Chapter 1 CYTOLOGY, CELL CYCLE AND CELLULAR TRANSPORT

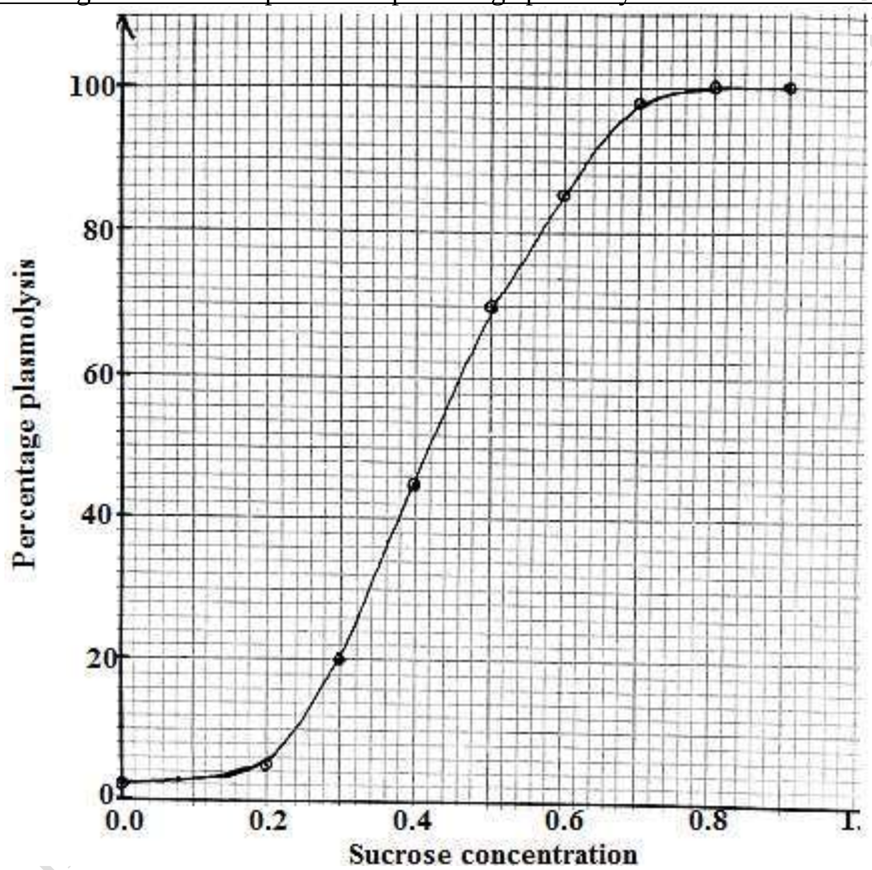
Question 1.

In an experiment to determine the water potential of plant cells, leaf strips of commelina of equal dimensions were immersed in equal volumes of sucrose solutions of different concentrations. After a standing time of 30 minutes the strips were removed and several epidermal strips were mounted in the same bathing solution. The average total number of cells in the field of view and the total number of plasmolysed cells was recorded from which the percentage plasmolysis at each sucrose solution was established. Results are shown below.

Sucrose concentration	0.0	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
Percentage plasmolysis	2	5	20	45	70	85	98	100	100

(a).Represent the data in the above table graphically ***(06 marks)***

A graph showing the relationship between percentage plasmolysis with sucrose concentration



(b).Explain the shape of the graph ***(11 marks)***

Generally the percentage of cells plasmolysed increases with increase in sucrose concentration. The plant cells tend to lose water by osmosis to the hypertonic solution and their protoplasm shrinks leading to plasmolysis. From 0.0M to 0.2M sucrose concentration, percentage cells plasmolysed increases very slowly. This solution is relatively dilute. More cells are turgid than the cells that are plasmolysed. In the hypotonic solution most of the cells take in water by osmosis and become turgid rather than plasmolysed. From 0.2M to 0.45M sucrose concentration, the percentage cells plasmolysed increases more gradually then increases drastically up to 0.55M sucrose concentration. As the sucrose solution tends to the isotonic solution more cells are plasmolysed than those which are turgid. At the isotonic solution percentage cells plasmolysed is in equilibrium with the turgid cells. Above 0.55M sucrose concentration, percentage cells plasmolysed increases gradually to a maximum at 0.8M sucrose concentration remain constant thereafter with further increase in sucrose concentration. This is because in the hypertonic sucrose solution, the plant cells lose water by osmosis. Many plant cells then become plasmolysed and by 0.8M sucrose concentration and above all the cells are plasmolysed in the hypertonic solution.

Explain why;

(i).Leaf strips of equal dimensions were used? ***(03 marks)***

Leaf strips of equal dimensions were used to have comparable osmotic effects in all solutions and generate comparable results; for accuracy/ minimizing experimental errors.

(ii).Epidermal strips were mounted in the same bathing solution? ***(02 marks)***

Epidermal Strips were mounted in the same bathing solution to maintain the osmotic conditions of the strips as they are observed under the microscope.

(iii).Equal volumes of the bathing solution were used? ***(02 marks)***

Equal Volumes of bathing solution were used to have comparable osmotic effects in the different test tubes

(iv).Epidermal strips were used for mounting? ***(02 marks)***

Epidermal strips were used for mounting since the epidermal cells are thin and can undergo rapid osmotic changes that are easy to observe within a short time.

(d).Determine the sucrose solution that relates to the water potential of the cells in this investigation.

Explain your answer ***(04 marks)***

0.42M sucrose concentration, at this concentration there is 50% plasmolysis. The cells plasmolysed equal the cells that are turgid. This implies that loss of water and uptake of water by osmosis are in equilibrium. Hence no net osmosis occurs in this isotonic solution.

(e).With reference to the test tubes with 0.2M and 0.7M sucrose concentration, suggest what would happen by the end of the experiment to:

(i).the volume and density or the batting solution ***(06 marks)***

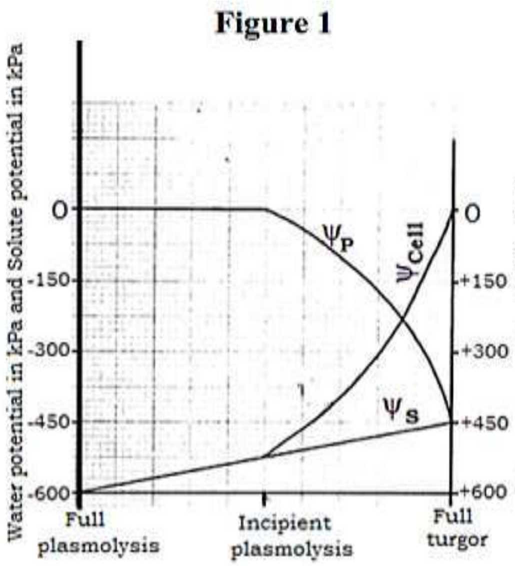
With 0.2M sucrose concentration, the solution is hypotonic, the cells would take up water by osmosis from the bathing solution. This implies that the volume of the bathing solution decreases and hence its density would decrease. With 0.7M sucrose concentration the solution is hypertonic, the cells would lose water by osmosis to the bathing solution. This implies that the volume of the bathing solution would increase and hence its density would increase.

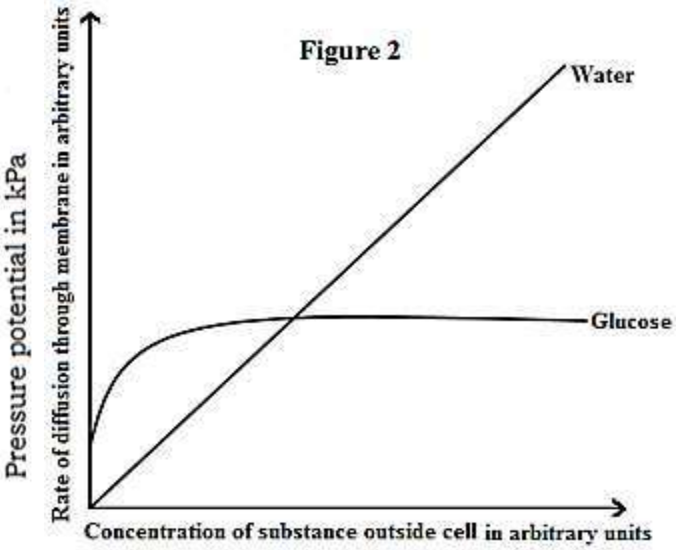
(ii).Solute potential and water potential ***(04 marks)***

In 0.2M sucrose solution the water potential and solute potential would increase i.e. become less negative due to the osmotic uptake of water from the hypotonic solution. In 0.7M sucrose solution the water potential and solute potential would decrease i.e. become more negative due to the osmotic loss of water to the hypertonic solution.

Question 2.

Figure 1 shows changes in the different potentials of a fully plasmolysed plant cell placed in a hypotonic solution. Figure 2 shows the rate of movement of two different substances across a phospholipid membrane; glucose by facilitated diffusion and water by simple diffusion, at varying extracellular concentration.





(a).From figure 1, compare the changes in pressure potential and water potential from full plasmolysis to full turgor. ***(05 marks)***

Similarities

Both ψ_{cell} and ψ_P generally increase from incipient plasmolysis to full turgidity

For both ψ_{cell} and ψ_P, attain maximum at full turgidity

Differences

Pressure potential	Water potential
Non-existent between full plasmolysis and incipient plasmolysis	Increases slowly between full plasmolysis and incipient plasmolysis
Attains a higher maximum value at full	Attains lower maximum value at full turgidity
Increase in pressure potential begins at incipient Plasmolysis	Increase in water potential begins at full plasmolysis
Non-existent at full plasmolysis	Extremely low at full plasmolysis

(b).As indicated in figure 1, explain the change that occur in water potential from full plasmolysis to full turgor. ***(15 marks)***

Initially water potential is very low/most negative; because of highest concentration of solutes since pressure potential is zero; water potential is equal to solute potential; thus water potential is 100% dependent on solute potential; Water potential increases slowly/becomes less negative from full plasmolysis to incipient plasmolysis because the cell has began taking in water by osmosis & the solute potential becomes less negative and so does the water potential. At incipient plasmolysis, water potential begins to increase more rapidly because the proto-plasmic contents have just began establishing contact with the cell wall; then pressure potential begins building up. From incipient plasmolysis to full turgidity, water potential increases rapidly because pressure potential increases rapidly because of the tightening contact between the protoplasm and the cell wall thus the water potential is being accounted for by both solute potential and pressure potential and since pressure potential is positive; water potential becomes less negative/ tends towards zero. At full turgidity, there is maximum water potential because the cell has expanded to its elastic limit; pressure potential being maximum at this point.

From figure 2:

(c).Describe the effect of increasing extracellular concentration:

(i).on glucose uptake. ***(07 marks)***

The rate of diffusion of glucose initially increases rapidly at lower extracellular fluid concentration; With further increase in extracellular fluid concentration; rate of diffusion of glucose slows down/ increases gradually to attain maximum rate of diffusion and then levels off/ remains constant thereafter.

(ii).on water uptake ***(05 marks)***

Rate of diffusion of water generally increases lineally or directly proportional to extracellular fluid concentration.

(d).Explain the observed rates of uptake of glucose and water. *(08 marks)*

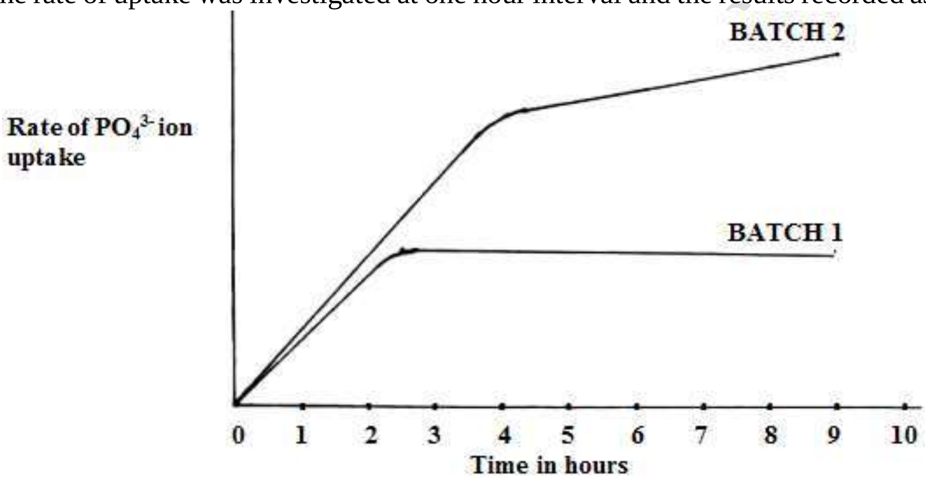
For glucose uptake;

Rate of diffusion initially increases rapidly because of the very steep concentration gradient permitting fast rate of diffusion. Rate of diffusion increases gradually/ slows down because the carrier proteins are progressively getting saturated with glucose molecules; reducing the number of free carrier proteins. Rate of diffusion finally levels off/ remains constant because the carrier proteins are fully saturated with glucose molecules such that the rate of loading of carrier protein molecules with glucose is equal to that of offloading; None of the carrier proteins is thus available for binding any extra glucose molecules. Concentration gradient ceases.

For Water uptake;

Rate of diffusion increases rapidly following a linear pattern; because an increasing extracellular fluid concentration lowers the relative solute potential but of the cell. Water potential of the cell increases thus water is lost from the cell to the extracellular fluid by osmosis.

(e). The rate of uptake of phosphate ions by roots of spinach was investigated. Roots were cut into slices & divided into batches. Batch 1 was treated with cyanide after one and half hours of the experiment. Batch two was left as a control. The rate of uptake was investigated at one hour interval and the results recorded as a graph below.



(i).Comment on the effect of cyanide on the rate of uptake of phosphate ions *(02 marks)*

Cyanide has no effect immediately after it is applied; such that there is still rapid uptake of phosphate ions even after its application. After one hour of its application, rate of uptake remained constant ie no more new phosphate ions were taken up.

(e)(ii).Explain the effect of cyanide on the rate of uptake of phosphate ions *(08 marks)*

The uptake is not affected one hour after application because the roots are storing energy inform of ATP which is used for active transport of the phosphate ions. Besides the concentration gradient is still steep and so the phosphate ions diffuse passively. After one hour of application; the uptake ceased to increase because the concentration gradient had ceased to exist and all the stored energy inform of ATP had been used up. The cyanide now inhibits enzymes of respiration; no more ATP was made and no more active uptake possible which would be the alternative to passive diffusion since the gradient had ceased to exist.

(iii).Compare the rates of uptake for phosphate ions by both batches 1 and 2 *(03 marks)*

For the first two & half hours of the experiment; in both batches the root slices took up phosphate ions rapidly Between two and half hours to three and half hours; roots in batch one had stopped taking up phosphate ions but for roots n batch 2, uptake continues to be rapid. Beyond three and half hours of the experiment, roots in batch 2 continue to gradually take up phosphate ions while those in batch 1 ceased to take up phosphate ions**.**

(iv). Suggest explanations for the differences and similarities in the rate of uptake by roots of both batches

There is rapid uptake in the first two hours of the experiment due to passive diffusion since the gradient is still steep. For batch 2, uptake continues gradually after three and half hours but for batch 1, uptake ceases because the gradient had ceased to exist and any more uptake is by active transport. This is inhibited for batch one because of the presence of cyanide ion which is a metabolic poison; that inhibits respiration from taking place. For batch 2, uptake continues due to absence of a metabolic/respiratory poison thus respiration continues to release energy inform of ATP; that continuously runs the active process of taking in phosphate ion intake.

Question 3.

In a physiological investigation, screened red blood cells were placed indifferent concentrations of aqueous sodium chloride solution. In each case an average total of five thousand cells were viewed and the total number of haemolysed cells recorded. The results of this investigation are shown in the table below.

Sodium chloride concentration/g/100 ml	0.33	0.36	0.38	0.39	0.42	0.44	0.48
Number of cells haemolysed x10^3	4.9	4.5	4.0	3.4	1.5	0.8	0.1

(a)(i). Calculate the percentage cells haemolysed at each sodium chloride concentration.

Percentage cells haemolysed= $\frac{\text{number of cells haemolysed}}{\text{Average total cells viewed}}$ x 100

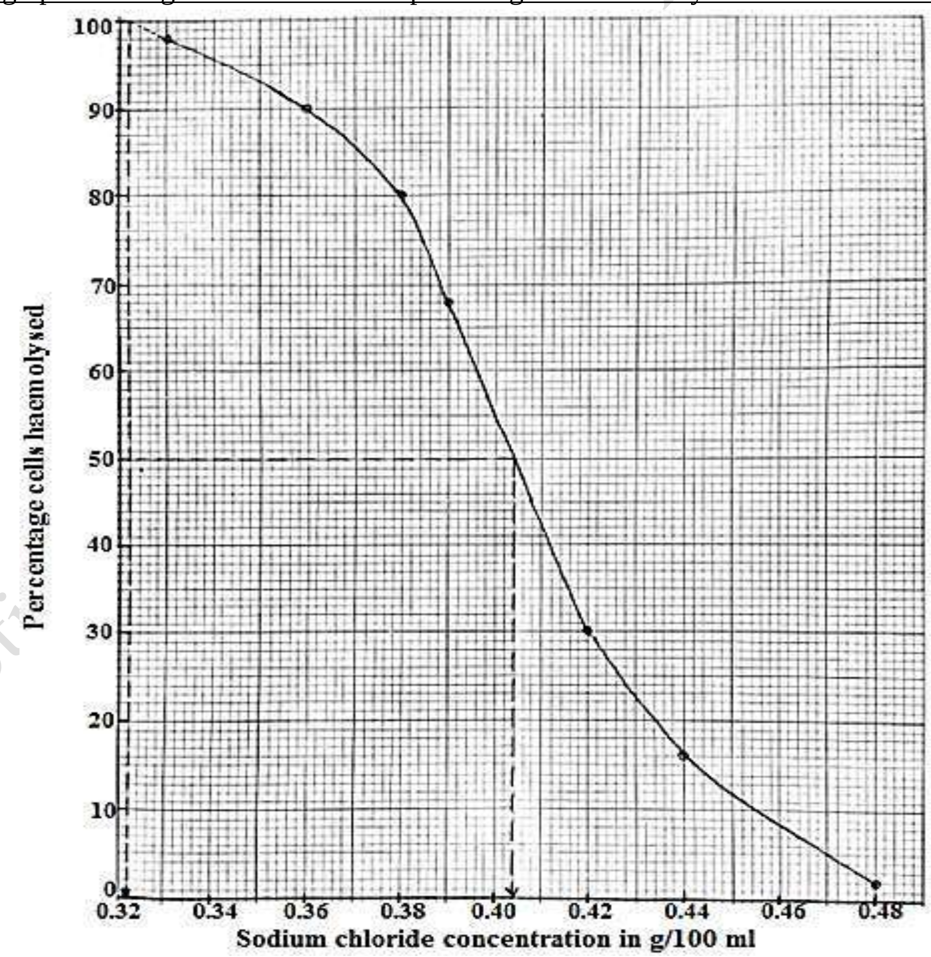
Average total cell viewed= 5

Percentage cells haemolysed = 20 x number of cell haemolysed

Sodium chloride concentration/g/100 ml	0.33	0.36	0.38	0.39	0.42	0.44	0.48
Number of cells haemolysed x10^3	4.9	4.5	4.0	3.4	1.5	0.8	0.1
Percentage cell haemolysed (%)	98	90	80	68	30	16	2

(ii).Plot a graph to show variation of percentage cells haemolysed with NaCl concentration

A graph showing the variation in the percentage cells haemolysed with NaCl concentration



(b)Describe the shape of the graph

Percentage cells haemolysed decreases with increase in salt concentration. Initially percentage cells haemolysed decreases gradually with increase in salt concentration from 0.33 to 0.38g/100ml. Then percentage cells haemolysed decreases drastically/rapidly with increase in salt concentration from 0.39 to 0.42g/100ml. Finally, percentage cells haemolysed decreases slowly with further increase in salt concentration.

(c).Explain the shape of the graph.

In hypotonic solution the red blood cells take up water by osmosis, cell volume increases and the relatively weak plasma membrane bursts releasing the cell contents. Since the bulk of the red blood cells is filled with haemoglobin or bursting a lot of haemoglobin is released hence haemolysis takes place with increase in salt concentration the bathing solution becomes less hypotonic and hence the percentage cells haemolysed gradually decreases. Towards the isotonic salt concentration, there is a drastic decrease in percentage cells haemolysis as the percentage cells haemolysed is almost in balance with the normal and crenated cells. Above the isotonic solution, the red blood cells lose water by osmosis, cell volume decreases and the red blood cells shrink (crenated). Therefore, the percentage cells haemolysed gradually decreases, as more cells are crenated.

(d) From the graph, determine the sodium chloride concentration

(i) At which 100% haemolysis occurs

100% haemolysis occurs at 0.322g/100ml ***(range is 0.321-0.323)***

(ii) isotonic to the red blood cells. (explain your answer)

Isotonic solution is 0.402g/100ml; ***(range is 0.401-0.403)***

At this salt concentration, there is 50% haemolysis. The solution is isotonic to the red blood cells; no net osmosis takes place. The cells haemolysed as a result of water uptake by osmosis in equilibrium with the cells crenated as a result of water loss by osmosis.

(e) Suggest what would happen if the red blood cells were placed in sodium chloride concentration of;

(i) 0.6 g/100ml

This salt concentration is hypertonic to the red blood cells. The red blood cells would lose water by osmosis; cell volume would decrease. The red blood cells would shrink and appear crenated. The percentage cells haemolysed would be very low.

(ii) 0.1g/100ml

This is hypotonic to the protoplasm of red blood cells. Red blood cells would take up water by osmosis; cell volume would increase and the red blood cells would burst releasing haemoglobin. The percentage cells haemolysed would increase.

(f).Give reasons why the red blood cells haemolize over a wide range of salt concentration.

In hypertonic solution they tend to take up ions such as chloride ions to reduce their osmotic pressure and hence reduce water loss by osmosis. In hypotonic solution the red blood cells tend to lose ions such as hydrogen carbonate ions, to lower their osmotic pressure and hence reduce the chance of taking up water by osmosis which would lead to bursting and hence haemolysis.

(g).Criticize a nurse who injects a patient with distilled water instead of medication for malaria.

The distilled water would make the blood hypotonic to the red blood cells. The red blood cells would take up water by osmosis & burst. This would instead worsen the condition of the patient hence the nurse would have made a grave mistake.

Question 4.

In an investigation, several potato tissue cylinders of approximately equal size were obtained using a cork borer; the cylinders were divided into two groups A and B. The mass of each of the cylinders were measured and recorded. Each of the cylinders in group A were placed in sucrose solution of a given concentration. Cylinders from group B were treated similarly except 0.1g of gibberellic acid (GA) was added to each sucrose solution. The setups were left to stand for 4 hours, then after 4 hours each cylinder was removed from its solution, reweighed and the percentage change in mass calculated. The results obtained were recorded in the table below.

Sucrose molarity (M)	**Percentage change in mass**	
	Group A	Group B
	Sucrose solution only	Sucrose solution + GA
0.0	+7	+42
0.1	+6	+38

0.2	+5	+36
0.3	+1	+27
0.4	-4	+6
0.5	-8	+3
0.6	-14	-3
0.7	-17	-4
0.8	-16	-7

Gibberellic acid(GA) is produced naturally in potato tubers and it stimulates the production of carbohydrase enzyme

(a).What precautions should be taken by the investigator to ensure that accurate results are obtained in this experiment ***(04 marks)***

• Cylinders must be from the same tissue
• Cylinders must be from the same plant.
• Volume of sucrose solutions must be the same.
• The cylinders must be weighed immediately to eliminate losing mass due to evaporation of water.
• Cylinders must be dried using a piece of tissue to remove excess water

(b)(i).Plot a graph of to show percentage change in mass of cylinders in groups A and B at different sucrose concentrations

(ii).Using the graph for group A; explain how change in concentration of sucrose affected the mass of the cylinders ***(04 marks)***

From 0 to 0.32M sucrose molarity, mass of cylinders increases; the solutions are hypotonic/dilute /less concentrated compared to the cell sap of tissues; the cells in potato tissue cylinders gains water molecules from the surrounding sucrose by osmosis. At 0.32M sucrose solution; no change in mass occurs; the sucrose solution is isotonic to the cell sap of cells in the tissue; no net movement of water occurs: Above 0.32 sucrose molarity, the mass of the cylinders decreases; the sucrose solutions are hypertonic/ more concentrated than the cell sap of the cells in the tissues; cells in the tissue lose water by osmosis to the surround-ding sucrose solution;

(iii).Explain the difference in the results obtained for groups A and B at the different sucrose concentrations ***(07 marks)***

Percentage increase in mass for group B is higher than that for group A; Gibberellic acid added diffused into the cells of potato tissues; loosening the cell wall; increasing its extensibility; and also lowers the water potential of the cells; water potential gradient between the cell sap of cells and sucrose solutions increased, allowing faster gaining of water by cells in the tissue from sucrose solutions; by osmosis; greatly increasing the mass; Percentage decrease in mass for group B is lower than that for group A, water potential of cells of tissues in group B is lower than that in group A; less water is lost from cells of tissues in group B to sucrose solutions; decreasing in mass.

(c)(i).From the graph, state the molarity of sucrose solution which would have the same water potential as the potato cylinders. Give a reason for your answer

(ii).Explain why the water potential of a sucrose solution always has a negative value ***(02 marks)***

Sucrose solutions always contain solute molecules which always reduce the free energy of water molecules present lowering water potential/ solutes reduce water potential since there are fewer free water molecules in the sucrose solution.

(d). State

(i).two ways in which similar results can be obtained without measuring masses of cylinders ***(03 marks)***

• Determining change in length of cylinders
• Determining change in volume of sucrose solutions bathing cylinders
• Determining change in diameter of cylinders.

(ii)the precautions necessary when using each of the methods ***(06 marks)***

Determining change in length of cylinders

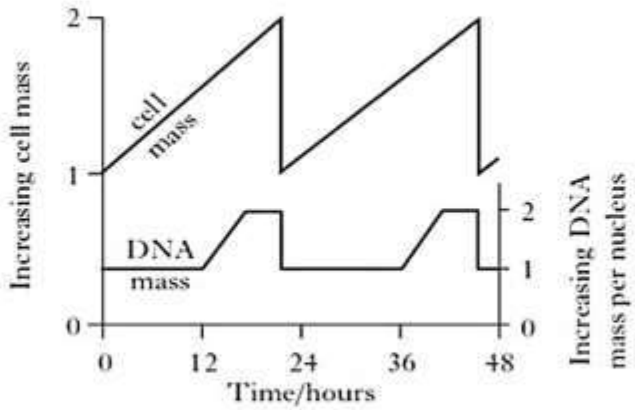
• All cylinders must be trimmed to the same length.
• Accurate timing must be ensured
• Measurements taken immediately the cylinders are obtained and even after the experiment

Determining change in volume of sucrose solutions bathing
• Solutions accurately delivered to measuring cylinders.
• Experiment carried out in graduated test tubes/measuring cylinder

Determining change in diameter of cylinder
• Cork borers used must be of uniform diameter
• Average measurements taken

Question 5.

Figure 1 below shows changes in the quantities of nuclear DNA and cell mass during repeated cell cycle.



(a).For one cell cycle only, describe the changes in:

(i).Mass of DNA ***(02½ marks)***

One cell cycle lasts from 0 hour to about 23 hours; DNA mass remains constant from 0 to 12hours; increases rapidly to about 18 hours; remains constant up to about 23 hours; decreases suddenly to original mass at about 23 hours;

(ii) Cell mass ***(01½ marks)***

Cell mass increases rapidly from 0 hour to a peak at about 23 hours; Decreases suddenly; to original mass at about 23 hours;

(b)For one cell cycle only, explain the trend in:

(i).Mass of DNA ***(08 marks)***

From 0 hour to 12 hours is the first growth (G1) phase; cell contents replicate except DNA; from 12 hours to about 18 hours is the synthesis (S) phase; DNA replicates to double original mass; from 18 hours to about 23 hours is the second growth (G2) phase and mitosis; no DNA synthesis at about 23 hours; cytokinesis occurs; halving the DNA mass in each new cell to the original mass;

(ii).Cell mass ***(08 marks)***

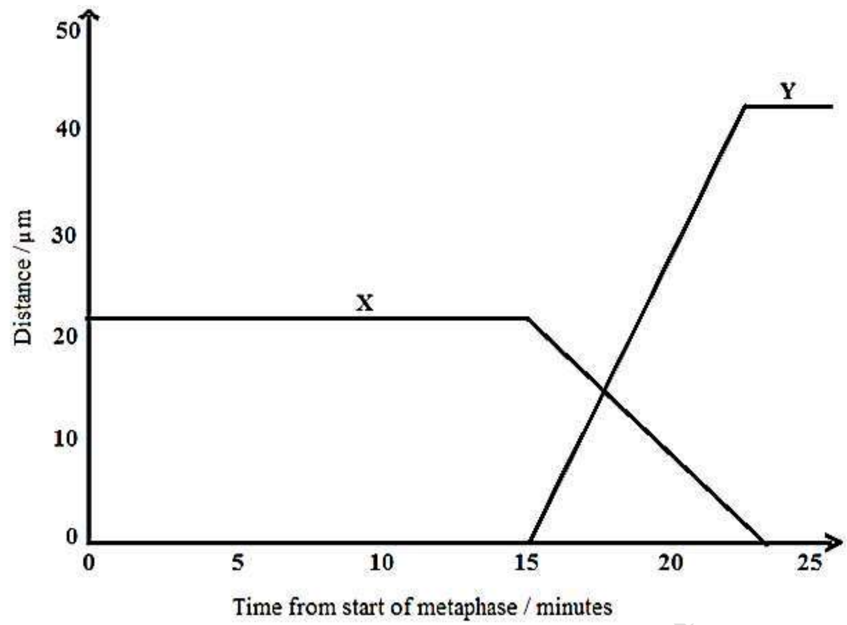
0 hour to about 23 hours marks the period of interphase and mitosis; during which organelles like mitochondria, cytoskeletal elements, endoplasmic reticula, ribosomes, Golgi apparatus, centriole, etc replicate and increase in number; and the cell grows (G1 phase); DNA replicates; and the chromosome content doubles; histones and other nuclear proteins are synthesized(S phase); Synthesis of additional proteins that support cell metabolism occurs (G2 phase); At about 23 hours cytokinesis divides the parent cell into equal sized daughter cells;

(c).Explain the significance of the observed changes in mass of DNA from 12 hours to about 23 hours.

From 12 hours to about 23 hours the mass of DNA increases rapidly to double the original mass; so that each daughter cell produced by cytokinesis gets a complete genome as it is in the parental cell;

In figure 2 below, the graphs represent changes during mitosis in the distance between:

(i).Centromeres of chromatids and pole of the cell.



(d) Identify what curves X and Y represent ***(01 marks)***

X represents distance between centromeres of chromatids and cell poles;

Y represents distance between centromeres of sister chromatids;

(e).Explain the trend in distance represented by:

(i).Curve X ***(08 marks)***

From 0 minute to about 15 minutes the distance between centromeres of chromatids and poles of the cell is relatively long; and remains constant; because the cell is in metaphase stage; chromosomes are at metaphase plate; with sister chromatids still held at centromeres; From about 15 minutes to about 23 minutes the distance between centromeres of chromatids and poles of the cell decreases rapidly to 0 µm; because after split-ting during anaphase stage; sister chromatids are pulled rapidly towards poles by microtubules (spindle); and eventually arrive at the poles during telophase stage;

(ii).Curve Y ***(07 marks)***

From 0 minute to about 15 minutes the distance between centromeres of sister chromatids was 0 µm; because sister chromatids were still joined at their centromeres during anaphase; From about 15 minutes to about 23 minutes the distance between centromeres of sister chromatids increased rapidly to a maximum; because after splitting during anaphase stage; sister chromatids are separated from each other rapidly by the pulling of microtubules (spindle) towards poles; After about 23 minutes the distance between centromeres of sister chromatids is very long and remains constant; because sister chromatids have arrived at the respective poles during telophase stage;

(f).Explain the variation in the maximum distance achieved in X and Y ***(03 marks)***

The maximum distance for Y (between centromeres of sister chromatids) is almost twice longer than for X (distance between centromeres of chromatids and poles); During metaphase, chromosomes are at metaphase plate which is equidistant from either pole of the cell therefore maximum for X is shorter; Maximum for Y is longer since spindles pull chromatids to the extremes of the cell (poles) which are very distant apart;

Question 6.

