{(s)} + CO_{2(g)}$$

Blende is oxidised

$$ZnS_{(s)} + O_{2(g)} \longrightarrow ZnO_{(s)} + SO_{2(g)}$$

Also galena (PbS) which is the chief impurity is oxidized

$$PbS_{(s)} + O_{2(g)} \longrightarrow PbO_{(s)} + SO_{2(g)}$$

The solid product of roasting is mixed with limestone and coke and fed into a furnace; hot air is blown into the furnace
Coke burns to form carbon dioxide

$$C_{(s)} + O_{2(g)} \longrightarrow CO_{2(g)}$$

Carbon dioxide is reduced by unburnt coke to carbon monoxide

$$C_{(s)} + CO_{2(g)} \longrightarrow 2CO_{(g)}$$

The carbon monoxide produced under high temperature reduces zinc oxide and lead oxide to zinc and lead respectively

$ZnO_{(s)} + CO_{(g)} \longrightarrow Zn_{(g)} + CO_{2(g)}$

$PbO_{(s)} + CO_{(g)} \longrightarrow Pb_{(l)} + CO_{2(g)}$

Zinc has a lower boiling point and it distills off as vapour which is cooled by a spray of molten lead, zinc crystallizes and floats on top of molten lead

Limestone decomposes to quick lime which combines with silicon(iv) oxide (silica) present as impurity to form calcium silicate(slag) which flows off.

$CaCO_{3(s)} \longrightarrow CaO_{(s)} + CO_{2(g)}$

$CaO_{(s)} + SiO_{2(s)} \longrightarrow CaSiO_{3(l)}$

<u>Uses of zinc</u>

- ✓ Used for galvanizing iron
- ✓ Making alloys
- ✓ Used in drycell batteries

3. EXTRACTION OF IRON

The ores include
Haematite ($Fe_2O_3.2H_2O$)
Magnetite (Fe_3O_4)
Siderite/spathic ore ($FeCO_3$)
Iron pyrites (FeS_2)

For haematite
The ore is roasted to convert all the iron ores to iron(iii) oxide and drive off water of crystallization

$$Fe_2O_3.2H_2O_{(s)} \longrightarrow Fe_2O_{3(s)} + 2H_2O_{(l)}$$

For siderite carbonate/ spathic ore
It is pulverized and heated strongly in air to form iron (iii) oxide

$$4FeCO_{3(s)} + O_{2(g)} \longrightarrow 2Fe_2O_{3(s)} + 4CO_{2(g)}$$

For pyrite
It is heated strongly in air to form iron(iii) oxide

$$4FeS_{2(s)} + 11O_{2(g)} \longrightarrow 2Fe_2O_{3(s)} + 8SO_{2(g)}$$

Other raw materials include coke and limestone
The oxide is mixed with coke and limestone and the trio fed into a blast furnace from the top
A blast of hot air enriched with oxygen is allowed into the furnace through small pipes called tuyeres.
Hot air oxidizes coke to carbon dioxide

$$C_{(s)} + O_{2(g)} \longrightarrow CO_{2(g)}$$

The reaction is highly exothermic which rises temperature of the furnace
Further up in the furnace, carbon dioxide is reduced by the unburnt coke to form carbon monoxide

$$C_{(s)} + CO_{2(g)} \longrightarrow 2CO_{(g)}$$

Carbon monoxide reduces the ore to form molten iron and it is oxidized to carbon dioxide

$$Fe_2O_{3(s)} + 3CO_{(g)} \longrightarrow 2Fe_{(s)} + 3CO_{2(g)}$$

Also coke can reduce the ore

$$Fe_2O_{3(s)} + 3C_{(s)} \longrightarrow 2Fe_{(s)} + 3CO_{(g)}$$

The limestone added together with coke decomposes to form quicklime and carbon dioxide

$$CaCO_{3(s)} \longrightarrow CaO_{(s)} + CO_{2(g)}$$

The calcium oxide produced the reacts with silicon dioxide (sand), the chief impurity to form slag

$$CaO_{(s)} + SiO_{2(s)} \longrightarrow CaSiO_{3(l)}$$

The molten iron and slag both flow to the bottom, molten being denser than slag settles at the bottom, this is advantageous in that it prevents molten iron from being oxidized by the incoming hot air.

The slag is tapped off and molten iron is collected as cast/ pig iron which is impure as it contains carbon, silicon, manganese, sulphur, phosphorus which makes it weak

It is made pure by heating it with Fe_2O_3which oxidizes all the impurities to form pure iron

The waste gases contain mainly$N_2, CO_2$and CO. The mixture of N_2 and CO is called producer gas. They are used to heat the incoming air

4. EXTRACTION OF COPPER

The chief ore is copper pyrite ($CuFeS_2$)
Other ores include
Cuprites (Cu_2O)
Copper glance (Cu_2S)
Malachite ($CuCO_3.Cu(OH)_2$))

Extraction from copper pyrite
The ore is crushed into powder and concentrated by froth flotation in which the crushed ore is mixed with water and the frothing agent
A current of air is blown through the mixture producing a froth which contains copper bearing particles
The earthly impurities are wetted and these sink to the bottom of the tank
The froth is skimmed off, filtered and dried

Roasting of the ore
The dried concentrated ore is roasted in *limited supply of air* to convert the ore to molten copper (i) sulphide, iron (ii) oxide and sulphur dioxide

$$2CuFeS_{2(s)} + 4O_{2(g)} \longrightarrow Cu_2S_{(s)} + FeO_{(s)} + 3SO_{2(g)}$$

The products of roasting are heated in a furnace containing sand (silicon dioxide) to form iron (ii) silicate which floats on top of the copper (i) sulphide and is therefore tapped off

$$FeO_{(s)} + SiO_{2(s)} \longrightarrow FeSiO_{3(l)}$$

Molten copper (i) sulphide is then heated in *controlled amount of air* causing partial oxidation of copper (i) sulphide to copper (i) oxide

$$Cu_2S_{(l)} + 3O_{2(g)} \longrightarrow 2Cu_2O_{(s)} + 2SO_{2(g)}$$

The mixture of copper (i) oxide formed and copper (i) sulphide is then heated strongly in *absence of air* to form blister copper

$Cu_2S_{(s)} + 2Cu_2O_{(s)} \longrightarrow 3Cu_{(s)} + SO_{2(g)}$

The blister copper is purified by electrolysis using a direct current, with blister copper as the anode and a pure sheet/ strip of copper as the cathode, copper (ii) sulphate is used as an electrolyte.
At the anode, copper dissolves in the electrolyte
$Cu_{(s)} \longrightarrow Cu^{2+}_{(aq)} + 2e^-$

At the cathode, pure copper is deposited
$Cu^{2+}_{(aq)} + 2e^- \longrightarrow Cu_{(s)}$
The above electrolysis is essentially the transfer of copper from the anode to the cathode

Uses of copper
It is used in making electric cables and flux which are good conductors of electricity
Used in making alloys e.g, Dutch metal(Zn/Cu)

<u>Questions about extraction</u>

1. (a) What is meant by the term an ore? (01 marks)
   (b) Briefly describe how the following ores can be purified
   i) Zinc blende (04 marks)
   ii) Bauxite (06 marks)
   (c) Write equation(s) to show how aluminium metal can be extracted from the purified ore in (b) (ii) above. ($1\frac{1}{2}$ marks)

   (d) Describe how
   i) Aluminium reacts with sulphuric acid (05 marks)
   ii) Zinc reacts with sodium hydroxide ($2\frac{1}{2}$ marks)

2. a) Describe how pure Aluminium can be extracted from bauxite. Your answer should include equations for the reaction that take place. (10 marks)

b) (i) Briefly describe how hydrated Aluminium chloride ($AlCl_3 6H_2O$) can be prepared ($2\,^1/_2$ marks)

(ii) State what would be observed when hydrated aluminium chloride is strongly heated and write equation for the reaction that takes place. *($2\,^1/_2$ marks)*

(iii) Explain what would be observed where sodium carbonate solution is added to a concentrated solution of aluminium chloride. (05 marks)

3. (a) Describe how zinc is extracted from zinc sulphide. (07 marks)
(b) Explain the following observations:
(i) Zinc belongs to the *d* – block in the Periodic Table and yet it is not a transition metal.
[*Atomic number of zinc = 30*]. (02 marks)
(c) State **two** reactions in which zinc resembles magnesium and write equations for the reactions. (05 marks)
(d) Dilute ammonium hydroxide solution was added drop-wise until in excess to zinc sulphate solution. State what was observed and write equation for the reaction. (03 marks)

4.. During the extraction of aluminium from bauxite, the ore is first heated, powdered and then powdered material is heated with sodium hydroxide solution and finally filtered.

(a) State why the
(i) Ore is first heated before changing it to the powder, (01 mark)
(ii) Powdered ore is heated with sodium hydroxide solution and then filtered. (02 marks)
(b) Write equation for the reaction between the powdered ore and sodium hydroxide solution. (02 marks)
(c) Briefly describe how pure aluminium can be obtained from the products from the reaction in (b). (*Your answer should include equations.)* (08 marks)
(d) Write equation for the reaction between aluminium and

(i) $Fe_2O_3(s)$
(ii) $Mn_3O_4(s)$
(iii) $Cr_2O_3(s)$ (4 ½ marks)

(e) Explain why aluminium utensils should not be washed using soap solutions. (2 ½ marks)

5..a) Describe how iron can be extracted from iron (ii) carbonate ore (*Your answer should include equations for the relevant reactions*) (07 marks)

b) Write equations and state the conditions for the reaction between iron and

i) Oxygen (02 marks)

ii) Water ($2\frac{1}{2}$ marks)

c) State how the following chlorides of iron can be prepared in the laboratory in the anhydrous forms. (*Your answer should include equations*)

i) Iron (ii) chloride ($2\frac{1}{2}$ marks)

ii) Iron (iii) chloride ($2\frac{1}{2}$ marks)

d) State what would be observed and write equation for the reaction that would take place if solutions containing iron (ii) ions and iron (iii) ions were separately treated with potassium thiocynate (KSCN) ($3\frac{1}{2}$ marks)

S5 BILOGY NOTES CONTINUED… (MR.LUBEGA)

ECOLOGY

Ecology refers to the study of the relationships of living organisms with each other and their non-living/ physical surroundings.

Organisms live within a relatively narrow sphere (land, water and air) and the earth's surface in which life permanently exists, this is known as **Biosphere/ecosphere**. The biosphere is divided into four major habitats namely;

- ♣ fresh water (lakes and ponds, rivers and streams, wetlands),
- ♣ marine water(oceans) ,
- ♣ Estuaries.
- ♣ Terrestrial covering a few meters deep in the soil and a few kilometers into the atmosphere.

On land, there are several biogeographical zones, in each of which there is characteristic plant and animal life. These zones are called **Biomes** (*a large ecological area on earth's surface with distinctive plant and animal groups which are adapted to that particular environment*)

Biomes include;

- ❖ ***Tropical rain forests***,
- ❖ ***Tundra :***where the ground is frozen much of the year and vegetation is sparse found in arctic and Antarctic regions
- ❖ ***Desert including Hot and dry desert*** (where evaporation is high and there is too much heat) and ***Cold deserts*** (precipitation coming from colder water sources than rain, such as snow or ice),
- ❖ ***Temperate deciduous forests***.
- ❖ ***Temperate rain forests***
- ❖ ***Boreal coniferous forest (taiga)***
- ❖ ***Mediterranean scrub forest***
- ❖ ***Grassland e.g. steppe and savanna***

Within each biome only those organisms with the necessary adaptations for surviving the physical conditions are found e.g.

(i) Tundra and coniferous forest biomes have organisms capable of withstanding long periods of extreme cold

(ii) Desert organisms must be able to cope with intense heat and drought

(iii) Marine organisms must be able to thrive in salt water

Biomes are further divided into smaller units called zones, each with its unique properties e.g.

- A forest biome is divided into **ground zone** (consisting of millipedes & earthworms), and **canopy zone/aerial zone;** (consisting of birds & monkeys); with each of these zones supporting different animals that are adapted to the conditions within them.
- Aquatic biome divided into **surface**, **intertidal,** & **benthic zones;** with the organisms in the intertidal zone withstanding wave action e.g snakes, snails, those in benthic zone not able to withstand wave action e.g sponges, while organisms requiring much air supply e.g. photosynthetic algae inhabiting surface zone.
- Desert biome divide into **surface** and **subterranean zones**; with those in surface zone adapted to withstand extreme heat, while those in subterranean able to survive in low oxygen content.

ECOLOGICAL NICHE*:*

This is an organism's entire way of life e.g. behavior, feeding habits and its role in the community.

Types of ecological niche.

(a) Realized niche

Is a most restricted area of a habitat that an organism occupies as a result of presence of predators, competitors, and parasites; limiting the habitat and roles performed by an organism, it's smaller in size.

(b) Fundamental niche

Is an entire area an organism can occupy in the absence of predators, competitors, and parasites; allowing the organism experience a larger habitat and perform a variety of roles.

N.B: A species' ecological niche is usually less extensive when competitors and predators are present than when these are absent

COMPONENTS OF ORGANISM'S ENVIRONMENT

Organisms

An **organism** is a life form consisting of one or more cells. All organisms have properties of life, including the ability to grow and reproduce. These properties of life require energy and materials from the environment. Therefore, an organism is not a closed system. Individual organisms

depend on and are influenced by the environment.

ENVIRONMENT

An environment refers to all conditions in which organisms live. This may be divided into the abiotic and biotic components,

Abiotic components: these are non-living components of the environment, they may be physical or chemical and include air, water, soil and components of climate such as light, temperature and wind.

Biotic components: these are the living components of an environment including plants and animals e.g. microbes, man, protozoans, arthropods.

FACTORS AFFECTING THE DISTRIBUTION OF ORGANISMS

The factors which determine where an organism lives are either biotic (living) or abiotic (chemical and physical)

(a) ABIOTIC FACTORS

(i) Temperature

Environmental temperature is an important factor in the distribution of organisms because of its effect on biological processes such as cell division, reproduction, excretion, photosynthesis etc. Cells may rupture if the water they contain freezes (at temperatures below 0^oC) by the formation of ice crystals, and the proteins of most organisms denature at temperatures above 45^oC. In addition, few organisms can maintain an active metabolism at very low or very high temperatures, though extraordinary adaptations enable some organisms, such as thermophilic prokaryotes and bacteria to live outside the temperature range habitable by other life. Most organisms function best within a specific range of environmental temperature. Temperatures outside that range may force some animals to expend energy regulating their internal temperature, as mammals and birds do.

Fluctuations in temperature within aquatic environments are relatively small, since water has a high specific heat capacity and therefore provide more stable habitats for many kinds of ectothermic creatures than terrestrial environments.

Note:

Actual temperature of any habitat may differ in time according to the season and time of day, and in space according to latitude, slope, degree of shading or exposure.

Effect of temperature on the distribution of living organisms

Living organisms only survive in narrow ranges of temperature because enzymes in their bodies work in narrow optimum ranges.

Most organisms are distributed in regions of moderate temperature such as tropics and temperate regions where temperatures are favorable for activity of their enzymes,

Temperate plants and animals are distributed in relatively cool regions whose temperature rarely exceeds 25^{o}C while those that can withstand high temperature are distributed in the tropics or even deserts.

In deserts, daytime temperature is very high and causes water to evaporate very quickly, hence the major problem faced by living organisms being how to resist or tolerate desiccation therefore inhabited by mostly xerophytic plants such as cacti, insects and a few mammals mostly camels with such adaptations.

On the fringes of polar areas, the air temperature for much of the year is nearly always below freezing point. Only lichens, mosses, a few flowering plants and endothermic animals such as penguins and polar bears can tolerate such conditions, for similar reasons high mountain ranges have a typical alpine flora and fauna.

Temperature also influences the distribution of plants by affecting their photosynthetic physiology.

- C_3 plants have enzymes which fix carbon dioxide better at relatively low temperatures and are distributed in cool temperate regions.
- C_4 plants have enzymes with higher optimum temperatures for carbon dioxide fixation and are distributed in hotter tropical conditions
- CAM plants are distributed in regions with very high temperatures such as deserts, because they can close their stomata during the day when it is very hot to minimize water loss and open them at night when it is cool to take up carbon dioxide.

(ii) Light

Light absorbed by photosynthetic organisms such as green plants and bacteria provides the energy that drives most ecosystems, thus light is a fundamental necessity and too little sunlight can limit the distribution of photosynthetic species.

In forests, shading by leaves in the treetops makes competition for light especially intense, particularly for seedlings growing on the forest floor.

In aquatic environments, every meter of water depth selectively absorbs about 45% of the red light and about 2% of the blue light passing through it. As a result, most photosynthesis in aquatic environments occurs relatively near the surface.

There are three basic aspects of light that influence activities of living organisms

- **Light intensity:** the amount of light energy per unit area reaching a place per second. It relates to brightness of the light. This influences activities such as photosynthesis in plants and vision in animals
- **Light quality:** the relative wave length or colours present in light. Only light at certain wavelengths can be used by different photosynthetic pigments affecting distribution of organisms mostly in aquatic environments e.g. some sea weeds such as red algae, with different light intercepting pigments can survive in locations where green algae would find light quality limiting.
- **Light duration (photoperiod):** relating to relative length of day and night, plants and animals show photoperiodic responses that synchronise their activities with seasons such as flowering and germination in plants, migration, hibernation and reproduction in animals.

Effects of light on activity of organisms

(a) Positive effects

- Provide energy required in synthesis of organic compounds by photosynthetic organisms
- Required in synthesis of chlorophyll
- Triggers conversion of etioplasts to chloroplasts
- Far red light can cause elongation of internodes resulting in etiolation
- Light causes leaf expansion in plants
- It provides vision which enables organisms to see around their environments in order to search for food, escape predation.
- Stimulus for timing of diurnal / circadian rhythmic behavior and seasonal rhythmic behavior e.g seasonal migration in birds and breeding seasons in many animals
- Stimulates germination of some seeds i.e. photoblastic seeds
- Stimulates flowering of many plants

- ♣ Ultra-violet light stimulates synthesis of vitamin D by the skin of mammals
- ♣ Provides most of the heat necessary in temperature regulation of many organisms e.g. ectotherms
- ♣ Phototaxic movements of animals and unicellular plants are important for locating suitable habitat
- ♣ Light breaks dormancy of seeds
- ♣ It enables the mechanisms photoreceptions in eyes
- ♣ Stomatal opening and closure; with most plant species opening their stomata during day(when there is light) to allow excretion, gaseous exchange and closing during night (in absence of light/darkness).
- ♣ Courtship; with some animals preferring light so as to carry out courtship while others prefer darkness
- ♣ Phototropism, by redistributing auxins on the darker sides of shoots and roots, with cells on darker side elongating more than those on illuminated side.

(b) Negative effects

- ♣ Ultra-violet light can cause skin cancer
- ♣ The sun's rays having more ultraviolet radiation are more likely to damage DNA and proteins in alpine environments limiting the survival of organisms.
- ♣ In other ecosystems, such as deserts, high light levels can increase temperature stress if animals are unable to avoid the light or to cool themselves through evaporation.
- ♣ Excessive can cause bleaching of chlorophyll reducing photosynthetic productivity of the ecosystem
- ♣ Infra-red absorbed by water increase water temperature as well reducing amount of dissolved oxygen in water, making water unfavorable for life of some aquatic organisms.

(iii) Humidity

This is often expressed as relative humidity, it is a measure of the moisture content of the atmosphere and is expressed as a percentage. Relative humidity of air is influenced by its temperature.It influences the rate of evaporation of water from surfaces of living organisms and rate of transpiration in plants in turn affecting the ability of organisms to withstand drought

A decrease in humidity increases rate of evaporation or transpiration putting living organisms at a risk of desiccation

Living organisms are generally favoured by relatively high humidity as this reduces the rate of waterloss from their bodies.