The table below shows the percentage of red blood cells haemolysed and the percentage of plasmolysed onion epidermal cells when the tissues are separately placed in a series of sucrose solutions ranging from 0.0 to 0.6M in covered dishes at a constant temperature of 20°C:

Concentration of sucrose concentration in mol/dm^3	Percentage of red blood cells haemolysed	Percentage of plasmolysed onion epidermal cells
0.00	100	0
0.10	93	0

0.20	86	0
0.25	82	1
0.30	65	2
0.40	27	4
0.45	10	13
0.50	6	70
0.55	3	100
0.60	0	100

(a)(i). Represent the information graphically using the same set of axes. ***(08 marks)***

(ii). Describe the percentage of plasmolysed onion epidermal cells with increasing concentration of sucrose solution. ***(06 marks)***

From 0.0 to 0.2 sucrose concentration, percentage of onion cells plasmolysed was constant. From 0.2 to 0.4M sucrose concentration, percentage of onion cells plasmolysed increased gradually. From 0.4 to 0.6M sucrose concentration; percentage of plasmolysed onion cells increased rapidly reaching maximum at 0.6M and then remained constant.

(iii). Compare the percentage of red blood cells haemolysed and the percentage of plasmolysed onion epidermal cells. ***(05 marks)***

Interval of sucrose concentration in moldm^{-3}	**Percentage of red blood cells haemolysed**	**Percentage of onion epidermal cells plasmolysed**
0.0 to 0.25	Decreased gradually	Was constant
0.25 to 0.45	Decreased rapidly	Increased gradually
0.45 to 0.55	Decreased gradually	Increased rapidly
0.55 to 0.6	Decreased gradually	Was constant
0.0 to 0.44	Was higher	Was lower
0.45 to 0.6	Was lower	Was higher

(b)(i).From the graph, determine the concentration of the onion epidermal cells to be used to determine their solute potential. ***(02 marks)***

0.47moldm^{-3}

(ii) Fully explain how you arrived at your answer in (b) (i). ***(08 marks)***

Using the relationships: Water potential = solute potential + pressure potential

Water potential = solute potential of solution, of a cell. When the two are in equilibrium; Ψcell = Ψsolution, when Ψp= 0. At incipient plasmolysis the protoplasts have shrunk to the point where they begin to pull away from the cell walls, and the pressure potential is zero (Ψs=0), since no pressure is exerted by the protoplasts against the cell walls. So Ψcell=Ψs = Ψsolution=Ψs solution (from (1) and (2) above). Hence the solution causing incipient plasmolysis has the same solute potential as the cell sap. But solute potential varies between cells in the same tissue and incipient plasmolysis is said to have been reached when 50% of the cells have plasmolysed.

(c) Give an explanation of each of the following:

(i) Red blood cells placed in a 0.0M sucrose solution swell & burst while plant cells do not ***(06 marks)***

Red cells like any other animal cells have no cell wall to build up pressure potentials that permit movement of water by osmosis. Filling their cytoplasm with water only causes rupture of the plasma membrane. Such a pressure potential only builds up in plant cells due to resistance created by the cell wall.

(ii) Fully explain how you arrived at your answer in (b) (i). ***(08 marks)***

Using the relationships: Water potential = solute potential + pressure potential

Water potential = solute potential of solution, of a cell. When the two are in equilibrium; Ψcell =Ψsolution, when Ψp= 0. At incipient plasmolysis the protoplasts have shrunk to the point where they begin to pull away from the cell walls, and the pressure potential is zero (Ψs=0), since no pressure is exerted by the protoplasts against the cell walls. So Ψcell=Ψs = Ψsolution=Ψs solution (from (1) and (2) above). Hence the solution causing incipient plasmolysis has the same solute potential as the cell sap. But solute potential varies between cells in the same tissue and incipient plasmolysis is said to have been reached when 50% of the cells have plasmolysed.

(c) Give an explanation of each of the following:

(i).Red blood cells placed in a 0.0M sucrose solution swell & burst while plant cells do not ***(06 marks)***

Red cells like any other animal cells have no cell wall to build up pressure potentials that permit movement of water by osmosis. Filling their cytoplasm with water only causes rupture of the plasma membrane. Such a pressure potential only builds up in plant cells due to resistance created by the cell wall.

(ii) Red blood cells haemolize over a range of sucrose solution concentrations rather than at one particular sucrose concentration. ***(02 marks)***

Individual red blood cells have different concentrations of cytoplasm and will only take in water by osmosis and burst when placed in sucrose solutions of concentrations sufficiently lower than that of their cytoplasm in order to cause hemolysis.

(iii). Dishes containing the red blood cells or onion epidermal tissue are covered during the experiments

To eliminate the water potential gradient created by the dry air around the set up. This would cause osmotic loss of water.

To eliminate possibility of fungal and bacterial attack

(iv).The solutions are kept at a constant temperature of 20^{o}C during the experiments. ***(01 marks)***

Temperature increases the rate of diffusion so variation in temperature would cause different rates of movement in and out of the cells.

Question 7.

(a). Explain the term water potential and pressure potential ***(02 marks)***

Water potential is the tendency of a system to lose water

Pressure potential is the effect of application of a hydrostatic pressure on the water potential.

(b). Discuss the water relation of a;

(i). A turgid cell ***(07 marks)***

A turgid plant cell has pressure potential equaling to solute potential and water potential of 0). Cell which has taken in maximum amount of water by osmosis increases its ability to give out water. The resulting expansion of the protoplasm being opposed by the pressure potential as a result of its rigid cellulose cell wall which builds up becoming more positive as more water is taken in. The dilution has an effect on the solute concentration hence the osmotic potential which is usually negative goes on declining until it reaches 0 at full turgor.

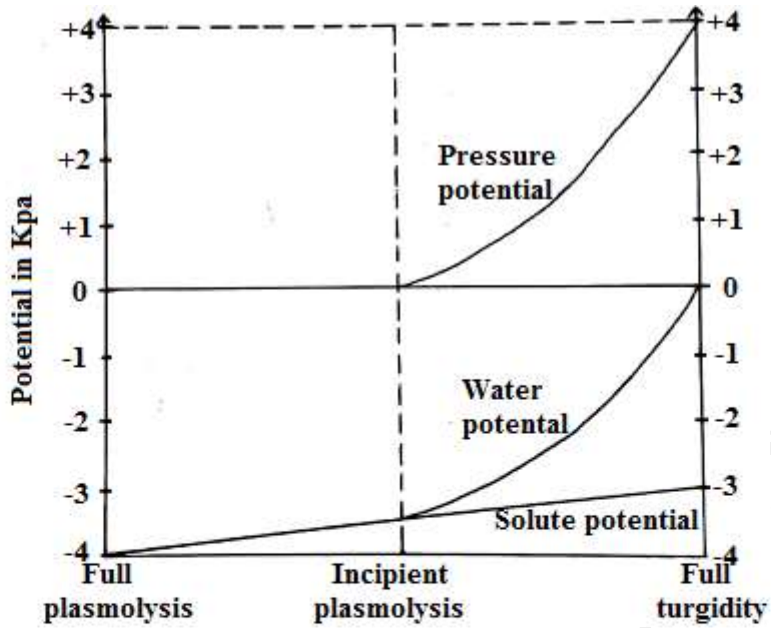
(ii). A plasmolysed cell ***(07 marks)***

A fully plasmolysed cell has a pressure potential of 0 & water potential of the cell equals to the solute potential. The cell has lost almost all its water and the cytoplasm has shrunk and pulled away from the cell wall hence the cellulose cell wall is not exerting pressure hence its pressure potential is 0. The capacity of such cell to give off water is low hence the water potential of the cell is very negative/ low while the water potential increases/ becomes more negative correspondingly as the solute concentration increases with the loss of water until both the water potential equals to the solute potential.

(c). Explain why osmotic potential of solution are always negative ***(04 marks)***

A solution contains solute dissolved in water; solute potential which is a negative component of water potential is increased; pressure potential (positive component of water potential) is almost zero in plasmolysed cells; progressively becomes more positive when the cells osmotically take in water such that protoplast establishes contact with the cell wall. From $\psi = \Psi s + \Psi p$, Ψs being greater than Ψp, renders water potential of any solution a negative value but keeps tending towards zero as Ψp progressively increases.

(d). The graph below shows changes in different water potential of a full plasmolysed plant cell in a hypotonic solution.



(e).Describe and explain the shapes of the graph corresponding with the;

(i). Water potential ***(12 marks)***

At full Plasmolysis, the water potential of the cell is low/ very negative due to increase in the concentration of solute molecules in the cell; so water enters into the cell osmosis from the hypotonic solution which has a higher or negative water potential than the cell components; From full turgidity to incipient plasmolysis; osmotic entry of water into the cells causes both water potential and incipient plasmolysis to increase at the same gradual rate since pressure potential is zero and so water potential = solute potential. So at incipient plasmolysis and full turgor, expansion of the protoplast due to osmotic influx of water presses the protoplast against the rigid cell wall causing a rapid rise in pressure potential. Since water potential = solute potential + pressure potential there is a rapid rise in water potential until it becomes 0 at full turgor, when the pressure potential becomes equal and opposite to the solute potential and can no longer take in water or expand pressure potential. From full plasmolysis to incipient plasmolysis, the pressure potential remains constant at 0 KPa, then from incipient plasmolysis to full turgor, the pressure potential increases rapidly (0 Kpa to 4 KPa)

(ii). Solute potential ***(02 marks)***

From full plasmolysis to full turgor, the osmotic entry of water into cell gradually reduces the concentration of solute molecules in the cell causing a gradual increase in its solute potential.

(iii).Pressure potential ***(06 marks)***

At full plasmolysis, pressure potential is zero, since the protoplast is completely pulled away from the cell wall so the cell wall still exerts no pressure against the protoplast. Between incipient plasmolysis and full turgor, the pressure potential remains zero since the protoplast remains pulled away from the cell wall so the cell wall still exerts no pressure against the protoplast. Between incipient plasmolysis and full turgor, the osmotic influx of water causes the volume of protoplast to increase in the protoplast exerts pressure against cell wall and the rigidity or cell wall causes a rapid increase in the hydrostatic pressure inside the cell hence rapid rise in water potential.

Question 8.

In an experiment, carrot discs were first washed thoroughly in pure water. The discs were then immersed in aerated potassium chloride solution of known molarity at varying temperatures. The results are given in the table below. After four hours of the experiment, the carrot discs at 25°C were treated with potassium cyanide. The absorption of potassium ions in $\mu g g^{-1}$ of fresh carrot tissue was obtained as shown below

Time in minutes	Potassium ion uptake in $\mu g g^{-1}$ fresh mass of carrot	
	At temperature 2°C	At temperature 25°C
0	0	0
60	90	170

120	105	300
240	130	480
300	130	500
360	130	500

(a).Represent the data graphically ***(05 marks)***

(b).Describe the changes in the rate of potassium ion uptake within the first hour at 25ºC. ***(02 marks)***

From 0 to 60 minutes, the rate of potassium ion uptake increased rapidly

(c).During the 1st hour of the experiment, some K^+ enter the carrot disc cells passively. Suggest any two passive means of their movement. In each case, state a condition needed for their movement. ***(04 marks)***

Diffusion; requires a steep concentration gradient, high temperature, large surface area, short distance
Facilitated diffusion; requires a steep diffusion gradient, carrier proteins

(d).Calculate mean rate of absorption of potassium ions at 2ºC between the 2nd & 6th hour of the experiment

Mean rate of absorption of ions $=\frac{105+130+130+130}{4h}$

Mean rate of absorption of ions $=123.75\mu g g^{-1}h^{-1}$

(e).Explain the effects of treating the effects of treating the carrot cells with potassium cyanide on the rate of potassium ion uptake. ***(03 marks)***

From the graph, addition of potassium cyanide reduces uptake of potassium ions by the carrot discs because uptake beyond the first hour occurs by active transport and requires energy derived from respiration. Cyanide binds respiratory enzymes changing their conformation making them unable to catalyze ATP formation. It also destroys binding surfaces for the potassium ions in the cell surface membrane.

(f).Suggest;

(i).The aim of the experiment ***(01 marks)***

To determine/ investigate the effect of temperature on the rate of uptake of potassium ions by carrot discs

(ii).Why the carrot discs were first washed in pure water. ***(02 marks)***

To remove/ flush out any ions adhering to the surface of the carrot discs

(iii).Why the potassium chloride solution was aerated ***(01 marks)***

(g).Describe the mechanism of functioning of the sodium-potassium pump. ***(08 marks)***

The pump is a transmembrane protein that binds Na^+ from the cytoplasm and K^+ from the extracellular fluid. Binding of cytoplasmic Na^+ stimulates ATP hydrolysis providing inorganic phosphate which binds to carrier proteins in the membrane. Phosphate binding causes a conformational change in the channel protein which expels sodium to extracellular fluid. Expulsion of Na^+ results in binding of extracellular K^+. Binding of K^+ results in release of the inorganic phosphate. Loss of the inorganic phosphate restores the original conformation of the protein.

(h).Explain three factors that affect the rate of diffusion according to Fick's law. ***(06 marks)***

Steepness of the concentration gradient; A higher concentration of molecules means many are allowed to move freely to regions of low concentration.

Surface area; A large surface area increases diffusion because many molecules are in contact over a wider area.
Distance over which molecules diffuse

Thickness of membranes; The membranes must be thin to increase the speed of movement of materials by diffusion.

(i).Why must transport occur across the cell surface membrane? ***(05 marks)***

• Obtaining nutrients
• Excretion of wastes
• Secretion of useful substances
• Generating ionic gradients essential for nervous and muscular activity
• Maintaining suitable pH and ionic concentration within the cell for enzyme activity

Question 1.

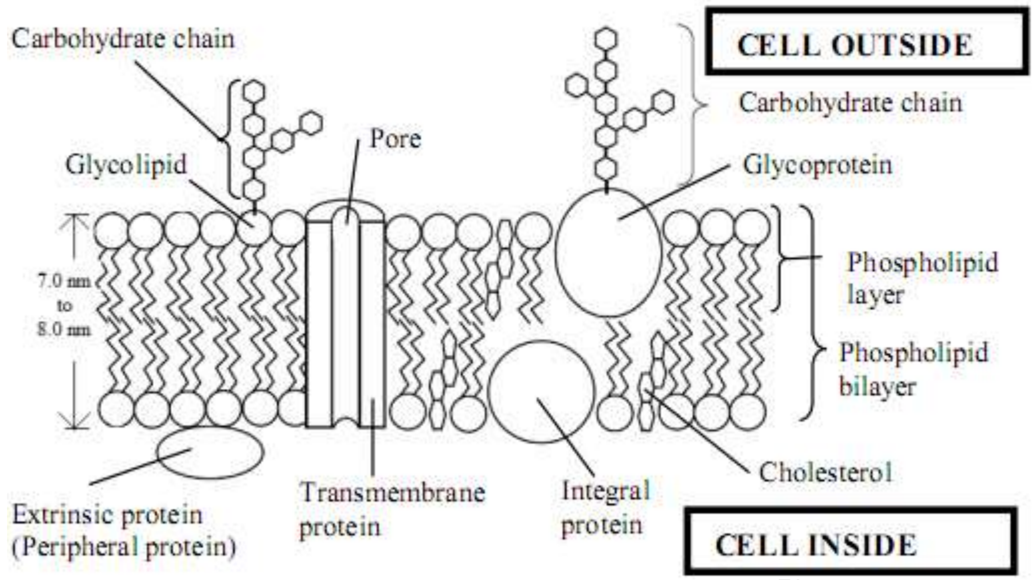
(a).Describe the structure of the plasma membrane according to the fluid mosaic model ***(07 marks)***

(b).Explain why the fluid mosaic model of the plasma membrane called so? ***(03 marks)***

(c)(i).Explain how exocytosis and endocytosis occur across the plasma membrane ***(05 marks)***

(c)(i).State the roles of proteins within the plasma membrane ***(05 marks)***

(a).



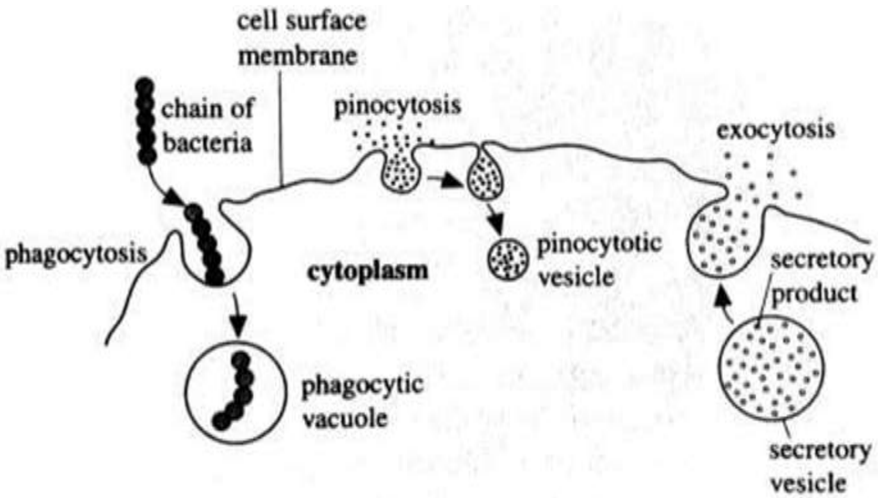
Fluid mosaic model describes the plasma membrane as a fluid bi-layer; in which proteins are embedded in a pattern constantly changing/randomly distributed; some proteins are peripheral/ extrinsic; others are integral or partially embedded/ intrinsic. Phospholipids have hydrophilic phosphate polar heads; and hydrophobic non-polar tail; fatty acid chain, glycoproteins and glycolipids, channel proteins/pores and cholesterols. In between the phospholipids molecules are protein molecules.

(b).

The fluid mosaic model is called so because it appears to have properties of a fluid rather than a solid (the protein component can, for example move through the phospholipid component), and the protein and lipid components form a pattern like a mosaic made up of small pieces of coloured glass or stone.

(c)(i).

Exocytosis; involves movement of materials out of the cells; vesicles approach the plasma membrane; fuse with it and releases contents outside the cell. **Endocytosis;** process by which materials are engulfed or taken into the cell, either by pinocytosis or phagocytosis, or transcytosis. In this, the plasma membrane invaginates to enclose the tiny particles or droplets of fluid, fuse at the point of contact, small vesicles enclosing the particles pinch off the plasma membrane inwards into cytoplasm; vesicles degraded by lytic enzymes to release content into intracellular fluid.



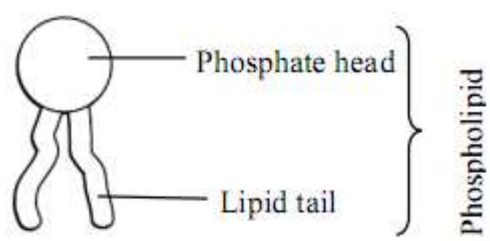
(c)(ii).

- Anchoring cells; to the outside membranes and also to microfilaments within cells.
- Transport; channel proteins allow selective permeability of ions/ carrier proteins/ facilitated, ATPase pumps which allow active transportation of materials
- Enzymatic activity; making the membrane enzymatically active.
- Signal transduction; possession of GTP coupled trans-membrane proteins.
- Receptors; bind with signal molecules e.g hormones allowing signal transduction.
- Cell recognition; performed by glycoproteins and glycolipids.
- Proteins act as identification tags; preventing cellular autolysis.
- Cellular communication; through acting as tight junction (adherens molecules);
- Integral proteins provide the structural integrity of the cell membrane
- Antigens: Some proteins act as antigens and induce the process of antibody formation
- Cell adhesion molecules or integral proteins are responsible for attachment of cells to their neighbours or to basal lamina or adhesion with adjacent cells.

Question 2.

(a).Describe the structure and arrangement of the phospholipids in a cell ***(03 marks)***
(b).How do properties of phospholipids maintain cell membrane structure ***(06 marks)***
(c).Compare prokaryotic and eukaryotic cells ***(11 marks)***

(a).



The phosphate head is composed of glycerol and phosphate and the tail made from two fatty acids, which could be saturated or unsaturated fatty acid. Phospholipids are arranged in a bilayer within the plasma mem-brane, where the heads face outside the membrane and the tails face inside the membrane/ hydrophobic interior / hydrophilic exterior of membrane. Phospholipids are held together by hydrophobic interactions. The phospholipid layers are stabilized by interaction of hydrophilic heads and surrounding water.

(b).

- Phospholipids are held together by hydrophobic interactions
- Phospholipid layers are stabilized by interaction of hydrophilic heads and surrounding water

• Phospholipids allow for membrane fluidity/ flexibility
• Fluidity/ flexibility enable membranes to be functionally stable
• Phospholipids with short fatty acids and those with unsaturated fatty acids are more fluid
• Fluidity is important in breaking and remaking membranes (e.g. endocytosis / exocytosis)
• Phospholipids can move about laterally (horizontally) / "flip flop" (move transversely) to increase fluidity
• Hydrophilic / hydrophobic layers restrict entry/ exit of substances.

(c).

Similarities

Both contain vacuoles, DNA, ribosomes, vesicles, cell wall, cytoplasm, cell membrane.

Structural Differences

Feature	Eukaryotic Cell	Prokaryotic Cell
Cell size	Much larger (10µm -100µm)	Much smaller (0.2µm -10µm)
Cellularity	Usually multicellular	Mostly multicellular unicellular, some cyanobacteria are multicellular
Nucleus	Present with nuclear envelope and nucleolus	Absent
DNA shape	DNA is linear	DNA is circular (has no ends)
DNA composition	DNA complexed with proteins called histones	DNA is naked, without histones
Main organelles	Present	Absent
Ribosomes	Many, larger (80S type) and 70S (in cytoplasm)	Smaller (mainly 70S type) and few
Flagella	If present there's 9+2 microtubule arrangement i.e. 9 peripheral doublets surround 2 central singlets.	If present, lack 9+2 microtubule arrangement
Cell wall	Chemically simpler. In plants, cellulose wall, fungi chitinous cell wall, in animals, no wall	Cell wall usually chemically complexed with peptidoglycan
Plasma membrane	Sterols and carbohydrates present	No carbohydrates and generally lacks sterols
Glycocalyx	Present in some cells that lack a cell wall	Present as a capsule or slime layer
Cytoplasm	Cytoskeleton present	No cytoskeleton

Functional differences

Feature	Eukaryotic Cell	Prokaryotic Cell
Cell division	Occurs by mitosis	Occurs by binary fission
Sexual reproduction	Involves meiosis	Occurs by conjugation
Cytoplasm activity	Cytoplasmic streaming occurs	No cytoplasmic streaming
Nitrogen fixation	Does not occur	Occurs in some bacteria

(a).How is the structure of the plasma membrane related to function? ***(08 marks)***
(b).Explain the factors that affect the fluidity of the plasma membrane ***(10 marks)***
(c).Outline the importances of regulating membrane fluidity ***(02 marks)***

(a).

• Glycoproteins work as antigens in immunity.
• Channel proteins allow diffusion of polar ions and molecules across the membrane.
• Some membrane proteins have enzymatic properties e.g. ATP synthase for ATP synthesis.
• Some membrane proteins work as electron carriers in electron transport chains.
• Glycolipids are involved in cell-to-cell recognition.
• Cholesterol stabilizes membrane structure by preventing phospholipids from closely packing together.
• Lipid bilayer, being semi-permeable, it controls movement of substances in and out of the cell.

• Membrane proteins provide sites for cytoskeleton filaments to anchor to support and maintain cell shape
• Membrane proteins join cells together forming tissues which perform specific functions.
• Transport proteins move ions or solutes by active transport e.g. sodium ions or by facilitate diffusion e.g glucose, amino acids across the membrane
• Glycoproteins are involved in cell-to-cell recognition by cells of complimentary sites e.g specific hormones
• Cell surface receptor proteins are involved in signal-transduction by converting an extracellular signal to an intracellular one.

(b).

Temperature; Low temperature decreases membrane fluidity because lipids are laterally ordered, the lipid chains pack well together, mobility reduces to allow many stabilizing interactions. Increase in temperature increases membrane fluidity because lipids acquire thermal energy to become mobile and reduce stabilizing interactions.
Length of lipid tails; Lipids with shorter chains are more fluid because they quickly gain kinetic energy due to their smaller molecular size and have less surface area for Van der Waals interactions to stabilize with neighboring hydrophobic chains. Lipids with longer chains are less fluid because their large surface area enables more Van der Waals interactions hence increasing the melting temperature.
Lipid saturation; Lipid chains with double bonds (unsaturated fatty acids) are more fluid because the kinks caused by double bonds make it harder for the lipids to pack together. Lipids that have single bonds (saturated fatty acids) have straightened hydrocarbon chain which pack together to reduce membrane fluidity.
Presence of cholesterol; At low temperatures, cholesterol increases membrane fluidity by preventing fatty acid hydrocarbon chains from coming together and crystallizing there by inhibiting the transition from liquid to solid (decreases the membrane freezing point). At warm temperature (e.g 37^{o}C) cholesterol decreases membrane fluidity by interacting with lipid tails to reduce their mobility, thereby increasing the melting point. At high concentrations, cholesterol also prevents fatty acid hydrocarbon chains from coming together and crystallizing.

(c).

• Membranes must be fluid to work properly by ensuring flexibility.
• Biological processes stop when bilayer fluidity reduces too much e.g. membrane transport & enzyme activities.

Question 4.

(a).How do the components of the plasma membrane ensure its fluidity? ***(06 marks)***
(b)Relate the function of each of the following to the fluidity and porosity of their membranes
(i).Plasma membrane ***(06 marks)***
(ii)Rough endoplasmic reticulum (RER) ***(05 marks)***
(iii)Golgi apparatus ***(03 marks)***

(a).

Numerous cholesterols in between phospholipids preventing close packing of the phospholipids; unsaturated fatty acid chains of phospholipids form bends or kinks; that prevent close packing of the phospholipids. Glycoproteins allow association with polar molecules, glycolipids allow association with non-polar molecules; proteins provide the skeletal frame work to membranes and phospholipids show both hydrophobic and hydrophilic interractions.

(b)(i).

Plasma membrane must be porous and fluid to function as a selective barrier regulating chemical composition by allowing some substances to readily pass between the cell and external environment while impeding others. The membrane must allow passage of gases, nutrients and wastes; it must also allow flexibility or elasticity (stretch), self-repair, bud vesicles; interact with cytoplasmic structures and can be capable of division. The membrane must orientate cell junctions for intercellular communication.

(b)(ii)

Fluidity is essential to provide a large surface area to volume ratio inside the cell for enzymatic activities; and to divide cells into components for different biochemical functions. The organelle has a granular appearance due to ribosomes present; and on the outer membrane, ribosomes are the sites for protein synthesis. Lipids are also synthesized in the organelle. The RER must therefore bud vesicles; which contain assembled proteins and lipids. The fluid nature allows transport of various chemical substances from one part of the cell to another; including regulating cytoplasmic calcium

(b)(iii).

Fluidity is a key feature of the Golgi apparatus; which functions mainly in processing and packaging proteins. The organelle is highly developed in secretory cell vesicles containing substances for secretion pass to the Golgi apparatus to form mew golgi apparatus membranes which bud vesicles moving to plasma membranes or another membrane within the cell depending on the address given during processing.

Question 5.

Explain how distribution of membranes is related to functions ***(20 marks)***

Distribution	Function
Plasma membrane	• Forms a protective barrier between the cell inside and outside. • Determines and maintains shape and size of the cell • Selectively regulates entry and exit of substances. • Absorptive surface for nutrients and other materials • Excretory surface for waste products of metabolism from the cell • Surface for exchange of gases like oxygen and carbondioxide. • Maintenance of shape and size of the cell: and size of the cell.
Nuclear envelope	• Separate nuclear contents from cytoplasm hence limits DNA within the nucleoplasm but allows exit of RNA. • Controls flow of information to nucleus and DNA that are carried by the macromolecules.
Outer mitochondrial membrane	• Allows entry of ATP, NADH and from glycolysis
Inner mitochondrial membrane	• Contains electron carriers in electron transport chain
Rough Endoplasmic Reticulum	• Intracellular transport and sites for ribosome attachment
Smooth Endoplasmic Reticulum	• Intracellular transport
Outer chloroplast membrane	• Allows photosynthetic products out and substrates in
Thylakoid membranes of chloroplasts	• Store photosynthetic pigments e.g. chlorophyll • Contains electron carriers
Golgi complex membrane	• Storage of glycoprotein • Synthesis of polysaccharides e.g. cellulose in plants
Lysosomes	• Isolates autolytic enzymes from unnecessary digestion of cell components
Tonoplast	• Limits cell sap within the vacuole
Membranes surrounding vesicles	• Limit the contents of the vesicles within until when ready for exit e.g. calcium ions and neurotransmitters in neurones, undigested materials in phagocytic vesicles, etc.
Neurilemma of neurones	• Contains protein pumps for Na^+ and K^+ which bring about impulse propagation
Myelin sheath membrane	• Insulates nerve fibre to increase transmission speed

Question 6.

(a).Explain the role of vesicles in transportation of materials within cells. ***(08 marks)***

(b).Outline the reasons for cell division in living organisms. ***(06 marks)***

(**c). Describe how the distribution of cell inclusions is related to function** ***(06 marks)***

(a).

Vesicles are membrane bound packages/droplets; formed by pinching off/budding off a piece from membrane; can carry proteins. Rough ER synthesizes proteins, proteins enter/accumulate inside the ER; transported to Golgi apparatus for processing; targeted to/transported to specific cellular organelles; fuse with membrane of organelle so contents of vesicle join the organelle; transported to the plasma membrane; fuses with plasma membrane releases/secretes contents exocytosis;

(b).

• Increase the number of cells in an organism

• Allow differentiation/ cell specialization for greater efficiency
• Allows replacement of damaged/ lost cells e.g binary fission.
• Asexual reproduction of unicellular organisms
• Gamete/ spore formation.
• Control of cell division sometimes lost leads to tumor formation.

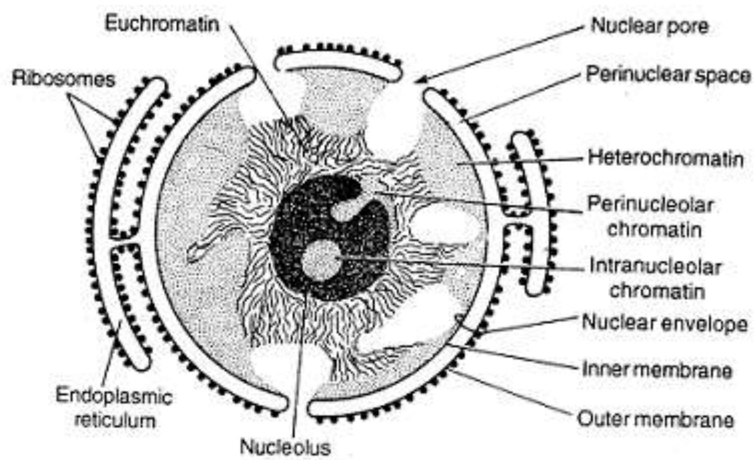
(c).

Starchy granules; found only in plant cells & abundant in cells of storage tissues like tubers, rhizomes, stems
Glycogen granules; found only in animal cells and are abundant in liver and muscle tissues where serve as glycolgen stores.
Fat droplets; found in both plants and animal cells. In animal cells, they are found abundant n cells of adipose tissues where they form adipocytes. In plants, they are found in cells of seeds that store lipids eg sunflowers, castor oil etc

Question 7.

(a).Describe the structure of the nucleus in a cell ***(07 marks)***
(b).Outline the functions of the nucleus ***(07 marks)***
(c).How is the nucleus adapted to perform the above functions in (b) above ***(06 marks)***

(a).



Cell nucleus is enclosed / bound by a double-layered nuclear membrane (nuclear envelope); Outer membrane is connected to the endoplasmic reticulum; A fluid-filled space (perinuclear space) exists between the two layers of a nuclear membrane. Nuclear membrane is perforated by nuclear pores ~50 nm in diameter. Enclosed within the inner membrane is the nucleoplasm (Karyoplasm), nucleolus and chromosomes (chromatin); Nucleolus is a dense, spherical shaped structure; Chromosomes (chromatin) are thread-like and contain heterochromatin which stains darkly, genetically inactive, tightly coiled and euchromatin: loosely packed, genetically active and enriched.

(b).

• Controls the heredity features of an organism.
• Controls protein synthesis, cell division, growth and differentiation.
• Stores DNA, the heredity material
• Stores proteins and RNA in the nucleolus.
• Site for transcription in which messenger RNA are produced for protein synthesis.
• Nucleolus produces ribosomes, which are the protein factories.

(c).

• DNA is long to store many genes
• Nuclear membrane has pores; for exchange of DNA and RNA between the nucleus and cytoplasm;
• Presence of nucleolus; enables production of ribosomes which are protein factories;
• Nuclear envelope; isolate nucleus from interference by processes in cytoplasm;
• Nuclear pores are narrow; regulate entry and exit of substances

Question 8.