Organisms with large moist surface area are in particular very sensitive to humidity changes. These organisms are distributed and restricted to humid areas or become active only under humid conditions e.g. toads, slugs, mosses and liverworts

Controls other activities of animals like feeding, hunting, and movements e.g earth worms experience a larger ecological niche when the environment is humid.

Controls opening and closure of stomata; therefore affecting rate of photosynthesis and transpiration.

(iv) Rainfall

This influences lives of organisms both directly and indirectly as it is main source of water utilized by organisms. Amount of rainfall in a given area determines the abundance, distribution and types of organisms in the area

Where temperatures are relatively high all year around with a hot drought period favors survival of deciduous plants capable of dropping their leaves in dry seasons and growing them again in cooler, wetter seasons

Excessive water in soils which aren't well drained may result into water logging which may not favour most plants. However, some plants such as rice, sugar cane etc. are highly distributed in waterlogged soils.

Most organisms are distributed in areas where there is abundant water supply and animals in particular are abundant in areas near water sources

However, the actual distribution of organisms depends on the extent to which an organism is dependent on water for its activities and on its ability to conserve it.

Where rainfall is quite low like in hot deserts only organisms with adaptations to prevent excessive water loss for plants (xerophytes) and animals that can conserve water using diverse methods can survive hence their higher abundance.

Ecological significances of water

- Habitat for many aquatic organisms e.g. frogs, fish etc
- Raw material for photosynthesis
- High thermal capacities leads to cooling of terrestrial organisms upon evaporation e.g. plants during transpiration, some animals during sweating.

- Agent for fruit, seed, spore, larva and gamete dispersal
- Condition for germination
- Highly transparent; therefore allowing light to reach acquatic organisms, for photosynthesis; and aquatic predators to locate their prey
- Important factor in decay and decomposition; therefore increases in recycling of nutrients in an ecosystem.
- Is an agent for soil formation through its effects like frost action during weathering of rocks.
- Offers support to aquatic animals enabling their locomotion
- A medium for chemical reactions in cells of living organisms
- A medium for transport of dissolved substances e.g. mineral salts
- Source of dissolved oxygen upon which aquatic organisms dependent for their respiration

Attention: Clegg fig. 3.23 page 59

(v) Atmospheric pressure

On the surface of the earth, atmospheric pressure varies with altitude. Variations in atmospheric pressure affects the amount of oxygen available for respiration and of carbon dioxide for photosynthesis. These gases in turn affect the distribution of organisms

Availability of oxygen

Most living organisms are aerobes and require oxygen gas for the release of energy in respiration
At high altitudes there is the same proportion of oxygen present as sea level, but its partial pressure is less so it is not readily absorbed by living organisms together with low temperature, it explains why there is very little mountain fauna above a height of about 4.5 km, where the partial pressure of oxygen is roughly half that at sea level

In water there is less oxygen about less than 1% by volume of the gas and is still less accessible to aquatic organisms, near the surface of water bodies where the water is in contact with air the water may be saturated with oxygen. Photosynthetic plants help to maintain high concentrations of dissolved oxygen. Deeper down, where there are no photo-autotrophs and because oxygen diffuses very slowly through water, much less dissolved oxygen is present, thermal convection currents carry some oxygen downwards from the upper layers.

In the deepest waters there may be little or no oxygen gas available, here only invertebrates whose oxygen-carrying pigments become saturated at very low oxygen tensions and anaerobic bacteria can survive.

Factors determining amount of oxygen in aquatic environments

- Its solubility,
- The temperature,
- Partial pressure of oxygen in the air,
- Amount of solutes dissolved in water and on the rate at which it is consumed by aquatic organisms.

Availability of carbon dioxide

Carbon dioxide is one of the raw materials essential for photosynthesis.

At high altitudes the partial pressure of carbon dioxide gas is low together with the low temperatures, growth of plants at a height of more than 6km in mountainous areas.

However, carbon dioxide has a high solubility in water but a very low partial pressure and thus volume of carbon dioxide dissolved in water is generally small. Never the less aquatic plants do not get short of carbon dioxide for photosynthesis as water contains large quantities of carbonate and hydrogen carbonate ions formed when carbon dioxide reacts with water, thus growth of plants is not limited.

EDAPHIC/ SOIL FACTORS

Soil is the upper, weathered layer of the earth's crust. It consists of disintegrated rock, organic matter, air, water, dissolved minerals and various living organisms. The study of soil is known as pedology.

Importance of soil

- Provides habitat for some soil living organisms e.g. rats, moles
- Provides plants with anchorage for roots
- Supplies water and inorganic nutrients to plants
- Supplies plants with essential air for root growth

(i) Soil Ph

Influences physical properties of soil and availability of certain minerals e.g. phosphates, calcium ions magnesium and iron to plants, thus affecting their distribution in soil; i.e. tea and coffee plants thrive well in acidic soils

Affects activity of decomposers e.g. in acidic medium, the rate of decomposition is reduced, subsequently recycling of matter in an ecosystem reduced. This influences the distribution of vegetation.

(ii) Water content;

Water in the soil probably exerts the greatest influence on plants.

Types of soil water

(i) **Gravitational water:** is water that drains away under the influence of gravity when soil is over supplied with water, it temporarily displaces air from spaces between soil particles.

(ii) **Capillary water:** this is the bulk of soil water after gravitational water has drained away. It is the main source of water to plant life.

(iii) **Hygroscopic water:** is a thin film around the surface of mineral particles, it is unavailable to plants as it is held by strong surface forces such as hydrogen bonds.

(iv) **Chemically combined :** this is retained within mineral substances as part of chemical structure e.g. water in hydrated iron (iii) oxide

Note:

Field capacity is when soil holds maximum possible quantity of capillary water.

Addition of more water which cannot be drained away leads to water logging; and anaerobic conditions, affecting mineral ion uptake by active transport, subsequently affecting osmotic uptake of water, due to decreased osmotic potential gradient, causing plants to dry out.
Plants like rice, marshes, and sedges have developed air spaces among root tissues, allowing some diffusion of oxygen from aerial parts to help supply the roots.

(iii) Biotic content;

Microorganisms like bacteria and fungi carry out decomposition of dead organic material, therefore recycling nutrients back to the soil. b

Burrowing organisms (macro organisms) e.g. earthworms, termites and rodents

- Improve drainage and aeration by forming tunnels in the soil.
- Earthworms also improve soil fertility by mixing of soil, as they bring leached minerals from lower layers within reach of plant roots.
- They also improve humus content, by pulling leaves into their burrows

- Also press soil through their bodies making its texture fine.

Interest: fig page 63 clegg and mackean

(iv) Air content;

Volume of air in soil largely depends on the shape and size of the mineral particles.

Spaces between soil particles is filled with air from which plant roots obtain oxygen by diffusion for aerobic respiration, Also essential for aerobic respiration by microorganisms in the soil that decompose the humus.

In waterlogged soils, with soil air displaced by water, plant roots are deprived of oxygen and plants in such conditions may die if the conditions persists.

(v) Mineral salts

A wide variety of minerals is necessary to support healthy plant growth. Different species make different mineral demands and therefore the distribution of plants depends to some extent on the mineral balance of a particular soil.

Ways used by plants growing in mineral salt deficient soils obtain certain mineral salts

- Insectivorous plants such as pitchers, Venus fly trap etc. trap insects either using their leaves or flowers and release enzymes that digest the insect so that the soluble products of digestion rich in minerals are absorbed.
- Leguminous plants form association with nitrogen fixing bacteria of the rhizobium genus which are found in root nodules, these fix nitrogen into ammonium and nitrates which can be utilized by the plant
- Most plants enter mychorrhizal relationships where a fungus grows on the surface of the roots (ectotrophic mychorrhiza) or sends out its hyphae to penetrate into the root (endotrophic mychorrhiza). The fungus absorbs mineral salts especially phosphates which are availed to the plants while the fungus in return obtains support from the plant root as wellas organic nutrients e.g. carbohydrates
- Parasitic plants e.g. striga (witch weed) and cuscuta (dodder) obtain nutrients from their host plants.
- Direct fixation of nutrients into the soil e.g. by lightening which causes nitrogen in air to react with oxygen to form nitrogen dioxide which subsequently reacts with oxygen and water to form nitrates that are deposited, dissolved in rain water into the soil.

(vi) Soil temperature

- This affects physical e.g. soil formation, chemical e.g. decay and biological e.g. respiration and nitrogen fixation processes in the soil.
- Influences the rate of water absorption which decreases with temperature. High soil temperatures in particular reduce the amount of water in the soil.
- Influences seed germination. Germination is higher when soils are warm than when they are cold
- Influences root growth and growth of underground plants parts like tubers
- Influences the activity of soil microorganisms. Among the other factors affecting soil temperature are colour, texture, structure, water content, humus content and the presence and absence of vegetation.

HOW BIOTIC FACTORS AFFECT THE DISTRIBUTION AND ABUNDANCY OF ORGANISMS

NB. Biotic factors are those that relate to how living organisms influence each other. And how relationships between them influence their distribution and population. These include:

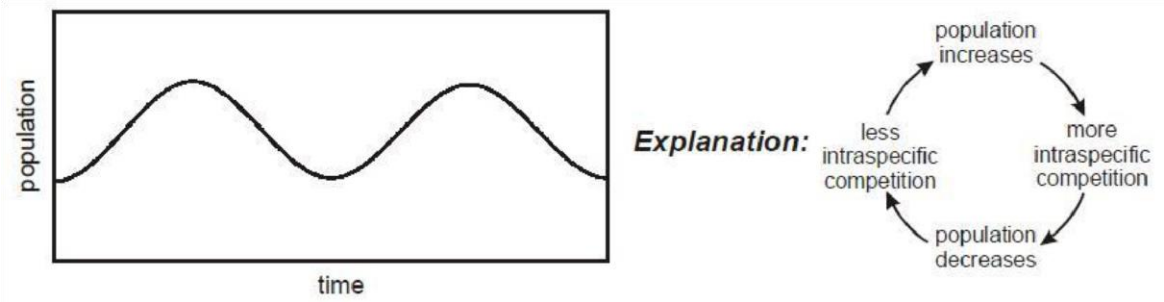
- ✓ competition
- ✓ predation
- ✓ antibiosis and allelopathy
- ✓ mimicry
- ✓ symbiotic relationships such as parasitism, commensalism and mutualism
- ✓ pollination &dispersal,
- ✓ human influence

(i) Competition

This is a relationship whereby two individuals of the same species or different species struggle to obtain same environmental resources which are in limited/short supply within the same ecological habitat. This can be classified as

(i) Intraspecific competition: is the competition between organisms of the same species for the same resources. This may be for nutritional needs, for mates, or for breeding sites.

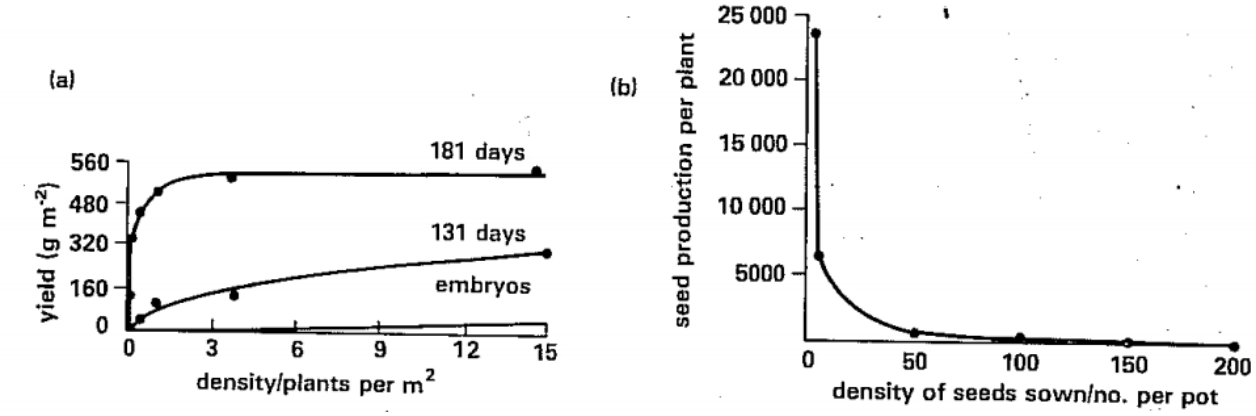
Intraspecific competition tends to have a stabilizing influence on population size. If the population gets too big, intraspecific population increases, so the population falls again. If the population gets too small, intraspecific population decreases, so the population increases again.



Note: Intraspecific competition for limited resources can lead to evolution of new special forms of behavior such as territoriality, ritualized fighting, and dominance hierarchies.

Application

A graph showing the effect of sowing density on (a) yield (dry crop) of clover and (b) seed production by shepherd's purse



Total dry mass produced per unit area of soil is the same over a wide range of sowing density (a). This may come about because many seedlings die when seeds germinate close to each other. The few plants that survive then have an adequate share of resources so they grow quite well or most of the seedlings may survive and grow into mature plants, but each plant has a lesser share of resources so is smaller than normal

Seed production (b) is reduced when plants are overcrowded, because many fail to flower and set seeds

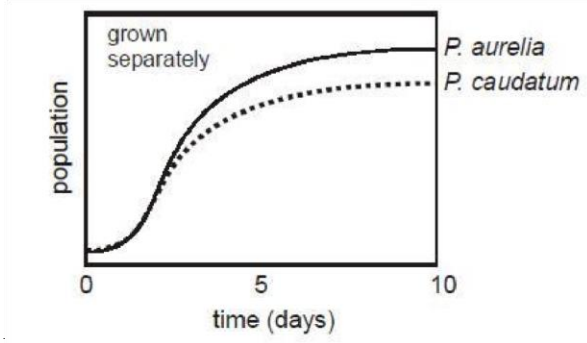
(ii**) Interspecific competition**

Is an interaction that occurs when individuals of different species compete for a resource that limits their growth and survival. E.g. weeds growing in a garden compete with garden plants for soil nutrients and water, grasshoppers and cows in fields compete for grass they both eat.

Interspecific competition is very intense when competitors occupy the same niche or have significantly overlapping niches, in this case one of the competing species must;

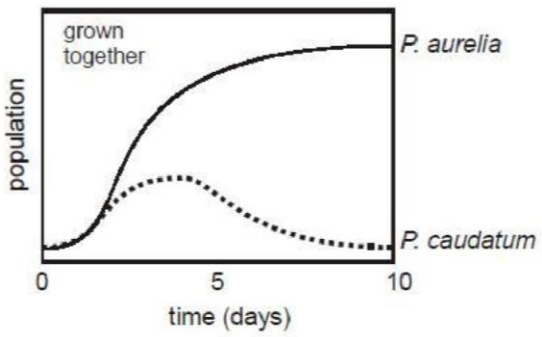
- migrate to another area if possible
- shift its feeding habits or behaviour through natural selection and evolution
- suffer a sharp population decline to the point of extinction
- reach an equilibrium situation in which neither species succeeds as well as it would in the absence of the competitor.

To explore this type of competitive interaction, G. F. Gause conducted a series of experiments on two closely related species of ciliated protists, *Paramecium aurelia* and *Paramecium caudatum.* He cultured the species under stable conditions, adding a constant amount of food every day. When Gause grew the two species in separate cultures, each population grew rapidly and then remained constant at what was apparently the carrying capacity of the culture



But when Gause cultured the two species together, *P caudatum* was driven to extinction in the culture. Gause inferred that *P. aurelia* had a competitive edge in obtaining food, and he concluded that two species competing for the same limiting resources cannot coexist in the same place.

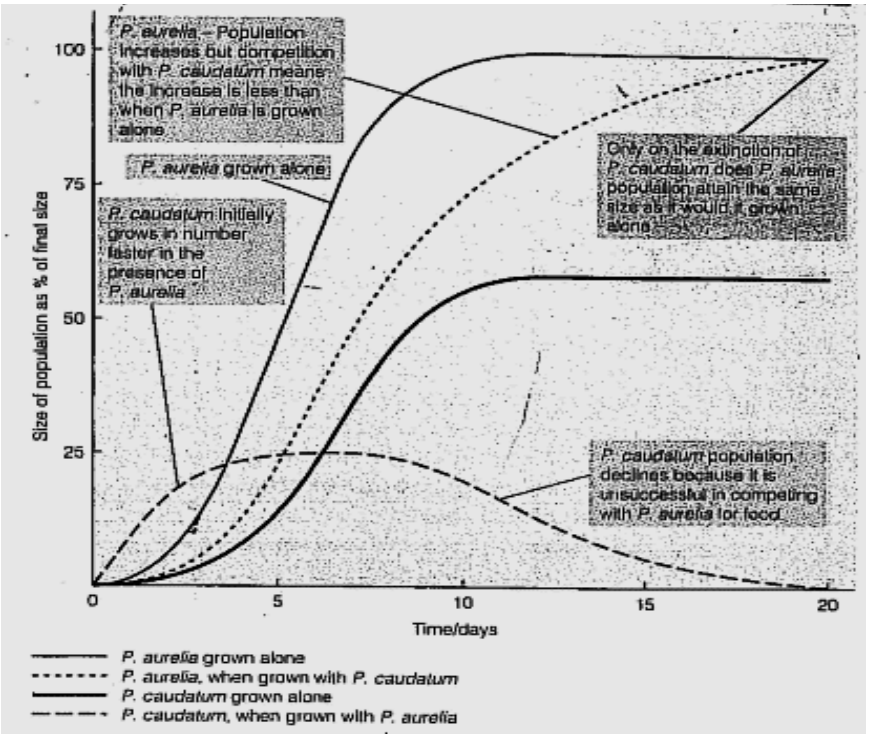
In the absence of disturbance, one species will use the resources more efficiently and thus reproduce more rapidly than the other. Even a slight reproductive advantage will eventually lead to local elimination of the inferior competitor, an outcome called **competitive exclusion**.



Competitive advantages of *P.aurelia* are;

- High rate of reproduction.
- High growth rate.
- Good nutrient absorptive capacity/greater efficiency in obtaining food.
- Being small in size, it requires less food hence can easily survive when food is scarce.
- Producing chemical substances which inhibit or affect growth of p.caudatum without affecting itself
- Survivorship, long life span.

A graph showing the population growth of two species of paramecium grown separately and together



Gause's (Russian biologist) competive exclusion principle states that "*onmly one species (population) in a given community can occupy a given ecological niche at any one time"*

Other experiments

(i). Two species of flour beetles, *Tribolium castenum* and *T. confusum* were kept in the laboratory in bottles of flour acting as a habitat and providing food for them, under variable temperature conditions(24-34) and humid condtions (very humid , 70%RH& 30% RH).

Table 31.1 Interspecific competition between flour beetles (after Park 1954)

Temp. °C	% RH	Percentage remaining *T. castaneum*	*T. confusum*
34	70	100	0
34	30	10	90
29	70	86	14
29	30	13	87
24	70	29	71
24	30	0	100

Observation. At high temperatures and in very humid conditions, *Tribolium castenum* succeded better, while at low temperatures and very dry conditions *T. confusum* did better. Whatever the conditions, only one of the species eventually survived.

(ii) in dark weeds where lemma gibba effectively outcompetes lemma polyrrhiza

MECHANISMS OF COEXISTENCE: NICHE DIFFERENTIATION

Two species cannot coexist permanently in a community if their niches are identical. However, ecologically similar species *can* coexist in a community if there are one or more significant differences in their niches. When competition between species with identical niches does not lead to local extinction of either species, it is generally because one species' niche becomes modified. In other words, evolution by natural selection can result in one of the species using a different set of resources. The differentiation of niches that enables similar species to coexist in a community is called **resource partitioning.** This occurs living organisms potentially occupying the same niche divide resources e.g. space among themselves so that each utilizes a limited amount of resources within the environment. Resource partitioning results into niche differentiation

Niche differentiation refers an evolutionary change in resource use, caused by competition over generations

Forms of resource partitioning/ niche differentiation

- Specialization of morphology and behavior for different foods, such as beaks of birds which may be modified for picking up insects, drilling holes, cracking nuts, tearing flesh e.g. When three species of ground finches of Galapagos Islands occur on separate islands, their bills tend to be the same intermediate size, enabling each to feed on a wider range of

seeds, but where they co-occur, there is divergence in beak size to suit each finch species to feeding on seeds of either small, medium or large size, but not all sizes.