(a).Account for the negative water potential of any solution ***(04 marks)***
(b).Explain the changes in the water relations of a plasmolysed plant cell when inserted in a hypotonic solution ***(10 marks)***
(c)(i). Outline the differences between plasmolysis and wilting ***(02 marks)***
(c)(ii).State the roles of osmosis in organisms ***(04 marks)***

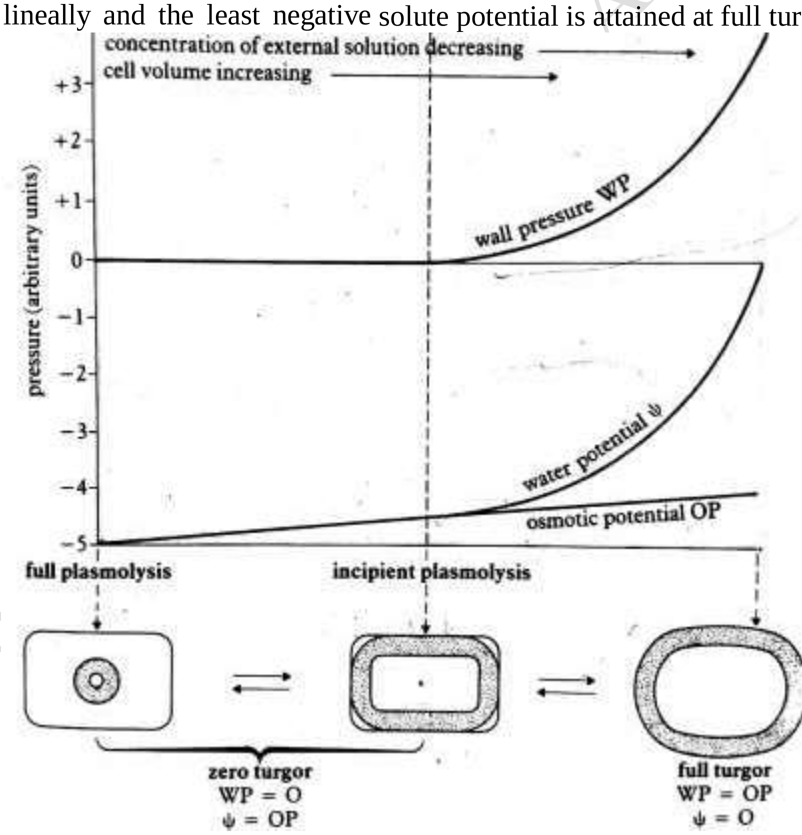
(a)

A solution contains solute dissolved in water; solute potential which is a negative component of water potential is increased; pressure potential (positive component of water potential) is almost zero in plasmolysed cells; progressively becomes more positive when the cells osmotically take in water such that protoplast establishes contact with the cell wall. From $\psi = \psi_s + \psi_p$, ψ_s being greater than ψ_p, renders water potential of any solution a negative value; but keeps tending towards zero; as ψ_p progressively increases.

(b).

Description

Pressure potential (ψ_p) is generally positive. At full plasmolysis pressure potential is zero; remains constantly zero up to incipient plasmolysis; then gets more positive/ ψ_p progressively increases towards turgidity; maximum ψ_p is attained at full turgidity. Water potential (ψ); is generally negative. At full plasmolysis, water potential is most negative; keeps getting less negative; towards incipient plasmolysis; then becomes less and less negative towards fully turgidity, maximum ψ is least negative close to zero and is attained at full turgidity. Solute potential (ψ_s) is negative; at full plasmolysis; ψ_s is most negative; gets less negative towards incipient plasmolysis; continues getting less negative lineally and the least negative solute potential is attained at full turgidity.



Explanation

At full plasmolysis, ψ_s is maximum; ψ_p =0, From $\psi = \psi_s + \psi_p$; maximum $\psi = \psi_s$; maximum osmotic influx of water into the cell occurs; due to most negative water potential. Protoplast keeps expanding towards the cell wall until the two cellular components establish contact. At this point it starts being opposed by ψ_p (inward pressure of the cell wall towards the protoplast). The more the cell expands the more the resistance offered by the cell wall. ψ_p keeps increasing as the ψ gets less and less negative. Eventually full turgidity is attained; cell cannot expand anymore; ψ_p is maximum thus counterbalances ψ_s.

(c)(i).

Plasmolysis	Wilting
Only protoplasm shrinks leaving cell wall behind.	The whole cell including the cell wall shrinks
Occurs when a plant cell loses water to a hypertonic solution by osmosis	A plant cell loses water through evaporation

(c)(ii).

• Providing support to non woody plants.
• Facilitating opening and closure of the stomata.
• Water and mineral ion re-absorption in the kidney tubules.
• Water absorption in the colon.

Question 9.

(a).Describe the structure of the plant cell wall ***(11 marks)***
(b).State the differences between the cell wall and the plasma membrane ***(09 marks)***

(a).

The cell wall consists of 3 main layers (regions) i.e. middle lamella; primary cell wall; and secondary cell wall. It is tough; usually flexible/bendable/fairly rigid; of variable thickness [1 µm to 10µm]; surrounding plant cells. The outermost layer (middle lamella) cements (binds/glues) adjacent plant cells together; and is rich in calcium and magnesium pectates and proteins; The next layer (primary cell wall); is generally a thin; flexible and extensible; It consists mainly of cellulose microfibrils; hemicelluloses; pectin; water; & protein; In plant epidermis it is usually impregnated with cutin and wax; to form an impermeable barrier called plant cuticle; The various chemical components are tightly (closely) bound together; In some cells there is the secondary cell wall inside the primary cell wall; It is thick/ has 3 layers; and contains several proteins; and polymers like: cellulose, hemicelluloses and lignin in wood and xylem; suberin in cork and root casparian strips; silica crystals in grass; Certain small areas of the cell wall remain unthickened to form pits; which concide in adjacent cells to form pit pairs in which the two cells are separated only by the middle lamella and through which plasmodesmata (cytoplasmic strands) pass;

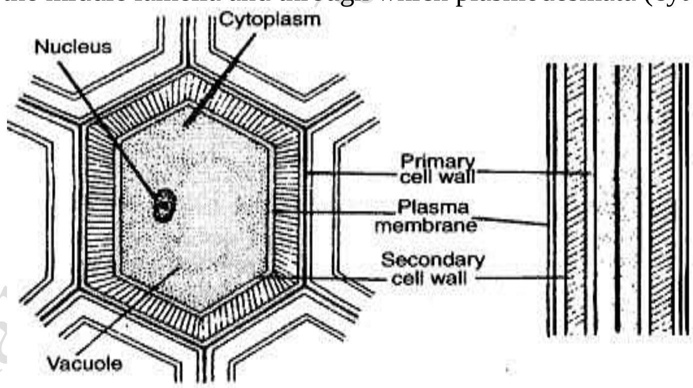


Fig. Structure of the cell wall

(b).

Cell wall	Plasma membrane
Rigid when mature	Flexible with a fluid mosaic pattern
Made up of cellulose, magnesium and calcium pectate, lignin and suberin	Made up of proteins, phospholipid bilayer, glycop-roteins and glycolipids
Has plasmodesmata	Has channel proteins instead of plasmodesmata
Fixed shape	Variable shape
Variable thickness	Fixed thickness
Freely permeable to material	Selectively permeable to materials
Lacks trans-membrane proteins	Has trans-membrane proteins
May be lignified or suberized	Lacks lignification or suberisation

Number of main layers/ regions varies	Constant number of main layers or regions.

Question 10.

(a).How is the structure of the plant cell wall adapted to function ***(07 marks)***
(b).What major roles do plant cell walls play in the life of cells? ***(08 marks)***
(c).Explain how the cell wall is thickened and strengthened in the different organisms ***(05 marks)***

(a).

• The relatively thick multiple wall layers provide mechanical support
• Secondary walls may be cutinized / suberized for preventing water loss
• The extreme rigidity of secondary wall provides compression strength
• Deposition of cellulose fibrils in alternating layers enables some degree of flexibility
• Semi-permeable nature Allows exchange of water, dissolved salts and small protein molecules
• The relatively thick multiple wall layers; provide mechanical support
• The variety of functional proteins like oxidative enzymes (peroxidases), hydrolytic enzymes (pectinases, cellulases) enable performing several functions like protection against pathogens, cell expansion and cell wall maturation.
• The diversity (variety) of functional proteins like oxidative enzymes (peroxidases), Hydrolytic enzymes (pectinases, cellulases); enable performing several functions like protection against pathogens, cell expansion, cell
• Cellulose polymers associate through very many H-bonds whose cumulative bonding energy provides high tensile strength of the cell wall for providing support and preventing rupturing wall maturation.

(c).

• Maintaining / determining cell shape.
• Provides support and mechanical strength to the cell against gravity.
• Pathway for water and dissolved mineral salt movement by the apoplast pathway.
• Prevents excessive entry of water to the cell in a hypotonic medium i.e resists turgor pressure.
• Has a metabolic role i.e some proteins in the wall are enzymes for transport and secretion.
• In suberized cells, acts as physical barrier to against pathogens and water loss.
• Carbohydrate storage; components of the wall can be re-used in other metabolic processes
• Allows turgor pressure/high pressure to develop inside the cell;
• Recognition responses; e.g. pollen-style interactions are mediated by wall chemistry;
• Cell signaling; fragments of cellwall, called Oligosaccharins stimulate ethylene synthesis as well as increasing cytoplasmic calcium levels;

(c).

• In plants or algae cell walls, cell wall is thickened by cellulose, cutin and wax
• In woody plants, it is thickened by lignin and suberin in addition to cellulose.
• In bacteria, it is thickened by murein or peptidoglycans.
• In fungi, the cell wall is thickened by chitin
• Algal cell walls are thickened by glucans and mannans.
• Archeal cell walls have pseudopeptidoglycans.

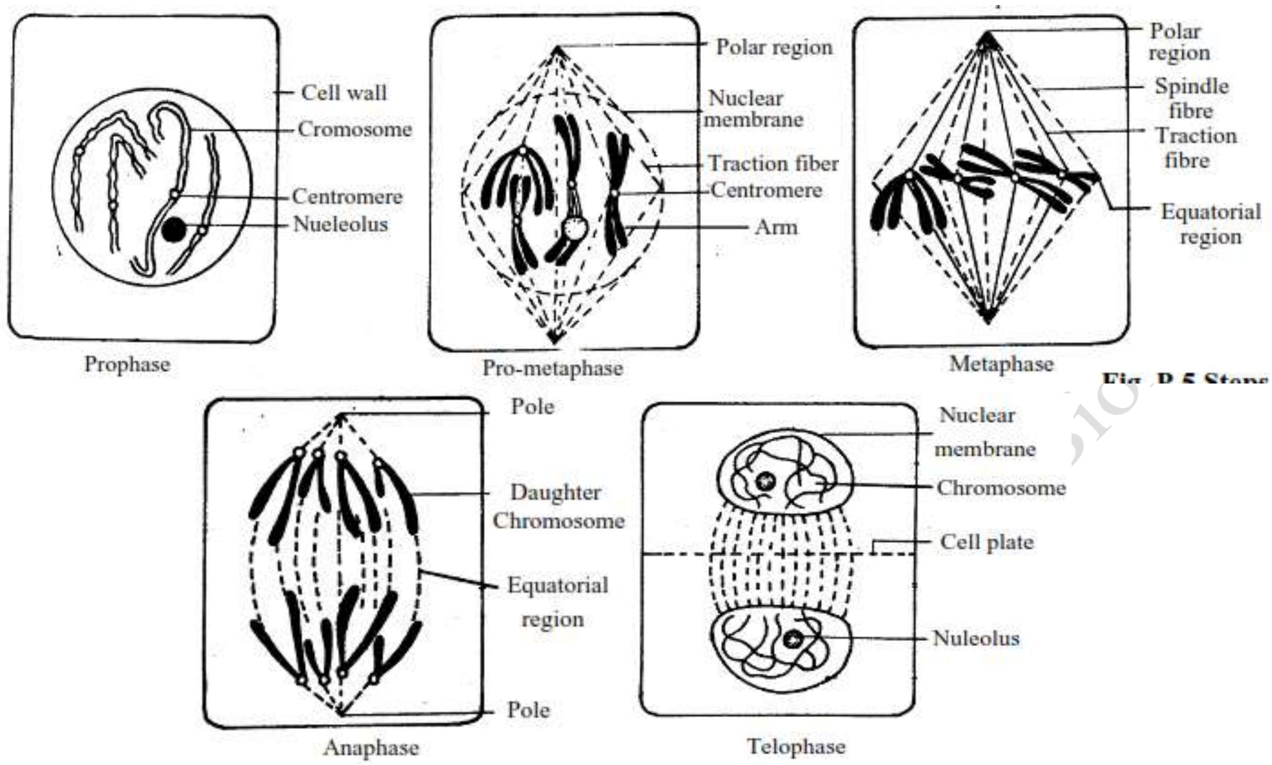
Question 11.

(a).Explain what is meant by mitosis ***(01 marks)***
(b).Describe the events that occur during mitosis in a cell ***(12 marks)***
(c).State the significance of mitosis ***(05 marks)***

(a).

This is nuclear division whereby one diploid or haploid parent cell produces two genetically identical daughter cells each with same chromosome number like the parent cell.

(b).



Prophase:

Changes occur in both the cytoplasm and nucleus, chromatin condenses into discrete chromosomes, centrioles move towards poles, chromosomes begin to migrate toward the cell centre, nuclear envelope breaks down & spindle fibers begin to form at opposite poles of the cell and nucleolus fades.

Metaphase:

Nuclear membrane disappears completely, centriole pairs reach the poles, spindle fully develops, chromosomes condense further and chromosomes align at the metaphase plate.

Anaphase:

Sister chromatids separate and orient towards opposite poles, chromatids make a V shape as the arms of the chromatid drag behind the centromere, which leads towards its pole, polar microtubule which run from one centriole to another (without attachment to chromosomes) pull & lengthen the cell. Therefore, the shape of animal cell changes.

Telophase:

Sister chromatids (now called Chromosomes) reach opposite poles, chromosomes de-condense, nucleolus begins to appear, nuclear envelope appears, spindle disappears, cell surface membrane folds in (invaginates) to divide the genetic content of the cell equally into two parts, cytokinesis begins prior to the end of mitosis and completes shortly after telophase.

(c).

- Ensures genetic stability by producing daughter cells that genetically identical to parents.
- Enables cell replacement when old cells die or get damaged.
- Repair of damaged tissues occurs by mitosis; maintain.
- Enables regeneration of body parts in some animals e.g. lizard tails.
- Basis of asexual reproduction or vegetative propagation.
- Basis of growth in multicellular organisms since somatic cell division occurs by mitosis.

Question 12.

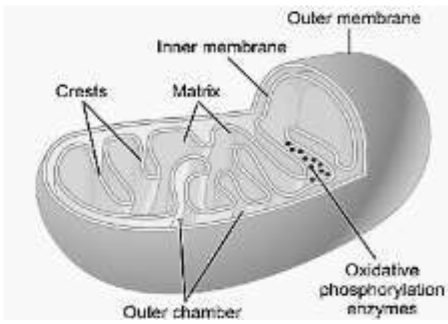
(a).Describe the structure of the mitochondria ***(08 marks)***

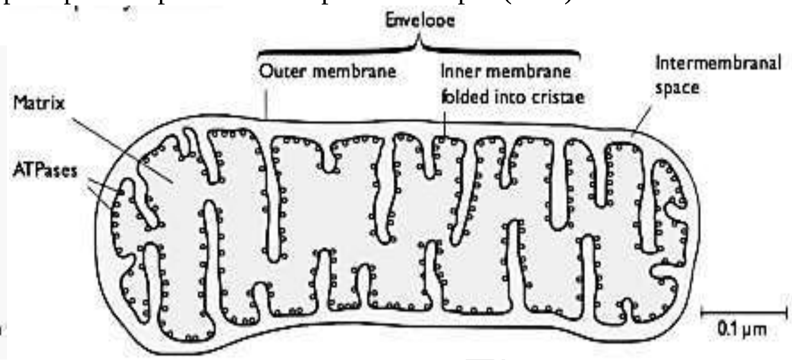
(b).How is the mitochondria structurally and physiologically modified to perform its functions?

(c).Explain why the mitochondria are regarded as semi-autonomous organelles ***(03 marks)***

(a).

Mitochondrion has a diameter of about 0.5–1µm, length of 2.0µm-7µm; & variable shape (may be spherical /rod shaped / filamentous); It is double membrane bound; outer membrane is entire; inner membrane folds into the mitochondrial matrix to form cristae; and in between the two membrane is the intermembrane space. Mitochondrial matrix is fluid filled, with several enzymes, small sized ribosomes and circular DNA. Each membrane is a phospholipid bilayer, with variable phospholipid compositions and protein to lipid (PTL) ratios.





(b).

- Double membranes isolate the mitochondrion from interference by processes in the cytoplasm
- Small size gives large surface are to volume ratio for rapid uptake / release of materials
- Matrix contains enzymes of Krebs cycle.
- Inner membrane are infolded to form cristae to increase the surface area for electron transport chain
- Inner membrane contains stalked particles that contains ATPase that makes ATP
- Narrow inter-membrane space enables steep proton gradient to be rapidly established for chemiosmosis
- Inner membrane contains molecules for electron transport pathway
- DNA is present to act as genetic material for synthesis of some protein
- Many ribosomes for protein synthesis to reduce on importing proteins from cytoplasm.
- Membranes to compartmentalize / separate from processes in the cytoplasm
- Proton concentration gradient rapidly established / steeper; allows chemiosmosis

(c)

Mitochondria contain their own circular DNA that co-ordinate process of protein synthesis; without nuclear control. Mitochondria thus synthesize its own proteins independent of the nucleus.

Question 13.

(a) Describe the process of meiosis in a cell ***(12 marks)***

(b).How does meiosis contribute to variation? ***(08 marks)***

(a)

Meiosis I

Interphase I; metabolically active stage involving DNA replication, organelle formation, and formation of energy reserves

Prophase l;

Leptotene; chromosomes condense, become visible, spindle fibres begin forming;

Zygotene; nucleolus shrinks, pair of homologous chromosomes associates bivalents form (synapsis)

Pachytene; The chromatids become visible as they move apart from each other; chromosomal crossing over occurs; non sister chromatids may exchange segments over the region of homology; chiasmata forms

Diplotene; chromatids continue to move apart as they shorten and thicken, each chromosome appears to be having a pair of sister chromatids joined at the centromere.

Diakinesis; chromosomes condense further; chiasmata moves to ends; nuclear membrane disintegrates.

Metaphase I; pairs of homologous chromosomes align themselves along the equator of the spindle fibres in a double row

Anaphase I; Homologous chromosomes attached to the spindle fibres by the centromere move to opposite poles of the cell.

Telophase I; chromosomes reach their destination; cell invaginates/ constricts in the middle. Two daughter cells ;each having half the number of chromosomes with each chromosome having its pairs of chromatid. Chromosomes uncoil back into chromatins.
Cells may enter interphase, or interkinesis with no DNA replication. Cells may on the other hand enter straight into meiosis II.

Meiosis II

Prophase II; nucleoli and nuclear envelope disintegrates again; Chromatids shorten and thicken; spindle fibres form again usually at right angles to that formed in meiosis I.
Metaphase II; Chromosomes arrange themselves along the equatorial plane of the spindle fibres
Anaphase II; chromatids part company; migrate to opposite poles of the cell.
Telophase II; De-condesation and lengthening of the chromosomes; spindles disassemble; nuclear envelope and nucleolus reform; cell finally cleaves Tetrad of daughter cells; each with a haploid chromosome set is formed.

(b).

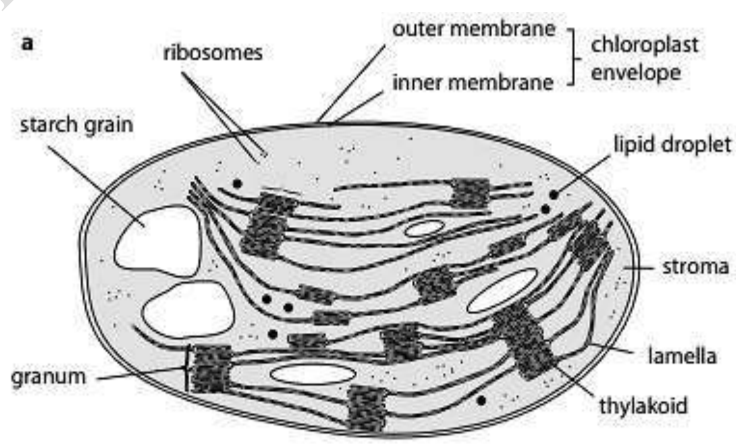
Random fertilisation; Meiosis produces haploid ♂&♀gametes which fuse during fertilisation to create new combinations of parental genes.
Crossing over during prophase I; of meiosis can separate & rearrange genes located on the same chromosome to form genetically non-identical gametes.
Independent assortment of homologous chromosomes on metaphase plate during metaphase I with respect to which paternal and maternal homologue is on either side forms different combinations of parental chromosomes in gametes.
During Segregation / separation of homologues in anaphase I and sister chromatids at anaphase II; alleles for dominant/ recessive traits go to opposite poles whereby only one of a pair of alleles goes into a single gamete.

Question 14.

(a).Describe the structure of the chloroplast ***(07 marks)***
(b).Outline the functions of the chloroplast ***(05 marks)***
(c).How is the chloroplast adapted to perform its functions mentioned above ***(08 marks)***

(a).

Chloroplast shape and size vary from biconvex in higher plants with length of~5μm to filamentous in algae, spherical, ovoid, etc. It is enclosed by an envelope of double membranes; outer membrane is semipermeable. Inner membrane surrounds the stroma, regulates entry and exit of materials to the chloroplast, and is a manufacturing centre for fatty acids, lipids and carotenoids. Inter-membrane space is narrow~10nm-20nm in between the outer and inner membranes. Stroma is semi-gel-like fluid alkaline, rich in protein (e.g. enzymes), with chloroplast DNA, 70S ribosomes, starch granules, lipid globules and thylakoid membrane system. Thylakoids are interconnected, membranous sacs, with chlorophyll in the membrane At intervals, thylakoids form piles (~10-20) known as grana.



(b).

• Site for manufacture of food by the process of photosynthesis.

• Ribosomes within mitochondria enable amino acid and protein synthesis.
• They produce fatty acids
• They store starch, but only temporarily
• Produce new chloroplasts and pigments

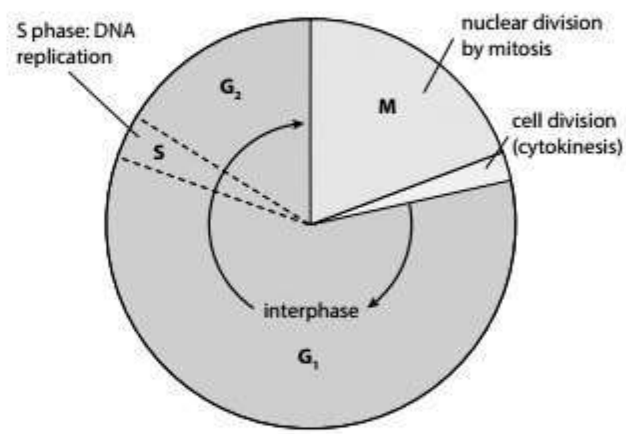
(c).

• Outer membrane is semi- permeable to regulate entry and exit of substances for maintaining internal chloroplast environment.
• Abundant light trapping pigments for photosynthesis
• Abundant enzymes catalyse photosynthetic reactions in the stroma.
• Extensive network of thylakoid membranes increase surface area for photosynthesis.
• Narrow inter-membrane space enables H^+ ion concentration gradient to be rapidly established for chemiosmosis to occur
• Inner membrane contains molecules for electron transport pathway
• DNA is present to act as genetic material for synthesis of some protein
• Many ribosomes for protein synthesis to reduce on importing proteins from cytoplasm.

Question 15.

(a).Explain what is meant by the cell cycle *(03 marks)*
(b).Describe the events that occur during the different phases of interphase *(09 marks)*
(c).How does cytokinesis occurs in a plant cell *(08 marks)*

(a).



Cell cycle is a complex sequence of events by which cells grow and divide into daughter cells. The main phases of the cell cycle: Interphase, which is divided into: Gap 1 phase (G_1), Synthesis phase (S), and Gap 2 phase (G_2). Mitosis phase (M), which is sequenced as Prophase, Metaphase, Anaphase and Telophase. Non-dividing cells e.g. most neurons, mature muscle cells and brain cells are in G_0 stage (not in cell cycle).

(b).

G_1 phase:
Occurs prior to DNA synthesis, cell increases in mass and organelle number, cell makes enough mitochondria, cytoskeletal elements, endoplasmic reticula, ribosomes, Golgi apparatus, cytosol. Centriole replication starts but is completed in G_2. All chromosomes exist in single-chromatid form as they are uncoiled.

S phase:
DNA replicates (during which gene mutations may occur), chromosome content doubles, each chromosome replicates into two identical sister chromosomes (chromatids) joined at kinetochores. Histones and other nuclear proteins are synthesised.

G_2 phase:
Occurs after DNA synthesis, prior to start of mitosis, additional protein synthesis, completion of centriole replication, ATP synthesis occurs, cell size increases and repairs errors in replicated chromosomes are corrected.

(c).

• Cell wall forms during telophase stage of cell division when cell plate forms between daughter cell.
• Cell plate forms from a series of vesicles produced by Golgi (Dictyosomes).
• Vesicles migrate along microtubules & actin filaments within phragmoplast & move to the cell equator.
• Phragmoplast contains mitotic spindles, microtubules, microfilaments, and endoplasmic reticulum surrounded by nuclear envelopes.
• Vesicles join up their contents, and the membranes of the vesicle become the new cell membrane.
• Dictyosomes synthesize the non-cellulosic polysaccharides like pectins & transported to build the middle lamella.
• Cellulose is made at the cell surface, catalyzed by the enzyme cellulose synthase.
• While the cell plate is growing, segments of smooth endoplasmic reticulum are trapped within it, later forming the plasmodesmata connecting the two daughter cells.

Question 16.

(a).Describe the events that occur during pachytene phase of prophase I ***(06 marks)***
(b).Outline the comparison between meiosis and mitosis ***(11 marks)***
(c).Explain the significance of meiosis ***(03 marks)***

(a).

Chromosomes become visible, shorten and flatten, associate by synapsis; form a bivalent; split into chromatids that wrap around each other. Chromatids of a bivalent repel each other; although remain joined at the chiasmata. It is at these points that they break and recombine with different portions of the chromatids (non-sister) exchanging genetic material (crossing over). Chromatids continue repelling each other although they remain attached at the chiasmata.

(b).

Similarities

• Both involve single replication of chromosomes
• Both involve replication of organelles and centrioles
• Both involve cytokinesis to form daughter cells from a parent cell
• Both follow similar sequence of events i.e. Interphase, prophase, metaphase, anaphase, telophase.
• Both include the breakdown of the nuclear membrane and lay down of spindle fibres during prophase.
• Both involve the separation of genetic material into two groups, followed by cell division
• Both involve the reformation of the nuclear membrane in each cell during telophase
• Both involve alignment of chromosomes on metaphase plate.
• Both can occur during formation of gametes in plants.

Differences

Meiosis	Mitosis
Occurs in cells involved in sexual cycle	Occurs in somatic cells
Cells involved in meiosis are always diploid	Cells involved can be diploid or haploid
Daughter cells are genetically different	Daughter cells are genetically identical
Crossing over occurs with chiasma formed	No crossing over; no chiasma formed
Homologous chromosomes pair up	No pairing of homologous chromosomes
Two divisions;	One division
4 haploid cells are formed	2 diploid cells are formed
Chromosome number is reduced by half.	Chromosome number remains the same.
Homologous chromosomes line up along metaphase plate in tetrads	Chromosomes line up singly on metaphase plate
Cytokinesis occurs twice i.e. in Telophase I and in Telophase II.	Cytokinesis occurs once i.e. in Telophase.
Centromeres do not separate during anaphase I, but during anaphase II.	Centromeres split during anaphase.
Karyokinesis occurs in interphase I i.e. one pre-meiotic S phase for both meiosis I and meiosis II	Karyokinesis occurs in interphase i.e. one premitotic S phase per cell division.

(b).

• Leads to formation of haploid gametes; which is the basis of sexual reproduction
• Meiosis preserves the genome size of sexually reproducing eukaryotes by halving the diploid chromosome number to haploid ($2n \rightarrow n$). The diploid state is restored during fertilisation.
• Meiosis leads to increased genetic variation, which is the basis for evolution

Question 17.

How does the structures of the following relate to their roles.
(a).Plasma membrane ***(11 marks)***
(b).Cell wall ***(09 marks)***

(a).

• The plasma membrane is thin for fast diffusion of material across the membrane.
• The membrane possesses carrier proteins; enhance facilitated diffusion.
• Channel proteins create pores to allow transport of polar molecules.
• Some membrane proteins act as enzymes and make the membrane metabolically active.
• Some protein molecules act as specific receptors; important in signal transduction
• Glycoproteins act as antigens enabling cellular communication.
• The membrane cholesterols disrupt close packing of phospholipids keeping them more fluid.
• Membrane cholesterols increase flexibility and stability of the membrane.
• Membrane cholesterols act as a plug reducing escape or entry of polar molecules through the membrane.
• The lipid molecules and derivatives like cholesterols make membrane fluid.
• The membrane proteins are involved in facilitated diffusion as they change shape to enable transfer of substances across the membrane.
• The arrangement of hydrophilic heads and the hydrophobic tails make the membrane selectively permeable; permitting only non-polar molecules.

(b).

• Extensive lignification in cell walls offers mechanical strength and skeletal support for individual cells and for the plant as a whole.
• Cell walls are rigid and resistant to expansion; allows turgidity and hence offer mechanical support especially in herbaceous plants.
• The rigid cell wall protects the cell from bursting as a result of osmotic uptake of water.
• The orientation of cellulose microfibrils in cell walls allows for stretching as the cell expands which is important in cell elongation and growth.
• The interconnected cell walls from an apoplast which is a major pathway for movement of water.
• The plasmodesmata occur as minute pores between the cells forming a living connection between cells & allow all the protoplast to be linked in the symplast system.
• Some cell walls are modified for food storage in some seeds.
• In xylem vessels, the lignified cell walls have high tensile strength to prevent tubal collapse during water conduction under tension.
• The cell walls of the root endodermal cells are impregnated with suberin that form casparian strip; that controls the movement of the solute through the root xylem.

Question 18.

(a).Explain how the distribution of vacuoles in cells is related to functions. ***(10 marks)***
(b).How is the structure of a prokaryotic cell like bacteria related to function ***(10 marks)***

(a).

• Contractile vacuoles serve as osmoregulatory devices in unicellular organisms particularly protozoans.
• In plants, vacuoles serve as stores for waste products of metabolism like tannins.
• In plant and animal cells, vacuoles act as food reserves; store sugars and mineral salts.
• In white blood cells, vacuoles are phagocytic devices in which engulfed foreign body gets lysed
• In plant cells, vacuoles enclose pigments like anthrocyanins, which give fruits and flowers their colour.
• Cell sap within vacuole of plant cells enhance osmotic intake of water offer support in herbaceous plants
• Some vacuoles of both plants and animal cells contain hydrolytic enzymes that digest act as lysosomes.
• The tonoplast isolates the vacuolar sap from the cytosol, enabling vacuolar pathway of water.

• In meristematic cells, vacuoles bring about growth by initiating cell elongation.
• Food vacuoles formed by phagocytosis (endosomes) enable bulk intake of food.

(b).

Cell wall; physical barrier; protects the prokaryote from mechanical damage & entry of some substances
Flagellum; propels the bacteria along
Mesosomes; sites of respiration; also involved in cell division and DNA uptake.
Chromosome/ DNA; possesses genetic information needed to replicate new cells.
Plasmids; circles of DNA; possess genes that aid survival of bacteria in adverse conditions.
Glycogen granules; store of carbohydrates for respiration
Lipid droplets; concentrated energy store; used in respiration.

Question 19.

(a).What are the main ideas of the cell theory? ***(04 marks)***
(b).Discuss possible exceptions to the cell theory. ***(04 marks)***
(c).Explain how surface area to volume ratio and nucleo-cytoplasmic ratio influence cell size. ***(12 marks)***

(a).

• All known living things are made up of one or more cell.
• The cell is the structural and functional unit of all living things.
• All cells arise from pre-existing cells by division
• Cells contains hereditary information which is passed from cell to cell during division.
• All cells are basically the same in chemical composition.
• All energy flow (metabolism and biochemistry) of life occurs within cells.

(b).

• Viruses are obligate intracellular parasites capable of replicating only inside host cells using host cell genome. Viruses are therefore considered biotic but not organisms.
• Coenocytic algae like Vaucheria and many fungi have a body that is a continuous mass of protoplasm with many nuclei but without cell wall separations i.e. are aseptate.
• Skeletal muscles have very long cells (up to 300 mm long) with hundreds of nuclei i.e. are Syncytial
• Giant algae is an organism made of one long cell (up to100 mm long) but with only one nucleus.
• Unicellular organisms can be considered acellular because they are larger than a typical cell/carry out all functions of life.
• Some tissues / organs contain large amounts of extracellular material e.g. vitreous humor of eye /mineral deposits in bone / xylem in trees.
• Fungal hyphae are (sometimes) not divided up into individual cells
• Some tissues/organs contain large amounts of extracellular material e.g. vitreous humor of eye/ mineral deposits in bone/ xylem in trees.

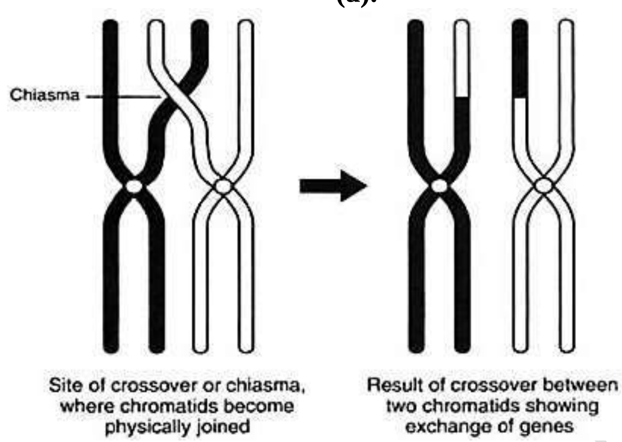
(c).

Surface area to volume ratio; Small cells have large SA:V ratio while large cells have a small SA:V ratio. A large SA:V ratio enables fast rate of diffusion while a small SA:V ratio slows the rate of diffusion. Small cells have low metabolic demands & form low amount of wastes while large cells have higher metabolic demands and form much amount of wastes. Therefore, the large SA:V ratio in small cells enables adequate supply of oxygen and nutrients and expulsion of wastes e.g. carbon dioxide via the surface of the cell by simple diffusion while the small SA:V ratio in large cells limits diffusion hence the supply of nutrients by simple diffusion is inadequate to meet the metabolic demands of the cell. Hence in animals, some large sized cells take in sub-stances in bulk by endocytosis and expel bulk substances by exocytosis to supplement on simple diffusion. Some animal cells increase their surface area by forming many tiny projections called microvilli and other cells divide when they reach a certain size to maintain suitable SA:V ratio. SA:V ratio particularly limits the size of bacterial cells, i.e. prokaryotic cells which are incapable of endocytosis and exocytosis.
Nucleo-cytoplasmic ratio; DNA in the nucleus provides instructions for protein synthesis hence controls activities of the whole cell. Each nucleus can only control a certain volume of cytoplasm. Specialization forms some long / large cells, therefore to overcome this limitation such cells are modified to become multinucleate /coenocyte e.g. skeletal muscle cells and fungal hyphae.

Question 20.

(a).Explain what is meant by crossing over *(03 marks)*
(b).Describe the structure of a chromosome *(03 marks)*
(c).Compare mitosis in plants and in animals *(14 marks)*

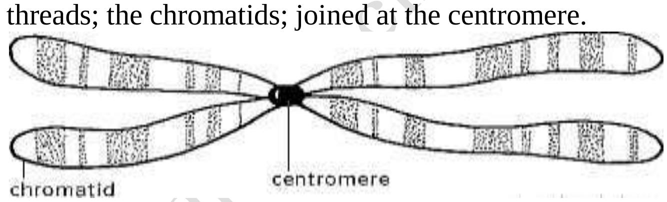
(a).



Crossing-over involves exchange/swapping of genetic material between non-sister homologous chromatids. It gives rise to new genetic recombination, causing variation which is the basis for evolution. The chiasma formed (one point of cross-over between non-sister chromatids) holds homologues together while they move into position on the spindle prior to segregation..

(b).

A chromosome is composed of DNA, proteins and a small amount of RNA. Chromosome appears long, thin and thread like consisting of two threads; the chromatids; joined at the centromere.



(c).

Similarities

In both:

- Spindle fibres form
- During Prophase, chromosomes condenses
- Before metaphase, the nuclear envelope breaks down.
- Spindle attaches to chromosomes at centromeres
- At metaphase, the chromosomes align at the equator
- At anaphase, chromosomes move towards opposite poles
- At telophase, the nuclear envelope appears again, chromosomes de-condense, and the spindle breaks down

Differences

Mitosis in animal cells	**Mitosis in plant cells**
Occurs almost all over the body	Occurs at apical, lateral & intercalary meristems only
Centrioles present	Centrioles absent
At telophase a contractile ring of actin and myosin forms halfway between the two nuclei.	At telophase a phragmoplast of actin, myosin, and microtubules, forms at the future site of cell wall.
Cytokinesis occurs by cleavage	Cytokinesis occurs by cell plate method
Cell becomes rounded before division	Cell shape does not change before division
A furrow is formed between two daughter cells	A solid middle lamella forms between two daughter cells

Mitotic apparatus contains asters	Mitotic apparatus lacks asters
Spindle degenerates at cytokinesis	Spindle in form of phragmoplast persists at cytokinesis.
Several hormones induce cell division, not one specifically	It is induced by a specific hormone called cytokinin

Question 21.

(a) Distinguish between cell organelle and cytoplasmic inclusion ***(03 marks)***
(b) Describe the structure of the Golgi complex ***(12 marks)***
(c) How is the structure in (b) above suited for functioning? ***(05 marks)***

(a).

Cell organelle is a separate structure within a cell which performs specific function e.g. mitochondria, chloroplast, etc while Cytoplasmic inclusion is an insoluble, non-living substance suspended in the cytosol of a cell not capable of carrying out any metabolic activity e.g glycogen granules in liver and muscle cells, lipid drop-lets in fat cells, melanin pigment in melanocyte cells of skin and hair, water filled vacuoles.

(b).

Golgi complex is made up of piles (stacks) of flattened sacs called cisternae with vesicles budding (pinching) off at edges of sacs; One cisterna is a flattened sac, with a lumen enclosed by a single membrane. Between 4-8 cisternae pile up to form a stack which bends to form a semi-circle. A cell may have 40 to 100 stacks. An individual stack of the cisternae is a dictyosome. The Golgi complex contains a number of separate compartments, as well as some that are interconnected. The cisternae stack has 4 functional regions: the cis-Golgi network, medial Golgi, endo-Golgi and trans-Golgi network. The cisternae carry structural proteins important for their maintenance as flattened membranes which stack upon each other. The cis face is adjacent to the endoplasmic reticulum and the trans-Golgi points towards the plasma membrane.

(c).

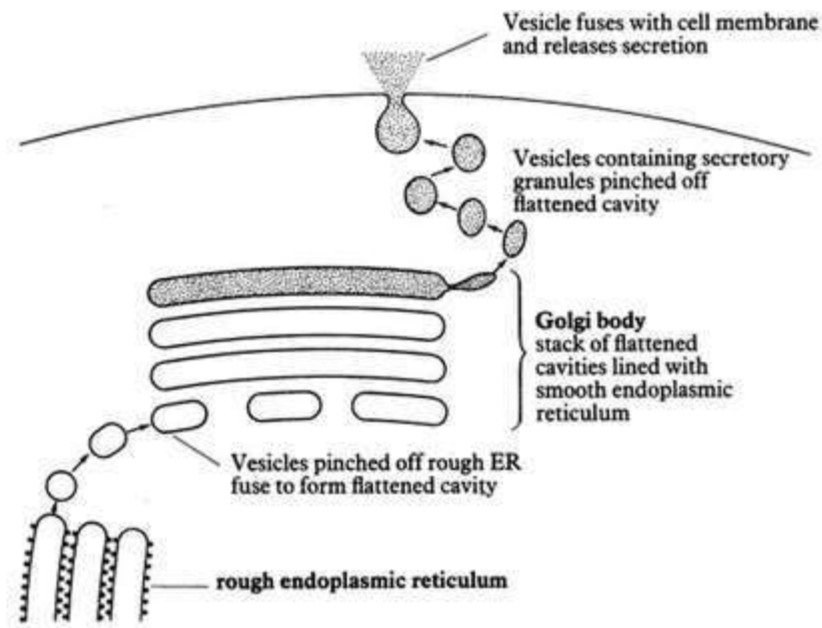
• Cisternae are enclosed by selectively permeable membranes, which isolate the inside cavity from cytosol for efficient functioning.
• Tubular structure enables transportation of soluble protein and lipids from the endoplasmic reticulum for modification.
• Variety of enzyme systems for modifying proteins by adding carbohydrates and phosphate by the process of glycosylation and phosphorylation respectively.
• Many cisternae increase the surface area for modifying synthesised macromolecules.
• There are many compartments at the cis, located at the beginning of the Golgi apparatus to facilitate passage of proteins through the Golgi apparatus.

Question 22.

(a) Describe the functioning of Golgi apparatus in animal cells. ***(10 marks)***
(b) Explain the roles of lysosomes in animal cells. ***(10 marks)***

(a).

Proteins made at Rough Endoplasmic Reticulum (RER) have, as part of their amino acid sequence, a signal that directs them where to go, just like an address directs a letter to its destination. Proteins arriving at cis Golgi but having RER retention signal (were wrongly sent), are repackaged into vesicles then returned to RER. Soluble or properly folded macromolecules (proteins, lipids and polysaccharides) from RER enter cis-Golgi network via transport vesicles. Within cis-cisternae, macromolecules are partly modified i.e carbohydrates are added to proteins (glycosylation), phosphate is added to protein (phosphorylation) etc. After partial modification, coated vesicles bud (pinch) off the swollen ends of cis-cisternae and fuse with ends of medial cisternae. Within medial-cisternae, different enzymes further transform macromolecules differently, depending on their structures and destination i.e. some are modified for secretion, others for the membrane, and some for lysosomes. After further modification within the medial-cisternae, coated vesicles bud (pinch) off the swollen ends of the medial-cisternae and fuse with the ends of trans- cisternae for further transformation. From trans-cisternae, the transformed macromolecules exit the Golgi and are sorted into different transport vesicles.



(b).

Autophagy; Primary lysosome fuses with worn-out cellular components like mitochondrion to form autophagic vacuole in which digestion occurs by lysosomal enzymes into end products which leave by diffusion or with the aid of specialized transporters into cytoplasm while undigested materials (residual body) are released outside by exocytosis.

Heterophagy (Cellular digestion); Primary lysosome fuses with food vacuole engulfed by endocytosis to form heterophagic vacuole in which digestion occurs by lysosomal enzymes into end products which leave by diffusion or with the aid of specialized transporters into cytoplasm while undigested materials(residual body) is released outside by exocytosis.

Autolysis; Primary lysosome releases hydrolytic enzymes within a dead cell to digest the whole cell.

Development processes; Tadpole metamorphosis (regression of tail) & regression of Wolffian ducts involve shedding of tissues with removal of whole cells and extracellular material by lysosome enzymes. During bone development, osteoclasts release lysosomal enzymes that remodel bones.

Role in fertilization; Acrosome in spermatozoa releases enzymes which digest the limiting membrane of the ovum to enable sperm entry and start fertilization. The lysosome in cytoplasm of Ova enables digestion of stored food.

Role in immunity Leucocytes (WBC); digest foreign particles, bacteria and viruses enabled by lysosomes.

GERL system; Golgi, Endoplasmic Reticulum and Lysosome system regulates the secretory activities of the Golgi and ER as well as modification of secretory products.

Question 23.

(a) Describe the structure and location of any two named cytoskeletal elements ***(08 marks)***

(b) State the roles of each of the named cytoskeletal elements above to cells. ***(08 marks)***

(c).State the limitations of each of the following in the study of cells

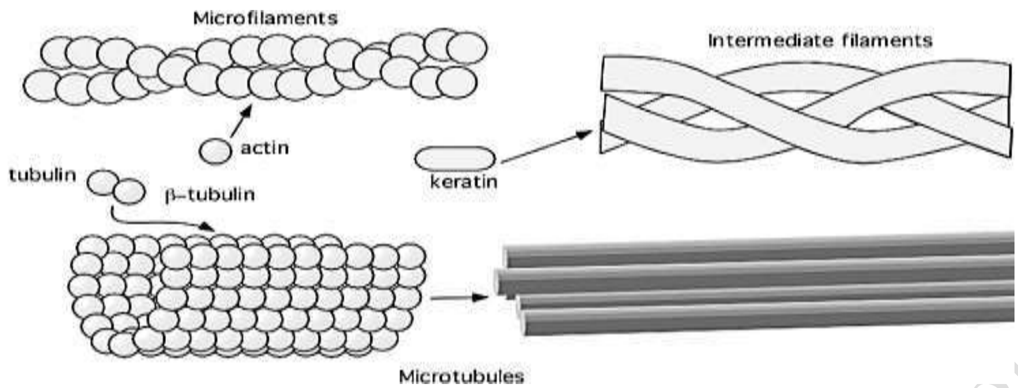
(i).Light microscope ***(02 marks)***

(ii)Electron microscope ***(02 marks)***

(a).

Microfilaments (actin filament); Two strands of actin, (a globular protein) twist around each other to form a solid, right-handed, long helical-shaped rod, about 5nm-9nm in diameter. They nucleate at the plasma membrane, with the cell periphery (edges) having the highest concentration.

Microtubule; Two alternating strands of alpha-tubulin and beta-tubulin (globular protein) bind together in a helical shape to form a hollow, straight cylinder with length of 200nm-25µm and diameter of about 25nm. They are found throughout the cytoplasm of all eukaryotic cells, forming part of cytoskeleton that gives structure and shape to cells.



(b).

Functions of the microfilaments

- They enable a dividing cell membrane to pinch off into two cells
- Involved in cell movement e.g. amoeboid movement, phagocytosis, pinocytosis, etc.
- Associate with myosin to cause muscle contraction.
- Support the cell membrane and maintain cell shape.

Functions of microtubules:

- Serve as conveyor belts moving other organelles throughout the cytoplasm.
- Are the major components of cilia and flagella in cell motility
- They form spindle fibers during cell division.
- Give shape and mechanical support to the cell.
- Enable vesicles to move during cell wall formation in plants.

(c)(i).

- Low maximum resolution/ magnifies objects up to 2000 times
- The depth of field is restricted;

(c)(ii).

- Preparation of material is lengthy and requires considerable expertise;
- Material usually distorted during preparation;
- Living material cannot be observed;
- Very large can only be operated in special rooms

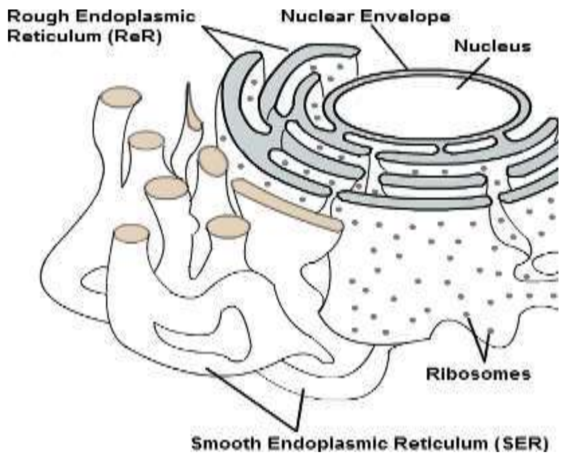
Question 24.

(a)Describe the structure of the endoplasmic reticulum ***(10 marks)***
(b)State the differences between Cilia and flagella ***(05 marks)***
(c).State the functions of Golgi apparatus and how its adapted to function ***(05 marks)***

(a).

Rough/granular Endoplasmic Reticulum (RER); RER is an extensive membrane network of cisternae (sac-like structures) which are held together by the cytoskeleton. A phospholipid membrane encloses a space, the lumen from the cytosol, which is continuous with perinuclear space. The surface of the rough endoplasmic reticulum is studded with ribosomes, which give it a rough appearance hence the name rough endoplasmic reticulum. A part of RER is continuous with the nuclear envelope.

Smooth/agranular Endoplasmic Reticulum (SER); The SER is a folded structure composed of a network of interconnected disc-like sacs and tubules called cisternae which are held in their place by the cytoskeleton. The SER is bound by a phospholipid membrane enclosing a fluid-filled space known as cisternal space or lumen. The lumen or cisternal space is continuous with the perinuclear space. A part of SER is continuous with the nuclear envelope; some other part may be at the periphery of the cell.



(c).

Functions of the Golgi apparatus

• Modify, sort and package proteins that are made at the rough endoplasmic reticulum for secretion (export) or for use within the cell.
• Form carbohydrates e.g. polysaccharides are attached to a protein to form proteoglycans present in the extracellular matrix of the animal cell.
• Transport of lipid molecules around the cell.
• Formation of lysosomes containing hydrolytic enzymes.
• Formation of peroxisomes.
• In plant cells, Golgi produces vesicles that join to form cell plates during cell division.
• Secretory vesicles produced by Golgi contain a variety of important substances e.g. neurotransmitters, hormones, mucin, zymogen e.g. pepsinogen, etc.
• Fusion of Golgi vesicles with cell membrane maintains the membrane which is used to form phagocytic vacuoles and pinocytic vesicles.

Adaptations of the Golgi apparatus to function

• Cisternae are enclosed by selectively permeable membranes, which isolate the inside cavity from cytosol for efficient functioning.
• Tubular structure enables transportation of soluble protein and lipids from the endoplasmic reticulum for modifcation.
• Variety of enzyme systems for modifying proteins by adding carbohydrates and phosphate by the process of glycosylation and phosphorylation respectively.
• Many cisternae increase the surface area for modifying synthesised macromolecules.
• There are many compartments at the cis, located at the beginning of the Golgi apparatus to facilitate passage of proteins through the Golgi apparatus.

Question 25.

(a).Describe the structure and location of
(i). Cilia and flagella *(05 marks)*
(ii).Centrioles *(04 marks)*
(b).Outline the functions of the structures mentioned in (a) above *(11 marks)*

(a)(i).

Both the cilia and flagella arise from a small granular structure called basal body. Cilia and flagella are cove-red by a unit membrane, which is an extension of the cell membrane. There is a central filament called axoneme formed of 11 microtubules arranged in the pattern of 9+2 i.e. 2 central singlets (single microtubules) and 9 peripheral doublets (pairs of microtubules). Basal bodies are at the base of each flagellum and cilium and appear to organize their development.

(a)(ii).

Centrioles are found only in animal cells near the nucleus in the centrosome which serves as an organizing centre for microtubules.
Structure: Two cylinders, held at right angle to each other, each about 0.3µm-0.5µm long and 0.24µm in diameter, made of nine triplets of microtubules arranged in a ring in a 9+0 pattern.

(b).

Functions of cilia and flagella

- Ciliary movement enables paramecium to drive food into their gullet.
- In certain molluscs Ciliary movement facilitates gaseous exchange by passing water currents over the gills
- In echinoderms Ciliary movement enables locomotion by driving water through the water vascular system.
- Cilia lining respiratory tract of humans drives away microbes and dust particles towards the nose or mouth.
- Cilia in the oviduct or fallopian tubes of human female moves ova towards the uterus.
- Cilia in nephridia of annelids e.g. earthworms moves wastes
- Flagellum of sperms enables their swimming movement.
- Flagellum enables the movement in certain protozoans like euglena.

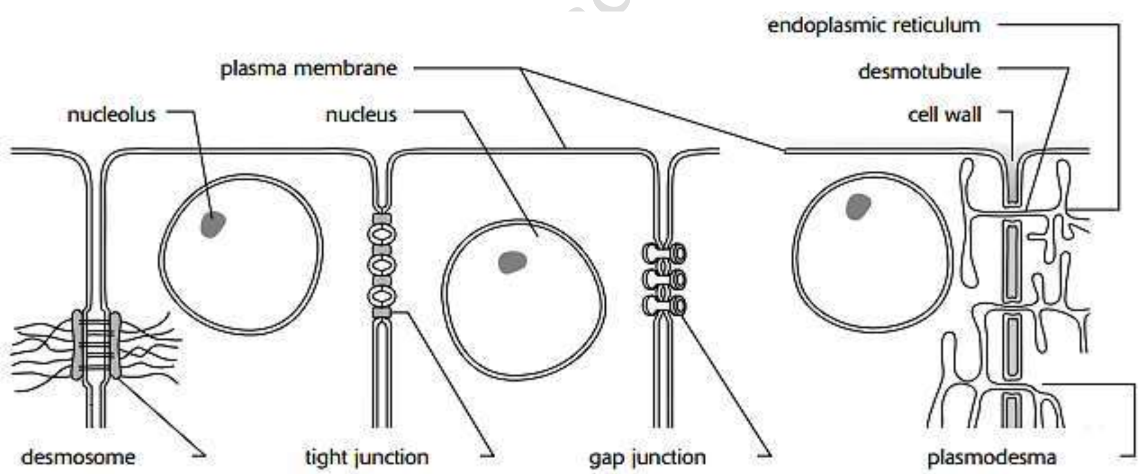
Functions of centrioles

- In animal cell division, centrioles organize microtubules to form spindle fibers which separate chromosomes.
- Cellular organization - centrosomes are involved in organizing microtubules, whose position determines po-sition of organelles e.g. nucleus
- Ciliogenesis-In ciliated and flagellated organisms, the mother centriole which becomes the basal body deter-mines the position of these organelles.

Question 26.

(a).Explain what is meant by a cell junction ***(02 marks)***
(b). Discuss how the distribution and structure of the different types of cell junctions is related to function

(a).



Anchoring junctions are protein attachments between adjacent animal cells. One such junction, the desmosome, consists of proteins (including the protein keratin) that bind adjacent cells together, providing mechanical stability to tissues. Desmosomes are also associated with protein filaments that extend into the interior of the cell and serve to hold cellular structures together.
Tight junctions; are tightly stitched seams between animal cells. The junction completely encircles each cell, producing a seal that prevents the passage of materials between the cells. Tight junctions are characteristic of cells lining the digestive tract where materials are required to pass through cells (rather than intercellular spaces) to penetrate the blood stream.
Communicating junctions; are passageways between cells that allow the transfer of chemical or electrical signals
Gap junctions; are narrow tunnels between animal cells that consist of proteins called connexins. The proteins prevent the cytoplasms of each cell from mixing, but allow the passage of ions and small molecules. In this manner, gap junctions allow communication between cells through the exchange of materials or through the transmission of

electrical impulses. Gap junctions are essentially channel proteins of two adjacent cells that are closely aligned. Because the proteins of each cell extend beyond the plasma membranes before they meet, a small gap occurs between the two plasma membranes.

Plasmodesmata; are narrow channels between plant cells. A narrow tube of endoplasmic reticulum, called a desmotubule, surrounded by cytoplasm and the plasma membrane, passes through the channel. Material exchange through a plasmodesma apparently occurs through the cytoplasm surrounding the desmotubule.

Question 27.

(a).Describe the various ways in which the plasma membrane permits interactions with the outside environment. ***(06 marks)***

(b).Proteins in the plasma membrane provide a wide range of functions. How are the various proteins of significance in the functioning of the plasma membrane ***(14 marks)***

(a).

The plasma membrane is a selectively permeable membrane. Small molecules, like oxygen and carbondioxide, readily diffuse through the membrane. The movement of larger molecules is regulated by proteins in the plasma membrane; Channel proteins provide passage for certain dissolved substances; transport proteins actively transport substances against a concentration gradient. The glycocalyx consisting of the oligosaccharides from glycolipids, recognition proteins, and other glycoproteins, provides adhesion or participates in cell-to-cell interactions. Receptor proteins recognize hormones and transmit their signals to the interior of the cell. Various substances can be exported into the external environment by exocytosis. In exocytosis, substances are packaged in vesicles that merge with the plasma membrane. Once they merge with the membrane, their contents are released to the outside. In an opposite kind of procedure, food and other substances can be imported by endocytosis. In endocytosis, the plasma membrane encircles the substance and encloses it in a vesicle.

(b).

Channel proteins; provide open passageways through the membrane for certain hydrophilic (water soluble) substances such as polar and charged molecules.

Ion channels; allow the passage of ions across the membrane. In nerve and muscle cells, ion channels called gated channels open and close in response to specific chemical or electrical stimuli to allow the passage of specific ions (such as Na+ and K+).

Porins; are proteins that allow the passage of certain ions and small polar molecules through membranes. **Aquaporins;** found in the plasma membranes of certain cells (such as those found in kidneys & plant roots); dramatically increase the passage rate of H_2O molecules.

Carrier proteins; bind to specific molecules, which are then transferred across the membrane after carrier protein undergoes a change of shape. The passage of glucose into a cell is by a carrier protein. Transport proteins use energy (ATP) to transport materials across the membrane by active transport. The Na^+-K^+ pump, for example, uses ATP to maintain higher concentrations of Na^+ and K^+ on opposite sides of the plasma membrane.

Recognition proteins; give each cell type a unique identification. This provides for a distinction between cell types, between self cells and foreign cells, and between normal cells and cells infected. Recognition proteins are glycoproteins because they have short polysaccharide chains (oligosaccharides) attached. The oligosaccharide part of the glycoprotein extends away from the surface of the membrane.

Adhesion proteins; attach cells to neighboring cells or provide anchors for the internal filaments and tubules that give stability to the cell.

Receptor proteins; provide binding sites for hormones or other trigger molecules. In response to the hormone or trigger molecule, a specific cell response is activated.

Question 28.

(a).Describe the three unique features of meiosis that occur in reproductive cells ***(09 marks)***

(b).What is the significance of each of the above unique feature described in (a) above ***(06 marks)***

(c).Discuss the advantages of possessing membrane bound organelles in eukaryotic cell ***(10 marks)***

(a).

Synapsis; It happens early during prophase I of first nuclear division. Following chromosome replication, the homologous chromosomes homologues pair all along their length or associate with each other forming bivalents.

Homologous Recombination; genetic exchange occurs between the homologous chromosomes while they are still physically joined .The exchange process that occurs between paired chromosomes is called ***crossing over*** which also occurs in prophase I. Chromosomes are then drawn together along the equatorial plane of the dividing cell; subsequently, homologues are pulled by microtubules toward opposite
poles of the cell. When this process is complete, the cluster of chromosomes at each pole contains one of the two homologues of each chromosome.
Reductive division; the chromosomes do not replicate between the two nuclear divisions, so that at the end of meiosis, each cell contains only half the original complement of chromosomes.

(b).

Synapsis; draws homologous chromosome together; creating a close vicinity in which the two chromosomes can physically exchange portions through crossing over;
Homologous recombinations; random distribution of chromosomes, crossing over and independent assortment allows formation of new gene combinations; a basis for variations.
Reduction division; by omitting a chromosome duplication before meiosis II, it produces haploid gametes, thus ensuring that chromosome number remains stable during the reproduction cycle.

(c).

• Membranes offer protection to important molecules from the highly variable intracellular environment e.g DNA material is protected by the nuclear membrane from ever changing cytoplasmic conditions.
• Enable cells to confine potentially harmful proteins and molecules protecting the rest of the cells from their harmful effects e.g lysosomes.
• Membrane bound organelles compartmentalize the cell such that each reaction in the organelle is separated from those of the other organelles avoiding interference.
• Enables cells to concentrate and isolate enzyme and reactants in a smaller volume; increasing surface area to volume ratio; thereby raising the rate and efficiency of chemical reactions.
• Membrane bound organelles easily establish logical proximity with others that have related functions enhancing efficient cellular functionality e.g organelles producing proteins within cell are near those transporting proteins out of the cell.
• Membranes regulate entry and exit of different materials in the various cellular compartments e.g the nuclear membrane regulate the materials entering and exiting the nucleus.

Question 29.

(a).Describe how carbohydrates exist within the plasma membrane ***(06 marks)***
(b)(i).State the roles of carbohydrates in the functioning of the plasma membrane ***(03 marks)***
(b)(ii)Explain how HIV interacts with T cell membrane to cause immune suppression ***(02 marks)***
(c).Explain the functions of the plasma membrane ***(09 marks)***

(a).

Some of the carbohydrate molecules present in cell membrane are attached to proteins and form glycoproteins (proteoglycans). Some carbohydrate molecules are attached to lipids and form glycolipids. Carbohydrate molecules form a thin and loose covering over the entire surface of the cell membrane called glycocalyx.

(b)(i).

• Glycocalyx from the neighboring cells helps in the tight fixation of cells with one another
• Some carbohydrate molecules function as the receptors for some hormones.
• Carbohydrate molecules are negatively charged & do not permit the negatively charged substances to move in & out of the cell.

(b)(ii).

The carbohydrate component of a glycoprotein, projecting from the cell surface membrane acts as receptor site. The shape of the carbohydrate component may fit that of T cells, making the receptor site specific to these cells.

(c).

Protective function; Cell membrane protects the cytoplasm and the organelles present in the cytoplasm
Selective permeability: Cell membrane acts as a semipermeable membrane, which allows only some substances to pass through it and acts as a barrier for other substances
Absorptive function: Nutrients are absorbed into the cell through the cell membrane

Excretory function: Metabolites and other waste products from the cell are excreted out through the cell membrane

Exchange of gases: Oxygen enters the cell from the blood and carbon dioxide leaves the cell and enters the blood through the cell membrane

Maintenance of shape and size of the cell: Cell membrane is responsible for the maintenance of shape and size of the cell.

Question 30.

(a).Outline the major steps involved in the transport of proteins within a cell ***(08 marks)***

(b).State the reasons why mitosis leads to little genetic variation ***(04 marks)***

(c).How do the following affect the plasma membrane

(i).Temperature ***(03 marks)***

(ii).Addition of ethanol ***(03 marks)***

(d).How is the effect in (c)(ii) been applied in day to day life ***(02 marks)***

(a).

- Protein made at ribosomes when translated by mRNA
- Protein enters RER cavity; and packaged in the rough endoplasmic reticulum
- Proteins are folded and assume their final 3dimensional shape
- Proteins then packaged into membrane-bound vesicles, vesicles form; move to Golgi apparatus
- Vesicles fuse with the Golgi body and protein moves through Golgi apparatus.
- Golgi body modifies protein; e.g. adds carbohydrates to make a glycoprotein etc
- Water is removed (to concentrate)
- Modified proteins are secreted via vesicles (if extracellular e.g. enzyme); by fusing with the membrane

(b).

- Low genetic diversity due to a low number of different alleles in gene pool
- Asexual reproduction leads to offspring genetically identical to parent
- No recombination & no new combinations of maternal-paternal chromosomes
- Variation only possible as a result of mutation which is very rare.

(c)(i).

- Increase in temperature makes phospholipids move more; cell membrane become more permeable
- Proteins denature above certain temp; increase permeability as well as distorting membrane morphology
- Pigment escapes when disrupted; disruption of vacuolar membrane

(c)(ii).

- Ethanol dissolves lipids of plasma membrane causing the membrane to be disrupted
- Proteins denatured by ethanol; disrupting the integrity of the membrane
- Disrupts the vacuole membrane; result in escape of pigment

(d).

Alcohol has been used as an antiseptic/ disinfectant to kill micro-organisms before and after performing medical or surgical procedures.

Question 31.

(a).Briefly discuss the factors affecting the rate of diffusion ***(10 marks)***

(b).Compare the advantages and disadvantages of the light and electron microscopes ***(06 marks)***

(c).Suggest different ways in which reversible changes in the cell volume maybe important in flowering plants ***(04 marks)***

(a).

Temperature: Increase in temperature increases the rate of diffusion since temperature increases the kinetic energy of the molecules hence more collisions and vice versa.

Size of diffusing particles: The larger the particles the lower the rate of diffusion and the smaller the particles the higher the rate of diffusion.

Surface area over which diffusion occurs/ Fick's law: The larger the surface area the greater the rate of diffusion and vice versa.

Concentration gradient: The greater the concentration gradient, the higher the rate of diffusion & viseversa.

Density of the diffusing particles/molecules: The denser the diffusing particles the lower the rate of diffusion & vice versa.
Distance over which diffusion occurs: The larger/bigger the distance the

(b).

Light microscope	Electron microscope
(advantages)	**(disadvantages)**
It is easy and cheap to operate since it uses little or no electricity.	Difficult and expensive to operate since it requires much electricity to produce an electron beam.
Natural colour of the specimen can be observed.	All images are in black and white.
It is small and portable.	It is very large and operated in special rooms.
It can view living and dead materials.	The high vacuum required kills the living materials.
Preparation of material is quick.	Preparation of material is lengthy and requires special equipment.
Materials are not changed/distorted by preparation.	Materials are changed or distorted by preparation.
Disadvantages	**Advantages**
It has a low resolving power i.e. 200nm.	Has a high resolving power of about 1nm.
Has a low magnifying power i.e. up to 1500 times.	High magnifying power i.e. up to 500,000 times.

(c).

- Stomatal movements/ opening and closing of the stomata for gaseous exchange
- Opening and closing of flowers to allow pollination
- Opening and closing of the leaves in nastic responses to avoid unfavourable weather.
- Changes in turgidity of cells is responsible for support in herbaceous plants
- Absorption of water by plant roots

Question 32.

(a).Discuss the diversity of cells & their functions within bodies of lower animals like hydra ***(10 marks)***
(b).State the main differences between plant and animal cells ***(10 marks)***

(a).