- Spatial separation e.g. stratification such as canopy dwellers and forest floor dwellers

  Examples:

  (i) Each of the five species of common warblers (insect-eating birds) minimises competition with the others by (i) spending atleast half its feeding time in a different part of spruce tree branches e.g. some hunt at the extreme top, others at the lower portion, some mid way etc (ii) Consuming somewhat different insect species.

  (ii) micro-organisms cultured in long cylindrical vessels can partition space where one occupies lower layers of the vessel while the other occupies upper layers of the container

- Temporal separation e.g. different species of eagles in a forest feed at different times of the day e.g. bald headed eagles are most active early mornings and evenings while the white-breasted eagles feed vigorously towards noon, Hawks and owls feed on similar prey, but hawks hunt during the day and owls hunt at night..

The tendency for characteristics to be more divergent when populations belong to the same community than when they are isolated is termed **character displacement** e.g. variation in beak size between different populations of the Galapagos finches e.g. *Geospiza fulginosa* and *Geospiza fortis*.

Ecological significance of competition

- Has an evolutionary significance of increasing biological fitness of species by weeding out organisms with a competitive disadvantage leaving only well adapted individuals to survive
- Regulate population size of living organisms especially intraspecific competition
- Influences distribution of living organisms, where living organisms usually become distributed in areas where competition is minimum.
- Leads to colonization of wide range of habitats
- Leads to polymorphism; the existence of the same species of organism in two or more genetically discontinuous forms or morphs living within the same habitat, resulting in maximum utilization of resources in a wide range of environment

- ❖ Leads to adaptive radiation

Application

Question.

1.(a). Explain the role of competition in regulating the size of population.

(b). Duck weed grows on or near the surface of ponds. Its growth can be measured by counting the number of fronds. Two species of duckweed , *Lemna trisulca* and *Lemna minor* were grown separately, and together , in identical beakers in the laboratory

	Total number of fronds.			
	Species grown separately		**Species grown together**	
Days	***L. trisulca***	***L. minor***	***L. trisulca***	***L. minor***
0	30	30	30	30
16	63	78	48	105
36	126	142	84	234
46	177	225	84	324
54	165	276	48	360
60	129	219	45	354

(i).Draw graphs to compare the rates of growth of the two species when grown separately and when grown together.

(ii) What do the graphs suggest about the growth rate of the two species grown separately?

(iii)Account for this difference.

(iv)Offer an explanation for the interaction of the two species when grown together.

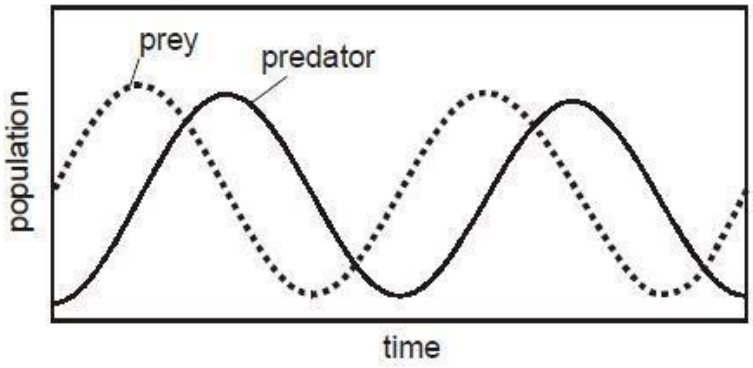
(v).Account for the changes in the growth rate between 46 and 60 days for *Lemna trisulca when grown together.*

(ii) Predation. This is an interspecific relationship whereby one organism, the predator attacks, kills and feeds on another organism of different species, the prey. Predation influences distribution of living organisms where predators are found mostly where there is prey e.g. herbivores are found where there is suitable plant material whereas prey tend to avoid areas occupied by their predators.

A predator is an organism which hunts, attacks and feeds on another organism.

A prey is an organism that is fed on by the predator.

PREDATOR- PREY INTERACTIONS IN ECOSYSTEMS



Initially, the population of the prey is higher that the population of the predator.

Populations of prey increase rapidly, prey provide an abundant food supply to predators which therefore reproduces rapidly and their population increases rapidly.

The increase in predator population results into over consumption of prey, decreasing prey population rapidly; few prey are remain, thus predators start to compete for the few remaining prey those predator species lacking competitive advantage fail to get prey and die due to starvation, this results in rapid decrease in the population of predators which allows the prey population to recover and fluctuations go on.

Predator prey populations are therefore regulated by a negative feedback mechanism that keeps the population at levels that the environment can support.

The cyclic fluctuations are out of phase because the predator population attains a peak after the prey population has started declining

The fluctuation above occur in a natural environment without influences of the other species.

Differences in the fluctuations may be caused by

(i) Human influence e.g.

(ii) Where the predator has alternative sources of food , it may cause the population of of a preferred prey to decrease to extinction without its numbers declining since it feeds on alternatives.

CO-EVOLUTION OF PREDATOR AND PREY

Co-evolution is a process in which two organisms of different species associate overtime and eventually develop a relationship of mutual dependence and benefit over time as a result of natural selection.

During co-evolution species become so adjusted to each other's presence that overtime, through natural selection, may develop a relationship of mutual dependence and benefit.
In predation, prey with better defense strategies such as being able to run fast, ability to camouflage, possess defense weapons such as horns are the ones most likely to escape predation, on the other hand, predators with better hunting strategies e.g. fast locomotion, ability to camouflage so that they aren't seen and having weapons like horns etc. are more likely to capture prey. This has led to co-evolution of predators and prey through natural selection i.e. as predators evolve better hunting strategies, prey evolves better defensive strategies to combat them.
Overtime, this has led to evolution of better adapted predator and prey

Evolutionary significance of predator –prey

Predation usually eliminates the unfit (aged, sick, weak). This gives the remaining prey access to the available food supply and also improves their genetic stock hence, enhances the chances of reproductive success and longtime survival, thus pass on their good traits to their off springs increasing their survival.

Ecological significance of predation

- Source of food to predator
- Provides a selection pressure that eliminates poorly adapted predators or prey resulting in evolution of better adapted predators and prey
- Regulates the population of both predator and prey by negative feedback
- Minimizes interspecific competition among predators and prey through regulation of their population size
- Minimizes intraspecific aggression among prey species
- Utilized by man in biological control
- Influences population distribution of predator and prey

How are the predation suited for capturing prey?

- Ability to camouflage in their environment therefore not easily seen by the prey
- High locomotory speed to out run, out swim or out fly the prey
- Have long and sharp canine teeth which pierce and kill the prey
- Group hunting increasing chances of capturing prey
- Strong curved claws for capturing and holding the prey
- Some have soft pads in the soles to minimize noise when stalking prey

- Being nocturnal, they hunt, capture and feed at night when the prey are resting or when their sense of vision is poor
- Formation of traps which they use to capture prey e.g. cobwebs of spiders
- High intelligence associated with well-developed brains so as to use foot marks, sounds, droppings to locate their prey
- Well developed olfactory organs that give a predator an excellent sense of smell in order to detect prey at a distance and those in hiding by the smell
- Well developed sense of sight to see the prey at a distance
- Some have stinging cells for paralyzing prey

How are prey species suited to avoid predation?

- Warning calls: this is sound made by some animals to warn others about approaching predators. Such calls are made by birds and mammals which exhibit parental care
- Protective resemblances where the animal resembles objects in its environment to confuse the predators e.g. most insects resemble plant parts e.g. twigs and flowers
- Group defense where animals live in groups like herds so that each gains collective protection from members e.g. schools of fish, herd of antelope, flocks of birds, deers
- Some preys secrete poisonous or repellant substances e.g. scorpions, caterpillars, some grasshoppers, culex mosquito eggs
- Defensive weapons e.g. horns, spines which they use to physically defend themselves against the predators
- Possession of protective body covers e.g. scale in snakes and fish, shells in tortoises.
- Production of mucus on the body making their body slippery so as to easily escape from predators e.g. fish
- Production of nasty smell which irritate the predators for example hedgehogs, cockroaches
- High speed of locomotion by some preys so that they can out swim, out run, out fly their predators
- Some prey **camouflage** by changing colour e.g. chameleon and cuttlefish, or having deceptive colours that blend with the background e.g. arctic hare in its winter fur blends into snow.

- Some prey species discourage predators with chemicals that are poisonous (e.g. oleander plants), irritating (e.g. bombardier beetles), foul smelling (e.g. stinkbugs and skunk cabbages) or bad tasting (e.g. monarch butterflies and buttercups)
- Some species gain protection to avoid predation by mimicking (looking and acting like) other species that are distasteful to the predator e.g. the non-poisonous viceroy butterfly mimics the poisonous monarch butterfly.
- The electric fish Malapterurus (a cat fish) produces high voltage discharge of up to 350v that shocks any predator that makes contact with it.
- Some prey scare predators by puffing up e.g. blowfish, or spreading wings e.g. peacock.

Browsing (grazing)

This is a form of predation in which animals feed on plant materials. Such animals are called browsers if they feed on branches of shrubs e.g. elephants, giraffes and they are called grazers if they feed surface plant materials such as grasses e.g. cows, goats

Adaptations of plants to deter (resist) browsers and grazers

- Have thorns, hairs that reduce palatability and also used as defence devices
- Some are brightly coloured palatabl parts which may not be attractive to some herbivores
- Secretion of bitter sap / foul smelling chemicals
- Some plants like *Mimosa pudica* show positive haptonasty upon touch by herbivores
- Some open their leaves at night and close them during day to avoid them being fed on by herbivores
- Maintaining palatable parts e.g. leaves at greater heights where they are inaccessible by browsers or grazers
- Possession of very tough covering e.g. barks of trees or shells of nuts
- Secretion of chemicals substances that induce moulting in the effensive stage of the life cycle of the animal e.g. buttercap produces chemicals that induce moulting of the larvae of butterflies into a non leaf eater butterfly
- Some secrete toxic/ poisonous chemicals e.g. alkaloids

Adaptations of herbivores to obtain plant materials

- Possession of a highly flexible tongue that can move in all directions to easily pluck off the vegetation

- Some possess horny pad which is very hard for plucking plant materials and minimizes the piercing effect of the thorns
- Some have long snouts to probe through the thorns in order to get leaves
- Some have long necks to enable them graze on leaves high up on the canopy
- Wide molars to provide a large surface area for crashing plant materials

Ecological significance of plant-grazer relationship

- It determines the distribution of grazers since they tend to be more abundant where there are suitable pastures \
- Man uses grazers to biologically control plant species that may compete with the crops e.g. the cactus moths control the cactus plants
- It may lead to dispersal of fruits, spores, seeds, parasites since grazers move from place to place in search of pastures.

(iii)<u>Antibiosis;</u> is the secretion by organisms chemical substances into their surrounding that may be repellant to members of the same species or different species

Two types of antibiosis

- **Intraspecific antibiosis** secretion of chemical substances by organisms into their surrounding that may be repellant to members of the same species e.g. male rabbits secrete pheromones from their submandibular salivary glands that are used to mark territory as a warning to other bucks that the territory is occupied.
- **Interspecific antibiosis** secretion by organisms chemical substances into their surrounding that may be repellant to members of the different species e.g. penicillium (a fungus) secretes antibiotics that inhibit bacterial growth, ants release pheromones to warn off other members of a species in case of danger, sunflower releases chemicals from its roots and fallen leaves which inhibit germination of seeds of other species giving sunflower a competitive advantage. This is also referred to as **allelopathy.**

Ecological significance of antibiosis

- Some organisms which produce antibiotics are used to biologically control pests, pathogens and weeds
- It influences the distribution of organisms in a habitat where pheromones are produced
- Interspecific antibiosis reduces competition by inhibiting growth and survival of competitors

(iv) Human influence.

Humans are one single species with most influence on the distribution of other organisms, through man's activities such as hunting, fishing, farming, bush burning, reclamation of swamps, urban development, and pollution can dictate which organisms grow where. Man can change habitats and create new ones.

(v) Pollination

Flowering plants utilize insects such as bees, moths to transfer their pollen from one member of a species to another, this results in the development of a highly complex form of interdependence between the two groups. Therefore such insects are always most abundant in areas where flowering plants grow.

(vi) dispersal

Plants depend on a wide range of animal species for the dispersal of their seeds, such animals greatly influence the distribution of those particular plants.

(vii) Mimicry

This is where an organism resembles another organism which is either harmful, distasteful or unpalatable to predators in order to avoid predation. E.g. the African swallow tail butterfly (*Papilio dardinus*) resembles another unpalatable butterfly A*maurus albimaculata* so that predators avoid attacking it.

Forms of mimicry

(i) **Batesian mimicry** occurs when the palatable species mimics other distasteful species e.g. viceroy butterfly mimics the poisonous monarch butterfly, the harmless hoverfly mimics the painful stinging wasp.

(ii) **Mullerian mimicry** occurs when both the mimic and mimicked are unpalatable and dangerous e.g. the five spot Burnet and related moths.

(viii) Camouflage

This is where an organism possesses body colorations that resemble closely the color patterns of their environment/ background so that they are not easily spotted by their predators therefore escaping predation. Most organisms prefer to stay in habitats with a background resembling the colour pattern of their bodies

Exists in various forms;

(i) **warning colouration** , conspicuous colouring that warns a predator that an animal is unplalable or poisonous e.g. poisonous frogs, some snakes, monarch butterflies, and some grasshoppers

(ii) **disruptive colouration/patterning** , works by breaking up the outlines of an animal with a strongly contrasting pattern, thus decreasing detectability e.g. group of zebras

(iii) **cryptic colouration** allows an organism to match its background and hence become less vulnerable to predation e.g. chameleon.

N.B: For symbiotic relationships refer to nutrition

II- CONCEPT OF ECOSYSTEM

An ecosystem is a natural unit of living components together with the non-living components through which energy flow and nutrients cycle, influencing each other and interacting to form a relatively stable, self-perpetuating system.

Stable in a sense that it can adjust to changes within itself through a feedback process thus capable of self-regulation (homeostasis), it is self-perpetuating in that it can continue on its own without the necessity for humans or other influence, this they do through maintaining a balance between their input and output environments

Two major inputs in ecosystem include energy and nutrients.

Energy basically comes from the sun and flows through an ecosystem linearly and energy lost from an ecosystem can't be recovered

Nutrients these continuously flow between abiotic and biotic components within an ecosystem

STRUCTURE OF AN ECOSYSTEM

An ecosystem consists of biotic components and abiotic components

Abiotic components of an ecosystem include soil, water and climate. Soil and water contain a mixture of organic and inorganic nutrients

Climate include environmental variables such as light, temperature, humidity and rain or snow which influences the population size, types of organisms and distribution of organisms in an ecosystem

Biotic components consist of autotrophs, heterotrophs and decomposers

Autotrophs are producers while heterotrophs are consumers within an ecosystem

1. Producers:

These are autotrophs capable of synthesizing complex organic food materials from simple inorganic food raw materials e.g. carbon dioxide and water. Examples include; large green terrestrial plants e.g. trees, shrubs, grass.

For aquatic ecosystem, the producers are microscopic algae, blue green bacteria. Others are flagellates like euglena, volvox, chlamydomonas etc. These are collectively called **Phytoplanktons (**microscopic marine producers)

NB:

Some producers use chemical energy derived from breakdown of chemical compounds like sulphur to convert carbon dioxide and water into high energy compounds like carbohydrates e.g. sulphur bacteria i.e. they are **chemosynthetic**.

2. Consumers:

These are organisms that get energy and nutrients by feeding on other organisms or their remains. They are classified as;

(i) Primary consumers (Herbivores):

Are consumers that eat plants e.g. insects, birds, most mammals (grazers), some consumers do not eat the producer but live as plant parasites e.g. aphids, some fungi and even other plants e.g. broomrape, orobanche, mistletoe

In aquatic ecosystem, they include; water fleas, fish, crabs larvae, barnacles, molluscs, and protozoans, collectively known as **zooplanktons** (microscopic marine consumers).

(ii) Secondary consumers, tertiary and other top consumers:

Secondary consumers feed on herbivores and are therefore referred to as **carnivores** the tertiary and other top consumers feed on secondary consumers or tertiary as appropriate. Tertiary and other top consumers can be classified as

- Predators: that hunt and kill others for food
- Scavengers/ carrion feeders: that feed on dead organisms but do not kill them e.g. vultures, hyenas, marabou stocks etc.
- Parasites: which do not eat their prey but feed off the host organism while it continues to live

Detrivores and <u>decomposers</u>:

Decomposers are microorganisms, mainly fungi and bacteria which live as saprotrophs on dead organic matter

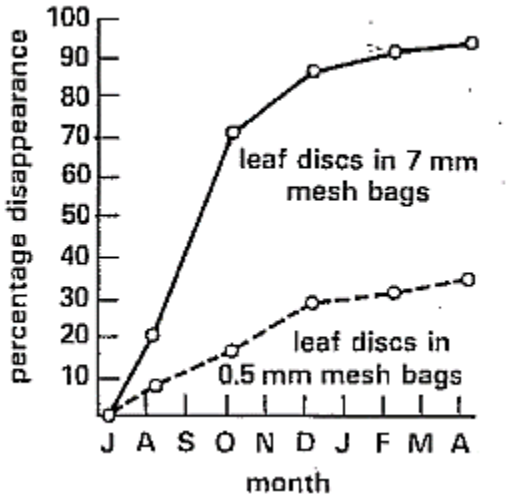
Detritivores

Are organisms that feed on small fragments of decomposing or dead material termed as detritus e.g. rag worms in estuarine environments, earth worms, mites, maggots, wood lice, termites and springtails in terrestrial ecosystems, sludge worms in fresh waters etc.

Significance of detritivores in decomposition process

Dead plant material is often deficient in nitrogen which limits microbial activity, the faeces of detritivores contain more nitrogen and moisture than the dead vegetation they eat, upon action of detritivores plant material is used much more readily by decomposer bacteria and fungi.

The role of detritivores in decomposition can be demonstrated through studying the effect of detritivores on the disappearance of oak leaf discs buried in nylon bags of mesh size 7mm and those less than 0.5mm as shown on the figure below.

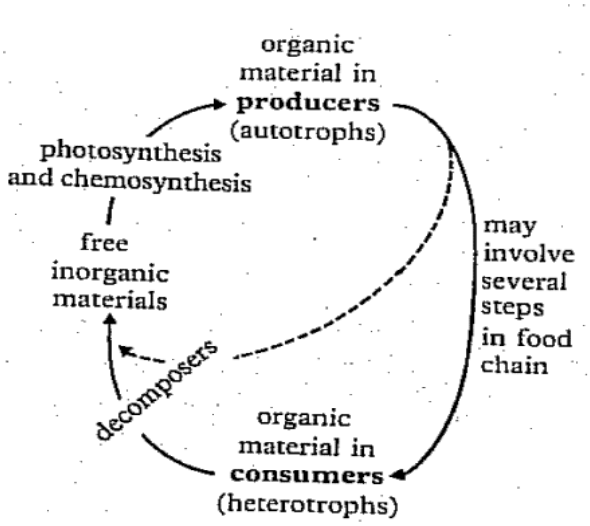


The mesh size determined which decomposers and detritivores had access to the leaf discs, in 7mm mesh size bags, where earthworms could get into, the discs were broken down much faster than in those with mesh size less than 0.5mm, where only microbes could enter

Relationship between producers, consumers and decomposers

Organic materials synthesized by producers are eaten and assimilated by consumers. With the aid of decomposers, all the organic materials incorporated into the bodies of the consumers are

eventually broken down into inorganic materials, these are then rebuilt into organic compounds by the synthetic activities of the producers



Properties or characteristics of an ecosystem

- Feeding relationships
- Energy flow / energy transfer
- Cycling of materials
- Succession and climax (changes in an ecosystem)
- Homeostasis of an ecosystem/ balance of nature
- Productivity in an ecosystem

ENERGY FLOW THROUGH AN ECOSYSTEM

The energy flow in an ecosystem is basically non-cyclic. It is passed along a feeding hierarchy in a chain called food chain. Each feeding stage (feeding level) in a food chain is called trophic level
The source of energy in an ecosystem is the sun. Sun energy is received inform of electromagnetic radiations. Most of the sun's radiation is reflected or absorbed immediately from the clouds, dust, soil, water or vegetation in the atmosphere and the earth's surface.
Only about 1% of the sun's radiation is trapped by the photosynthetic organisms such as green plants which are primary producers (autotrophic organisms) and converted into chemical energy in a process of **photosynthesis.** It is then transferred from one feeding level to another through feeding relationships like ***food chains*** or ***food webs***

Along the food chain, only a small proportion of the available energy is transferred from one feeding level to another; much energy is lost as heat during ***sweating and evaporation***, ***excretion*** , ***respiration***, **egestion,** and some remains locked up in indigestible parts of the plant like cellulose, or bones, hooves, hair, skin etc. of animals.