Within the body of a hydra, there are seven types of cells and these include:
Epithelial cells: possess a shape suitable for lining the surface of the body, organs and cavities within it.
Glandular cells: These are suitable for producing a secretion e.g. mucus.
Erythrocytes (red blood cells): These convey oxygen around the body since they are loaded with a red pigment haemoglobin.
Leucocytes (white blood cells): These defend the body against diseases.
Nerve cell/neuron: These contain slender arm-like processes that transmit electrical impulses through the nervous system.
Sensory cells: These are capable of electrical activity which is generated by specific kinds of stimulation like light, sound, touch, etc.
Muscle fibres: These are capable of movements since the electrical activity is accompanied by contraction since they are elongated.
Other cells found in animals below the level of mammals i.e. skin of animals include the following;
Flame cells: These are found in flatworms and play an important role in osmoregulation.
Nematoblast/stinging cells: These are found in sea anemones, hydra and jelly fish for piercing and poisoning prey due to their toxic fluid.
Musculo-epithelial cells: These contain one side that contributes to the lining of the body.

(b).

Plant cells	Animal cells
Cell wall present in addition to the cell membrane.	Cell wall absent, cell membrane surrounds the cell.
Pits and plasmodesmata present.	Pits and plasmodesmata absent.
Plastids e.g. chloroplasts & leucoplasts are present.	Plastids absent.

Mature cells have large single central vacuole filled with cell sap.	Vacuoles e.g. contractile vacuoles if present are small and scattered throughout the cell.
Tonoplast present around the vacuole.	Tonoplast absent.
Cytoplasm confined at the periphery of the cell.	Cytoplasm present throughout the cell.
Nucleus at the edge of the cell.	Nucleus anywhere in the cell but often central.
Lysosomes absent.	Lysosomes present.
Cilia and flagella absent.	Cilia and flagella present.
Starch granules used for storage.	Glycogen granules used for storage.
Middle lamella present.	Middle lamella absent.
Only meristematic cells are capable of division.	All cells are capable of division.
Few secretions released.	A variety of secretions released.

Question 33.

(a)(i).Explain the features of the endosymbiont theory of evolution of eukaryotic cells. ***(08 marks)***
(a)(ii)State any plausible evidence for the endosymbiont theory. ***(05 marks)***
(b).How are chloroplasts similar to mitochondria? ***(03 marks)***
(c).Why are bacteria claimed to be the most ancient group on earth? ***(04 marks)***

(a)(i).

The endosymbiont theory suggests that mitochondria and chloroplasts were once separately existing small aerobic bacteria and photosynthetic bacteria respectively; Larger anaerobic bacteria engulfed the smaller bacteria by the process of endocytosis, but digestion failed; Initially, the smaller bacteria could have lived inside larger bacteria either as parasites or phagocytic vesicles, after which a mutually benefiting relationship called endosymbiosis resulted, where the larger cell provided protection and shelter while the smaller organisms removed oxygen which was toxic to the anaerobic larger cell. With time, mitochondria and chloroplasts were modified into organelles suited for respiration and photosynthesis inside the larger eukaryotic cells

(a)(ii).

• Mitochondria and Chloroplasts have their own DNA
• Mitochondria and chloroplasts divide independently of the cell they live in.
• Aerobic cells appeared at about 2.5 Billion years ago, followed by mitochondria, chloroplasts and eukaryotic cells at almost the same time, approximately 1.5 billion years ago
• Mitochondrial DNA and chloroplast DNA is short hence provides only a small part of the genome needed for binary fission, hence the process in organelles is controlled by the nucleus which contains the larger genome
• Mitochondrial DNA and chloroplast DNA is short, therefore can only code for a few of the proteins needed, hence some of the required proteins are imported from the cytoplasm of the main cell where the organelle stays

(b).

Both chloroplasts and mitochondria
• Have naked DNA
• Contain systems for electron transport
• Are bound by double membranes
• Have their own ribosomes; and thus self-autonomous.

(c).

• Occupy a variety of environments ranging from thermal springs to frozen areas
• Have a simple structure which seems modified in modern eukaryotes
• Have a simpler physiology in many cases seemingly primitive compared to eukaryotic cell physiology
• Have maintained a simple body plan of unicellularity accounting for the evolution into other kingdoms.
• Utilization of complex chemical compounds as food e.g. iron and hydrocarbons, may have simplified colonization for absorptive and ingestive feeders.

Question 34.

Briefly describe the various mechanisms of material exchange across the cell ***(20 marks)***
Simple diffusion; net movement of molecules or ions from their region of high concentration to their region of

low concentration along the diffusion gradient until equilibrium or uniform distribution is attained. Simple diffusion is a passive process. Gaseous exchange along cells occurs by simple diffusion.
Facilitated diffusion; some ions & other larger polar molecules diffuse across the plasma membrane through channel and carrier proteins. Facilitated diffusion is involved in glucose uptake, ion exchange e.g chloride shift in red blood cells etc
Osmosis; net passage of water molecules from a region of their high concentration (less negative water potential) to a region of their low concentration (more negative water potential) via a semi-permeable membrane until equilibrium is attained. Process is passive and occurs along the osmotic gradient.
Active transport; materials are exchanged across the plasma membrane against the concentration gradient and the process requires energy from ATP hydrolysis. Membrane carrier proteins/protein pumps actively transport molecules/ions from one side of the membrane to another e.g the sodium-glucose symport that transports glucose and hydrogen ions in the same direction, sodium-potassium antiport that pumps sodium and potassium ions in opposite directions.
Endocytosis; is an active process involving bulk intake of material through the membranes. Cell membrane invaginates to form a vesicle/ vacuole that enclose the material. **Phagocytosis** is endocytosis in which material is taken up in solid form e.g white cell take up bacteria by phagocytosis. **Pinocytosis** is endocytosis involving intake of material inform of liquid e.g human egg cells take up nutrients from the surrounding follicle cells, intake of thyroglobulin by the thyroid follicular cells occur by pinocytosis.
Exocytosis; here materials are removed from the cells e.g solid undigested remains, enzymes, secretions like hormones, neurotransmitters are released by exocytosis. Here the vacuole fuses with the plasma membrane; then spill out the contents to the extracellular environment.

Question 35.

(a).Describe the nature, distribution and function of the various plastids in plant cells ***(12 marks)***
(b).State the differences between;
(i). Smooth endoplasmic reticulum and rough endoplasmic reticulum ***(04 marks)***
(ii).Active transport and diffusion ***(04 marks)***

(a).

Chloroplasts; photosynthetic pigments; contain chlorophyll hence appearing green. They are mainly found in leaves though present in young stems and fruits. They trap light essential in photosynthesis.
Chromoplasts; non-photosynthetic; contain red, orange or yellow pigments. They are found in fruits like red pepper tomatoes, where they attract dispersal agents, in flower petals as pollinator attractants. They also give colour to tubers like carrots.
Leucoplasts; non-photosynthetic; colourless as they lack pigments. They are abundantly found in storage organs like roots, seeds and in young leaves eg the amyloplasts store starch in many tubers.

(b)(i).

Smooth endoplasmic reticulum	Rough endoplasmic reticulum
Has smooth tubular membranes without ribosomes	Has rough membranes with numerous ribosomes
Consists of mainly tubule and vesicles	Consists of many cisternae and few tubules
Associated with synthesis of steroids and lipids	Associated with protein synthesis
Found abundant in cells secreting lipids and steroids like gonads	Abundant in protein secreting cells eg liver cells and muscle cells

(b)(ii).

Active transport	Diffusion
Energy is required	Passive process without energy requirement
Movement is against concentration gradient	Movement follows a concentration gradient
Rapid process	Slow process
Selective and particular ions are transported by active means	All molecules can move from their high to low concentration

Question 36.

(a).Distinguish between fluid mosaic & Danielli-Davson models of plasma membrane. ***(06 marks)***

(b) Explain how the;
(i) golgi bodies function in cells. *(06 marks)*
(ii) Plasma membrane allows transport of materials across it. *(04 marks)*

(a).

Danielli-Davson model	Fluid mosaic model
Membrane is a protein lipid sandwich	Membrane is a fluid mosaic of phospholipids and proteins
Proteins coat the outer surface of the membrane	Peripheral proteins are either bound to the inner or outer surface of the membrane
Proteins donot permeate the lipid layers	Integral proteins permeate the lipid layers
Membrane has a rigid phospholipid bilayer	Phospholipids are fluid and move more laterally
Lacks cholesterols.	Has cholesterols that make the membrane fluid
Lacks glycoproteins and glycolipids	Has glycoproteins and glycolipids

(b)(i).

Soluble or properly folded macromolecules (proteins, lipids and polysaccharides) from RER enter cis Golgi network via transport vesicles. Within cis-cisternae, macromolecules are partly modified i.e carbohydrates are added to proteins (glycosylation), phosphate is added to protein (phosphorylation) etc. After partial modification, coated vesicles bud (pinch) off the swollen ends of cis-cisternae and fuse with ends of medial cisternae. Within medial-cisternae, different enzymes further transform macromolecules differently, depending on their structures and function. After further modification within the medial cisternae, coated vesicles bud (pinch) off the swollen ends of the medial-cisternae and fuse with the ends of trans- cisternae for further transformation. From trans-cisternae, the transformed macromolecules exit the Golgi and are sorted into different transport vesicles.

(b)(ii).

- The thinness of the membrane permits material exchange by simple diffusion
- The membrane utilizes its non-polar lipid bilayer to allow exchange of non-polar substances.
- The membrane utilizes its channel proteins to permit facilitated diffusion of polar substances
- The membrane utilizes its pores between channel proteins to allow transport of polar substances
- The membrane utilizes its transmembrane proteins; move substances by active transport eg Na-K pumps

Question 37.

(a).Describe behavior of chromosomes during cell cycle involving mitotic cell division *(09 marks)*
(b). Explain how the following contribute to variation among organism: *(11 marks)*
(i). Independent assortment.
(ii).Crossing over.

(a).

Interphase; Chromosome content doubles following DNA replication; and appear unwound in the chromatin
Prophase: chromatin condenses into discrete chromosomes; Each chromosome appears to have a pair of chromatids jointed at the centromere; chromosomes begin to migrate toward the cell centre
Metaphase: Chromosomes reach the centre; then align at the metaphase plate/equatorial plane along spindle fibres.
Anaphase: Sister chromatids separate & orient towards opposite poles; chromatids make a V-shape as the arms of the chromatid drag behind the centromere; chromatids finally part company to the opposite poles of the cell.
Telophase: sister chromatids (now called Chromosomes) reach opposite poles; chromosomes de-condense or un-wind, nucleolus begins to appear; nuclear envelope appears and envelopes the chromosomes.

(b)(i).

During independent assortment in metaphase I, chromosomes are distributed randomly at the equator and segrega-te (separate). It is by pure chance as to which chromosome from each homologous pair ends up in each daughter cell at the end of meiosis. Therefore all sorts of allele combinations are possible in the gametes. This reshuffles the existing alleles thereby producing new genetic recombinations of the gametes.

(b)(ii).

With Crossing over, there is exchange of genetic material between the non-sister chromatids of homologous chromosomes during pachytene stage of prophase I of meiosis. This produces new linkage groups and so provides a major source of genetic recombination of alleles on chromosomes.

Question 38.

(a) Explain how the following process occur in the cell and significance.

(i). Autophagy. ***(04 marks)***

(ii).Autolysis. ***(04 marks)***

(b).Describe the role of;-

(i).Cell wall ***(06 marks)***

(ii).Cell membranes. ***(06 marks)***

(a)(i).

Autophagy the primary lysosome fuses with worn out cellular components like mitochondria to form an auto phagocytic vacuole in which hydrolytic enzymes digest products which leave by diffusion while the undigested material residual body can be released by exocytosis.

(a)(ii).

Autolysis; is referred to self-digestion, the content of the lysosomes are poured into cell and breakdown of the structure resulting into the breakdown of the whole cell thus shows suicide mission.

(b)(i).

- Make cells turgid to osmotic in flow of water because cell walls are fairly rigid & resistant to expansion.
- Limit cell growth and shape by orienting the cellulose micro fibril that stretch to allow growth
- Provides a major pathway of water by apoplast where the walls are held together by the middle lamella.
- Develops a coating of waxy cuticle; reducing the water loss
- Food reserves in some cell wall e.g. hemicellulose in some seeds.
- Develops increased surface area hence increasing efficiency of transfer of material by active transport.

(b)(ii).

- Channel proteins are involved in selective transport of polar molecules and ions across the membrane
- Cholesterol reduces the escape or entry of polar molecule through the membrane.
- Glycolipids with branching carbohydrates side chain and are involved in cell recognition.
- Membranes have antigens which enable the cell to recognize other cells.
- Have receptor molecules with specific shape for chemical signaling.
- Membranes have enzymes which catalyze the breakdown of substrates

Question 39.

(a). Account for the significance of the following theory in the field of cytology

(i). Cell theory ***(10 marks)***

(ii) Endo-symbiotic theory ***(10 marks)***

(a).

Cell theory states that the cell is the basic structure and functional unit of living organism, some organism are single celled and perform all the life processes cell contain hereditary information, which is passed from one organism to another organism, all cells have same chemical composition and all energy flow occur in a cell; an amoeba has one cell and is able to carry on with reproduction, osmoregulation, excretion and gaseous exchange which are life processes hence the cell is the most important unit of an organism.

(b).

Endo-symbiotic theory explain the origin of eukaryotic cell, it suggests that the mitochondria and chloroplast were once separated existing, small aerobic bacteria and photosynthetic bacteria by endocytosis the larger anaerobic bacteria engulfed the smaller bacteria but digestion failed by parasitic association ,the smaller bacteria lived inside and mutually benefited by endo symbiosis where large cell provided protection and shelter while the smaller organism removed the oxygen that was toxic to the anaerobic large cell, the chloroplast and mitochondria were known and modified into organelles suited for respiration and photosynthesis, the theory is evidenced by the mitochondria having their own DNA and divide independently of the of the cell they live in also the prokaryotic cell and also the organelles are similar.

Question 40.

What is the importance of the following membranes in cell physiology?

(a).Cisternae *(03 marks)*
(b).Cristae *(05 marks)*
(c).Thylakoids *(04 marks)*
(d).Tonoplast *(08 marks)*

(a).

- For formation and budding off of lysosomes;
- Processing of materials for secretion
- Modification of proteins for transport out of the cell.

(b).

- Attachment of proteins which act as enzymes for catalysis of respiratory reactions.
- Attachment of electron carriers for the electron transport chain
- Allowing entry of pyruvic acid from glycolytic reactions
- Allowing exit of acetyl CoA for entry into the Krebs cycle
- Maintaining graded redox potentials for the synthesis of ATP;

(c).

- Increasing surface area for the reactions of photosynthesis
- Supporting chlorophyll molecules in suitable positions to trap sunlight for photosynthetic reactions
- Allowing out ward diffusion of oxygen given off during photosynthesis.
- Supporting electron carriers in position to transfer electrons during photosynthesis.

(d).

- Control of osmosis in cells by maintaining osmotic gradients
- Diffusion of anthocyanin responsible for coloration of cells
- Penetration of light to cause coloration of cells hence attraction of pollinators
- Hydrolytic enzymes in vacuoles act as lysosomes causing autolysis upon cell death
- Diffusion of secondary products and wastes in cells;
- Some dissolved substances in cells are food reserves which diffuse across the tonoplast.
- Used in osmoregulation in cells since solutes and water diffuse across the tonoplast;
- Maintenance of cell shape as in osmosis resulting from turgor changes.
- Contribute to cell expansion in plants during growth by uptake of water.

Chapter 2; HISTOLOGY

Question 1.

(a).State the characteristics of epithelial tissues *(05 marks)*
(b).Explain how distribution of epithelial tissues in the mammalian body is related to function *(15 marks)*

(a).

- Cells rest on basement membranes
- Cells are cemented by intercellular substance
- Cells have a free end which may be modified to perform a specific function e.g ciliated
- They line internal and external surfaces of organs.
- They are arranged in layers or sheets of cells which may be single or multiple.
- They are avascular (lack blood vessels) and exchange of materials is by simple diffusion.
- Cells have a high regenerative capacity, replacing the worn out usually from the germinal layers.
- Multi-layered epithelia are found in areas of abrasion.
- Highly cellular (sparse intercellular space)
- Numerous intercellular junctions for attachment and anchorage

(b).

Protective roles;

- The skin has a cornified epithelium; heavily thickened and keratinized for protection of underlying structures against mechanical damage and entry of germs.

• Skin has melanocyte containing epithelial tissues, secrete melanin, which protects the skin against ultra violet radiations
• Gut epithelial lining has mucus secreting cells (goblet cells); protects the walls of the gut against corrosive effects of the digestive enzymes and juices

Absorption;

• Epithelium lining the ileum and renal tubules has numerous villi and microvilli; increase surface area for absorption of materials.
• Squamous epithelia in the blood capillaries are flattened and one cell layer thick to reduce distance of diffusion of materials.

Transport

• Epithelia lining the oviduct and respiratory tract are ciliated, beating of the cilia in the oviduct propels the ovum; where as in the respiratory tract, cilia sweeps germs and dust particles thus cleanses the air.

Secretion

• Glandular epithelial tissues in gut, mouth, eyes etc are highly folded; increasing surface area for secretion

Sensitivity and co-ordination;

• Retinal epithelium has photoreceptor cell (cones and rods); sensitive to light stimulation.
• Epithelium of the skin has pain receptors, baroreceptors and thermoreceptors; for detecting pain, pressure and temperature stimuli respectively
• Papilla (epithelium) of the tongue has taste buds that are sensitive to sour, sweet or bitter tastes.
• Epithelium lining the organ of Corti has sensory hair cells, Cupula has cristae and maculae organs; sensitive to hearing and balance respectively.

Reproduction;

• Germinal epithelia of testis & ovaries are actively mitotic aiding continuous spermatogenesis & oogenesis.

Storage;

• Stratified squamous transitional epithelium lining the urinary bladder and gall bladder is stretchable on distension; thus accommodate large amount of urine and bile respectively.

Gaseous exchange;

• Squamous epithelia lining the alveoli are made up of a flattened cell layer; reduce diffusion distance for respiratory gases.
• Part of the respiratory tract has a pseudo stratified epithelium to allow easy diffusion of gases.

Question 2.

(a).How are the following tissues related to functions

(i). Parenchyma tissues ***(09 marks)***

(ii).Collenchyma tissues ***(03 marks)***

(iii)Sclerenchyma tissues ***(03 marks)***

(b).State the functions of bones in animals ***(05 marks)***

(a)(i).

Parenchyma tissues

• Many intercellular spaces and loosely packed cells; for diffusion of gases
• Isodiametric or spherical or elongated cells; packing material; offers support/turgidity
• Thin cellulose cell wall; permit easy diffusion of material
• Transparent cell wall; permit entry of light for photosynthesis
• Permeable walls; allows entry of water for turgidity
• Large cell vacuoles; provide storage space for materials like sugars.
• Chloroplast present; traps light; allow photosynthesis
• Chromoplast present; in petals; provide colour to attract insects for pollination.
• Leucoplast present; store starch.

(a)(ii).

Collenchyma tissues

Cells are polygonal in cross section; thick cell wall due to heavy cellulose deposition; cells are elongated and parallel to the axis of the plant body; all aim at offering mechanical strength to the plant by supplementing support offered by parenchyma cells.

(a)(iii)

Sclerenchyma tissues

Elongated fibres and roughly spherical sclereids; heavily thickened and lignified cell wall; primary cell wall; mature cells possess empty lumens(dead cells); offer great tensile and compressional strength; augments other tissues in providing support and mechanical strength to the plant. Simple pits (aggregates of several plasmodesma) in the non-lignified area; permit material exchange between adjacent cell.

(b).

- Bone stores and releases calcium into the blood stream at required levels
- Bone serves as a rigid structure of the body giving it shape
- Bone protects delicate organs of the body against mechanical damage
- Acts as a lever for muscles and facilitates movement within the body
- Bone contains red bone marrow responsible for synthesis of red blood cells.

Question 3.

(a).Describe how the structure of cartilage tissue is related to function ***(08 marks)***

(b).Explain the appearance, distribution and functioning of the various types of cartilage ***(08 marks)***

(c).State the regressive stages of cartilage tissues and their significance ***(04 marks)***

(a).

Cartilage is tough, hard but flexible connective tissue to allow shock absorption, flexibility and rigidity when required. It is made of a semi solid matrix called chondrin in which fibres and other cartilage cells are embed-ed. Chondrin is enclosed by the perichondrium which is made up of white fibrous tissue. The cartilage cells enclosed are chondroblasts which later differentiate to chondroblasts. Chondroblasts occur singly in a space called lacuna while chondrocytes occur in groups of 2s, 4s or 8s in the same space the lacuna. Chondrocytes secrete chondrin which lacks blood vessels so exchange of materials between the matrix and cells is by simple diffusion.

(b).

Hyaline cartilage; found at bone ends, trachea, larynx and skeletons of cartilaginous fish. Its matrix is glass like, translucent with few fine collagen fibres giving it a fibre free appearance.

Elastic cartilage; found in ear lobes of mammals. It is made up of a network of yellow elastic fibres making it elastic and flexible. Its matrix is semi-opaque due to the numerous yellow elastic fibres.

White elastic cartilage/ fibrocartilage; found in between intervertebral discs. Its matrix has densely packed white collagen fibres providing greater strength and little flexibility making the vertebral column rigid with minimal flexibility. Also its shock absorbing role offers s a cushioning effect in the intervertebral discs.

(c).

Regressive changes represent critical steps in endochondral bone formation.

Stages of regression

- Chondrocytes hypertrophy and secrete alkaline phosphatase that provides a calcifiable matrix.
- Calcium phosphate is deposited in the matrix, prohibiting diffusion of nutrients to the chondrocytes.
- Chondrocytes die, leaving behind empty lacunae and the calcified matrix.

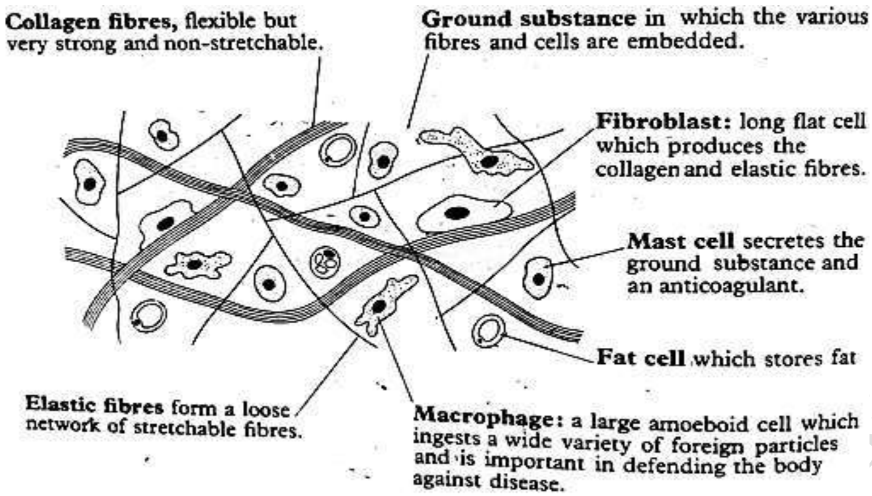
Question 4.

(a).Describe how the structure of areolar tissue is related to function ***(07 marks)***

(b).Outline the functions of areolar tissues ***(04 marks)***

(c).Compare structure and function of parenchyma, collenchyma and sclerenchyma tissues ***(09 marks)***

(a).



- Matrix; forms the ground substance in which several cells and fibres are suspended.
- The white collagen fibres appear in bundles; flexible but inelastic to provide strength.
- The yellow elastic fibres are branched, flexible and elastic allowing flexibility of tissue.
- The fibroblasts are numerous, elongated and flattened; enabling secretion of the fibres.
- Fat droplets in the fat cells/ adipocytes; serve as fat stores
- Mast cells; secrete matrix as well as the anticoagulant (heparin).
- Amoeboidal macrophages; engulf foreign bodies.

(b).

- Binds organs together and fills up spaces between organs preventing displacement.
- Stores fat; which is an energy store; also offers insulation against heat loss.
- Macrophages; protective against infection by destroying noxious organisms and other foreign bodies.
- Fibroblasts make new fibres; hence participate in repair and regeneration.

(c).

Parenchyma tissues	Collenchyma tissues	Sclerenchyma tissues
Living tissue	Living tissue	Dead tissue
Cell wall made up of pectins cellulose, and hemicellulose	Cell wall made up of pectins cellulose, and hemicellulose	Mainly made up of lignin, cellulose and hemicellulose
Isodiametric cells at times elongated.	Elongated and polygonal cells with tapering ends.	Elongated and polygonal cells with interlocking ends.
Functionally unspecialized	Offers mechanical support	Support and protection
Have intercellular spaces	Lack intercellular spaces	Lack intercellular spaces
Thin cell wall	Thick cell wall	Very thick cell wall
Large vacuoles	Small vacuoles	Smallest vacuoles
Distributed in the pith, medullary rays, packing tissue in xylem and phloem	Outer regions of the cortex eg at the angles of stems, midrib of leaves.	Outer regions of the cortex, pericycle of xylem, xylem and phloem and seed coats.

Question 5.

(a)(i).Explain what is meant by a polarized cell in relation to epithelial tissues ***(02 marks)***
(a)(ii).How is the structure of epithelial tissue related to function. ***(03 marks)***
(b).Compare the xylem and phloem tissues in plants ***(08 marks)***
(c).Outline the differences between connective tissues and epithelial tissues ***(07 marks)***

(a)(i).

A polarized cell is one that exhibits contrasting properties or structures on opposite sides of the cell. Because epithelial tissues face a free surface, the function of the apical surface is often very different from that at the base of the cell.

(a)(ii).

• Basement membrane which provides support and attachment for the epithelial cells as well as serving as seletive diffusion barrier.
• Basal surface contacts the basal lamina of the basement membrane.
• Free surface interfaces with the external environment or spaces within the body.

(b).

• Both are distributed in the vascular system of plants.
• Composed of a mixture of dead and living cells
• Both are elongated and tubular
• Both are composed of cellulose, pectin and hemicellulose

Xylem	Phloem
Composed of tracheids and vessels.	Composed of sieve tube cells and companion cells.
Made up of dead tissue	Made up of living tissue
Lignified walls	Walls mainly made up of cellulose, pectin & hemicellulose
Translocates water and mineral salts	Translocates organic solutes
Provide support	Offers little or no supportive role
Contain parenchyma cells	Lack parenchyma cells
Lack sclereids	Have sclereids
Have thick rigid walls	Have thin and more extensible walls
Have low sap concentration	Have a high sap concentration
Have no turgor	Have turgid cells
Translocation is under high speed	Translocation is very slow.

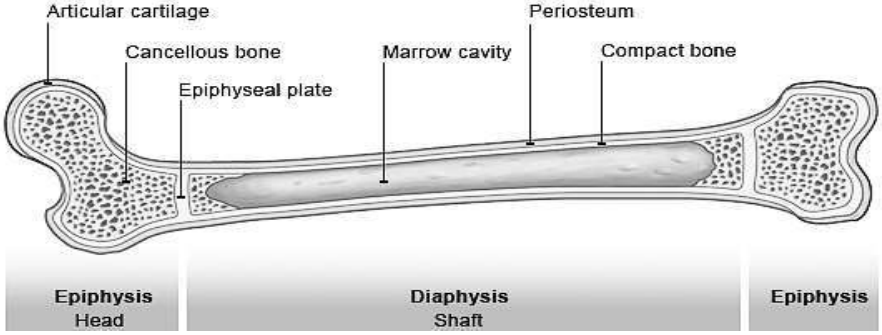
(c).

Connective tissues	Epithelial tissues
Consists of few cells separated by large amounts of intercellular substance.	Consists of many cells tightly fitted together
Lack a continous layer or sheet	Form a sheet of cell covering a body surface or a lining of a cavity.
Has a variety of cells embedded in large quantities of ground substance (the matrix)	Has few cells normally attached to the basement Membrane
Lack modifications like cilia, villi or keratin	Modified with cilia, villi or keratin
Has fibres such as collagen, elastic or reticular	Lack fibres
It is very abundant	Less abundant
Slow rate of division	Rapid rate of division
Cells not arranged in definite layers	Cells are arranged in definite layers.

Question 6.

(a) Describe the gross structure of a long bone ***(06 marks)***
(b).State differences between spongy bone and compact bone ***(05 marks)***
(c).How is cartilage replaced by bone? ***(09 marks)***

(a).



Bone is a hard, tough connective tissue made up of mainly calcified material. It has hard matrix called osteum made up of protein ossein. Osteum embeds bone cells (osteocytes, osteoclasts and osteoblasts). Long bones consist of hollow shaft/ diaphysis; with expanded head or epiphysis at each end. Covering the entire bone is a sheath of tough connective tissue; the periosteum; made up of mainly collagen fibres. The diaphysis is composed of compact bone material while the epiphyses at each ends are made up of spongy bone; covered by a thin layer of compact bone. Fatty yellow marrow occupies the marrow cavity of the diaphysis while the red marrow is present in the bony struts (trabeculae) of the epiphyses. Small openings penetrate the bony surfaces through which nerves and blood vessels cross into the marrow and the bone tissue.

(b).

Spongy bone	Compact bone
Lacks organized harvesian canal systems	Harvesian canals arranged in concentric circles
Has air spaces between the bony struts	No air spaces; matrix is dense
Matrix is relatively soft due to low deposition of calcium salts.	Matrix is solid and hard due to lots of inorganic calcium salts deposited.
Forms the epiphyses of long bones	Forms the diaphysis of the bone of long bones
Red marrow present in the bony struts	Fatty yellow marrow filling the marrow cavity of the diaphysis of long bones

(c).

Endochondral ossification occurs in the cartilage surrounded by the perichondrium and it begins with establishment of the primary ossification centres in the middle of the cartilage. Fibroblasts from the perichondrium invade the area; lay down collagen-fibres. Chondroblasts arrange themselves in rows begin absorbing calcium salts; calcified cartilage formed. Process continues with more deposition of collagen fibres and calcium deposition. Perichondrium changes into the periosteum and the Chondroblasts together with the fibroblasts transform into osteoclasts; which takes over the role of calcium absorption. Calcified regions gets progressively hardened and compact bone gradually forms. Cellular specialization occurs in the compact bone; osteoblasts erode through the bone forming channels of blood vessels and nerves; osteoblasts that are no longer capable of matrix secretion transform into osteocytes (the resting bone cells). Bones of the limbs, vertebrae column and pectoral girdles are formed by endochondral ossification.

Question 7.

Discuss how the structure of the following tissues is adapted to function

(a).Voluntary muscle tissue ***(10 marks)***

(b).Parenchyma tissue in plants ***(10 marks)***

(a).

• Elongated fibres; allow considerable contraction
• Parallel fibres; give maximum contractile effect
• Fibre ends are tapered and interwoven; provide strength
• High mitochondrial content; provide plenty of ATP
• Highly vascularized; provide enough oxygen and nutrients
• Has myoglobin; stores oxygen; releases it when the oxygen levels are low
• Motor end plates; initiate the stimulation of the muscle.
• Sarcoplasmic reticulum and numerous T systems; act as calcium reserves.
• Actin and myosin arrangement in sarcomere; allows contraction by filaments sliding over each other
• Myoglobin presents 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.
• Phosphocreatine; acts as an alternative ATP sources when primary sources are depleted.

(b).

• Unspecialized cells; provide a variety of functions
• Has many intercellular spaces; allows gaseous exchange
• Has thin cellulose cell walls; to allow passage of materials.

- Has transparent cell wall; allow entry of light for photosynthesis.
- Has permeable walls; allows water entry for turgidity
- Has large cells with large vacuoles; for storage
- Cells have chloroplasts for photosynthesis.
- Cells have chromoplasts; for formation of carotenoid pigments.
- Isodiametric cells; act as packing material
- Leucoplasts present to store starch.

Question 8.

(a).How is the chloroplast suited for function ***(08 marks)***
(b).Describe the modifications of parenchyma tissues in the different parts of the plant and state functions
(c).Explain the distribution pattern of mechanical tissues in plants. ***(05 marks)***

(a).

- Chloroplasts are bound by double membranes; to isolate photosynthetic reactions from other cellular activities.
- Contains numerous lamellae/ grannae /thylakoids; to hold chlorophyll; in a suitable position for trapping light.
- Thylakoids are stacked on top of each other; to provide a large surface area within little space.
- Lamellae are located within a watery matrix (stroma); with enzymes responsible for reduction of carbondioxide; and for storage of photosynthetic end products.
- Chloroplasts has a stroma matrix; site for light independent reactions.

(b).

- Transfer cells are used for transport of water and sugars out of the vascular bundles
- Companion cells for energy production in the phloem.
- Chromoplasts determine the colour of petals in flowers.
- Epidermal cells are elongated and flattened; in single layer over the entire plant body; for protection from desiccation and infection.
- Mesophyll cells located between upper and lower epidermis of leaves; possess chloroplasts for photosynthesis, spongy mesophyll for gaseous exchange; and pallisade mesophyll for photosynthesis.
- Endodermis around vascular tissue; forms a selective barrier to movement of water and mineral salts; between the cortex and the xylem.
- Pericycle in roots between central vascular tissue & endodermis retains meristematic activity to produce lateral roots.

(c).

- Xylem is centrally distributed in roots to withstand strains as aerial parts bend and lean over.
- Xylem is located peripherally in a ring in dicot stems and scattered in monocot stems such that separate rods run through to provide more support.
- Secondary xylem is added by secondary growth to support large structures of trees and shrubs.
- Collenchyma in the stems and petiole is peripheral just below the epidermis in the outer region of the collenchyma; to increase support.
- Collenchyma tissues in young herbaceous plants and organs without secondary growth; to supplement the turgid parenchyma.
- Sclerenchyma is distributed according to stress in organs; strengthened by arrangement of the strands or sheets of tissues scattered to give firmness.
- Mechanical tissues are distributed in the vascular bundles/ cortex/ pith around the periphery of stems where they resist compression and extension; as the stems get bent.

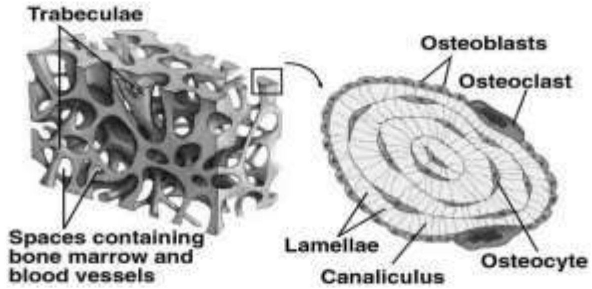
Question 9.

(a).Describe the structure of
(i). Spongy bone ***(07 marks)***
(ii).Compact bone ***(08 marks)***
(b).State the adaptations of long bones to functions ***(05 marks)***

(a)(i).

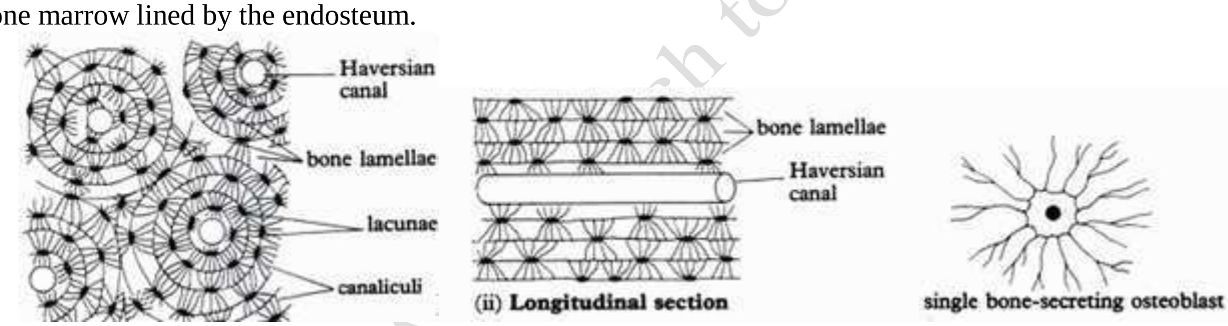
Spongy bone consists of a network of interlocking bony struts called trabeculae. Its matrix contains less inorganic materials making it soft. The spaces between the trabeculae are filled with a soft marrow called red bone marrow;

important in synthesis of blood cells. The matrix has three types of cells i.e osteoblasts which are active bone cells that secrete matrix, the osteocytes which are inactive or resting osteoblasts and osteoclasts which absorb calcium forming calcified matrix. The spongy bone occurs in the embryo, growing animals and at the ends/ epiphyses of long bones like femur.



(a)(ii).

Compact bone is made up of a number of harversian canal systems arranged in concentric circles. Each harversian system has bone cells (osteoblasts, osteocytes and osteoclasts). Osteoblasts are the active bone cells that secrete osteum, osteoblasts are inactive bone cells and the osteoclasts are used to absorb calcium. Bone cells are found in fluid filled spaces called lacunae consisting of a single bone cell. The lacunae have fine projection canaliculi which make connections with other lacunae. The lacunae are arranged in concentric circles forming bone lamellae. In the centre of each harversian system is the harversian canals that permit blood vessels and nerves. Each canal is made up of an outer fibrous layer called cement. Enclosing the harversian system is the periosteum on the outside and endosteum on the inside. Both of which are made up of collagen fibres. In the centre of the compact bone lies a bone marrow lined by the endosteum.



(b).

• Long bones are hollow; reducing weight of the organism.
• Diaphysis has calcified compact bone; withstands tension and compressional forces
• Bony struts with air spaces in the head of the femur reduces weight but struts maintain rigidity.
• Marrow cavity offers a point along which compressional and tensional forces diminish.
• The cartilage at the epiphysis acts as cushion absorbing mechanical shock & reducing friction between articular surfaces.

Question 10.

(a).Compare the structure of bone and cartilage *(08 marks)*
(b).How is the structure of cartilage related to functions *(06 marks)*
(c).Describe the process of intramembrane ossification *(06 marks)*

(a).

Similarities

• Both are supportive connective tissues.
• Both are made up of cells within a non-cellular ground matrix.
• Both contain yellow elastic fibres and white collagen fibres.
• Both contain fluid filled spaces; called lacunae.

Differences

Cartilage	Bone

Comparatively soft, elastic and flexible	It is tough, rigid and elastic
Matrix is chondrin	Matrix is osteum.
Matrix lacks deposition of calcium salts	Matrix has deposition of calcium salts
Lack regular arrangement of cartilage cells	Cells are arranged in concentric circles
Each lacuna has 2 ,4 or 8 chondrocytes.	Each lacuna has one bone cell/osteoblasts
Matrix is synthesized by chondroblasts	Matrix is synthesized by osteoblasts
Lacunae lack cannaliculi	Lacuna has cannaliculi
Lacks the harversian canal system	Has harversian canal system
Enclosed by perichondrium; made up of white elastic fibres	Enclosed by periosteum made up of white fibrous fibres.
Matrix lacks blood vessels so exchange of materials occurs by simple diffusion.	Matrix has a dense network of blood vessels
Three basic types; hyaline, elastic and white fibrous Cartilage	Two basic types; spongy and compact

(b).

• Semi solid matrix called chondrin; allows flexibility of the cartilage.
• Collagen fibres; provides mechanical strength to the tissues.
• Yellow elastic fibres; make the cartilage elastic; augments flexibility on stretch.
• Chondroblasts differentiated into chondrocytes secrete chondrin
• Lack blood vessels; al1ow exchange of materials by simple diffusion.
• Perichondrium made up of white fibrous fibres; enclose chondrin and other constituent components of cartilage.
• Lacunae have chondrocytes in 2s, 4s or 8s, act as reservoirs of the chondrin secreting cells
• Lacks calcium deposits in the matrix makes the cartilage soft, elastic and flexible.

(c).

Here the bone is laid in fibrous connective tissues like the dermis of the skin. Begins by fibroblasts invading areas where the bone is to be formed; then lay down collagen fibres followed by osteoclast aggregation done so in rows; absorb calcium resulting in calcified matrix. Net effect is formation of flat bony plates close to the skin surface. These increase in size and become calcified by absorbing more calcium salts. The bony plates eventually sink further to become part of the skeleton. Membrane bones form components of skull, jaws, hip bones or pelvic girdles.

Question 11.

(a).Explain the significance of the location of the compound epithelial tissues in living organisms.*(08 marks)*
(b).How does the structure of the compact bone suited to its function(s)? *(12 marks)*

(a).

• Transitional compound epithelium; in the urinary bladder; is extensible/ elastic allowing expansion of the organs for storage of urine temporarily;
• Cornified /keratinized stratified squamous epithelium; lining the skin surface; dead and impermeable to water; protect the skin from desiccation.
• Stratified cuboidal / columnar epithelium; lining of ducts of glands is multi-layered; offering tissues protection from mechanical and chemical stress.
• Keratinized squamous epithelium; lining buccal cavity and vagina; is impregnated with keratin; hardened; and capable of plucking away for protection of underlying tissues from mechanical damage.

(b).

• Lined with a tough periosteum increasing tensile strength to resist compressional forces.
• Has cannaliculi for communication between different lacunae
• Harversian canals to allow passage of blood vessels for efficient exchange of materials
• Volkmann‘s canals for communication between the harversian canal systems
• Numerous osteoblasts for secretion of bone matrix
• Numerous fibroblasts for secretion of collagen fibres that form the endosteum and periosteum
• Yellow marrow for storage of fats
• Hollow centre to reduce overall weight of the bone

• Numerous nerves in harversian canals; for effective nervous co-ordination in the bone.
• Dense deposition of inorganic salts in the bone; enhances bone strength.

Question 12.

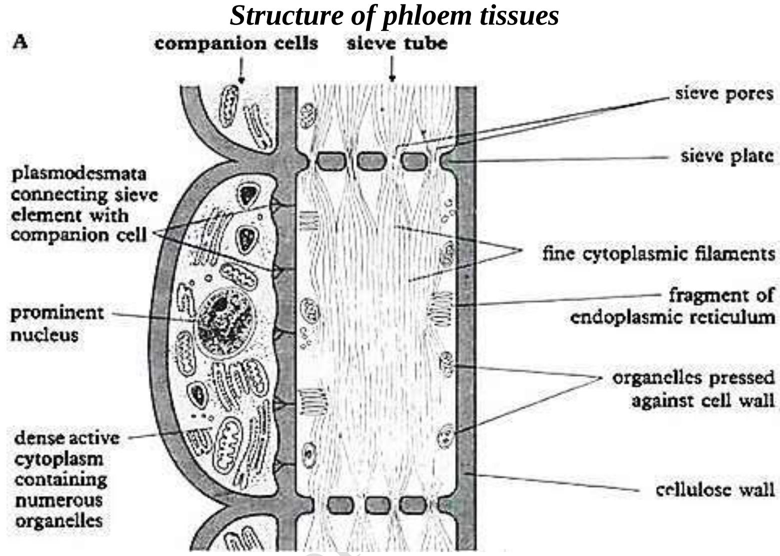
(a).Give an outline of the classification of muscular tissues ***(03 marks)***
(b).Describe the structure of the phloem and cardiac tissues ***(07 marks)***
(c).Explain how structure of phloem and cardiac tissues are adapted to function ***(10 marks)***

(a).

• Skeletal muscles
• Smooth muscles
• Cardiac muscles

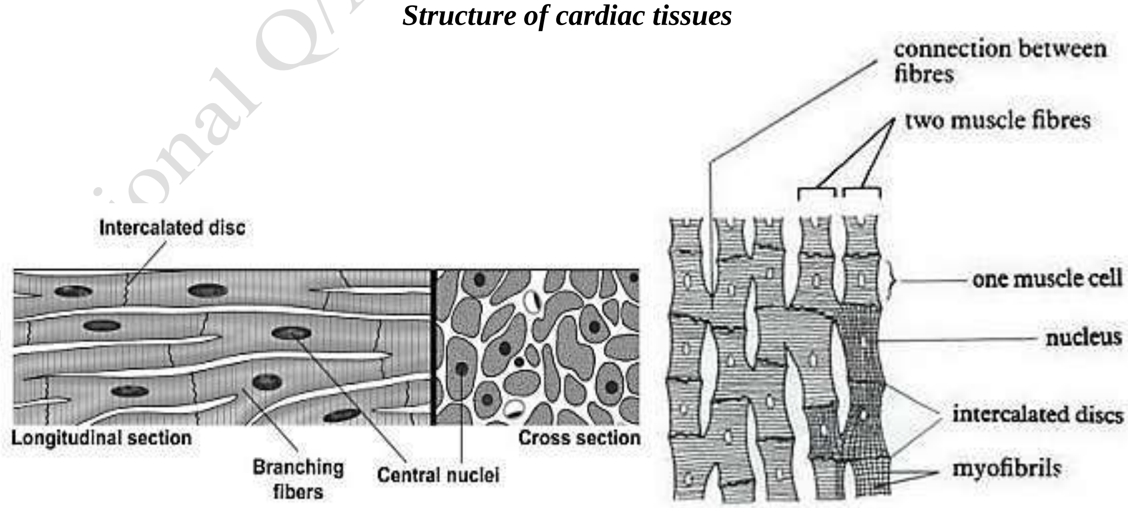
(b).

Structure of phloem tissues



Phloem consists of sieve tubes, companion cells, parenchyma, fibres or sclereids. The sieve tubes are formed by the end to end to fusion of sieve elements. Between the adjoining sieve element is a sieve plate; with sieve pores; the sieve elements have large lumen with peripheral cytoplasm. The companion cells have a dense cytoplasm, thick nucleus, numerous mitochondria and perforated plasmodesmata. The perforated parenchyma are elongated cells; the phloem fibres and sclereids have thick deposits of lignin.

Structure of cardiac tissues



Cardiac tissue consists of branched muscle fibres; each possesses one or two nuclei, numerous mitochondria; in the sarcolemma. Each fibres made up of many myofibrils that contain actin and myosin filaments. There are many striations with numerous intercalated discs separating individual muscle cells. Specialized cardiac tissue forms the sinoatrial node, atrial ventricular node, bundle of His which branches into purkyne tissue. The tissue is highly supplied with a network of blood capillaries and heavily innervated.

(c).

Phloem tissue

• Sieve tubes are joined end to end permitting continuous flow of materials
• The empty lumen of sieve tubes and peripheral cytoplasm; allows enough space for bulk flow
• Cytoplasmic strands facilitate translocation of materials by cytoplasmic streaming.
• Cellulose cell walls provide mechanical support; with stand pressure.
• Plasmodesmata allows communication of the sieve tubes with the companion cells
• Numerous mitochondria in companion cells; produce enough energy inform of ATP.
• The sieve plate produces a structure across which the potential difference can be developed for electro- osmosis
• The sieve pores allow transfer of materials from one sieve tube element to the next
• The sieve wall of cellulose of phloem parenchyma offers mechanical support.
• The lignified fibres and sclereids offer mechanical support.

Cardiac tissues

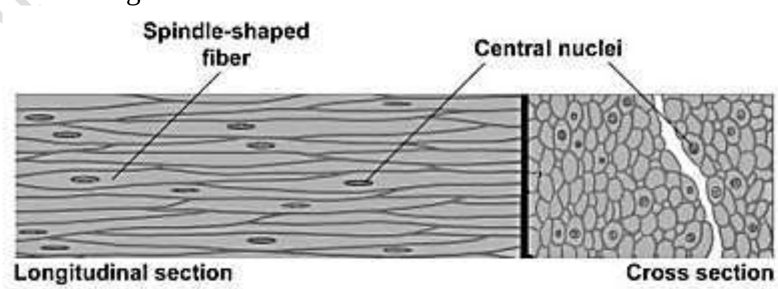
• Numerous mitochondria; produce adequate ATP to meet the high energy demands of cardiac tissue.
• Elongated muscle fibres spread contractions over long distances
• Numerous sarcoplasmic reticulum which act as Ca^{2+} reservoirs required in muscle contraction.
• Specialized cardiac tissue such as the SAN; permit myogenic initiation of contractions
• Numerous branched muscle fibres for rapid spread of excitations and contractions.
• Myocytes are highly branched and joined by intercalated disc; allow extended electrical excitation.
• Numerous blood capillaries ensure a steep concentration gradient for exchange of materials; maintaining cardiac tissue metabolically active.
• It is innervated by vagus nerve and sympathetic nerves; permitting autonomic control.

Question 13.

(a).Describe the structure and location of the following tissues
(i). Smooth muscles ***(06 marks)***
(ii).Skeletal muscles ***(08 marks)***
(b).Explain the role of the triad system in the muscle contraction ***(06 marks)***

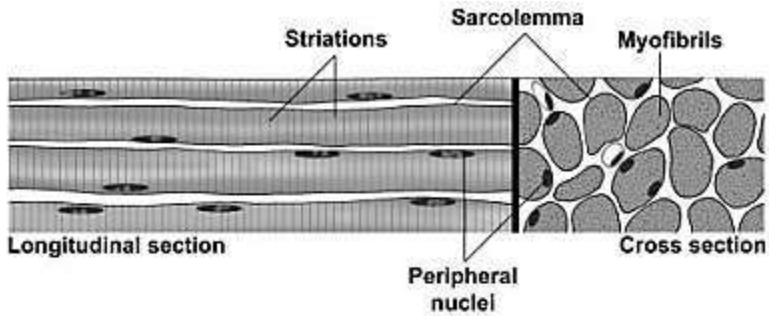
(a)(i).

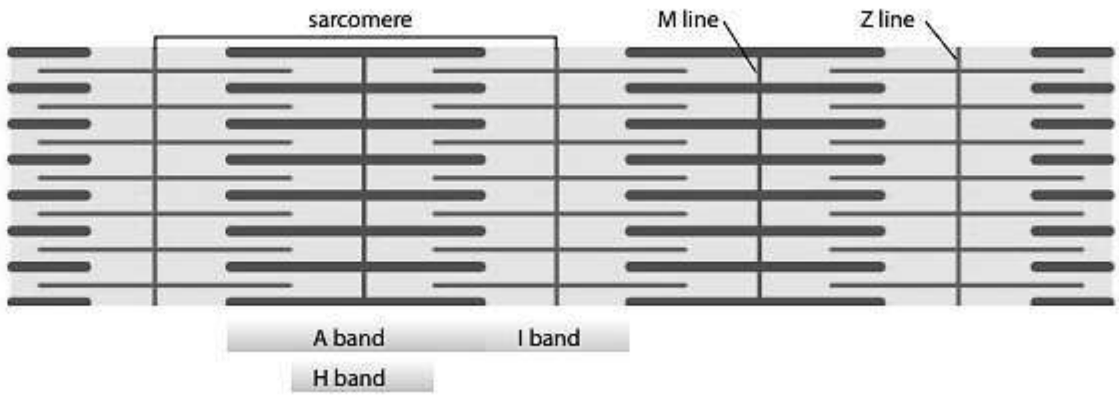
Smooth muscle occurs mostly as sheets, which form the walls of most hollow organs with the exception of the heart. Smooth muscle is also prominent in the walls of blood vessels, many respiratory passage ways, and some genital ducts and a number of visceral organs. Smooth fibres are made up of unbranched spindle-shaped fibers which are elongated with tapering ends and unbranched, possess a single, centrally placed, oval nucleus, which can appear spiraled or inch-worm shaped when the fiber is contracted. Organelles are clustered at the poles of the nucleus. The fibrils are thin actin and thick myosin filaments but they are non-striated; no myofibrils are present. Each fibre is served by its own single nerve cell.



(a)(ii).

Skeletal muscles are found attached to skeletal tissues i.e bone. Each muscle fiber is cylindrical, unbranched, and multinucleated. The multiple nuclei are located at the periphery of the muscle fiber immediately beneath the sarcolemma. Extensive smooth endoplasmic reticulum is called the sarcoplasmic reticulum. Fibers show prominent, alternating light and dark bands (cross striations) due to the alignment and overlap of the myofilaments within myofibrils. A band appears dark and contains actin and myosin, I band appears light and contains actin only, Z-line, composed of alpha-actin, is located in the center of the I band, H band is located in the center of the A band and represents the area where actin is not present, M band is located in the center of the H band and represents areas of cross-connections between myosin filaments Sarcomere forms a contractile unit of striated muscle fibers, extends from Z-line to Z-line, sarcomeres are repeated in series along the length of each myofibril. Adjacent myofibrils maintain the alignment of sarcomeres.





(b).

A nerve impulse arriving at the muscle fiber depolarizes the sarcolemma at the neuromuscular junction. The membrane depolarization propagates along the sarcolemma and extends down the T-system (composed of one T-tubule plus two adjacent terminal cisterns of the sarcoplasmic reticulum). T-tubule depolarization is transmitted to the terminal cisterns and the remainder of the sarcoplasmic reticulum, causing release of stored calcium. Calcium initiates the interaction between actin and myosin myofilaments, leading to muscle contraction. Calcium is recaptured by sarcoplasmic reticulum during relaxation.

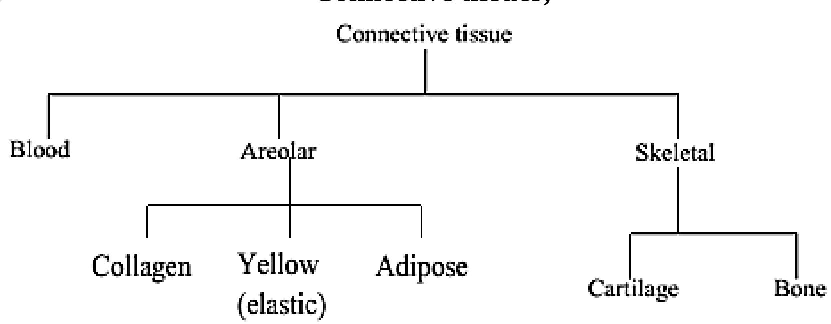
Question 14.

(a).With the aid of a schematic diagram, classify connective and epithelial tissues (07 marks)

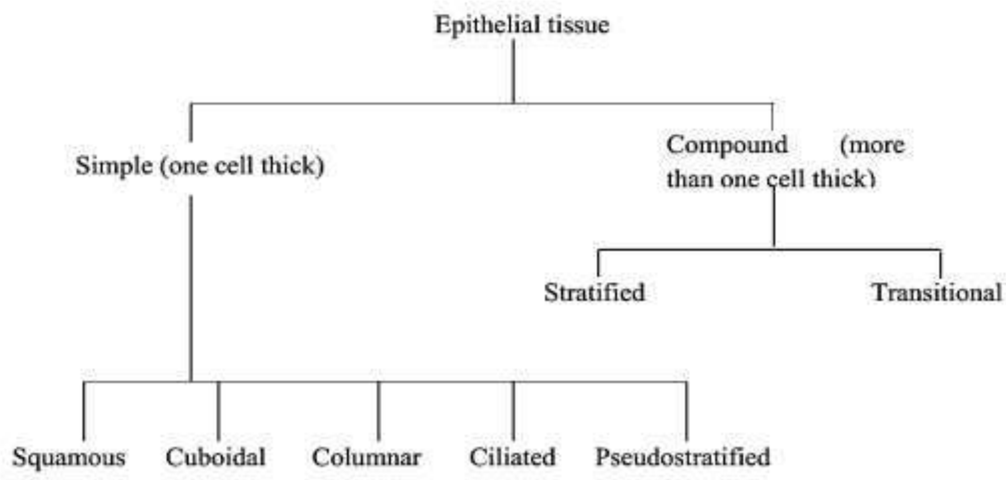
(b).Describe the structure and location of simple epithelial tissues and how they are adapted to function

(a).

Connective tissues;

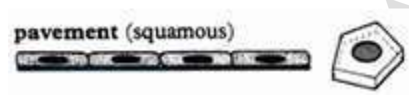


Epithelial tissues.

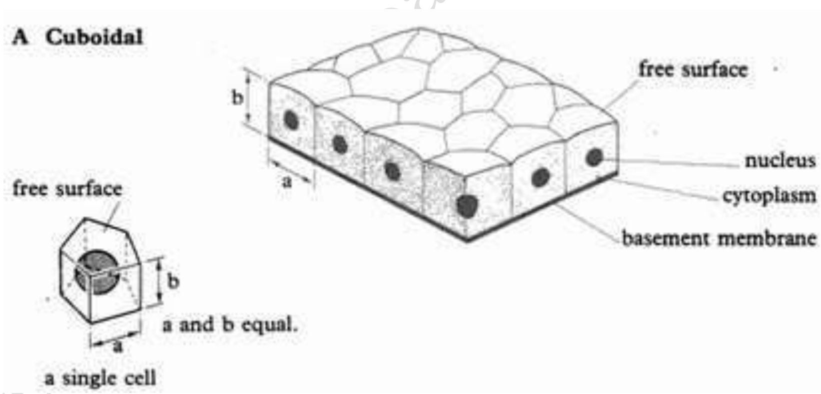


(b).

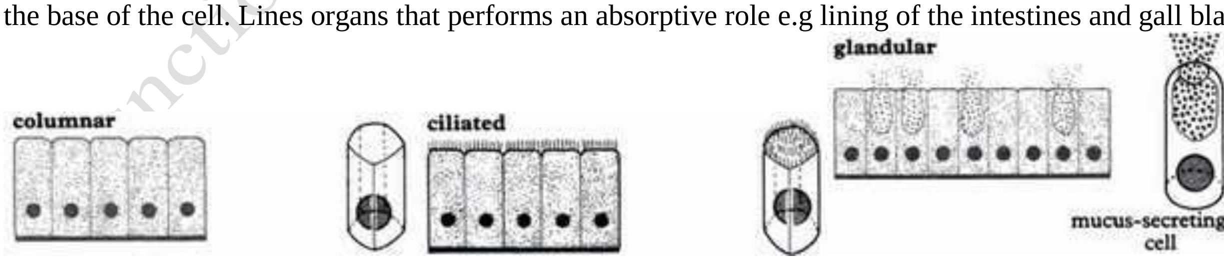
Squamous epithelial (pavement epithelial): cells form a single layer attached to basement membrane. The cells are thin, shallow and flattened. Such epithelia form structures and surfaces over which diffusion can occur hence are important in the alveoli of the lungs, Bowman's capsule and in capillary walls. Their smooth surface provides a friction free lining for blood vessels



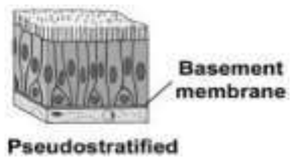
Cuboidal/cubical epithelial; such epithelium has a secretory function in glands like thyroid, sweat and salivary glands. It also has a non-secretory function e.g. the lining of the kidney collecting tubules, proximal and distal convoluted tubules, pancreatic ducts, etc. Its cells are cuboidal and form a single layer attached to a basement membrane.



Columnar epithelium; Cells are much taller than they are wide. Nucleus is oval shaped, generally located toward the base of the cell. Lines organs that performs an absorptive role e.g lining of the intestines and gall bladder



Pseudostratified epithelium; the nuclei of this type of epithelium appear to be at several different levels because not all the cells reach the free surface. The epithelium is still one layer or one cell thick with each cell attached to a basement membrane. It is found lining the urinary tract and respiratory passages.



Pseudostratified

Question 15

(a).Describe the structure of sclerenchyma tissues in plants ***(06 marks)***
(b).Explain the roles of parenchyma tissues in the different parts of the plant ***(06 marks)***
(c).How the structure and location of compound epithelial tissues in animals is related to function

(a).

It consists of fibres which are elongated cells and sclereids (torn cells) which are roughly spherical. Primary cellulose cell wall is thickened with deposits of lignin and mature cells have an empty lumen hence are dead cells. Simple pits appear in the walls as they thicken and they interconnect adjacent cells. A secondary cell wall is built up in the layers.

(b).

- Parenchyma tissue stores food when tightly parked eg in tubers
- Their turgidity provides support in herbaceous plants.
- Some are photosynthetic (parenchyma cells) are known as chlorenchyma.
- The epidermis is a specialized parenchyma capable of forming a waxy cuticle of cutin that prevents desiccation.
- Parenchyma also forms guard cells within the lower epidermis.
- In roots, cellular hairs near root tips are also made up of parenchyma tissues that assist in water uptake.

(c).

Stratified epithelium; It is made of many layers of cells and therefore thicker than the simple epithelium and forms a germinating layer that undergoes cell division. As new cells form, older ones are pushed near to the surface changing shape and flattening to form squamous. The squamous may remain un keratinized as in the oesophagus or may be heavily thickened with keratin (cornified) e.g. the skin where there is intense abrasion such as inside the mouth and vagina. Therefore they are for protection from abrasion to areas exposed to wear and tear.
Transitional epithelium; It is found in structures which must stretch e.g. the urinary bladder and parts of the kidney. It comprises of 3 or 4 layers of cells which may be flattened towards the surface which are not shed like those of the stratified epithelium. Transitional epithelium lacks a basement membrane.

Question 16.

(a).With examples, classify glandular tissues according to the mechanism of secretion ***(08 marks)***
(b).Explain how the structure and distribution of glandular tissues in vertebrates is related and adapted to function ***(12 marks)***

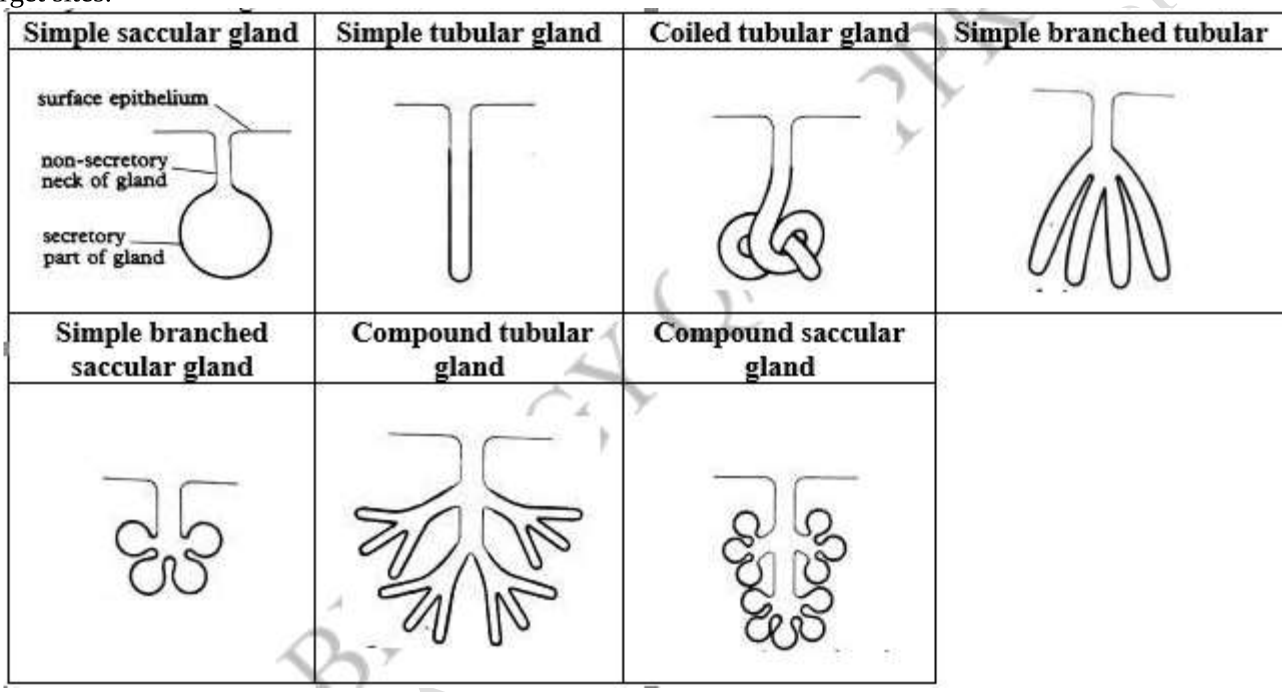
(a).

Merocrine glands; secretions are produced within cells and then passed through the cell membrane at the free surface by simple diffusion into the glandular lumen. This occurs in goblet cells, sweat glands and the exocrine part of the pancreas.
Apocrine glands; here a portion of the cell cytoplasm is lost as the secretion is released. The secretion gets concentrated in the portion of the cytoplasm which pinches off from the cell and goes with the secretions e.g secretion of milk in the mammary glands.
Holocrine glands; here the whole cell containing the secretion leaves the basement membrane to release the secretion e.g the sebaceous gland that releases sebum on the skin surface.
Mixed glands; where the gland secretes different materials but each is secreted differently e.g the mammary glands secrete the lipid product by apocrine and protein by merocrine mechanisms

(b).

- Secretory part of the simple saccular gland in the mucus glands of skin of amphibians like frogs is large and saclike to increase surface area for secretion of mucus on the skin surface.
- Secretory part of the simple tubular gland in the crypts of Lieberkuhn in the wall of mammalian small intestines is long to increase surface area for production of intestinal juice/ succus entericus.

• Secretory part of the coiled tubular gland in the sweat glands in the human skin are coiled/ folded to increase surface area for secretion of sweat.
• Secretory part of simple branched tubular glands in the gastric and Brunner's are branched/ finger-like to increase surface area for secretion of gastric juice and duodenal secretions respectively.
• Secretory parts of sebaceous glands in mammals is simple branched saccular; increase surface area for secretion of sebum.
• Compound tubular glands in the salivary glands have multiple branched ducts and secretory parts; increasing surface area for secretion of saliva and its delivery to target release sites.
• Compound saccular glands eg in part of the pancreas that secretes digestive enzymes has multiple branched ducts and multiple saccular secretory parts; increase surface for release and delivery of pancreatic enzymes to the target sites.