The number of organisms decrease at each successive feeding level because of the great energy losses, so the energy left in organisms is little to support large numbers of top consumers; limiting the length of food chain(not exceeding five trophic levels(feeding level in a food chain containing given amount of energy).

Energy flows out of the trophic levels in the following ways

- Lost as heat
- In structures synthesized by the plant but not contributing to increase in biomass e.g. shedding leaves, bark, flower and production of seeds for dispersal
- Death in plants and animals
- Plants eaten by herbivores

TROPHIC EFFICIENCY/ ECOLOGICAL EFFICIENCY

Is the percentage of energy at one trophic level that is converted into organic substances at the next trophic level.

The rate at which this chemical energy is formed and stored by the primary producers (green plants) per unit time is known as gross primary productivity (GPP). Some of this chemical energy is utilized by green plants and in the process lost as heat through respiration and photorespiration. The remaining energy stored in form of carbohydrates per unit area per unit time after respiration and photorespiration is known as Net primary productivity (NPP). The NPP becomes available to the primary consumers which are the herbivores at the next trophic level. The herbivores feed on the primary consumer to acquire this chemical energy. The rate at which primary consumer (the herbivores) accumulate and store this chemical energy per unit area per unit time is called secondary productivity (SPP). Some energy is lost in the primary consumers as heat through respiration, excretion, growth, repair, reproduction, inedible plant parts, egestion, etc. the remaining energy is passed into the secondary and tertiary consumers in the next trophic levels when they feed on the herbivores. In the process energy is again lost as heat through the same processes. Decomposers which include bacteria and fungi utilize energy from every trophic level when the organisms in each stage of feeding relations die and begin to decompose.

PRODUCTIVITY IN AN ECOSYSTEM.

Productivity refers to the rate at which energy and biomass or organic matter is produced per unit time in a unit area by organisms in an ecosystem.

Can be measured using several methods i.e

- Harvest crop
- Through oxygen production of the given area of the ecosystem.
- Amount of carbon dioxide consumed during photosynthesis.
- Rate of consumption or use of raw materials

Can be divided into;

1. **Gross productivity**; is the total amount of energy and organic matter stored in an organism over a period of time.
2. **Net productivity**; is the amount of energy and organic matter stored in an organism and passed onto the next trophic level.
3. **Primary productivity.** Is the rate at which certain amount of energy and Biomass is produced and stored by primary producers per unit time in a unit area. It is further divided into,

(i) Gross primary productivity (GPP).

Is the rate at which certain amount of energy and Biomass is produced and stored by primary producers per unit time in a unit area before any loss of energy due to respiration and photorespiration.

(ii) Net primary productivity (NPP).

Is the amount energy and biomass available per unit time in a unit area after loss of some energy from the Gross primary productivity due to respiration and photorespiration

i.e NPP = GPP - Respiration.

In C_3 plants, NPP = GPP - Respiration + Photorespiration.

Note: C_3 plants have a lower NPP than C_4 plants.

4. Secondary productivity; Is the amount of energy incorporated into the body of consumers.

Gross secondary productivity (GSP).

Is the rate at which certain amount of energy and Biomass is produced and stored by primary consumers per unit time in a unit area.

The amount of the energy and biomass that remains in primary consumer per unit time in a unit area after some energy have been lost from the GSP due to excretion, egestion and respiration is referred to as the ***Net Secondary Productivity (NSP).***

Carnivores have higher Net secondary productivity (NSP) than herbivores because of the following reasons,

- The diet of carnivores is rich in proteins which is easily digested and soluble products efficiently absorbed. In this case, very little energy is lost, while herbivores feed on diet rich in carbohydrate cellulose (plant material) which is not easily digested or only partially digested, a lot of energy is lost in the undigested parts and hence herbivores have lower NSP.
- Carnivores do not have symbiotic microbes to consume part of the energy from their diet, while herbivores have Cellulase secreting bacteria in their guts, these bacteria utilize some of the energy from the cellulose.
- Their faeces contain much less undigested matter.

Note

Net secondary productivity is higher in exotherms than in endotherms, because;

Energy from absorbed food, is used in replace the lost heat to their surrounding, inorder to maintain a constant body temperature, unlike exotherms that depend mostly on behavioral means to maintain their body temperature.

FACTORS THAT INFLUENCE PRODUCTIVITY OF AN ECOSYSTEM.

- Level of nutrients especially phosphate and nitrates. The higher the level the greater the productivity as they are used in protein synthesis hence more dry matter is formed.
- Temperature. The higher the temperature the higher the productivity since temperature activate enzymes involved in photosynthesis.
- Carbon dioxide concentration. The higher its concentration in air, the greater the productivity since carbon dioxide is a raw material for photosynthesis. The lower the concentration of carbon dioxide the, the lower the productivity.
- Amount of light available. The higher the light intensity, the more energy fixed and the greater the productivity. Lower light intensity results into decreased productivity.

- Availability of water. Plenty of water increases rate of photosynthesis since water is a raw material for photosynthesis, hence more energy is fixed raising the productivity.
- Length of growing season. The greater the length, the higher the productivity. The shorter the length, the lower the productivity.
- Relative population size of primary producers. The greater size of green plants, the more energy fixed and the higher the productivity.
- Nature and type of tree species. Certain tree species tend to be more productive than others, therefore the more abundant these tree species are, the greater the productivity. The fewer such tree species, the lower the productivity.
- Concentration of pollutants in air. The higher the concentration, the lower the amount of photosynthesis and less energy fixation, hence the lower productivity.
- Chlorophyll concentration in case of aquatic ecosystem, upper zones of lake have higher chlorophyll content than deeper zones, hence the greater the concentration of chlorophyll, the higher the productivity.
- Soil fertility, humus, mineral content. Productivity increases with increase in Soil fertility, humus, mineral content. They are utilized in protein synthesis and formation of new organic matter. Decrease in Soil fertility, humus, mineral content, decreases productivity.
- Abundance of decomposers which enable nutrient recycling making the nutrients available for synthesis of new organic matter. This will increase productivity. Few decomposers reduce productivity.

FEEDING INTER-RELATIONSHIPS IN AN ECOSYSTEM.

This is biotic factor which influence an environment, they include,

- Food chains.
- Food webs.
- And ecological pyramids.

The feeding inter-relationships arise due to grazing, predator-prey relationship, parasitism, mutualism, symbiosis, etc.

FOOD CHAINS AND FOOD WEBS.

Food chain is a linear sequence or series of organisms existing in an ecosystem through which chemical energy formed and stored (Carbon compounds produced) by the green plants and other photosynthetic organisms are systematically transferred.

Each organism in the series feeds on and derives energy from preceding one, it is also consumed by another organisms following it and provides energy for that organism. The energy in the food chain is passed along the hierarchy in a chain called food chain. Each feeding level in a food chain is called trophic level. Some energy is lost when it passed from one level to another; this is why food chains are short.

TYPES OF FOOD CHAINS.

There are two types of food chains,

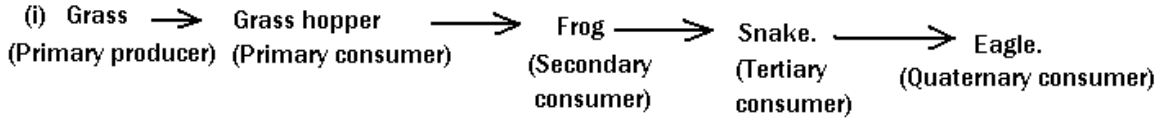
(i) Grazing food chains.

(ii) *Detritus food chains.*

GRAZING FOOD CHAINS

Is the linear nutritional sequence of organisms in an ecosystem where the chemical energy is passed in which the first trophic level is occupied b a green plant or green algae and the second trophic level is a grazing animal (Herbivore) and the subsequent levels by the carnivores.

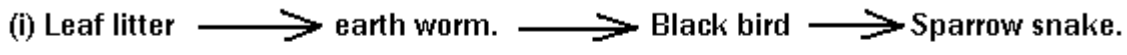
EXAMPLES.

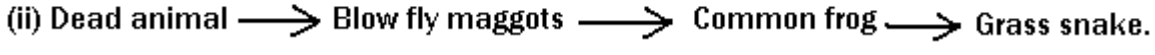


DETRITUS FOOD CHAINS

Is the linear nutritional sequence of organisms in an ecosystem through which a chemical energy is passed and in this case the first trophic level is occupied by the detritus, second by detritivores and the subsequent levels by the carnivores.

EXAMPLES.





Fragments of decomposing materials are called detritus and many small animals feed on them, contributing to the process of breakdown (decomposition), these animals are called detritivores. Examples of detritivores include,

(i) Wood land detritivores.

Earth worms, wood lice, blow fly maggot,

(ii) Sea shore detritivores.

Ragworm, dog whelk, sea cucumber.

(iii) Terrestrial detritivores.

Earth worms, wood lice, millipedes, mites, nematodes, termites, springtails etc.

HOW SOME DETRITIVORES INFLUENCE THE COMPONENTS OF TERRESTRIAL ECOSYSTEM.

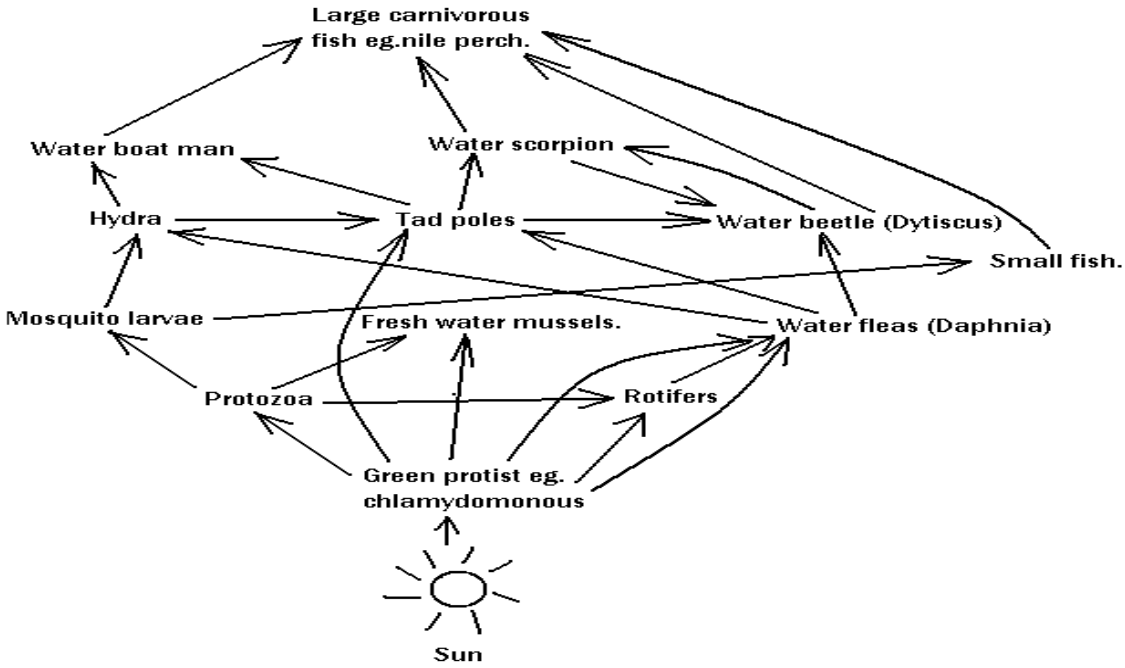
Termites live in nests called termitaria, they build galleries below the soil surface with cemented walls, and this prevents free aeration in the soil and reduces proper drainage of the soil. Termites also carry plant materials into the soil and break them into smaller fragments, increasing their surface area for the process of decomposition by aerobic bacteria. This releases nutrients to the soil. Termites eat other organisms, lowering organic matter content of the soil. Their faecal materials contain uric acid which is incorporated into the termitarion but also adds into the humus content of the soil.

Earth worms burrow into the soil, burrowing promotes and improves aeration of the soil, oxygen is available for activities of aerobic bacteria which increases the rate of decomposition of organic matter, more nutrients are released into the soil. The nitrogenous wastes of the earth worms add more ammonia and nitrates in the soil. Dead individuals are decomposed to add humus into the soil. Earth worms ingest the soil particles and mix the plant materials within the soil. Earth worms contain mucus and bacterial polysaccharides which hold together the fine particles, improving the crumb structure of the soil. The crumbs are not easily dispersed by water and promote the granular texture of the soil.

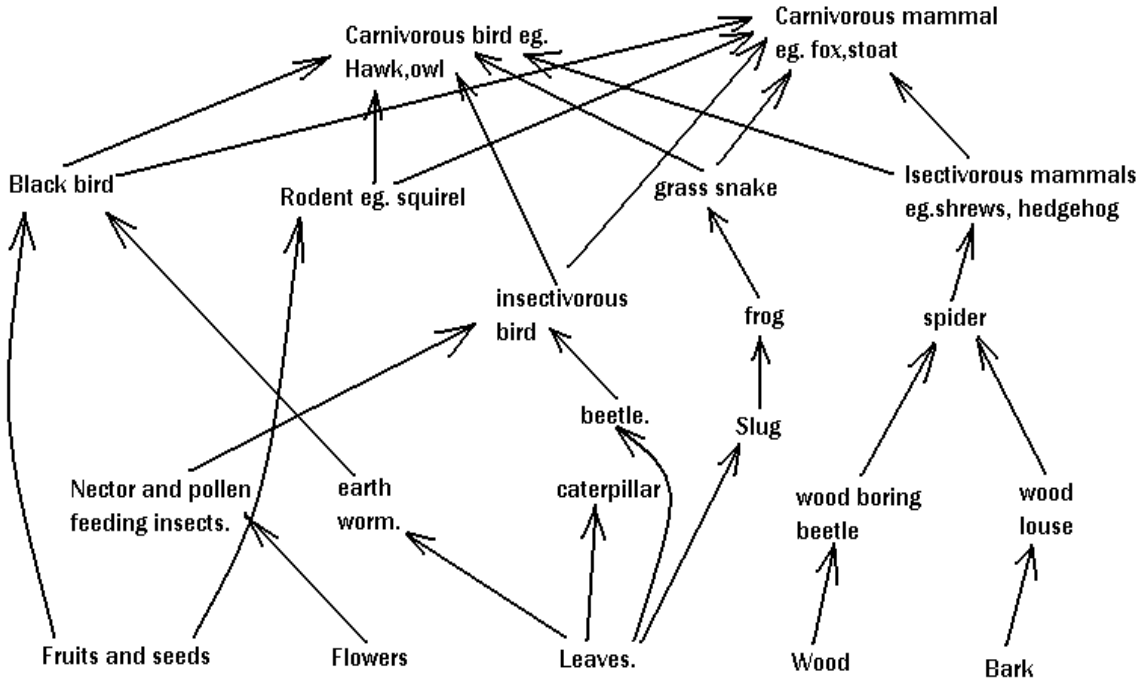
FOOD WEB.

Is an interconnected food chains in which an animal or organism at one trophic level has several alternative animals that it can feed on at different trophic levels, and also has many other animals that can feed on it at different trophic levels.

EXAMPLE OF A FOOD WEB IN A TYPICAL FRESH WATER POND.



EXAMPLE OF FOOD WEB IN WOODLAND.



ECOLOGICAL PYRAMIDS.

Feeding relationships and energy transfers through the biotic component can be quantified and shown diagrammatically as ecological pyramids. Ecological pyramids provides basis for

comparing, different ecosystems, seasonal variation within an ecosystem, changes in an ecosystem.

There three types of ecological pyramids, these include the following,

- ❖ Pyramid of numbers.
- ❖ Pyramid of Biomass.
- ❖ Pyramid of Energy.

Short comings of the Ecological pyramids include the following,

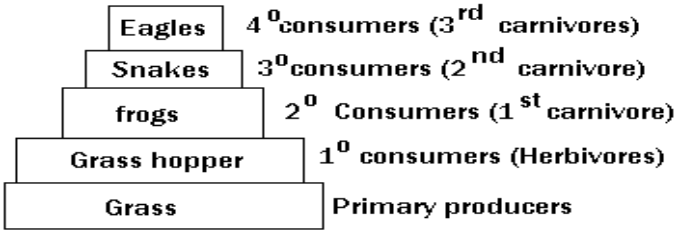
- ✓ It is quite not easy to identify the trophic levels of an organism as many organisms feed at several trophic levels.
- ✓ It omits the detritivores organic matter content, yet much of the energy fixed may be passed into the detritivores.
- ✓ It only considers energy stored by the green parts of the plant and consumed by the herbivores, yet some herbivores cannot digest chlorophyll, others eat only seeds or fruits or nectar.

TYPES OF ECOLOGICAL PYRAMIDS.

PYRAMID OF NUMBERS.

Is a bar diagram indicating the relative numbers of individuals at each trophic levels in a food chain.

Example.



The length of each bar indicates the relative number of organisms at each trophic level. It can be noticed from the pyramid of numbers that there is progressive decline in the number of individuals at each trophic level. This is because, a lot of energy is lost each time it passed from one trophic level to another in a food chain. This places a natural limit or reduces the biomass and this loses of energy causes the food chain be short, i.e. not more than six levels exist. Therefore, to support individuals at one trophic level more energy from the individuals at the levels below is required and is achieved by having more individuals at the lower trophic levels.

ADVANTAGES OF PYRAMID OF NUMBERS.

(i) It is easy to carry out.

(ii) It is relatively cheaper to conduct, does not require many equipment to do measurements.

DISADVANTAGES OF PYRAMID OF NUMBERS.

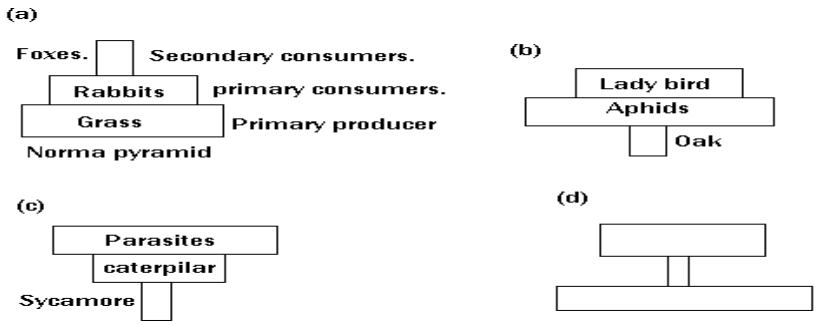
(i) All individuals are counted as the same, yet not all individuals have the same sizes. For example, an oak tree is counted as one individual in the same way as an aphid.

(ii) No account is made for juveniles and other immature forms of species whose diet and energy requirements may differ from that of the adults.

(iii) The numbers of some individuals is so large that it is difficult to represent them accurately on the same scales other species in food chain with considerable numbers. For example, Millions of black flies may feed on a single rose-bush and this relationship cannot be effectively drawn to scale on a pyramid of numbers. Such conditions give rise to unusual pyramids of numbers.

(iv) Does not indicate the source of energy in an ecosystem.

EXAMPLES OF UN USUAL PYRAMIDS OF NUMBERS.



(a) In a normal pyramid of numbers for comparison.

(b) The producer is a single plant such as a single tree.

(c) Producer is a single plant, infested with parasites (primary consumers) and the later are parasitized by further parasites.

(d) A large number of producers are eaten by a single primary consumer which is infested with parasites (Secondary consumers)

Some of the disadvantages are overcome by use of a pyramid of Biomass.

PYRAMID OF BIOMASS.

Is a bar diagram of proportionate length indicating dry mass of all organisms at each trophic level. Biomass is the weight of living material per unit volume or area.

ADVANTAGES OF PYRAMID OF BIOMASS.

(i) Biomass provides a relatively accurate measure of the amount of energy in each trophic level.

(ii) It gives the measure of total productivity in each trophic level.

DISADVANTAGES OF THE PYRAMID OF BIOMASS.

(i) It is impossible to measure exactly the biomass of all individuals in a population. A sample is usually taken and measured and this sample may not be a representative of all organisms at a particular trophic level.

(ii) The biomass of individuals varies from one season to another. For example, Biomass of deciduous tree in summer may be different from those in winter, so, the sample only measures the amount material present at a particular time. This is called standing crop and gives no indication of total productivity.

(iii) It involves destroying or killing of the living organisms in order to obtain the dry weight.

(iv) No source of energy is indicated.

(v) It is more laborious and expensive to conduct.

(vi) It is very much time consuming because it involves many steps.

(vii) The standing biomass or standing crop biomass which is the biomass at the time of sampling does not indicate exactly the productivity.

PYRAMID OF ENERGY.

Is a bar diagram in proportion to indicate the total energy utilized at each trophic level. The total productivity of primary producers of a given area can be measured for a given period. But obtaining the necessary data can be a complex and difficult affair.

ADVANTAGES OF PYRAMID OF ENERGY.

(i) It represents the amount of energy per unit area or volume passed from one trophic level to another. So, it is more accurate.

(ii) It represents total productivity at each trophic level.

(iii) It takes into account the energy from the sun which is the source of energy in an ecosystem.

(iv) It enables comparison of different ecosystems, so, the importance of one ecosystem to another can be determined.

(v) Unusual and inverted pyramids are not obtained.

(vi) The energy content of each individual is determined independently of the others; it shows that no two individual species can have the same energy content.

DISADVANTAGES.

(i) It is most difficult to obtain data for pyramid of energy since it requires a lot of technical know-how.

(ii) It is expensive to carry out because it requires some sophisticated equipment to do measurements.

ECOLOGICAL TECHNIQUES OF STUDYING FEEDING RELATIONS OF ORGANISMS.

(i) Direct observations of what the organism eats.

This method has some disadvantages,

- ✓ It can not be applied to aggressive animals.
- ✓ It can not be applied to organisms living in concealed and hidden habitat.
- ✓ It can not be applied on organisms which refuse to eat under observation. For example Rodents and some birds.

(ii) Faecal analysis.

This involves studying the content of faeces of a given animal.

This method has some disadvantages that include,

- ✓ Some food can not be seen in the faeces because they are already digested and absorbed.
- ✓ It can not be applied on animals which eat their faeces like Rabbits a practice known as ecopathy. The faeces are eaten because they still contain more nutrients following little digestion and absorption which occurred within the gut.

(iii) Examination of the stomach content.

This is to find out what they feed on and it requires identification skills after enzyme action and mastification.

(iv) Use of radio-active tracers.

It involves labeling available foods using radio-active substances and their trace their presence or absence in the animals gut. It can be used in all animals no matter their nature.

NOTE: To come up with more reliable information, more than one method is used.

CELL SPECIALIZATION IN MULTICELLULAR ORGANISMS

A multicellular organism is one whose body is made up of more than one cell. However these organisms develop from a single cell by sexual reproduction or as part of another organism by asexual reproduction.

Advantages of being multicellular

- It allows an organism to exceed the size limits normally imposed by diffusion. Single cells with increased size have decreased surface to volume ratio and hence difficulty absorbing sufficient nutrients and transporting them throughout the cells. Multicellular organism therefore have a competitive advantage of increase in size without its limitations.
- Multicellularity also permits increasing complexity by allowing differentiation of cell types within one organism.
- Multicellular organisms have a longer lifespan as they can continue living when individual cells die.
- Worn out cells are easily replaced by cell division.
- It allows tissue specialization which increases efficiency in performing body functions.

Disadvantages of being multicellular

- More energy/food is needed for normal functioning since multicellular organisms require more energy to feed multiple cells.
- The increased energy consumption also leads to an increase of waste created. This waste can at times be difficult to eliminate and can cause toxicity to the organism.
- When an organism requires much food to function correctly it will need to expend further energy in the search for food sources.
- Infection becomes a possibility when multicellular. Infection becomes impossible as a single celled organism since there is nothing smaller to cause infection. For multicellular organism, infection becomes a real risk from unicellular organisms that take advantage of larger organisms.
- Takes longer to reach maturity and to breed.
- If one cell group fails, they can all fail because they rely on each other to perform certain tasks to help with survival.
- They require specialized locomotory structures to enable motion.

In multicellular organisms, the cells undergo division producing a number of cells whose functions may vary depending on the need of the organism. This is called cell specialization.

Examples of specialized cells in plants:

- Parenchyma cells
- Collenchyma cells
- Sclerenchyma cells
- Epidermal cells
- Palisade cells
- Meristematic cells

Examples of specialized cells in animals:

- Red and white blood cells
- Osteoblasts and Chondroblasts
- Epithelial cells
- Muscle cells
- Nerve cells
- Egg cells and sperm cells.

The cells above and others do come together to perform specialized functions which sustain the life of an organism. This constitutes cell organization as:

Cell ⇨ Tissue ⇨ Organ ⇨ Organ system ⇨ Organism

A **tissue** is a group of physically linked cells and their associated intercellular substances which are specialized to carry out a specific function(s).

Examples of tissues in animals:

- Epithelial tissues.
- Connective tissues i.e. adipose tissues and blood.
- Support tissues i.e. bone and cartilage.
- Muscle tissues and nerve tissues.

Plant tissues:

- Meristematic tissues Epidermis tissues.
- Vascular tissues.
- Photosynthesis tissues and support tissues.

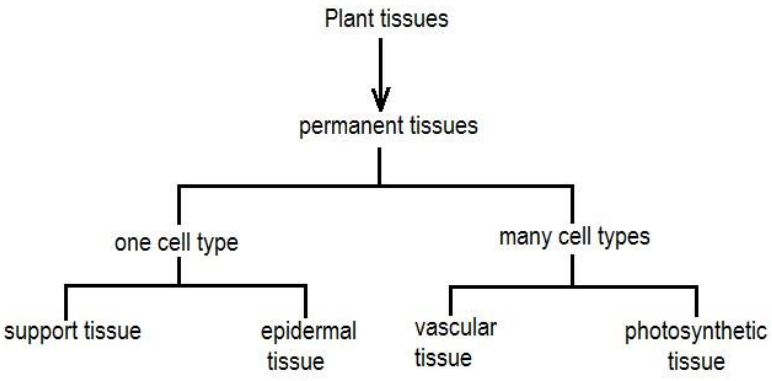
An **organ** is a collection of tissues working together as a functional unit e.g. nose, eye, skin and heart.
An **organ system** is a collection of organs and associated tissues working together as a functional unit. E.g. digestive system, respiratory system, circulatory system, etc.

PLANT TISSUES

The type of tissues in plants varies depending on the age of the plant and the cell types that make up the tissue. Depending on age, the plant tissues are grouped into two i.e.

i) **Temporary tissues (meristematic tissues):** These exist at the time of germination and they are replaced by other tissues in woody plants only. The remaining are the growing points of the shoot and root.
ii) **Permanent tissues:** These replace the temporary tissues in all non-herbaceous plants.

The tissues may be made up of one cell types or many cell types as shown below:



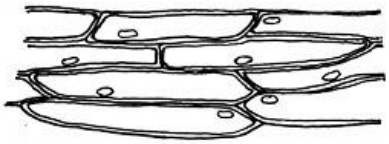
Plant tissues consisting of one type of cells

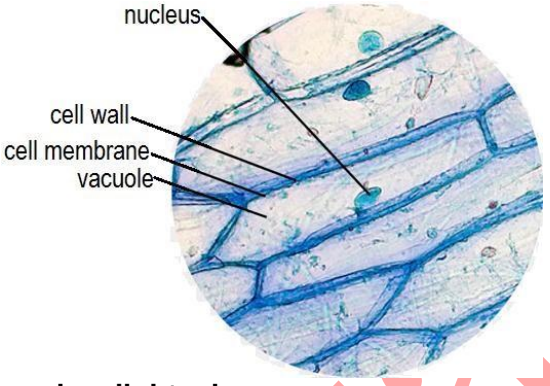
1) Epidermal tissue:

The epidermis forms the outermost layer of the primary plant body like young stems, roots, leaves and flowers. In roots, the outermost layer is called **piliferous layer**.

Characteristics:

- Cells are flattened and one cell thick.
- Cells are irregular in shape without intercellular spaces.
- The cells have no chloroplasts with exception to guard cells.
- The outer cellulose cell wall may be coated with a thick layer of cuticle.
- They may bear unicellular or multicellular hair.





- In young stems and leaves forming plant skins.
- As guard cells in leaves.

Epidermal tissue/cells as seen in a light microscope

Location:

- As piliferous layer in roots. The outer layer of leaves.

Functions:

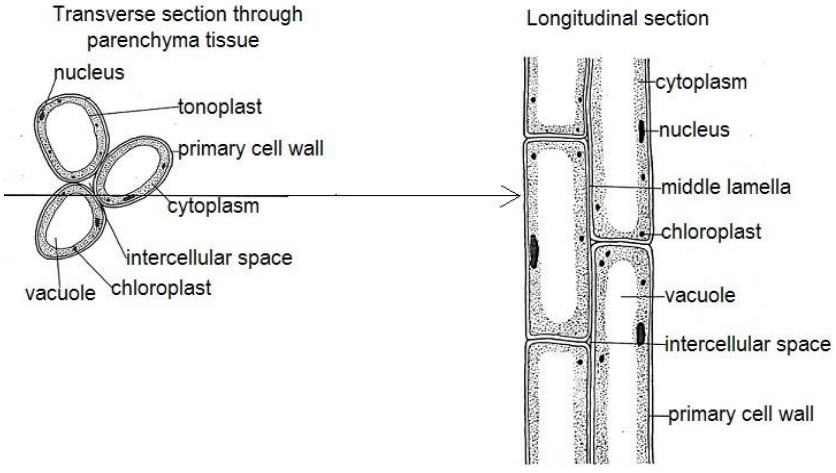
- The epidermis acts as a protective layer covering the plant body.
- The cuticle reduces excessive loss of water by evaporation from the plant body.
- The stomata allow exchange of gases and transpiration.
- It protects the plant from excessive heat or cold and from attack of parasitic fungi and bacteria.
- The piliferous layer forms the root hairs important in the absorption of water and mineral salts from the soil. It has no cuticle.

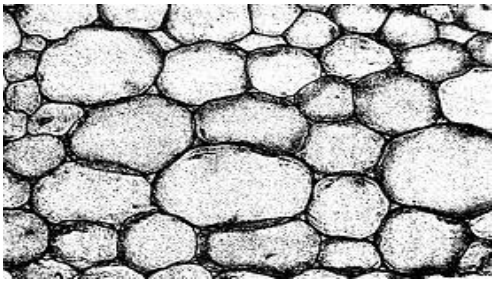
2) Support tissues (ground tissues):

These are parenchyma tissue, collenchyma tissue and sclerenchyma tissue.

Parenchyma tissue

It is the most common plant tissue made up of unspecialized cells which act as storage tissue between specialized tissues. It is the main tissue in young stems of herbaceous plants.





Characteristics and structure of the parenchyma tissue

- Cells are spherical in shape.
- They have thin transparent cell walls and large vacuole and therefore the cells can easily change their turgidity as a result of the osmotic uptake of water.
- Among the cells are large intercellular spaces.
- In aquatic plants they are modified as **aerenchyma**. They are star shaped and have a number of air cavities in between.

Location:

- They form the packing tissues between more specialized tissues such as pith, cortex and medullary rays.
- They are also found in the periphery of stems, roots and leaves.
- They are found in all soft parts which appear fleshy.

Functions of the parenchyma tissue They fill spaces between other tissues and hence acting as packing tissues.

- They offer support when they become fully turgid as a result of osmotic uptake of water especially in herbaceous plants.
- They are metabolically active carrying out biochemical reactions of plants like photosynthesis.
- Some may have air spaces between them to allow gaseous exchange.
- Food storage like the parenchyma cells of potato tubers.
- Their cell walls allow water transport by Apoplast pathways.
- Mesophyll cells are sites of photosynthesis.

Adaptations of parenchyma tissues to its functions Have unspecialized cells to carry out a variety of functions.

- Have many intercellular spaces to allow gaseous exchange/diffusion.
- Have thin cellulose cell walls to allow passage of materials.
- Have transparent cell wall to allow easy entry of light for photosynthesis.
- Large cells with large vacuoles for storage of food.
- Cells are closely packaged to provide support when they become fully turgid because of osmotic uptake of water.

Modifications of parenchyma tissues

The tissues may become specialized in certain parts. In such parts, they are modified to suit their functions. The modified forms include mesophyll, cortex and pericycle.

i) Mesophyll tissue:

This is made up of spherical, irregular or columnar cells. Their cell walls contains cellulose, pectin and hemicellulose.

Function:

- It facilitates gaseous exchange. This is aided by the large intercellular spaces which exist between the cells especially in the spongy mesophyll layer.
- It carries out photosynthesis. This is because they contain chloroplasts with chlorophyll. This type of parenchyma is called **chlorenchyma** due to the chloroplasts in their cytoplasm.

ii) Pericycle:

This is a living tissue which forms parts of the plant body. It is made up of polygonal cells in the outline. Sometimes the cells are spherical or elongated with cell walls containing pectin and hemicellulose.

Location: It is found in roots and stems between vascular tissues and endodermis.

Function: produce lateral roots and help in secondary growth. It is strong enough to provide tensile strength to the roots.

iii) Endodermis:

This is made up of parenchyma cells forming a selective barrier to movement of water and mineral salts between cortex and xylem.

Functions:

- The endodermal cell walls in the roots have **casparian strip** made of suberin which prevents movement of water along the cell walls of the cells by the Apoplast pathway.
- In the roots, the epidermal cells generate root pressure when they actively secrete salts into the xylem tissue creating a low water potential in the xylem. This draws water into the xylem by osmosis which causes a pressure in the roots that pushes water up the xylem.
- In the stems of dicots, the endodermis surrounds the vascular bundles and stores starch.

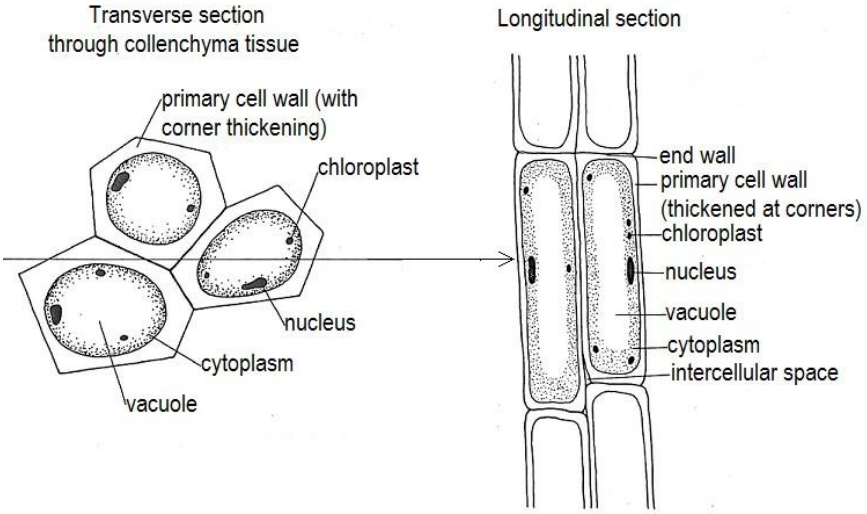
Adaptations of the endodermal cells to their function

- Cells have an impermeable strip of suberin the casparian strip which controls the passage of water into the xylem.
- In-folding of the cell wall which increases surface area of the cell membrane for transfer of solutes.
- Numerous mitochondria to provide energy for active transport.
- Numerous starch grains in endodermal cells which act as energy source.

Collenchyma tissue

It consists of living cells with the following characteristics:

- Cells are elongated, parallel to the longitudinal axis of the organ where they occur and appear polygonal in the transverse section.
- Cells have thick cellulose cell walls.
- The corners of the cells are thickened with extra cellulose. They have large vacuoles and little cytoplasm.



Location:

- In the cortex of the stems and roots.
- In the petiole and midribs of leaves.

Functions:

- Provides mechanical support to the organs on which they are located.
- It is the main supporting tissue in young stems and organs such as fruits and leaves and stems of herbaceous plants.

Sclerenchyma tissue

When mature, this tissue consists of dead cells. The tissue has cells with highly lignified cell walls and because of this, the tissue has a high tensile strength able to stretch without breaking.

As lignification continues in the cellulose cell wall, small pits are formed. There are areas of plasmadesmata. At maturity (when dead) these cells lose their living content.

Types of sclerenchyma tissues

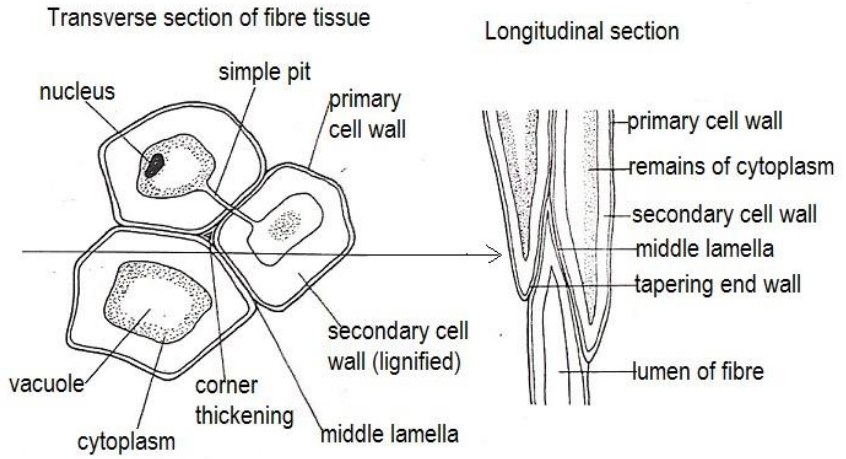
1) Fibres: This is made up of elongated polygonal cells with:

- Their cell wall is deposited with lignin in addition to pectin, hemicellulose and cellulose.
- The cells are densely packed without air spaces within them.
- The cell walls of these cells have some parts without lignin forming pits. This allows movement of materials from one cell to another.

Location:

They are located in the xylem, phloem and pericycle.

They are also found in the outer region of the cortex and the epidermis of especially fibrous plants.



Adaptations of sclerenchyma fibres to its functions

 Cells have highly lignified thick walls to provide enough resistance to forces of the environment.

- Cells are dead and therefore take no extra metabolic demand on the plant.
- Fibres are elongated and arranged in sheets/strands to increase strength.
- Fibres are interlocked to enhance their combined strength.

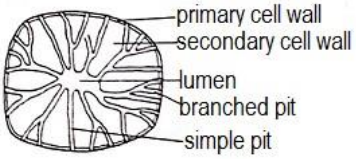
2) Sclereids (stone cells):

These are dead cells irregular in shape.

Their cell walls are highly lignified.

They have a narrow lumen and simple branched pits.

A sclereid tissue



Location:

- In the cortex, phloem of woody plants.
- Endocarps of seeds like coconut.
- Shells of nuts.