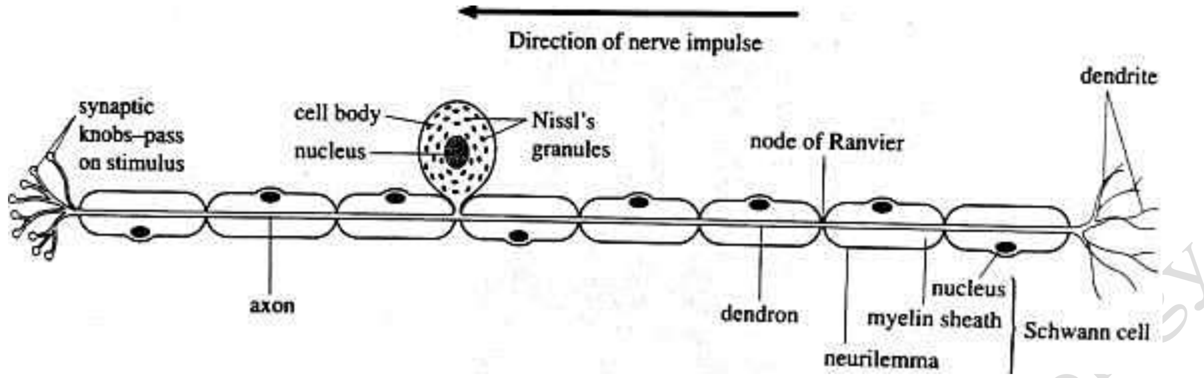
Question 17.

(a).Describe how the structure of neurone is related to function ***(12 marks)***
(b).Describe the role of mast cells in an allergic reaction. ***(04 marks)***
(c) Explain the adaptations of cartilage to its functions. ***(04 marks)***

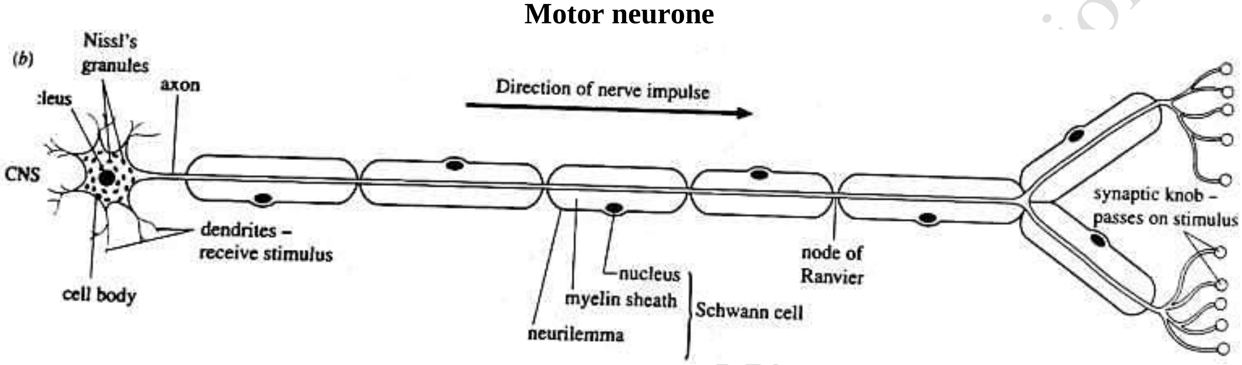
(a).

Cell body; this consists of a nucleus surrounded by a mass of cytoplasm. Nucleus controls all activities of neuron.
Axon; this is one or more long cytoplasmic extensions running from the cell body. Axons carry impulses over long distances in the body. Each axon is filled with cytoplasm called axoplasm.
Myelin sheath; this is a fatty material that covers the axon. The myelin sheath is secreted by cells called
Schwann cells; The myelin sheath insulates the axon and speeds up transmission of impulses. It also protects the axon from any injuries especially which may be as a result of contraction from muscles.
Dendrites; these are fine structures on the neuron that link up nerve cells to form a complex network of communication.
Schwann cell; this is a cell which secretes the myelin sheath.
Nissl"s granules; these are groups of ribosomes responsible for protein synthesis.
Node of Ranvier; this is the space on the axon between two adjacent myelin sheaths. It speeds up nervous transmission. Cytoplasm; this is a site for chemical reactions in the neuron.
Dendron; it is a branch through which impulses are transmitted to the body.

Sensory neurone



Motor neurone



(b).

Mast cells mediate immediate hypersensitivity reaction and anaphylaxis by releasing immune modulators such as histamine, serotonin, heparin and prostaglandins from cytoplasmic granules, in response to antigen binding with cell surface antibodies. Heparin performs anticoagulation role.

(c).

• Cartilage is tough, hard but flexible connective tissue to allow shock absorption, flexibility and rigidity.
• Hyaline cartilage contains numerous collagen fibers; providing tensile strength to cartilage
• Hyaline cartilage possesses numerous isogenous chondrocytes; secrete and maintain matrix deposition.
• Elastic cartilage has a visible network of interlacing elastic fibers in addition to collagen fibers permit flexibility.

Question 18.

(a).How is the distribution & modifications of the various stratified epithelia related to function ***(08 marks)***
(b).Describe the structure and distribution of the different surface specializations present on the various epithelial tissues ***(12 marks)***

(a).

• Non-keratinized (moist)stratified squamous lining wet cavities like the mouth, esophagus, rectum, vagina and anal canal; have nucleated and living surface; protects from physical abrasion and prevents from desiccation
• Keratinized (dry)stratified squamous epithelia lining the epidermis of the skin; have non-living surface cells; protects the underlying skin from physical abrasion.
• Stratified cuboidal/columnar epithelia lining the larger ducts of exocrine glands; create a large surface area for secretion.
• Transitional epithelium lining hollow organs like the urinary bladder and ureter are constructed to expand with distension; permitting temporary storage of materials like urine.

(b).

Microvilli; Finger-like extensions from the free surface of the cell. They are present in large numbers on each cell establishing a brush or striated border. Microvilli contain a core of actin microfilaments that are relatively non motile. Microvilli increase surface area for absorption. Microvilli are prominent on cells lining the digestive tract and proximal tubules in the kidney.

Stereocilia; large, non-motile microvilli; not cilia. Contain a core of actin microfilaments. Stereocilia increase surface area. They are present on cells lining the epididymis and ductus deferens in the male reproductive tract.

Cilia; Multiple hair-like extensions from free surface of the cell; Highly motile; beat in a wave-like motion. Function to propel material along the surface of the epithelium e.g. in the respiratory system and the oviduct of the female reproductive system. Core of a cilium is called the axoneme, in which nine pairs of microtubules surround a central pair of microtubules (9 + 2 arrangement). The axoneme of each cilum originates from a basal body that is located at the apex of the cell and is composed of nine triplets of microtubules.

Question 19.

(a).Outline the structural and functional roles of connective tissue proper ***(07 marks)***

(b).State the differences between loose (areolar) tissues and dense connective tissue ***(05 marks)***

(c).Describe the structure and functions of connective tissues with special properties ***(08 marks)***

(a).

Structural functions of connective tissue proper

- Forms a portion of the wall of hollow organs and vessels and the stroma of solid organs
- Forms the stroma of organs and subdivides organs into functional compartments
- Provides padding between and around organs and other tissues
- Provides anchorage and attachment (e.g. muscle insertions)

Functional roles of connective tissue proper

- Provides a medium for nutrient and waste exchange
- Lipid storage in adipocytes
- Defense and immune surveillance function via lymphoid and phagocytic cells

(b).

Areolar (loose) connective tissues	Dense connective tissues
Highly cellular, numerous cell types present	Fewer cells, mostly fibroblasts
Fewer and smaller caliber collagen fibers	Highly fibrous with larger caliber collagen fibers,
Abundant ground substance, allows for diffusion of nutrients and wastes	Minimal ground substance
Highly vascularized	Poorly vascularized
Provides padding between and around organs and tissues	Provides strength to tissues.

(c).

Adipose connective tissue; Consists of accumulations of adipocytes that are partitioned into lobules by septa of connective tissue proper. Provides energy storage and insulation.

Blood and hematopoietic (blood-forming) tissues; Blood is a special connective tissue consisting of cells and cell fragments (Red blood cells and white blood cells produced in the bone marrow; and platelets floating in a unique liquid extracellular matrix made up of plasma and serum.

Elastic connective tissue; Regularly arranged elastic fibers or sheets e.g. the vocal ligament.

Reticular connective tissue; A loosely arranged connective tissue whose fibers are reticular fiber. Forms the stroma of hematopoietic tissue e.g. bone marrow) and lymphoid organs (e.g. lymph node and spleen)

Mucoid connective tissue; Embryonic connective tissue with abundant ground substance and delicate collagen fibers; present in the umbilical cord.

Question 20.

(a).Outline the functions of the different cell lines present in bone tissues ***(07 marks)***

(b).Briefly describe the hierarchy of skeletal muscle organization in vertebrates ***(08 marks)***

(c).Outline the alterations that occur in sarcomere during a skeletal muscle contraction ***(04 marks)***

(a).

Osteoblasts

Secrete osteoid (inorganic component of bone matrix)

In the presence of alkaline phosphatase, osteoblasts facilitate deposition of calcium phosphate, thus mineralizing the osteoid.

Osteocytes

Transport materials between blood and bone and to maintain surrounding matrix; they do not divide or secrete matrix.

Osteoclasts

Resorb bone via the acid phosphatase and proteolytic enzymes they secrete

(b).

Myofilaments; Visible only with the electron microscope; composed primarily of actin, which forms thin filaments, and myosin, which forms the thick filaments.

Myofibrils; Visible with the light microscope; oriented parallel to the long axis of the cell; composed of bundles of overlapping myofilaments that are arranged in register, producing an alternating light-dark, striated banding pattern

Muscle fiber; Specialized term for a muscle cell, sarcoplasm is filled with hundreds of myofibrils, which are oriented parallel to each other and to the long axis of the muscle fiber.

Muscle fascicle; Collection of muscle fibers surrounded by perimysium; collections of muscle fascicles are surrounded by the epimysium and form a muscle.

(c).

- Sarcomere length shortens.
- Z-line interval narrows.
- Width of H and I bands decrease as actin is pulled past the myosin.
- A band width remains unchanged.

Question 21.

(a).Describe the

(i). Structure and distribution of smooth muscle fibres ***(08 marks)***

(ii) Organization of the contractile proteins in the smooth muscle fibres ***(06 marks)***

(b).State different ways smooth muscle contraction differs from skeletal muscle contraction ***(05 marks)***

(c).Explain why the xylem tissue cannot be used in plant tissue culture ***(03 marks)***

(a)(i).

Made up of unbranched spindle-shaped fibers which are elongated with tapering ends. Possess a single, centrally placed, oval nucleus, which can appear spiraled or inch-worm shaped when the fiber is contracted. Organelles are clustered at the poles of the nucleus. Non-striated; no myofibrils are present. External (basal) lamina is present along with reticular fibers with abundant gap junctions. Smooth muscle occurs mostly as sheets, which form the walls of most hollow organs with the exception of the heart. Smooth muscle is also prominent in the walls of blood vessels, many respiratory passage ways, and some genital ducts.

(a)(ii).

Actin and myosin myofilaments are present, but they are not organized into myofibrils. Myofilaments overlap as in striated muscle and crisscross throughout the sarcoplasm, forming a reticulum. Have dense bodies; serve as insertion points for myofilaments to transmit the force of filament sliding. Contain alpha-actinin and, thus, resemble Z-lines of striated muscle. Present in the cytoplasm and associated with the sarcolemma.

(b).

Smooth muscle contraction	Skeletal muscle contraction
Under autonomic/ involuntary control	Under voluntary control
Involves the calcium-calmodulin complex	Involves the calcium-troponin complex
Slower	Faster
Cause physiological effects in visceral organs	Cause movements of the musculoskeletal system
No T tubules involved/ have rudimentary sarcoplasmic reticulum	Has T tubules that produce calcium ions and propagate them into the muscle fibre.

(c).

Xylem tissue is dead & has no genetic material. It is also non-totipotent; as it is already differentiated and therefore, it is unable to divide via mitosis.

Question 22.

(a).Describe how distribution of different neurons is related to structure and function ***(09 marks)***

(b).Outline the functions of the different supportive cells present in the central and peripheral nervous system ***(05 marks)***

(c).Describe the connective tissues invested on nervous tissue ***(06 marks)***

(a).

Pseudo-unipolar neuron; perform an afferent/ sensory function and are found in selected areas of the CNS and in sensory ganglia of cranial nerves and spinal nerves (dorsal root ganglia).

Bipolar neuron; perform an afferent/ sensory function and are found associated with organs of special sense organs (retina of the eye, olfactory epithelium, vestibular and cochlear ganglia of the inner ear)

Multipolar neuron; Most numerous and structurally diverse type; perform an efferent function (motor or integrative function. Found throughout the CNS and in autonomic ganglia in the peripheral nervous system.

(b).

Supportive cells of the CNS

Astrocytes; offer physical support, transport nutrients, maintain ionic homeostasis and take up neurotransmitters

Oligodendrocytes; Produce the myelin sheath in the central nervous system.

Ependymal cells; Line ventricles; secretes cerebrospinal fluid

Microglia; Highly phagocytic cells

Supporting cells of the Peripheral Nervous System.

Schwann cells; Produce the myelin sheath around axons of peripheral nerves.

(c).

Peripheral nervous system

Endoneurium; Delicate connective tissue surrounding Schwann cells; includes the basal lamina secreted by Schwann cells as well as reticular fibers

Perineurium; Dense tissue surrounding groups of axons and their surrounding Schwann cells, forming fascicles; forms the blood-nerve barrier

Epineurium; Dense connective tissue surrounding fascicles and the entire nerve.

Central nervous system

Piamater; Thin membrane lying directly on the surface of the brain and spinal cord. Accompanies larger blood vessels into the brain and spinal cord.

Arachnoid; Separated from piamater by connective tissue trabeculae. Encloses subarachnoid space, which contains blood vessels and the cerebrospinal fluid (CSF) produced by the cells of the choroid plexus

Duramater; Outermost of all meninges. Dense connective tissue; includes the periosteum of the skull.

Question 23.

Describe in brief the three distinct major groups of plant tissues ***(20 marks)***

Ground tissues; Include three basic kinds of cells that differ mostly by the nature of their cell walls.

Parenchyma cells; the most common component of ground tissue, have thin walls and serve various functions (unspecialized) including storage, photosynthesis, secretion etc.

Collenchyma cells; which have thick but flexible cell walls, serve mechanical support functions.

Sclerenchyma cells; with thicker walls than collenchyma, also provide mechanical support functions.

Dermal tissue; Consists of epidermal cells that cover the outside of plant parts, guard cells that surround stomata, and various specialized surface cells such as hair cells, stinging cells, and glandular cells. In aerial portions of the plant, the epidermal cells secrete a waxy protective substance, the cuticle.

Vascular tissue; Consists of two major kinds of tissues, xylem and phloem; which occur together to form vascular bundles.

Xylem functions in the conduction of water and minerals and also provides mechanical support. There are two kinds of xylem cells, tracheids and vessel elements (or vessel members). In tracheids, which are long and tapered, water passes from one tracheid to another through pits on the overlapping tapered ends of the cells. Vessel members are shorter and wider than tracheids**.**

Phloem, and have less or no taper at their ends. A column of vessel members is called a vessel. Water passes from one vessel member to the next through areas devoid of both primary and secondary cell walls called perforations functions in the conduction of sugars. Phloem is made up of cells called sieve-tube members (or sieve tube elements) that form fluid-conducting columns called sieve tubes. sieve-tube members are living at maturity, although they lack nuclei and ribosomes. Pores on the end walls of sieve-tube members form sieve plates. Sieve tubes are associated with companion cells, living parenchyma cells that lie adjacent to each sieve-tube member. Companion cells, connected to adjacent sieve-tube members by thin tubes of cytoplasm called plasmodesmata, maintain physiological support to the nuclei-lacking sieve-tube members.

Question 24.

(a).State the functions of parenchyma tissues in plants ***(06 marks)***
(b).Describe how the distribution of parenchyma tissues is related to function ***(14 marks)***

(a).

• Parenchyma cells are metabolically active and carryout vital activities of the plant like respiration.
• Parenchyma cells are meristematic; capable of cell division resulting in growth, repair and regeneration
• Gaseous exchange since they contain a system of air spaces.
• Pathways for transport of materials; cell walls are thin &freely permeable to water and mineral salts.
• Some contain chloroplasts (chlorenchyma); contains chlorophyll; trap solar energy for photosynthesis
• Absorption of water by osmosis; maintain turgidity in cells; offers support in herbaceous plants
• Food storage eg stems and root tubers which store starch granules as amyloplasts eg irish potatoes contain densely packed parenchyma cells with starch globules.

(b).

• Epidermis; layer surrounds the plant body; made up of polygonal cells; protects the plant from dessication.
• Epidermal cells secrete a waxy cuticle; prevents water loss and entry of plant bodies.
• Guard cells; epidermal cells modified into guard cells that enclose a stoma; allow gaseous exchange.
• Chloroplasts contained in guard cells; carryout photosynthesis
• Epidermal cells grown into root hairs; facilitate absorption of water and mineral salts.
• Mesophyll; pallisade mesophyll modified to carryout photosynthesis; spongy mesophyll for gaseous exchange.
• Cambium; meristematic; can divide to give conducting tissues xylem and phloem.
• Cortex; neatly arranged parenchyma cells; provide support in non-woody plants
• Pith; neatly arranged parenchyma cells in the centre of the stem; provides support to non-woody plants.
• Endodermis; layer of parenchyma cells around the vascular tissues; used in development of branches.

Question 25.

(a).Describe the modifications of parenchyma tissues in different parts of the plant; to suit its function
(b).Explain the distribution of mechanical tissues in plants ***(07 marks)***

(a).

• Epidermal cells are elongated and flattened; in single layer over the entire plant body; for protection from desication and infection.
• Epidermal cells modified into guard cells that enclose a stoma; allow gaseous exchange.
• Epidermal cells grown into root hairs; facilitate absorption of water and mineral salts.
• Mesophyll cells are located between the upper and lower epidermis of leaves; possess chloroplasts for photosynthesis / spongy mesophyll for gaseous exchange; pallisade mesophyll for photosynthesis.
• Endodermis around the vascular tissue; forms a selective barrier to movements of water and mineral salts; between the cortex and xylem
• Pericycle in roots; between central vascular tissue and endodermis; retains meristematic activity; to produce lateral roots.
• Transfer cells; are used for transport of water and sugars out of the vascular bundles
• Companion cells in the phloem; for energy production;
• Chromoplasts determine the colour of petals in flowers
• Chloroplasts contained in guard cells; carryout photosynthesis
• Cambium; meristematic; can divide to give conducting tissues xylem and phloem.
• Cortex; neatly arranged parenchyma cells; provide support in non-woody plants
• Pith; neatly arranged parenchyma cells in the centre of the stem; provides support to non-woody plants.

(b).

• Xylem is centrally distributed in roots to withstand strains as aerial parts bend and lean over

• Xylem is peripheral in a ring in dicots and scattered in monocot stems; such that separate rods run through to provide more support
• Secondary xylem is added by secondary growth to support large structures of trees and shrubs
• Collenchyma in young herbaceous plants and organs without secondary growth; to supplement the turgid parenchyma
• Collenchyma in stems and petiole is peripheral just below the epidermis in the outer region of the cortex; to increase support.
• Sclerenchyma is distributed according to stress in organs; strengthened by arrangement of strands or sheets of tissues scattered to give firmness.

Question 26.

With specific reference to osseous tissue;
(a).Outline the process of its formation from a gristle template. ***(10 marks)***
(b).Distinguish between immature and Harversian osseous tissue ***(05 marks)***
(c).Describe the relationship between mature osseous tissue, gristle & dense connective tissue. ***(05 marks)***

(a).

Bone collar formation; a primary ossification center appears in the center of bone. This is the source of bone development. Cells secrete osteoid against wall of the diaphysis.
Cavitation; Chondrocytes enlarge and signal hyaline cartilage to harden into bone. They begin to die and leave small cavities leaving small spaces for vessels.
Periosteal bud invasion; Introduction of a nutrient highway to bone. Periosteal region is invaded by buds containing blood vessels and nerves. Osteoblasts and osteoclasts enter into cavities previously occupied by chondrocytes. They secrete matrix forming spongy bone.
Diaphysis elongation; Cell division in the primary ossification center powers elongation.
Epiphyseal ossification; Epiphyses develop own centers of ossification called secondary ossification centers. These go through the same process as primary ossification centers.

(b).

Harversian bone	Immature bone
Hard	Softer
Made of Harversian systems	No Harversian systems
No trabeculae	Prominent trabeculae
No marrow tissue	Marrow tissue
For strength and support	For resisting stress.

(c).

Mature osseous tissue/ compact bone is covered by a peritoneal lining the peritoneum which is pierced by pores providing passage for blood vessels and nerves as well as attachment for gristle/ cartilage. The periosteum also provides attachment for tendons and ligaments made of dense connective tissue.

Question 27.

(a) Describe the structure of simple plant tissues. ***(08 marks)***
(b).Explain different ways by which parenchyma is structural modified to suit various functions. ***(12 marks)***

(a).

Each consist of only one type of cell; they are normally grouped into parenchyma; collenchyma and sclerenchyma according to the degree of thickening present in the cell wall; parenchyma consists of cells with relatively thin walls consisting of cellulose; pectin; and hemicellulose; the cells are roughly round when seen in transverse section; elongated in longitudinal section; large in size; with prominent air spaces between cells; collenchyma consists of cells that are narrow and elongated in shape compared to parenchyma; with additional cell wall deposits of cellulose; pectin; and hemicellulose; at the corners of the cells; sclerenchyma consists of long; narrow; pointed cells called fibres; and also shorter; circular or more irregularly shaped cells called sclereids; the cells have thick walls; composed of layers of cellulose impregnated with lignin; with some unlignified regions forming pits;

(b).

Epidermis;

• Waxy substance secreted by epidermal cells protect the plant from desiccation and infection;
• Guard cells with distinctive shape form the stomata that allows gaseous exchange to occur;
• In roots, unicellular hairs grow from a region just behind the root tip and increase the surface area for absorption of water and mineral salts;
• In climbing plants, hooked hairs often occur and function to prevent the stems from slipping from their supports;
• Epidermal hairs assist the cuticle in reducing water loss by trapping a layer of moist air next to the plant, as well as reflecting radiation;
• Some hairs are water absorbing, notably on xerophytic plants;
• Have a mechanical protective function as with short, stiff bristles;
• Form Glandular cells in the epidermis which secrete a sticky substance that traps and kills insects, either for protection or if secretions contains enzymes, for digestion and subsequent absorption of food in carnivorous plants;

Mesophyll layer

• Chlorenchyma cells contains numerous layer; chloroplasts in their cytoplasm for photosynthesis to occur;

Endodermis;

• Modified to form casparian strip a band of suberin (a fatty substance) that runs round the cell for selective movement of ions and salts in the root;

Pericycle in roots;

• Made up of one to several cells thick, It retains its capacity for cell division and produces lateral roots;
• It also contributes to secondary growth if this occurs;

Companion cells in stems

• For movement of materials within phloem tissue;

Question 28.

(a).Describe the distinguishing features of different levels of organization in various organisms ***(10 marks)***
(b).Explain how various cells and tissues have attained specialization and modifications to perform particular functions ***(10 marks)***

(a).

Chapter 3; CHEMICALS OF LIFE

Uganda Mvule tree Chlorophora excelsa, has seedlings which store glucose, fructose, maltose, raffinose, starch, sucrose and xylose which are carbohydrates. The insect Phytolyma lays its eggs on C.excelsa and causes galls (swellings on the plant). An analysis of carbohydrate content in leaf, stem, root and galls was carried out in healthy and galled seedlings of C excelsa. The results are shown in the table below. Study the table and answer the questions that follow. Carbohydrate contents of healthy and galled seedlings of C excelsa. Data in (mg/g dry weight) of seedling are averages of three replicates.

Healthy seedlings

Part of seedlings	Starch	Raffinose	Maltose	Sucrose	Glucose	Fructose	Xylose	% of total carbohydrate
Leaf	63.8	8.3	8.3	19.9	20	16	5.2	29.7
Stem	40.4	32.3	20.2	20.3	10.3	2.1	2.3	26.9
Root	93.8	30.0	32.0	20.0	8.0	6.4	16	43.4

Galled seedlings

Part of seedlings	Starch	Raffinose	Maltose	Sucrose	Glucose	Fructose	Xylose	% of total carbohydrate
Leaf	62.6	12	10.3	8.0	20.0	14.2	3.2	23.0
Stem	32.0	2.0	13.3	10.0	20.0	2.0	2.0	17.6
Root	75.0	14.0	17.0	17.7	10.9	7.0	8.0	26.6
Gall	100.0	6.0	14.2	2.0	14.0	14.0	6.0	32.8

(a). Using the same axes, plot a graph of the percentage of the total carbohydrate in each part of seedling in health and galled seedlings of E. excelsa.

(b).Describe the pattern of carbohydrates content in different parts of a healthy C.excelsa seeding.

Pattern of carbohydrate content in different parts of a healthy C.excelsa seedling. Highest percentage total carbohydrate content was in roots, followed by leaves and least in the stem; The most abundant carbohydrate in all seedling parts was starch. Fructose and xylose were generally the least abundant in all seedlings parts; Sucrose content was nearly the same in all seedling parts. Raffinose and maltose showed similar abundance in the leaf and root. Maltose and sucrose showed nearly similar abundance in the stem. The least abundant carbohydrate in the leaves was xylose; while fructose was the least abundant carbohydrate in the stem and root. in the roots the order of abundance was starch > maltose> Raffinose > sucrose> xylose> glucose> fructose. In stem the order of abundance was starch > Raffinose >sucrose>maltose>glucose> fructose. In leaves the order of abundance was starch > glucose > sucrose> fructose> maltose = raffinose > xylose. The root had the highest content of starch, maltose and the least content of glucose. The stem had the highest content of raffinose and sucrose and the least content of xylose, fructose and starch. The leaf had the highest content of glucose, fructose and the least content of raffinose, maltose and sucrose.

(c).Describe the influence of galls on

(i). the seedlings of C.excelsa generally.

The seedlings of C .excelsa generally reduce the percentage total carbohydrate content; Lower the content of each carbohydrate except glucose in all parts and fructose in the root;

(ii).each part of the seed

The leaves; Galls had no effect on glucose content. Significantly reduced the content of sucrose and increased the content of raffinose and maltose.

The stem; Galls significantly reduced the content of raffinose, starch, maltose, sucrose; had a slight reduction on the content of fructose and xylose; increased almost by doubling the content of glucose.

The roots: Galls significantly reduced the content of raffinose; slightly reduced the content of maltose, sucrose, and glucose, significantly increased the content of fructose and xylose.

(d).Suggest how the Phytolyma may cause galls

The Phytolyma lays eggs on the plant; which stimulates the plant cells to start rapid cell division and expansion. This creates room for storage of the carbohydrates; resulting in swellings on the plant. The eggs may erode into inner tissues of the plant; blocking phloem vessels; this then leads to accumulation of carbohydrates in one part of the plant, causing galls.

(e).Suggest with reasons what would happen to E excelsa feeling if it is infected with phytolyma for a long time.

If E.excelsa feeling was infected with Phytolyma for a longtime death of the seedling could occur;

Reason: Carbohydrates could be diverted from the growing regions of the plant for storage in galls. With limited growth the plant seedling may fail to establish its self to a sustainable level and gradually withers to death.

Question 1.

(a).Explain what is meant by “chemicals of life”? ***(02 marks)***

(b).Explain the significance of the physical properties of water to organisms ***(13 marks)***

(c).Outline the importance of acids and bases to living organisms ***(05 marks)***

(a).

Organic and inorganic chemical substances that constitute the protoplasm of cells; They include proteins, lipids, carbohydrates, vitamins and mineral salts mainly in membranes; water; mainly in cytoplasm;

(b).

• Water is a liquid at room temperature; providing an intracellular environment & aquatic environment to live in.

• Water being a universal solvent; makes it dissolve more solutes than any other common solvent.

• Water having a high surface tension; forms a surface film at an air-water interface; allows some aquatic organisms like pond skaters to land and move on the water surface without sinking.

• Ice being less dense than water; enables it float on water leaving liquid water underneath allowing survival of aquatic organisms.

• Stronger adhesive forces of water; permits capillarity in which water moves through narrow channels along or against gravity.

• Water having a high specific heat capacity; enables the environment inside water to resist temperature changes thus enabling aquatic organisms to have a relatively stable temperature
• Water having a high specific latent heat of vaporization; enables an efficient cooling mechanism inform of sweating in mammals and transpiration in plants.
• Water has a high latent heat of fusion; makes cell contents and aquatic habitats slow to freeze in cold water.
• Water being colourless and transparent; enables light infiltration permitting photosynthesis in an aquatic environment.
• Water being denser than air; supports and disperses reproductive structures like larvae.
• Water being incompressible; enable support in plants and maintenance of a hydrostatic skeleton in earth worms
• Water being an important metabolite; enable it serve as a raw material in a number of biochemical reactions like photosynthesis.
• Water being less viscous; enables allows it freely flow through narrow vessels, can serve as lubricants e.g synovial fluid in bones.
• Water having a high tensile strength; allows a continous water column from the roots high up the stem without splitting.

(c).

Importance of acids

• HCl activates enzymes like pepsinogen, kills germs in food, provide an optimum acidic pH for enzymes
• Transportation of respiratory gases e.g carbonic acid is a form in which carbondioxide is transported
• Phosphoric acid is a component of phospholipids which form structures of membranes.
• Haemoglobinic acid forms an important component of the haemoglobin buffer.
• Nucleic acids mediate the protein synthesis process.
• Citric acid and ascorbic acid increase disease resistance and can be a food preservative.

Importance of bases

• Provide an optimum alkaline pH for the action of enzymes
• Neutralize acidic chyme.
• Constitute the bicarbonate and phosphate buffer systems in animals.

Question 2.

(a).With examples, explain the functions of lipids in organisms. ***(06 marks)***
(b) Why are carbohydrates able to form a variety of polysaccharides? ***(06 marks)***
(c)(i).Compare suitability of lipids and carbohydrates as storage compounds in organism ***(06 marks)***
(c)(ii)What advantages does fat have over carbohydrates as source of water rather than an energy source in organisms like camels? ***(02 marks)***

(a).

Structural functions

• Phospholipids are important components of the plasma membranes in cells
• Subcutaneous fat in dermis; blubbers in whales are important heat insulators
• Lipids are important components of neurilemma; whose plasma membranes form the lamella of myelin sheath;
• Lipids are deposited around delicate organs like kidneys for protection.
• Constituents of waxy cuticle on leaves, and exoskeletons of arthropods; secretions from sebaceous glands in the skin; have a waterproof activity.

Physiological functions

• Important long term energy stores; especially during starvation or fasting
• Solvents for fat soluble vitamins (A,D,E and K)
• Good sources of metabolic water to young birds, desert animals like camels, reptiles
• Makes up brown fat/ adipose tissue; essential in thermogenesis
• Lipid signaling; key in cellular communication done by sphingolipids, glycolipids e.g phosphatidylinositol.
• Derivatives (cholesterols) are important precursors of steroid hormones like sex hormones
• Important constituents of cardiolipins; abundant in inner mitochondrial membrane; activate enzymes of oxidative phosphorylation.

• Precursors of several eicosanoids like prostaglandins; mediators of inflammation; one of the primary body defensive mechanisms

(b).

• They form both 1,4 and 1,6 glycosidic bonds. This increases the variety of polysaccharides since branching can occur e.g cellulose has only 1,4 while glycogen and starch have both 1,4 and 1,6 glycosidic bonds.
• They use both pentoses and hexoses to form polysaccharides. In some cases one monosaccharide is used while in other cases, two or more different monosaccharides are used in alternating sequences.
• The difference in the level of branching shown by carbohydrate polymers, leads to the formation of different polysaccharides e.g glycogen is more branched than starch.
• The existence of both alpha and beta forms of certain monomers increases the variety of polysaccharides. This causes the difference between starch and cellulose.
• The high chemical reactivity of monomers makes them combine with other groups to form related monomer units. These combine to form different polysaccharides e.g cellulose differs from chitin.

(c)(i).

Similarities
• Both yield energy when respired
• Both release metabolic water when respired
• Both fold up becoming compact taking up little space.
• Both are osmotically inactive.

Differences

Lipids	Carbohydrates
Insoluble in water; none can be lost in solution	Some are soluble and a given proportion may be lost in solution
Yields more metabolic water	Yields less metabolic water.
Compact; occupies less space in the body	Non compact; occupies more volume
Higher calorific value;	Lower calorific value;
Less dense/ Lighter	More dense /heavier
Stored lipids perform secondary functions like insulation	Stored carbohydrates are primarily used as fuels

(c)(ii).

Only the hydrogen part of carbohydrate and fat molecules yield water on oxidation. Fats contain relatively more hydrogen than carbohydrates; on a weight basis.

Question 3.

(a). State the comparisons between translation and transcription ***(07 marks)***
(b).Describe the series of events that lead to formation of a polypeptide chain from the messenger RNA molecule. ***(08 marks)***
(c) Explain the role of translation in a cell ***(05 marks)***

(a).