Functions:

- Stones of fruits. Provide support, firmness and hardness where they occur.
- Flesh of fruits like guava and pea. Responsible for grittiness when the fruit is eaten.

Differences between fibres and sclereids

Fibres	Sclereids
Cells are elongated and polygonal.	Cells are broad/isodiametric (roughly spherical).
The pits are narrow and unbranched.	The pits are deep and branched.
Have tapering interlocking ends.	Have blunt broad ends.

Differences between collenchyma and sclerenchyma tissues

Collenchyma	Sclerenchyma
Consists of living cells	Consists of dead cells.
Cell wall thickened with cellulose.	Thickened with lignin.
Cell wall thickening is non-uniform.	Thickening is uniform.
Contain chloroplasts.	Don't contain chloroplasts.
It has no pores.	Has pores.
It has a wide cell cavity.	Cell cavity is narrow.

Plant tissues consisting of more than one type of cells

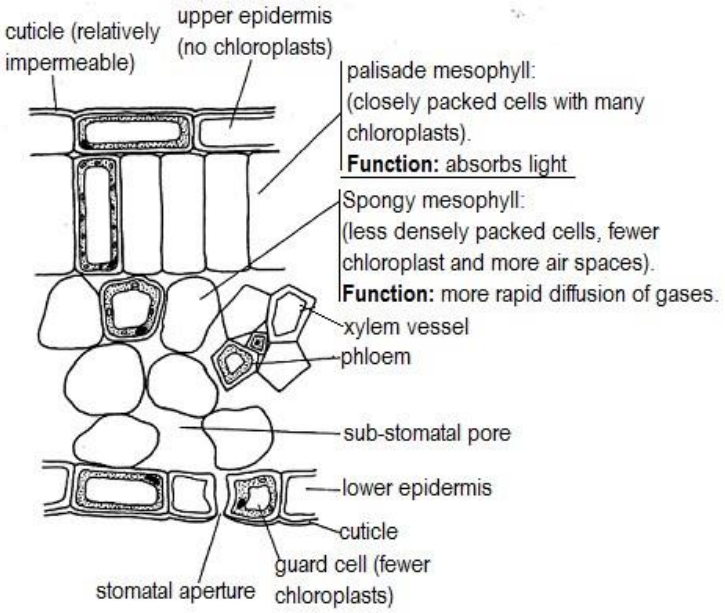
1) Photosynthetic tissues:

This has specialized cells for photosynthesis.

The cells have a lot of chloroplasts which store chlorophyll.

It occurs in the **palisade** and **spongy mesophyll** layers of the leaf.

Structure of a leaf showing the photosynthetic tissue



2) Vascular tissues:

These are tissues responsible for transport and translocation of materials from one part of the plant to another. They consist of the **xylem** and **phloem** tissues.

Xylem tissue

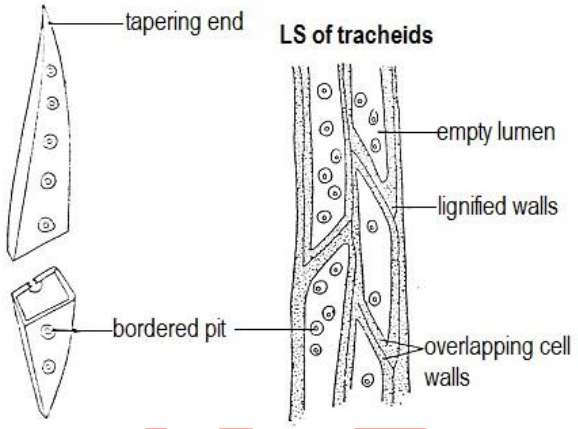
Structure:

Xylem is made up of ***tracheids, xylem vessels, parenchyma cells*** and ***fibres***.

The cell walls of these tissues have lignin and bordered pits. Xylem tissue is commonly called wood. **Function:** Primary function is to transport water and mineral salts from roots to leaves.

a) Tracheids:

Structure of tracheids



These consist of dead cells which are elongated and tubular. They have hard, thick and lignified cell walls.
The cell walls also contain lignin, cellulose, hemicellulose and pectin. The single cells have tapering end walls that overlap with adjacent tracheids.
The walls usually have one or more rows of bordered pits.

Location and distribution: They are predominant in lower vascular plants of ferns and gymnosperms.

Functions:

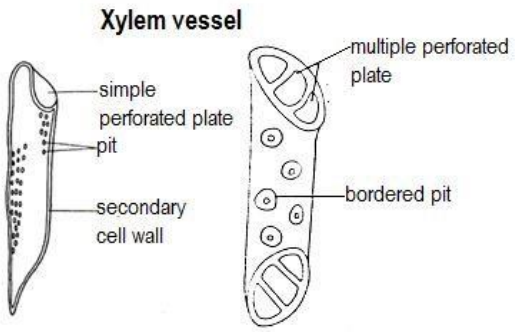
- They form primitive water conducting tissues of gymnosperms and ferns.
- They provide mechanical support.

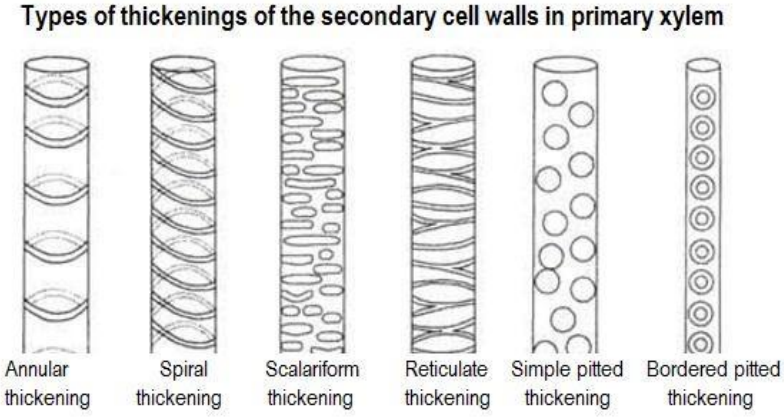
Adaptations:

- Tracheids have tapering end that interlock with the neighboring tracheids for firm support.
- They have empty lumens without any living tissues which allows smooth flow of water without any obstruction. They have pits through which water and mineral salts pass from one tracheid to another.

b) Xylem vessels:

These are made up of elongated cylindrical cells called xylem elements placed end to end.
The end walls of the vessel elements break down during development so that a continuous tube is made for flow of water.
The walls are impregnated with lignin for support with bordered pits.
The end wall may have a single opening called a **simple perforation plate** or many openings called **multiple perforation plate**.
The thickenings on the vessels could be ***annular, spiral, scalariform, reticulate or pitted*** forms.
Thickening/lignification gives the vessels additional strength and prevents the walls from curving in.





Formation and development of a xylem vessel element

The cells of the procambium strand divide by mitosis. The cell formed elongates/enlarges and the vacuoles appear in the cytoplasm. The horizontal end walls between adjacent cells breakdown/disintegrate forming perforation which is continuous with that of adjacent cells. A secondary wall is formed by addition of extra cellulose and lignin. Lignification causes the protoplasmic contents die leaving a hollow tube known as a vessel. The lignified walls are perforated with pits where lignin fails to be deposited.

Functions of xylem vessels

- They conduct water and dissolved mineral salts in angiosperms.
- They provide mechanical support to the plant due to their being lignified.

Adaptation of the xylem tissues for transport of water and mineral salts

- Tracheids and xylem vessels are placed end to end, the end wall of the vessel elements breakdown during development so that a continuous tube is made for flow of water.
- The walls are impregnated with lignin for support which increase adhesive force for upward movement of water.
- A xylem vessel is hollow allowing water to move freely without any obstruction.
- The side walls of the vessels and tracheids are perforated (has pits) to allow water and salts to move sideways between cells.
- The tracheids have elongated, tapering (sloping) end walls containing cellulose-lined pits that allow water to pass from one cell to another.
- Narrow lumen of tracheids and vessels enhances the upward movement of water by capillarity.

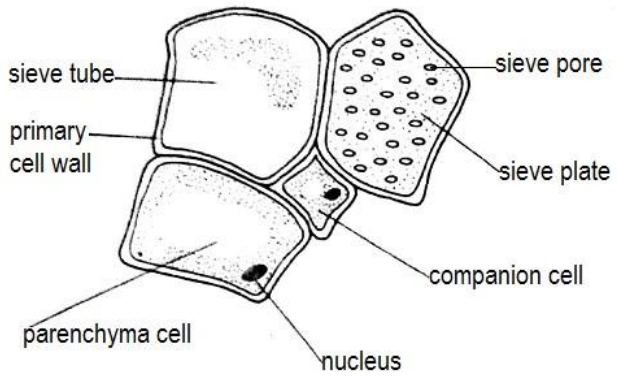
Differences between tracheids and vessels

Tracheids	Vessels
Single elongated cells	It is formed by fusion of several cells with dissolution of end walls.
Very short	Are medium in length.
End walls are not perforated and water moves through bordered pits on the walls	End walls may have one or several openings/perforations.
They are the only cells present in lower plants and predominant in gymnosperms for transportation of water and mineral salts.	Are predominant in angiosperms for transportation of water and mineral salts.
They have a narrow lumen.	They have a wider lumen.

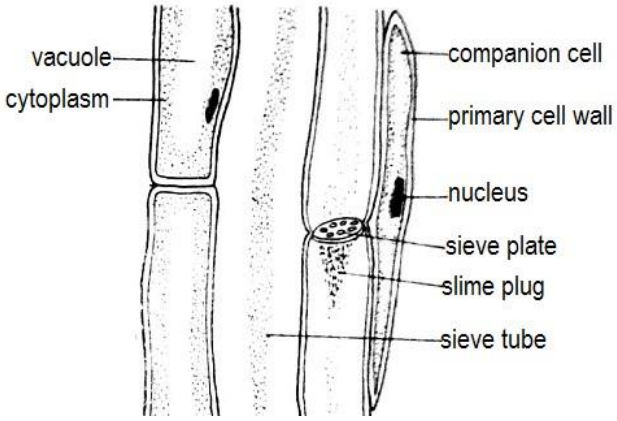
Phloem tissue

It is made up of three types of cells; **sieve tube elements**, **companion cells** and **phloem parenchyma (**in dicots only**).**

Transverse section of phloem tissue



Longitudinal section



a) Sieve tubes:

These are made up of tubular and elongated cells called sieve tube elements.
They have thin walls made of pectin, cellulose and hemicellulose.
They are formed by fusion of cells called sieve tube elements which lie to one another end to end.

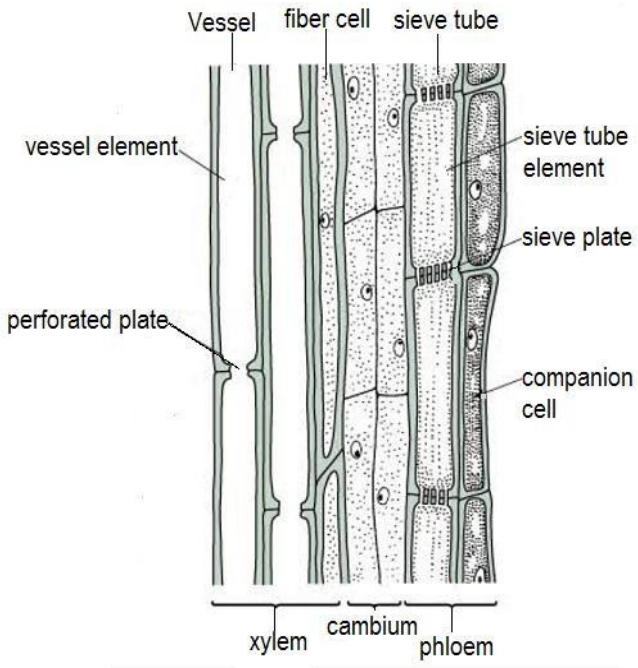
The cells lack a nucleus when mature. However they are living cells even at maturity.
When mature, they remain with very little cytoplasm in form of strands called cytoplasmic strands.
At the end walls, there exist pores which connect adjacent cells. The perforated end walls form one sieve element to the next. **Function:** Translocation of organic solutes e.g. sucrose, amino acids and other organic substances like growth hormones.

b) Companion cells

These cells are living cells found adjacent to the sieve tubes connected by simple pits.
They contain dense cytoplasm and have a prominent nucleus. They contain numerous mitochondria for provision of energy to enable the process of translocation.
They are connected to sieve tubes by simple pits and are present in angiosperms only.

Function:

They are metabolically active and they therefore provide the sieve tube elements with the necessary energy for translocation of organic solutes.



Comparison between xylem and phloem tissues Similarities:

- Both have perforated cells.
- Both are surrounded by parenchyma cells.
- Both are conducting tissues.
- Both have cells that lack a nucleus.

Differences:

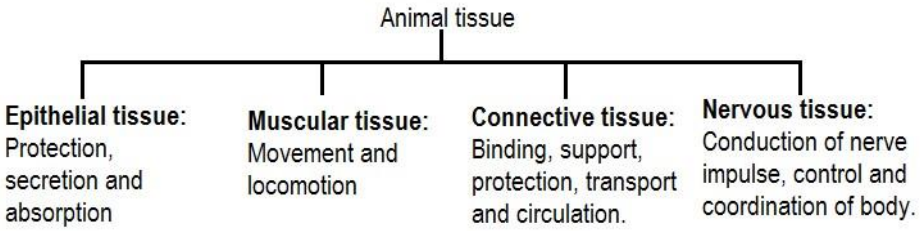
Xylem	Phloem
Has dead cells.	Has living cells
Made up of xylem vessels, tracheids, fibres and parenchyma cells.	Made up sieve tube elements, companion cells, parenchyma cells and fibres.
Have lignified walls	Walls made of cellulose.
They transport water and mineral salts.	For translocation of organic solutes.

Assignment:

1. *What is a tissue?*
2. *Make a labelled drawing of a living parenchyma cell of a plant.*
3. *How do the following structures differ from a parenchyma cell?*
   i) The leaf epidermal cell. ii) Apical meristem iii) Xylem tracheid
4. *How are the parenchyma cells adapted to their functions?*
5. *Describe structural adaptations of vascular tissues for support.*

ANIMAL TISSUES

There are 4 major groups of animal tissues i.e. epithelial tissue, connective tissue, muscular tissue and nervous tissue.



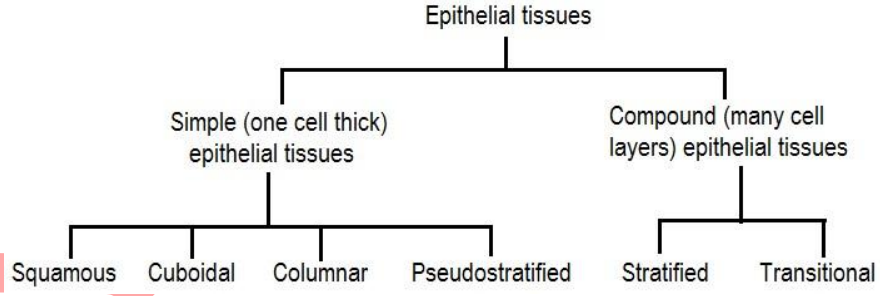
EPITHELIAL TISSUES

Epithelial tissues consist of a single or many layers of closely packed cells specialized to form the covering of external body surface or lining of inner body cavities.
Epithelial tissues cover tissues subject to mechanical damage.

General structure of epithelial tissues

The cells are closely packed and firmly attached to each other. They lack intercellular space.
Adjacent cells joined together by intercellular cement.
The bottom layer of epithelial cells rests on a basement membrane composed of a network of collagenous fibres. The basement membrane provides structural support for the epithelium and also binds it to the neighboring structures and serves as scaffolding/board upon which new cells attach during healing of injured epithelia.
The free surfaces may be modified into cilia and microvilli.
There are no blood vessels in epithelial tissues. However nerve ending may occur in the epithelium.
Epithelial tissues have a high regeneration capacity due to rapid cell division. This helps epithelial tissue to recover fast after any injury or abrasion.

Summary of epithelial tissues



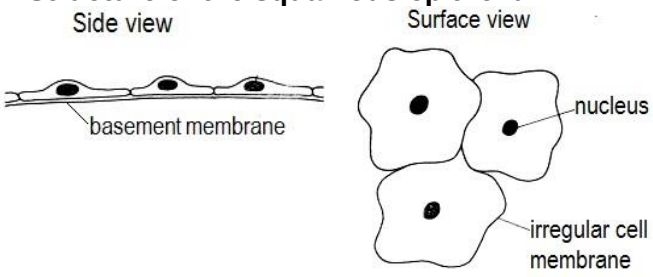
SIMPLE EPITHELIAL TISSUES

Simple epithelial tissue consists of a single layer of cells. All the cells rest on basement membrane. They include the following types:

1. Squamous epithelium (pavement epithelial):

Cells form a single layer attached to a basement membrane. In surface view, the cell outlines are irregular and closely packed. The cells are thin, shallow and flattened.
Adjacent cells may be joined by strands of cytoplasm.

Structure of the squamous epithelium



Location:

- Alveolar lining of the lungs.
- Inner lining of blood vessels and lining of blood capillaries.
- Bowman's capsule of kidney.

Functions:

- Diffusion of materials and gaseous exchange across the membrane.
- Provides a friction free lining for blood flow in blood vessels **Adaptations:**
- Made up of thin flattened cells to reduce diffusion distance across tissues.
- Their smooth surface provides a friction free lining for blood flow in blood vessels.

2. Cuboidal epithelial tissue:

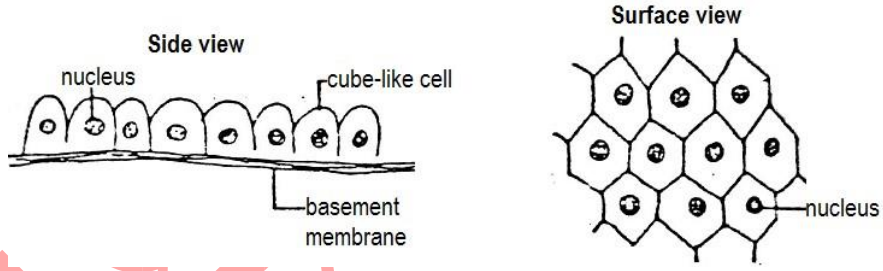
Its cells are cuboidal and form a single layer attached to a basement membrane. The nuclei are spherical and centrally located.

The cells appear pentagonal or hexagonal in surface view.

Location:

- Lining of salivary, collecting and pancreatic ducts (kidneys).
- Salivary, sweat and thyroid glands.

Structure of cuboidal epithelium



Functions:

- Secretion
- The ciliated cuboidal epithelium are for flow of nephric filtrate.
- The brush bordered cuboidal are for reabsorption of materials from fluid in tubules with microvilli which increase surface area.

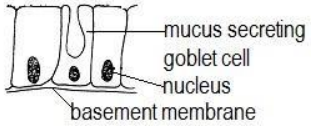
3. Simple columnar epithelium

Tall, column like narrow cells with nucleus at the basal end. It is often interspersed by goblet cells.

Location:

- Lining of stomach, intestine and gall bladder.
- Intestinal and gastric glands.

Side view of simple columnar



Functions:

- Secretion and/or absorption.
- Mucus protects the lining from the acidic content in the stomach and from digestion by enzymes and also lubricates the passage.

4. Brush bordered columnar epithelium

These are tall and narrow cells with a nucleus near their base.

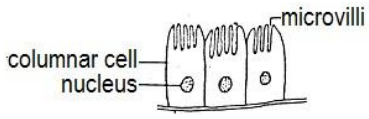
The surface area is increased by micro villi at the free end.

Secretory goblet cells are found within the columnar cells.

Location:

Side view of brush border columnar epithelium

Intestinal mucosa **Function:**
Increased surface area for absorption of nutrients.



Adaptations:

- Microvilli at free surface increase surface area for absorption of nutrients.
- Secretory goblet cells for secretion of mucus.

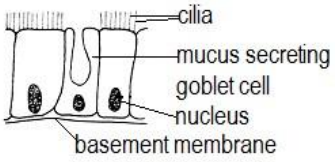
5. Ciliated columnar epithelium

It comprises of columnar cells with cilia at their free edges.
They have many mucus secreting goblet cells in between the cells.

Location:

- Oviducts, respiratory passage (bronchioles) and spinal canal.
- In flat worms, lines underside of the body where they aid locomotion.

Side view of ciliated columnar epithelium



Functions:

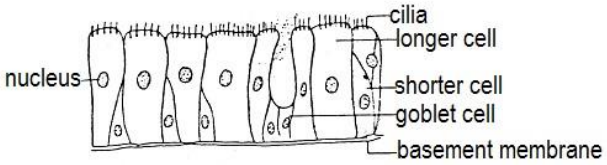
- Locomotion in flatworms.
- Movement of materials in a particular direction. The cilia sets up currents to move materials in a particular direction.
- The mucus protects the lining and lubricates the passage.

6. Pseudostratified epithelium

Consist of one layer of columnar cells that appear to be in two layers due to:

- Nuclei at different levels and

Side of pseudostratified epithelium



- All cells do not reach the surface.

Has two types of cells:

- Longer cells have cilia
- Shorter cells lack cilia and secrete mucus.

All cells rest on the basement membrane.

Location:

- Lining of trachea and primary bronchi.
- Part of the nasal epithelium.

Functions:

- Mucus traps bacteria and dust particles and prevent them from reaching the lungs.
  Cilia move mucus with trapped foreign particles up to the throat for swallowing.

COMPOUND EPITHELIAL TISSUES

Characteristics:

Consist of many layers of cells.
Only the lower most layer of cells rest on the basement membrane.
Compound epithelial may be stratified or transitional.

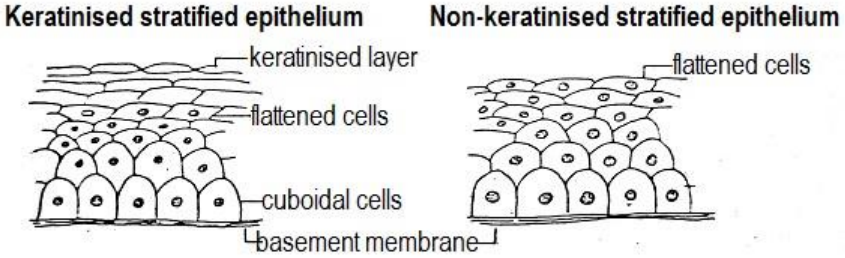
Types of compound epithelial tissues

1. Stratified epithelium

It is made of many layers of cells and therefore thicker than the simple epithelium.
The cells are formed by mitotic division of the germinal layer which rests on the basement membrane.

As new cells form, older ones are pushed near to the surface changing shape and flattening to form squamous.

In some areas the squamous cells may remain un keratinized as in the oesophagus or may be heavily thickened with keratin (cornified) e.g. the skin where there is a dead layer of cells.



Location:

- Areas or ducts that are delicate or have large flow of fluids.
- External skin surface, lining of buccal cavity and vagina.
- Lining of pharynx and oesophagus.

Function:

- Protection from abrasion to areas exposed to wear and tear.
- Protection of the tissue from mechanical damage by the food that is swallowed. Protection of the underlying tissue from mechanical damage.

Adaptations of stratified epithelium

- It is composed of several layers of cells which are tough impervious and some cells keratinized/cornified for protection against mechanical abrasions.
- Cells of germinal layer divide repeatedly by mitosis to replace the cells that are breaking off wearing off at the surface.
- Some cells can change their shape when subjected to tension to allow stretching where they are located e.g. in urinary bladder.

Practical check: An experiment to study the squamous epithelium from a temporary mount of check epithelium.

Procedure:

- *Take a tooth pick or sterilized spatula and scrape the mucous membrane from inner lining of mouth very lightly.*
- *Put the scrapings on a glass slide and add a drop of 0.9% NaCl solution (isotonic to mammalian tissue).*
- *Place the coverslip and put a drop of 1% methylene blue solution at the edge of coverslip. (Methylene blue stains the nucleus blue).*
- *Wipe off the excess dye with a blotting paper and observe the slide under the microscope.*
- *Draw and label at least 4 cells observed.*

2. Transitional epithelium.

It comprises of 3 or 4 layers of cells which may be flattened towards the surface which are not shed but can change their shape thus allowing stretching. Transitional epithelium lacks a basement membrane.

Location:

It is found in structures which must stretch e.g. the urinary bladder, ureter and urethra.

Function:

- By changing the shape, the transitional epithelium allows the expansion of the organ.
- It prevents the loss of water from blood to urine.
- Due to its thickness, it prevents the urine from escaping into the surrounding tissue.

Typical examination

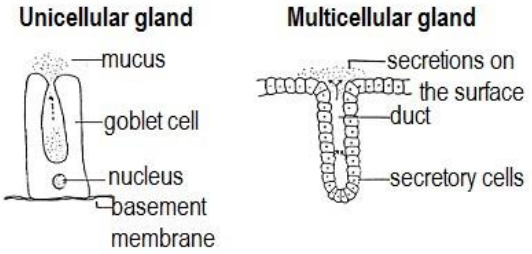
question *a) What is a tissue?*

b) Give one characteristic feature and one location of each of the following tissues in a mammal in the table below:

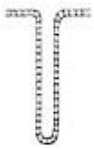
Tissue	***Characteristic feature***	***Location***
Squamous epithelium		
Columnar epithelium		
Stratified epithelium		

GLANDULAR EPITHELIUM

1. **Based on the kind of secretion and the duct present, glands are of two types;**
   i) **Exocrine glands**: these pour their secretions through the ducts to their respective sites of action e.g. salivary, tear intestinal and gastric glands. Their secretions are called enzymes.
   ii) **Endocrine glands:** these do not possess ducts and pour their secretions directly into the blood stream. Their secretions are known as hormones.
2. **Based on number of cells, the glands are of 2 types;**
   i) **Unicellular:** an individual epithelial cell is modified into a glandular cell as in goblet cells.
   ii) **Multicellular:** number of glandular cells aggregate to form a multicellular gland. Multicellular glands can further be divided into simple or compound glands e.g. sweat glands.



3. **Based on the shape and complexity, the exocrine glands are of 2 main types**; simple and compound glands which may further be modified.
   i) **Simple glands:** these have a single unbranched duct. The secretory part could be in the form of tube (called tubules) or sacs (alveolar/saccular). These could be coiled or uncoiled, branched or unbranched.

Simple tubular e.g. crypts of Lieburkuhn in intestine	Simple coiled e.g. sweat glands	Simple branched tubular e.g. gastric glands and Brunner's glands of intestine.	Simple alveolar e.g. mucous secreting glands in frog skin.	Simple branched alveolar gland where a number of sacs open into the same duct e.g. sebaceous glands.
				

Various forms of simple exocrine glands

ii) **Compound glands**: these have number of ducts forming a branching pattern.

Compound tubular glands e.g. salivary glands.	**Compound alveolar** e.g. mammary glands, pancreatic glands.	**Compound tubular alveolar** e.g. parts of salivary and mammary glands.
		

4. **Based on the mode of secretions, the exocrine glands are of 3 types;**
   i) **Merocrine glands**: the secretions produced within the cell are discharged on its cell surface without losing any of its cytoplasm. E.g. goblet cells, pancreatic glands and sweat glands.
   ii) **Apocrine glands**: in these glands, the cell loses a part of its cytoplasm while releasing its secretions. The secretions are stored in the apical part of the cell which bursts open to release the contents e.g. mammary glands.
   iii) **Holocrine glands:** the entire cell breaks down in order to release its secretions which extrude from the epithelial surface e.g. sebaceous glands.
5. **Based on the form of secretion, glands are of 3 types.**
   i) Mucous glands: secretion is in form of viscous mucous fluid. They are called mucocytes.
   ii) Serous glands: secretion is clear, watery fluid containing enzymes. They are called serocytes.
   iii) Mixed glands: secret both.

Functions of epithelial tissues

The epithelial tissues serve the following functions; protection, secretion, absorption, exchange of materials/gases and sensory.

1) Protection:

Epithelial tissues protect underlying tissues from injury by chemicals, pressure, abrasion and infection.

Adaptations:

- Stratified epithelium is composed of several layers of cells which are tough, impervious and some cells keratinized/cornified for protection against mechanical abrasions.
- Columnar epithelium lining the stomach is interspersed with goblet cells which secret mucus.
- The mucus protects the lining of the stomach from acidic contents of the stomach and from digestive juices.
- The mucus also lubricates the passage of food thereby protecting the lining from abrasion.
- The shorter cells of the pseudo stratified epithelium lining the trachea and bronchi secrete mucus which traps bacteria and dust particles in incoming air and the cilia on the longer cells beat expelling them in the outward direction.
- Melanin in deeper layer of the skin prevents penetration of dangerous ultra violet radiations.

2) Absorption:

Cuboidal and columnar epithelia are modified for absorption

Adaptations:

 Columnar epithelial cells lining kidney possess microvilli on free surface which increase surface area for selective reabsorption. Columnar epithelium lining the small intestine possesses microvilli which increase the surface area for absorption of nutrients.

3) Secretion:

A number of epithelia cells are modified to produce secretions such as mucus, enzymes or hormones. E.g. the columnar epithelium lining the stomach is interspersed with goblet cells which secrete mucus.

4) Movement of materials along a cavity of tubule:

Ciliated epithelium lining the inside of respiratory passage eliminates small particles of dust and other foreign materials which have got trapped in mucus secreted by goblet cells.

In oviducts, rhythmic beating of cilia moves the ovum towards the uterus along the fallopian tube.

5) Locomotion:

In flatworms, ciliated epithelium lines underside of the body where they aid locomotion.

6) Tissue replacement:

Replacement of worn out cells through rapid mitotic division of cells of germinal layer.

7) Reduction of friction:

The smooth, tightly interlocking epithelial cells that line endothelium of blood vessels reduce friction during blood flow.

8) Sensory function:

Epithelial tissues in the skin contains receptors which detect changes in the environment.

9) Exchange of materials:

Squamous epithelium which lines the alveoli of the lungs and the blood capillary walls is extremely thin and flattened to reduce diffusion distance.

CONNECTIVE TISSUE

Connective tissue is a composite tissue and has three basic components.

i) **Cells:** they are the living components that are widely separated from each other. They originate from the embryonic mesoderm.

ii) **Fibres:** there are several types of fibres scattered in between the cells. They form the extracellular material. Blood is devoid of any fibres.

iii) **Matrix:** tit forms the basic ground tissue in which both the cells and the fibres are suspended. It is nonliving, transparent, fluid or semi fluid in nature. It contains various organic and inorganic substances, the most important being hyaluronic acid. The kind of matrix varies in different tissues.

Location of connective tissue

 It is present in between different tissues and organs.

- It is present inside and around the body organs.
- The skeletal tissue is present in the form of bone and cartilage.

- Fluid connective tissue is present throughout the body.

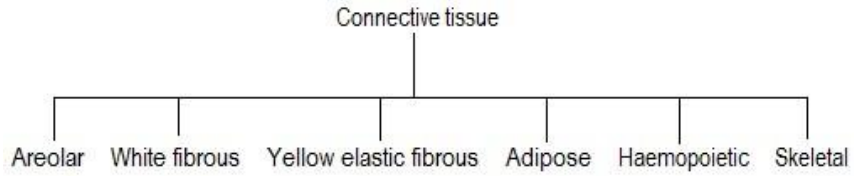
Functions of connective tissue

Connective tissue is basically a binding and packaging tissue but has many other important functions as well.

- It binds various tissues together like skin with the muscles and muscles with the bones.
- It forms sheaths around the body organs and makes a kind of packaging tissue.
- The areolar tissue protects the body against wounds and infection.
- The adipose tissue stores fat and insulates the body against heat loss.
- The supportive tissue forms shape and the frame work of the body.
- The haemopoietic tissue produces blood.
- The lymphatic tissue helps the body to build immunity by producing antibodies. **Types of connective tissue**

The type depends on the kind of matrix present. They include connective tissues proper, skeletal tissue and vascular (fluid/haemopoietic) tissue as summarized below

Summary of the connective tissue



1) Areolar tissue

This is found around all organs in the body. It consists of a semi-fluid matrix containing a variety of cells and fibres.

The cells are:

Fibroblasts: These are spindle shaped flattened cells with an oval nucleus. *They produce fibres* and so are generally seen close to them.

Mast cells: These are large oval shaped cells and contain granular cytoplasm. They secrete the matrix and chemicals heparin and histamine. ***Heparin*** is an anticoagulant while ***histamine*** is anti-inflammatory and is released from tissue when they are injured. **Macrophage or histocytes:** These are large amoeboid cells with a kidney shaped nucleus. They engulf bacteria or other foreign particles. They are capable of amoeboid movement and can ingest damaged cell tissues.

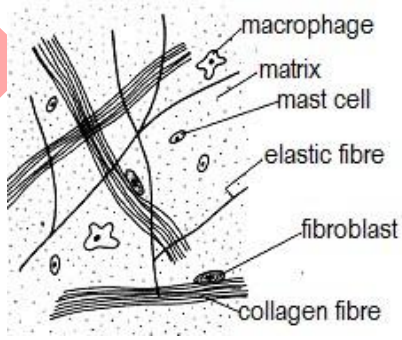
Plasma cells: these are small round or irregular cells. They produce antibodies that help in self-defense.

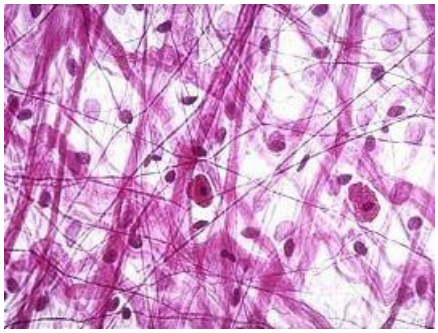
There are two types of fibres in areolar tissue:

The **collagen/white fibres:** these are long, wavy and unbranched fibres present in bundles. They are flexible but inelastic.

The **elastic/yellow fibres:** these are long, straight and branched fibres arranged singly. They are flexible and elastic as they contain protein elastin.

Transverse section of areolar





2) White fibrous tissue:

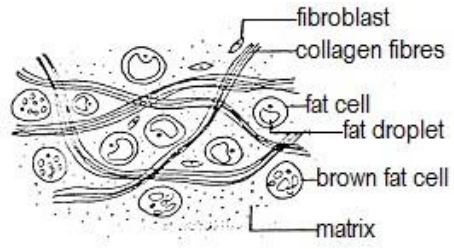
This consists of glycoprotein matrix containing densely packed collagen fibres. The collagen fibres are strong, flexible yet inelastic and have a high tensile strength. They are abundant in tendons and ligaments.

3) Yellow elastic fibrous tissue:

This consists of a glycoprotein matrix containing loose network of fibres. It is strong and elastic. Such tissue is found in ligaments where it binds bones to other bones. It is also found around the walls of arteries and it is also found as a component of the lungs and associated air passages as well as in the great cords of the neck. **4) Adipose tissue (fatty tissue):**

This is areolar tissue containing many **fat cells** which act as an energy reserve, for insulation and also act as a shock absorber.

There are two types of adipose tissue; **Adipose tissue structure i) White adipose tissue:**



The white adipose tissue is called so because the cells appear white due to accumulation of fats. It is distributed throughout the body particularly the deep layers of the skin.

ii) Brown/yellow adipose tissue:

This is commonly in young mammals and some hibernating mammals. It is important in temperature regulation.

It is supplied within blood capillaries and appears red. It differs from the white because of; It's coloured and has limited location in the body e.g. it is found around the neck.

 The fats in brown remain as small droplets i.e. do not form big globules. The nucleus of the brown remains centrally placed.

5) Haemopoietic tissue:

This forms the red and white blood cells and is located in the red bone marrow and lymphoid tissue of mammals.

6) Skeletal connective tissue: This is made up of cartilage and bone. **i) Cartilage:**

Cartilage is a tough, hard but flexible connective tissue. It can resist strain and can absorb the mechanical shock. It consists of solid or semi-solid **matrix** in which are embedded the cartilage cells called **chondrocytes** and the **fibres**.

Structure:

- The cartilage is enclosed in a sheath of white fibrous tissue called **perichondrin**.
- Next to perichondrin is a layer of **chondroblasts** which eventually form the chondrocytes.
- The **chondrocytes** are dispersed in the matrix and occur in the fluid filled spaces called **lacunae**.
- Each lacuna contains two to three chondrocytes.
- Each chondrocyte is a large, angular cartilage cell with a distinct nucleus.
- The matrix has a protein **chondrin** and lacks blood vessels.

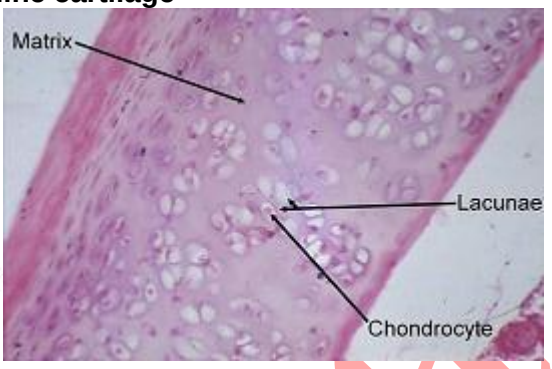
Types of cartilage

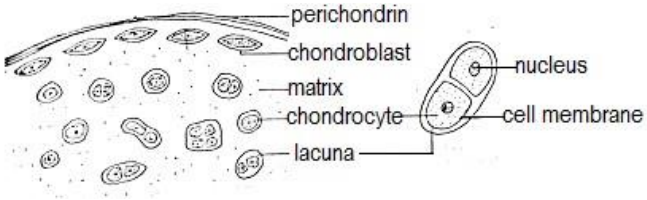
a) Hyaline cartilage

The simplest form of cartilage is known as hyaline cartilage which consists of only chondrin matrix and chondroblasts which secret it. It is glassy and semi-transparent in appearance and has very few or no fibres. It is slightly elastic and compressible.

It is found at the ends of the bones, larynx (voice box) and trachea. It forms the skeleton of cartilage fish.

Section through hyaline cartilage

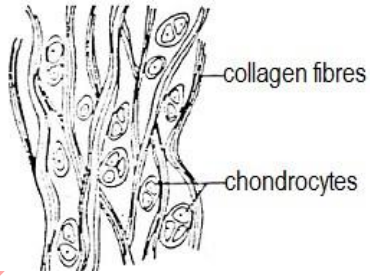




b) White fibrous cartilage

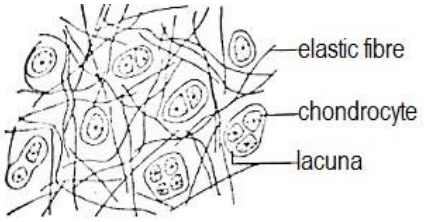
The matrix has bundles of densely packed white collagen fibres. It provides **Structure of white fibrous cartilage** great strength and a little degree of flexibility. It acts as a shock absorber by giving a cushioning effect.

It is found between the adjacent vertebrae.



c) Elastic cartilage

This has a semi-opaque matrix with many yellow elastic fibres. It is highly **Structure of elastic cartilage** flexible and elastic. The tissue recovers the shape quickly. It is found in external ear, eustachian tube, nose and the epiglottis.



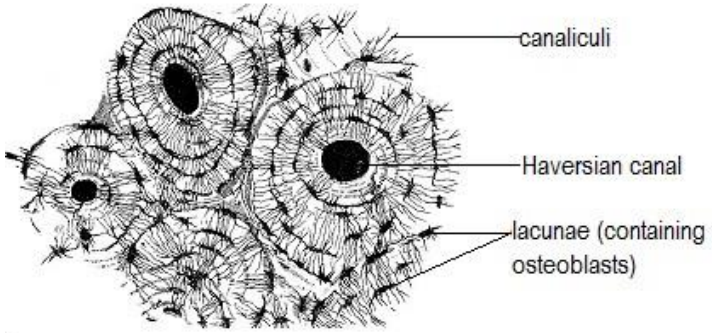
ii) Bone:

Bone is a supportive and protective tissue. The matrix is solid and **calcified**. Most bone mass consist of salts of calcium and phosphate. Small amounts of sodium, magnesium, potassium, chloride and fluoride are also present. The phosphates and carbonates of calcium and magnesium give hardness and strength to the bone. The matrix contains protein **ostein**. In the matrix are embedded the bone cells osteocytes and mainly the **collagen fibres.**

Structure of a bone:

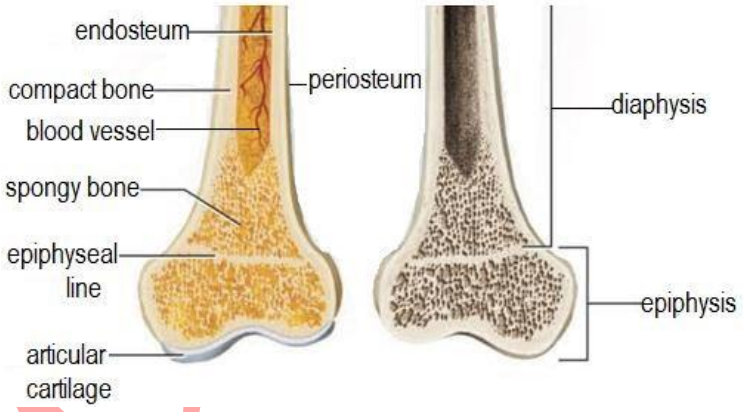
- Each bone is enclosed in a layer of white fibrous connective tissue called the **Periosteum**. It is through the Periosteum, the blood vessels and nerves pierce in.
- In a bone, the matrix is arranged in concentric circles called **lamellae.**
- In between the lamellae are present, a number of living bone cells called **osteoblasts** or **osteocytes**, in the fluid-filled cavities called **lacunae**. Osteoblasts are active bone cells while osteocytes are inactive osteoblasts.
- Each lacuna has fine cytoplasmic extensions called **canaliculi** which pass through lamellae and make connections with other lacunae.

Transverse section through a bone



Structure of a compact bone:

- A compact bone consists of concentric cylinders of bony **Longitudinal section of a long bone** lamellae surrounding a central **Haversian canal** with an artery and vein.
- Osteoblasts interspersed between the lamellae aid bone deposition.
- A layer of dense connective tissue, the **periosteum** covers the surface of the bone.
- In the centre of a compact bone is present a bone marrow cavity lined by **endosteum**.
- Throughout the bone, the lamellae are present in concentric circles except at the periphery where they are arranged circumferentially.



Differences between bone and cartilage

Bones	Cartilage
Matrix is ostein	Matrix is chondrin.
Matrix is firm, inelastic and rigid.	Matrix is firm, elastic and flexible.
Surrounded by periosteum.	Surrounded by perichondria.
Blood vessels and nerves present.	Blood vessels and nerves absent.
Have osteoblasts that form the osteocytes.	Has chondroblasts that form the chondrocytes.
Osteoblasts form the ostein matrix.	Chondrocytes form the chondrin matrix.
Have inorganic materials like Ca and P ions.	Lacks the inorganic molecules.
Marrow cavity is present in long bones.	Marrow cavities absent.
Have concentric circles of lamellae with lacunae and canalicunae.	Lacks the lamellae, lacunae and canalicunae.
Osteoblasts are star shaped.	Chondroblasts are spherical.
Relatively metabolically active.	Not metabolically active.
Osteoblasts are arranged in concentric circles.	Chondroblasts are scattered randomly in the matrix.
Can manufacture blood cells from the bone marrow.	Cannot manufacture blood cells.
Matrix has haversian canals.	Matrix has no canals.
Has a secretory function.	No secretory function.

MUSCULAR TISSUE

This is composed of specialized thin and elongated cells called muscle fibres. These muscle fibres have the capability to contract and relax. This property of contractility is due to presence of protein filaments myosin and actin present in their cytoplasm.

Basic structure:

- All muscles are made up of elongated and thin cells called **muscle fibres.**
- The muscle fibres contain specialized cytoplasm called **sarcoplasm** that contains a network of membranes called **sarcoplasmic reticulum.**
- The muscle fibre may be bound by a cell membrane called **sarcolemma.**
- Each muscle fibre may contain numerous thin **myofibrils.**

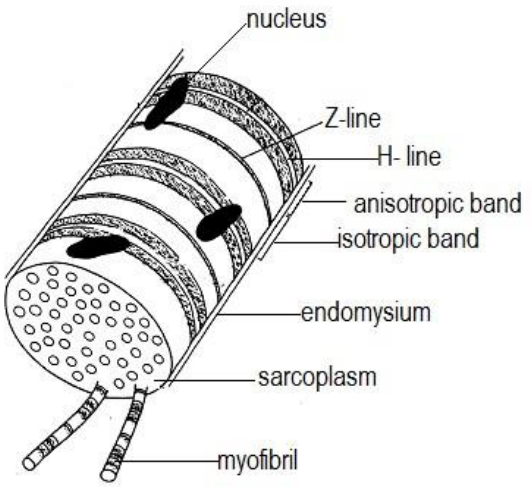
Types of muscles

1. Skeletal (striated/stripped/voluntary) muscles.
2. Smooth (involuntary/unstriated/unstripped) muscles.
3. Cardiac muscles.

1) Skeletal/striated muscles

These are voluntary in action i.e. they work under one's own will. **Skeletal muscle fibre** They bring about the movement of the organs and the locomotion of the body. They undergo powerful and rapid contractions with short rest periods and hence get fatigued easily.

Location: attached to the skeleton in the head, trunk and limb region.



Structure:

A skeletal muscle possesses distinct **cross-striations** in the form of light and dark bands or **I** and **A** bands respectively. **I** means **isotropic** i.e. that allows the light to pass through and so appears **lighter** while **A** means **Anisotropic** i.e. that does not allow light to pass through and so appears **darker.** A muscle is composed of a number of multi-nucleate cylindrical **muscle fibres**. Each muscle fibre further consists of numerous thin **myofibrils.**

2) Smooth or unstriated/involuntary muscles

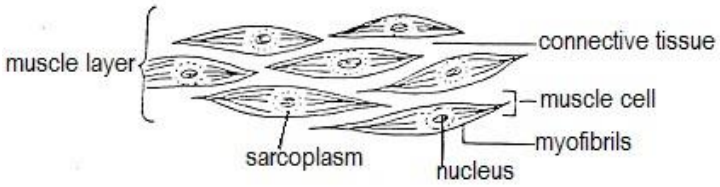
Smooth muscles are involuntary in action and cannot be moved by one's own will. The cells undergo prolonged and slow contractions and relaxations.

Location: walls of visceral organs like stomach, intestine, ureters, kidneys, blood vessels, etc.

Structure:

- A smooth muscle consists of sheets of densely packed elongated fibres running parallel to each other, bound together by connective tissue.
- Each muscle fibre is spindle shaped, tapering at both ends and uninucleate. It lacks sarcolemma.
- Each muscle fibre contains numerous fine contractile myofibrils arranged longitudinally.
- The nucleus is centrally placed and is surrounded by little sarcoplasm.
- The actin and myosin filaments are randomly distributed and hence there are no striations or light and dark bands.
- It is shorter than skeletal muscle
- It has less mitochondria and other organelles and much less extensive sarcoplasmic reticulum.

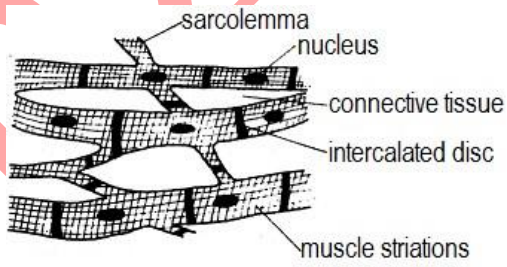
Longitudinal section of the smooth muscle from the alimentary canal



3) Cardiac muscle

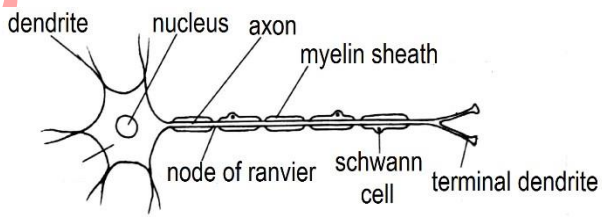
The cardiac muscles are **myogenic** meaning the contractions are generated within the muscle itself. They do not have to be initiated by the nervous system.
The rate of contraction can be influenced by the autonomic nervous system.
The cardiac muscles have rhythmical contractions and relaxations and do not get fatigued. They need a constant supply of a large amount of energy.
Location: Found only in the heart.
Structure:

- The muscle cells are short, cylindrical and branched cells joined end to end to form rows.
- They show faint, but regular cross striations (light and dark bands) **Structure of a cardiac muscle** indicating a regular arrangement of myosin and actin filaments.
- Each muscle fibre has numerous mitochondria, myofibrils with sarcomeres and many nuclei. It has abundant cytoplasm and glycogen granules.
- The cells are connected to each other by special zigzag junctions called **intercalated discs.**
- In between such discs generally one nucleus is present.



Nervous tissue

The nerve tissue is made up of millions of nerve cells called **Structure of a neuron neurons**. The neurons are highly specialized cells and form the nervous system of the body.
They provide the quickest mean of communication within the body and help the body give response to the external stimuli. The nervous tissue does not regenerate when damaged.



Roles played by dead cells in multicellular organisms

i) Support and protection:
- Nails, horns, hooves, down feathers and dead skin cells in animals.
- Sclerenchyma has thick walls for mechanical support.
- Heart wood gives a strong internal support.

ii) Protection from loss of fluids and invasion of harmful microbes in:
- The outer layer of skin in animals.
- The cork and bark of the tree.

iii) Create channels for conducting without leakage. Xylem vessels have dead walls which help conduct water and minerals to great heights without leakage.

iv) Development of other organs:

- During metamorphosis many tissues and organs like gills and tail in tadpole stage die and help it to become a frog.
- During maturation of xylem in cells of flowering plants, the cross walls dissolve giving rise to long columns to help in the conduction of water and minerals.

Biological life fact on death: *Death is a biological phenomenon which is a part of an organism's lifecycle. Each organism has a certain length of time for which he will survive. This is called its lifespan. It is a period from birth to death. It is different for all species. Even if an organism does not meet an accident, does not suffer from a disease, does not fall prey to predators, death comes as a last event of aging.*

Aging is a prerequisite for natural death. The deterioration in the structure and of body cells starts after adulthood where there is a gradual degeneration of organs. This is the final stopping of the vital organs like heartbeat and respiration of the body.

It is an irreversible process. It is necessary for the continuity of life on earth. Some of the advantages of death are:

- *The cells that die over a period of time play very important roles.*
- *Helps to regulate the number of individuals in a population. It prevents overcrowding and so maintains an ecological balance.*
- *The decomposers (microbes) act on dead and decaying organisms. They convert the complex organic molecules into simple forms like C, H, O, N, S, etc. these are returned to soil, air and water. The recycling of minerals helps in maintaining a balance in nature.*

WORKED OUT SAMPLE EXAMINATION QUESTIONS

1. Describe how the structures of the following tissues are adapted to their functions:
i) Striated (skeletal) muscular tissue ii) Parenchyma tissue in plants.

Note: In each instance it is essential to show clearly how the structure permits a specific function to be carried out efficiently. You ***do not*** have to present your answers in table format.

a) Skeletal muscle.

Structure	***Function***
Elongated fibres	*Allow considerable contraction.*
Parallel fibres	*Give maximum contractile effect*
Fibre ends tapered and interwoven	*Provide strength*
Large number of mitochondria	*Provide large amount of ATP*
Actin and myosin arrangement in sarcomere	*Allows contraction by filament sliding over each other*
Rich supply of blood vessels	*Provide adequate supply of oxygen and glucose.*
Myoglobin present	*To store oxygen for release when blood oxygen levels are low.*
Motor end plates	*Allow muscle stimulation*
Fibres arranged in motor units	*To allow variable degrees of contraction.*

b) Parenchyma tissue

Structure	**Function**
Unspecialized tissue	*Variety of functions*
Many intercellular spaces	*Diffusion of gases*

Isodiametric cells	*Packing material*
Thin cellulose cell walls	*Permit passage of materials*
Transparent cell wall	*Permits entry of light for photosynthesis*
Permeable walls	*Allow water entry for turgidity*
Large cells/large vacuoles	*Provide storage space*
Chloroplasts present	*Allow photosynthesis*
Leucoplasts present	*To store starch*

2. Describe the structural adaptations of vascular tissues for support.

Note: this question requires you to know the **structural** appearance and composition of all the tissues that make up the vascular tissues in plants and describe how they are adapted for support. You should not limit yourself to the **vascular system** i.e. xylem vessels and phloem vessels but all tissues in the system. The vascular tissues in plants are the phloem parenchyma, parenchyma, collenchyma, sclerenchyma, sclereids and tracheids.

- *Phloem parenchyma tissue has spherical/polygonal cells that form radial sheets/medullary rays for support.*
- *Parenchyma tissue has cells with a flexible membrane that allow the cells to expand and become turgid with cells closely packed hence offering hydrostatic support.*
- *Collenchyma tissue has polygonal/rectangular cells that have cellulose cell wall to offer tensile strength and compressional strength for extra support.*
- *Sclerenchyma tissue in the form of fibres is lignified, elongated and longitudinally arranged in sheets/bundles for support.*
- *Stone cells/sclereids are also a form of sclerenchyma which are also lignified, spherical and arranged in groups to offer firmness.*
- *Xylem also comprises of the tracheids and vessel elements that are also lignified to offer strength.*
- *In stems, vessels are at the peripheral of the stem for support.*
- *Tracheids have tapering ends that interlock with neighboring tracheids for firm support.*
- *Mature xylem completes development by annular or spiral or reticulate lignification to increase support.*

3. Describe the structure of the vascular system in higher plants.

Note: The vascular system in higher plants consists of two types of vascular tissue, the xylem and phloem.

- The xylem contains two types of conducting cells: tracheids and vessel elements. Both types of conducting cells are hollow, nonliving and lack end walls. They are connected end to end to form a continuous pipeline for water and mineral transport. The xylem elements have lignified side walls which are perforated by numerous bordered pits.
- The conducting cells of phloem are the sieve-tubes, each associated with a companion cell. Sieve-tube cells contain cytoplasm but no nuclei. Strands of cytoplasm, called plasmadesmata extend from one cell to another through the sieve plates (perforated cell end walls).
- The vascular system extends from the roots to the leaves and vice versa. In the roots, the vascular tissue is located in the vascular cylinder. In the stem, it forms vascular bundles and in the leaves, it is found in leaf veins.

4. How is the vascular system in plants adapted to its function?

Note: The vascular system in higher plants consists of two types of vascular tissue, the xylem and phloem.

Adaptations of xylem for its function.

- *Its cells have no end walls and so allow unimpeded flow of water.*
- *Lignin in the cellulose side walls makes it impermeable to water and solutes. This prevents wastage during transport.*

- *Having spiral and annular thickening gives it a high tensile strength and prevents the vessel from collapsing.*
- *Presence of pits allows passage of water in and out of the lumen.*
- *Lignin also strengthens the vessels in order to give structural support to the plant.*
- *Have elongated cylindrical cells for continuous flow of water.*
- *The torus in bordered pits acts as a plug for controlling passage of water in some plants.*

Adaptations of phloem for its function:

- *The sieve tubes are elongated, cylindrical cells connected end to end. Their end walls have sieve plates perforated with pores to allow continuous flow of materials.*
- *The sieve tubes have no nucleus, to create more room for movement of materials.*
- *Within the lumen of the sieve elements are cytoplasmic filaments/strands which are continuous from cell to cell to enable continuous flow of materials.*
- *The companion cells have nuclei and other organelles. They control the flow of materials through the phloem sieve tubes.*

5. How is support achieved in woody plants?

Note: state how the tissues in plants provide support to plants.

- *By use of turgid cells in young parts of the plant*
- *Collenchyma tissues with cell walls thickened with cellulose.*
- *By use of sclerenchyma tissues and xylem tissues in which cell walls are strengthened with deposition of lignin.*

6. Describe the changes that take place in a cell that eventually develops into a xylem vessel element.

Note: describe how xylem vessel element is formed from a single cell.

The cells of the procambium strand divide by mitosis. The cell formed elongates/ enlarges and vacuoles appear in cytoplasm. Cross walls between adjacent cells' cross wall disintegrate forming perforation which is continuous with that of adjacent cells. A secondary wall is formed by addition of extra cellulose and lignin. This results in death of the cells leaving the cell with an empty lumen/ hollow.

7. Make a labelled drawing of a living parenchyma cell of a plant.

Note: Only one cell of a parenchyma tissue is essential information to the question above. Note that 'living' means you restrict yourself to structures visible using a light microscope since electron microscope specimens are dead already.

8. a) How do the structure of the following differ from the parenchyma cell?

i) A leaf epidermal cell

ii) An apical meristem cell

and iii) A xylem tracheid

Note: The following table forms a basis for comparison but each cell type should be dealt with in turn and a structure should only be included where it differs from the parenchyma cell.

Structure	***Parenchyma cell***	***Leaf epidermal cell***	***Apical meristem cell***	***Xylem tracheid***
Shape	*Isodiametric*	*Flat and thin*	*Isodiametric*	*Long and cylindrical*
Vacuole	*Large*	*Small*	*Very small if present*	*None*
Cytoplasm	*Little*	*More present*	*Much and dense*	*None*

Cell wall	*Thin cellulose*	*Thick outer walls of cellulose and cutin.*	*Very thin with cellulose*	*Very thick and impregnated with lignin.*
Nucleus	*Small and at the peripheral*	*Fairly small and at the peripheral*	*Large and central*	*None*
Pits	*Few*	*Few*	*None*	*Many*
Storage granules	*Common*	*Few*	*None*	*None*
Chloroplast	*Sometimes*	*Rarely*	*None*	*None*

b) For each of the cells above in 8 (a), give an example of a cell or groups of cells which perform similar functions in a mammal. Comment on their differences.

Note: for any of the cells above, equate them to mammalian cells or tissues which perform similar roles. Compare them and write a brief comment on the difference stated. They are equated as follows:

Plant	Mammal
Leaf epidermis	**Stratified epithelium cells** of the skin
Apical meristem	Rapidly dividing tissue such as germinative cells of the **Malpighian layer** of the skin.
Xylem tracheid	• For transport (artery/vein as these contain muscular, connective and epithelial tissues. capillaries contain squamous epithelial cells). • For support (**bone tissue**).

Answer plan:

Leaf epidermis cell	***Stratified epithelium***	***Comment***
Has cellulose wall, vacuole and starch	*Not present*	*Plant/animal cell difference*
One cell thick	*Multiple celled layer*	*Animals move, more abrasion.*
Cutin present	*Keratin present*	*Cutin waterproof, keratin gives mechanical protection.*
Transparent	*Opaque*	*Light must penetrate for photosynthesis.*

Apical meristem	***Malpighian layer***	***Comment***
Restricted to apices	*Covers whole body*	*Plants grow at apices, animals all over.*

Xylem tracheid	***Bone***	***Comment***
Strengthened with lignin	*Strengthened with calcium salts*	*More rigidity in animals, flexibility at joints only. Slightly flexibility throughout plants.*
No nucleus or cytoplasm	*Nucleus and cytoplasm*	*Xylem dead, bone living*
Hollow with pits in wall	*Canals within bone but largely solid*	*Xylem also used to transport water.*

"Every adversity, every failure and every heart-ache carries with it the seed of an equivalent or a greater benefit"

Team #make sure it hurts