Similarities
• Both transcription and translation are involved in protein synthesis.
• Messenger RNA (mRNA) plays a central role in both translation and transcription
• Both processes involve reading information encoded on nucleic acids
• Both processes involve enzymatically controlled reactions

Differences

Transcription	Translation
Information is read from the cistron of DNA	Information is encoded on the mRNA from the transcribing strand of DNA.
Produces poIynuc1eotide (mRNA) molecules complementary to the transcribing DNA transcript.	Produces polypeptides whose base sequence for the amino acid is complementary to mRNA(same as that of DNA)

Occurs in the nucleus	Occurs in the cytoplasm
Primarily involves mRNA as the only active RNA	Involves participation of all the RNA molecules i.e
Post-transcriptional modification involves splicing	Post translational modifications are mainly
Fewer enzymes(RNA polymerases) are involved	Several enzymes and factors are involved; as three
Involves assemblage of nucleotides	Involves assemblage of amino acids

(b).

Binding of mRNA to ribosome; several ribosomes in the cytoplasm attach to mRNA; constitute a polyribosome/ polysome. Each ribosome has a major and minor subunit. Amino acid activation and attachment to tRNA; amino acids in their pool within the cytoplasm get activated by combining with specific tRNA molecules basing on the triplet base sequence of their tRNA anticodon. Process requires energy from ATP hydrolysis and is catalyzed by the enzyme aminoacyl tRNA synthase/ ligase. An aminoacyl tRNA complex is formed. Polypeptide chain initiation; the first two mRNA codons (total of 6 bases), enter the ribosome; first codon (AUG) binds to aminoacyl-tRNA molecule by complementary base pairing. The complex carries the first amino acid methionine).

Chain elongation; the second codon then also attracts an aminoacyl tRNA complex carrying complementary anticodons, complementary base pairing occurs and the two amino acids get linked by means of a peptide bond The ribosome then moves one codon forward i e translocates along the mRNA and a new aminoacyl tRNA complex enters The process repeats and more amino acids get continuously added to the growing polypeptide chain. The tRNA molecule which was previously attached to the polypeptide chain now leaves the ribosomes and passes back to cytoplasm to be re-converted into a new aminoacyl tRNA molecule. Chain termination; ensues when the stop codons i.e UAA, UAG and UGA since there are no responding tRNAs to these codons. Polypeptide chain elongation terminates. The proof reading enzymes ascertains right amino acid sequences and the protein now leaves the ribosomes.

Note; Post translational modifications may proceed; these include phosphorylation, summoylation, disulfide bridging, acylation etc

(c).

Translation leads to synthesis of proteins which after post-translational modification are important in;

- Nutrition, e.g digestive enzymes, fibrous proteins in granal lamellae, casein, ovalbumin etc
- Transport and protection; e.g hemoglobin, myoglobin, mucin, lipoproteins (in blood).
- Body defence e g antibodies, fibrinogen and prothrombin
- Growth e.g growth hormones, thyroxine
- Excretion; e.g ureases, enzymes of the urea/ ornithine cycle like arginases
- Structure, support and movement; e.g collagen, elastin and keratin, ossein and chondrin, actin & myosin
- Sensitivity and co-ordination; e.g hormones, phytochrome, rhodopsin, scotopsin, iodopsin, opsin
- Reproduction e.g peptide hormones like FSH and LH.
- Storage; zeatin (in corn seeds)/casein (in milk)
- Receptors; hormone receptor/ neurotransmitter receptor/receptor in chemoreceptor cell
- Movement; actin/myosin
- Enzymes; catalase/RuBP carboxylase
- Electron carriers; cytochromes
- Active transport; sodium-potassium pumps/calcium pumps.
- Facilitated diffusion - sodium channels and aquaporins for ADH system.

Question 4.

(a).What is meant by protein denaturation? ***(02 marks)***
(b).Explain the factors that may cause protein denaturation ***(06 marks)***
(c).Explain the role of proteins in living organisms ***(12 marks)***

(a).

Protein denaturation is the loss of the specific three dimensional shape and configuration of a protein molecule. Change in the molecular shape and configuration may be temporary or permanent; peptide linkages between the amino acids remain intact but the entire molecule unfolds and no longer performs its functions.

(b).

Heat or radiation; eg infrared and UV light. Kinetic energy supplied to the proteins; may cause its atoms to vibrate violently disrupting the weak hydrogen and ionic bonds. Coagulation then occurs.
Strong acids and alkalis and high concentrations of salts; disrupts ionic bonds and protein is coagulated. Long time exposure may result in peptide bond breakage.
Heavy metals; cations of heavy metals form strong bonds with anionic carboxyl groups on the R groups of the protein; often disrupting ionic bonds. They also reduce protein's electrical polarity thus increasing its insolubility; protein is thus made to precipitate out of solution.
Organic solvents and detergents; do disrupt hydrophobic (non-polar) groups of the protein; disrupting hydrogen bonding e.g alcohol denatures protein of any protein present.
Mechanical force; physical movement may break hydrogen bonds; eg stretching a hair breaks hydrogen bonds in the keratin helix.

(c).

Nutrition;
• Digestive enzymes like trypsin, amylase, lipase; catalyse the breakdown of polypeptides, starch to maltose & fats to fatty acids and glycerols respectively.
• Fibrous proteins in the granal lamellae; arranges chlorophyll molecules in position most suitable to receive maximum amount of light for photosynthesis.
• Ovalbumin and casein; storage proteins in egg white and milk respectively.
Respiration and transport
• Haemoglobin transports oxygen; myoglobin stores oxygen in muscles.
• Prothrombin, fibrinogen and clotting factors; important in blood clotting
• Mucin keeps respiratory surface moist thus maintains an efficient diffusion pattern of gases.
• Antibodies/immunoglobulins; defends the body against foreign antigens.
Growth
• Hormones like thyroxine, growth hormone; control Basal Metabolic Rate (BMR) &growth respectively.
Excretion
• Enzymes e.g ureases, arginases; catalyse reactions of the ornithine cycle thus important in protein breakdown & urea formation.
Support and movement
• Actin/myosin, for muscle contraction ossein and chondrin for structural support in bone & cartilage respectively; collagen gives strength with flexibility in tendons and cartilages, elastin gives strength and elasticity in ligaments and keratin; tough for protection e.g scales hooves nails skin
Sensitivity and co-ordination.
• Hormones e.g insulin/glucagon controls blood sugar levels; vasopressin controls blood pressure; rhodopsin /opsin which are photosensitive pigments in the retina; phytochromes controls flowering and germination
Reproduction
• Hormones such as prolactin induces milk production in mammals.
• Chromatin; gives structural support to chromosomes
• Keratin; forms horns/antlers; may be used for sexual displays.

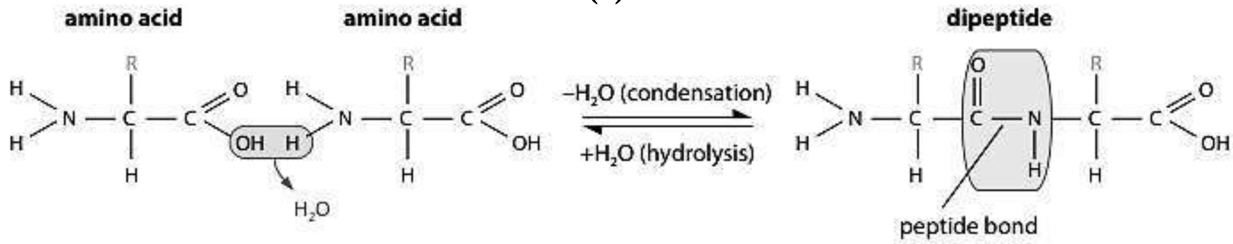
Question 5.

(a).Describe the significance of polar and non-polar amino acids. ***(05 marks)***
(b).Outline the role of condensation and hydrolysis in the relationship between amino acids and dipeptides.
(c).Describe the structure of proteins. ***(08 marks)***
(d).Discuss the solubility of proteins in water ***(04 marks)***

(a).

Polar amino acids
Hydrophilic and can make hydrogen bonds. They are found in hydrophilic channels/parts of proteins projecting from membranes and are found on surface of water-soluble protein.
Non-polar amino acids;
Hydrophobic, forms van der Waals/hydrophobic interactions with other hydrophobic amino acids; found in protein in interior of membranes and are in interior of water soluble proteins.

(b).



Condensation / dehydration synthesis: water produced (when two amino acids joined) i.e formation of di- peptide from amino acids occurs by condensation. Hydrolysis on the other hand requires water to break the peptide bond i.e break down of dipeptide bond to amino acids occurs by hydrolysis.

(c).

Primary structure is a chain of amino acids/sequence of amino acids (each position is occupied by one of 20 different amino acids linked by peptide bonds .secondary structure formed by interaction between amino and carboxyl groups. Weak hydrogen bonds are formed. (α) helix formed / polypeptide coils up or (ß-pleated sheet formed, tertiary structure is the folding up of the polypeptide stabilized by disulfide bridges / hydrogen/ ionic/ hydrophobic bond. Quaternary structure is where several polypeptide subunits join. Conjugated proteins are proteins which combine with other non-protein molecules for example metals / nucleic acids / carbohydrates / lipids.

(d).

Solubility depends on what amino acids /R groups are present; smaller proteins are more soluble than big ones; proteins with many polar / hydrophilic amino acids / R groups are more soluble / soluble and proteins with polar/ hydrophilic amino acids / R groups on the outside are soluble example of a polar amino acid / group. Globular proteins are more soluble than fibrous proteins. Solubility of proteins may also be affected by conditions (pH, temperature, salinity), denaturation makes proteins insoluble. Proteins do not form true solutions in water but colloidal solutions.

Question 6.

(a).Explain the evidence to show that DNA is the hereditary material ***(10 marks)***

(b).Explain how mutations leads to changes in the physiology of a cell ***(05 marks)***

(c).What is the significance of mutations in crop husbandry? ***(05 marks)***

(a).

Transformation experiments; Dead virulent pneumococci inoculated into mice did not cause death but when dead virulent bacteria and the live non-virulent bacteria were simultaneously inoculated into mice, they died. The transforming factor was found to be DNA in the dead virulent strain that got incorporated into the live non-virulent strain; that brought about virulence.

Transduction experiments; Here bacteriophage (virus with a protein coat and incorporated bacterial DNA) was observed to transmit virulence properties of the donor bacteria (E-coli) to the recipient bacteria. In other experiments, 35-S or 32-P labeled phage was incorporated into E-coli. Analysis of the genetic material in E coil had 32-P labeled molecules. Since DNA has P not S and protein has S not P, then DNA was found out to be the genetic material.

Metabolic stability; DNA is metabolically stable in that its able to replicate itself without loss of information. In non-dividing tissues such as nerves, DNA is not degraded, but other cellular molecules are constantly being recycled and replaced.

Localization of DNA within the nucleus; Nucleus protects it from the ever changing extracellular conditions such as pH, temperature etc; an aspect important in maintenance of viability of genetic material.

Identification of DNA as a component of chromosomes; which is implicated as the carrier of genetic material.

Mutations; mutagens that affect DNA molecules caused more phenotypic variations; pointing out DNA as the focus of variation.

Wavelengths of UV radiations that caused most mutations; were also those which pure DNA molecules absorbed strongest.

Evidence from the cell cycle; DNA is copied exactly during each cell cycle; and therefore consistent and self perpetuating.

Qualitative and quantitative consistence of DNA in a species; all cells in an organism have the same DNA type each with adenine: thymine and the cytosine: guanine ratios equivalent to 1; but DNA varies between species; A+ G is not equal to C+G).
Mass of DNA in somatic cells is constant; while gametes have half this mass.
Ability of DNA to be passed onto the next generation without change in constitution; DNA being the major constituent of gametes; implicates its ability to be passed on, implicates its ability to be passed on to the next generations after fertilization

(b).

Mutations alter structure (pattern of base alignment within DNA) or number of genes or chromosomes; causing an alteration in the expression of the affected genes. A change in DNA occurring inform of a deletion, insertion, substitution or duplication of nucleotides result in synthesis of mutant mRNA which attract complementary anticodons and amino acid tRNA complex such that during translation, the sequence of amino acids in the polypeptide chain being synthesised is altered. A mutant polypeptide chain with either a deletion, insertion, substitution or duplication is formed; whose activity deviates from the normal physiology of the correct polypeptide chain.

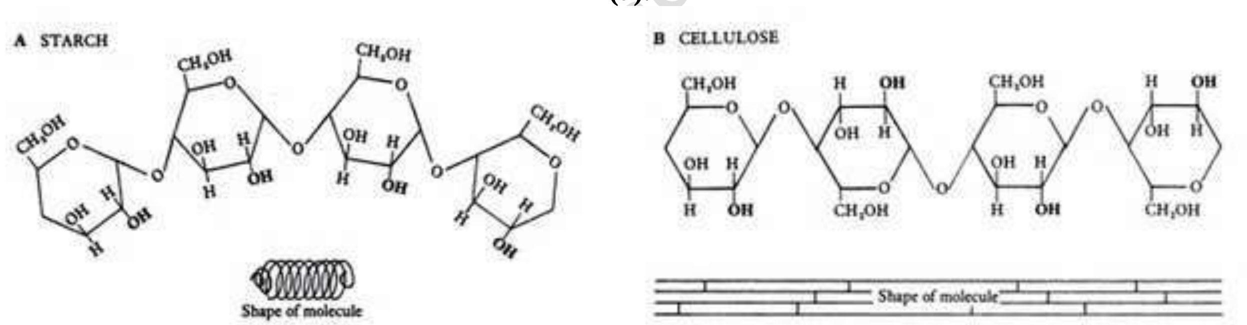
(c).

Polyploidy due to the associated hybrid vigour has been utilized in;
• Production of high yielding variety of crops.
• Production of fast maturing, pest and drought resistant varieties of crops.
• Production of crop varieties with increased resistance to adverse conditions and diseases.
• Production of crops with greater hardness.

Question 7.

Starch and cellulose are important polysaccharides in plants
(a).Compare the structures of starch and cellulose *(11 marks)*
(b).Describe the role of carbohydrates in plant life *(09 marks)*

(a).



Similarities

• Both are macromolecules made up of glucose monomers.
• In both, the glucose units are linked by 1,4-glycosidic bonds.
• In both, chain of glucose can be straight/ linear; amylose for starch and all forms of cellulose.

Differences

Starch	Cellulose
Made up of α-glucose units	Made up of β-glucose units
Glucose units are linked by alpha 1,4-glycosidic bonds	Glucose units are linked by beta 1,4-glycosidic bonds
Chain of glucose is linear, branched or mixed.	Has straight/linear un-branched chains that run parallel to one another.
Hydroxyl group of the glucose units project outwards.	Hydroxyl group of the glucose units project inwards
No hydrogen bonds are present between the adjacent chains	Microfibrils are cross linked by hydrogen bonds

Occurs in 2 forms; amylose (simple linear) and amylopectin (complex and branched)	Occurs in form of cellulose, hemicellulose or lignin
All glucose repeat units are oriented in the same direction.	Every other glucose repeat unit is rotated 180^{o} to the axis of the back bone.
Amylopectin also has l,6-glycosidic bonds responsible for its branching	Lacks 1,6-glycosidic bonds; lack branching.

(b).

- Monosaccharide molecules are components of membranes such as the plasma membrane.
- Polysaccharides such as starch serve as food storage compounds to the plant.
- Monosaccharides such as glucose are important respiratory substrates;
- Integral components of nuclei acids e.g Pentoses.
- Support and structural components like cellulose
- Modifiers of biological roles in cells such as cellular signaling e.g glycolipids .
- Monosaccharides are osmotically active; enable osmotic intake of water by plants.
- Carbohydrates such as Ribulose bisphosphate fix carbondioxide during photosynthesis in plants
- Polysaccharides such chitin form water proof waxy cuticles on surfaces of leaves; prevent dessication.

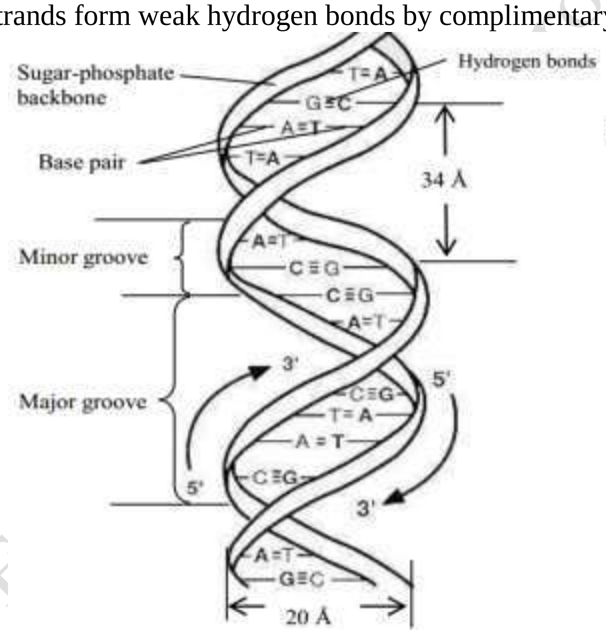
Question 8.

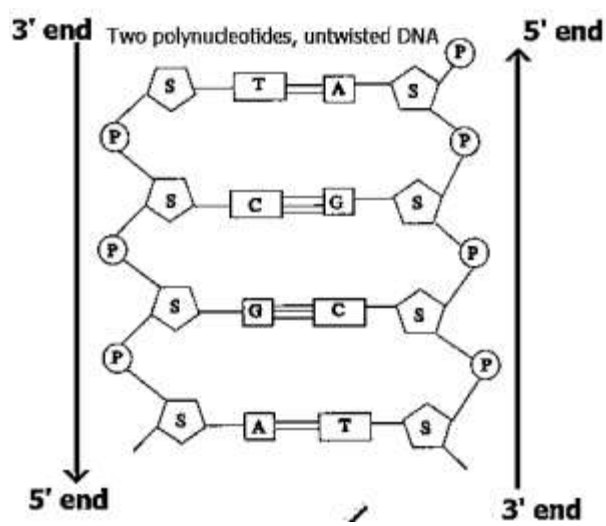
(a).Describe the structure of DNA ***(06 marks)***

(b).Give an account of the process that doubles DNA composition in chromosomes during interphase

(a).

DNA is a very large polymer of nucleotides. A DNA nucleotide is made up of three molecules: Phosphate group, deoxyribose sugar and nitrogen base-either adenine (A), guanine (G), thymine (T) or cytosine (C). The polynucleotide stands are antiparallel (face in opposite directions) i.e. one runs from 3‘to 5‘direction while another runs from 5‘ to 3‘ direction. Untwisted DNA is ladder-like, in which the sugar phosphate backbones represent the handrails while the nitrogen base pairs represent the rungs. Twisted DNA forms a double helix of major and minor grooves. The sugar-phosphate-sugar backbone is held by covalent phosphodiester bonds, while the nitrogen bases from the two strands form weak hydrogen bonds by complimentary base pairing i.e. A with T, C with G.





(b).

DNA replication occurs during the synthesis phase of interphase. DNA Helicase enzyme untwists & unzips DNA by breaking the hydrogen bonds to expose the bases, creating the Y-shaped replication fork, the two opened strands of DNA behind it (DNA is replicated a bit at a time and the whole molecule is never completely uncoiled). RNA primase enzyme lays down an RNA primer at the 3‘end of the old DNA strand to guide the action of DNA polymerase. DNA polymerase enzyme removes the RNA primer from the new strand then moves along the exposed base sequences, attaching free DNA nucleotides of complementary bases to create a new DNA strand as it goes. DNA ligase joins adjacent Okazaki fragments on the lagging strand (new strand laid down in the opposite direction of the replication fork) and any sections of new DNA on the leading strand (new strand laid down in the direction of the replication fork) that need to be joined. DNA polymerase reads the exposed code from 3‘to 5‘end and therefore assembles the new strand from 5‘to 3‘end. Several molecules of DNA polymerase act simultaneoussly at multiple sites, each assembling a separate section of the new strand of DNA. These new DNA segments are then joined together by the enzyme DNA ligase. The two new daughter molecules then coil up again to reform the double helix structure.

Question 9.

(a).Describe the genetic code. *(05 marks)*
(b).Explain the role of genes in protein synthesis *(04 marks)*
(c). Living organisms use DNA as their genetic material. Explain how;
(i). DNA is replicated within the cells of living organisms *(04 marks)*
(ii).the process of DNA replication depends on structure of DNA *(05 marks)*

(a).

The genetic code is composed of mRNA base triplets called codons. There are 64 different codons, each coding for the addition of an amino acid to a growing polypeptide chain. The genetic code is degenerate i.e more than one codon can code for a particular amino acid. The genetic code is universal i.e it is the same in almost all organisms (AUG is the start codon) and some (nonsense) codons code for the end of translation

(b).

Genes code for proteins/ polypeptides. One gene codes for one polypeptide. One gene is transcribed into one mRNA. mRNA is translated by a ribosome to synthesize a polypeptide. If the information on a gene is changed or mutated this may alter the structure of a protein and genetic information transcribed by eukaryotes is edited before it is translated.

(c)(i).

Helix is unwound; two strands are separated by helicase by breaking hydrogen bonds between bases and new strands formed on each of the two single strands. Nucleotides are added to form new strands. Complementary base pairing (A to T and G to C) and DNA polymerase forms the new complementary strands. Replication is semi-conservative in which each of the DNA molecules formed has one old and one new strand.

(c)(ii).

DNA molecule is double (stranded) with hydrogen bonds linking the two strands are weak/ can be broken. DNA can split into two strands by helicase. Helicase moves progressively down the molecules, backbones are linked by covalent/ strong bonds and strands do not therefore break/ base sequence conserved (semi-conservative replication). Base pairing/ sequences are complementary (A=T and C=G) and the two original strands therefore carry the same information. The two new strands have the same base sequence as the two original ones. The strands have polarity, base/ nucleotides added in 5`to 3`direction and the two strands have opposite polarity. Discontinuous segments/ Okazaki fragments added to one strand and DNA ligase needed to connect the segments.

Question 10.

(a).Compare the processes of DNA replication and transcription. *(09 marks)*
(b).Explain briefly the advantages and disadvantages of the universality of the genetic code to humans.
(c).Explain how DNA replication is carried out by eukaryotes. *(08 marks)*

(a).

Similarities

• Both involve unwinding the helix (helicase activity).
• Both involve separating the two strands of DNA
• Both involve breaking hydrogen bonds between bases
• Both involve complementary base pairing
• Both involve C pairing with G.
• Both work in a 5‘ to 3‘ direction
• Both involve linking/ polymerization of nucleotides (polymerase activity).
• Both require a start signal.

• Both occur in the nucleus

Differences

Replication	Transcription
Involves DNA nucleotides	Involves RNA nucleotides
Ligase/ Okazaki fragments with replication	No ligase/Okazaki fragments with transcription
Multiple starting points	One starting point
Gives two DNA molecules	Gives mRNA
Adenine pairs with thymine	Adenine pairs with uracil
Involves DNA polymerase	Involves RNA polymerase
DNA strands donot re-associate after replication	DNA molecules re-associate after transcription
Occurs during cell division	Occurs during protein synthesis
Whole DNA molecule involved	Only section of DNA called cistron is involved
Both DNA strands act as template for formation of new molecules	Only one strand of DNA is used as template

(b).

Advantages

• Genetic material can be transferred between species/ between humans
• One species could use a useful gene from another species
• Transgenic crop plants/ livestock can be produced
• Bacteria/ yeasts can be genetically engineered to make a useful product

Disadvantages

• Viruses can invade cells and take over their genetic apparatus
• Viruses cause disease

(c).

DNA replication is semi-conservative, helicase cause the double helix to unwind, separates the two strands of the DNA molecules. Hydrogen bonds between bases broken to separate the two strands. DNA polymerase attaches nucleotides which are in the form of deoxynucleoside triphosphates. Complementary base pairing/ A only pairs with T and C with G. DNA polymerase III can only work in a 5` to 3' direction, on the lagging/ 3`to 5`strand DNA replication occurs discontinuously. Okazaki fragments are formed on the lagging/ 3` to 5`strand. DNA polymerase III cannot start a new chain of nucleotides DNA polymerase I replaces the RNA primer/ nucleotides with DNA. DNA ligase seals the nicks between the nucleotides and RNA primase inserts a RNA primer.

Question 11.

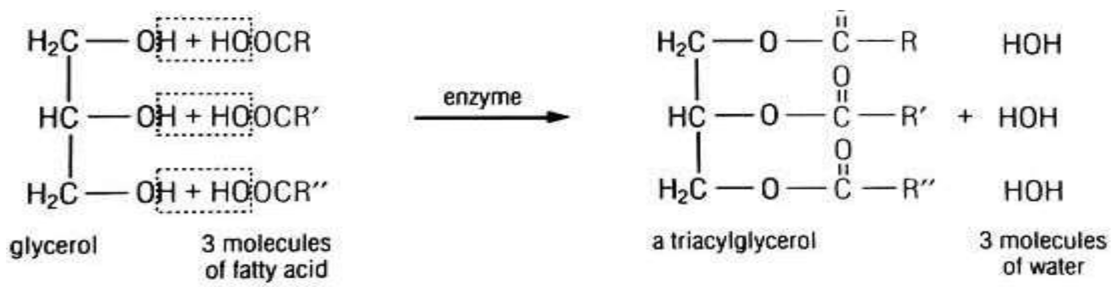
(a). Describe the formation and synthesis of;
(i). Polynucleotide *(05 marks)*
(ii).Triglycerides *(05 marks)*
(b).Compare DNA and RNA molecules *(10 marks)*

(a)(i).

Polynucleotide is formed from monomer units called nucleotides. Each nucleotide is formed by combination of the phosphate group (phosphoric acid); pentose sugar (deoxyribose or ribose); and one of the four nitrogenous bases; adenine, guanine, cytosine, uracil or thymine. Two nucleotide units combine in a condensation reaction water molecule eliminated; dinucleotide formed. Repeated polymerization results in a long chain of a polypeptide.

(a)(ii).

Triglyceride is formed by condensation reaction; in which three molecules of fatty acid combine with one molecule of glycerol with removal of three water molecule. Three ester linkages are formed.



Similarities

- Both DNA and RNA are nucleic acids.
- Both DNA and RNA have nucleotides as the monomeric building blocks.
- In both, nucleotides are linked to each other by phosphodiester bonds
- Both are part of the protein synthesis machinery.
- Both consist of pentose sugar, nitrogenous bases (purines and pyrimidines) and a phosphate group.

Differences

DNA	RNA
Double stranded	Single stranded
Pentose sugar is deoxyribose	Pentose sugar is ribose.
Nitrogen bases are thymine, adenine, cytosine and guanine	Nitrogen bases are uracil, adenine, cytosine and guanine
One basic type	Three types i.e. mRNA, rRNA and tRNA
Higher molecular mass	Lower molecular mass
DNA is permanent	RNA is temporary
New copies formed by continuous by continuous	New copies are formed as transcripts
DNA is insoluble	RNA is soluble
DNA is restricted to the nucleus	Found in both the nucleus and the cytoplasm

Question 12.

(a). Distinguish between the structures of carbohydrates and proteins ***(06 marks)***

(b). Explain the structures of carbohydrates that enable them exist in various types, exhibit different chemical properties and perform particular functions ***(14 marks)***

(a).

Carbohydrates	Proteins
Consists of carbon, hydrogen and oxygen alone	Consists of nitrogen, phosphorous in addition to carbon, hydrogen and oxygen.
Contain carbonyl groups	Contain carboxyl and amino groups
Made up of monosaccharide sugar units	Polymers of amino acids.
Glycosidic bonds link the building blocks.	Peptide bonds link the building units
Exist in straight or ring forms	Exist in straight and twisted/folded form
Sugars in carbohydrates do not exist as charged molecules	Amino acids exist as charged molecules (Neutral zwitterion of an amino acid)
Fewer bonds are present within the compound 1,4 and 1,6-glycosidic bond.	Many bond linkages; ionic, disuiphide, hydrogen and hydrophobic bond.
Neutral	Amphoteric

(b).

Carbohydrates are made up of elements; carbon, hydrogen, and oxygen; linked by covalent bonds forming simple sugar monosaccharide which are simple sweet soluble crystalline molecules of low molecular weight. Monosaccharides can be ketoses which contain ketone groups or aldoses which contain aldehyde groups. Monosaccharides are of variable number of carbon atoms. Trioses like glyceraldehyde and dihydroxyacetone are 3 carbon sugars. Pentoses like ribose and Ribulose are five carbon sugars, hexoses (6 carbon sugars) like glucose and fructose etc. Monosaccharides are oxidized to release energy, synthesize nucleic acids, co-enzymes, carbondioxide acceptors and are also intermediate compounds in the respiratory pathways. Two monosaccharides linked by a glycosidic bond (1,4-linkages) to form disaccharides which are also sweet soluble and crystalline molecules e.g maltose from two glucose units, lactose from glucose and galactose, sucrose from glucose and fructose. Maltose yields respiratory substrates on hydrolysis, sucrose; the most abundant in plants; is the major translocated organic food material. Several monosaccharide units polymerize to form polysaccharides which are non- sweet, insoluble and non-crystalline sugars of large molecular mass; exert no osmotic or chemical influence in a cell. The sugars are folded, compact, insoluble, and larger in size thus convenient storage molecules. Polysaccharides include starch, glycogen, and cellulose. Cellulose is a structural carbohydrate in plant cell walls.

Question 13.

(a).Explain what is meant by the following?

(i).Turnover number of the enzyme ***(02 marks)***

(ii).Specificity of an enzyme ***(02 marks)***

(iii).End product inhibition ***(02 marks)***

(b).Explain the mechanism of enzyme action by the lock and key hypothesis ***(08 marks)***

(c).Compare competitive and non-competitive inhibition of enzyme activity ***(06 marks)***

(a)(i).

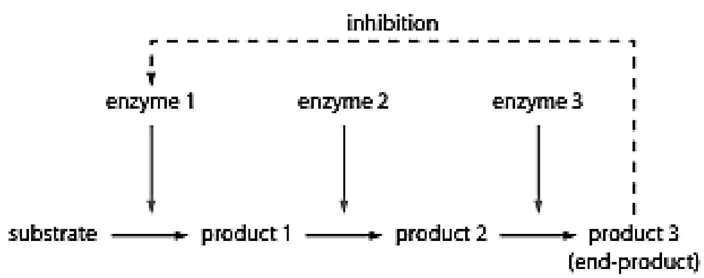
Turnover number refers to the number of substrate molecules acted upon by the enzyme per second. Catalase has the highest turnover number of around 40,000 substrate molecules/second.

(a)(ii).

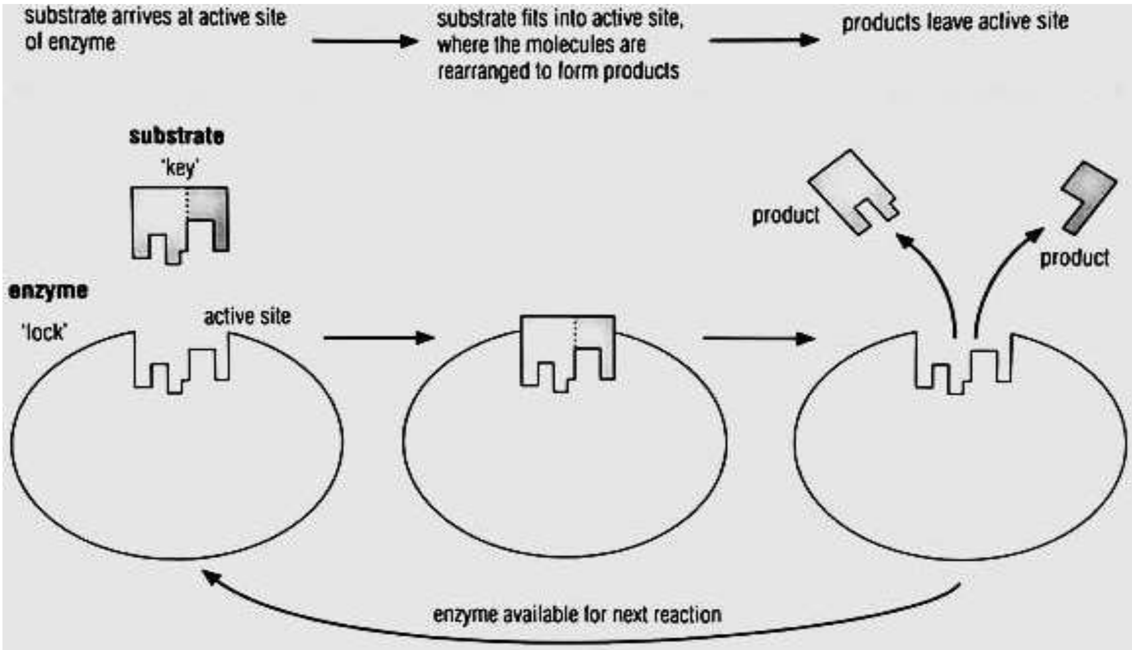
Specificity of the enzyme refers to the ability of the enzyme to bind with a substrate whose structural configuration is exactly complementary to that of the active site of the enzyme.

(a)(iii).

End product inhibition occurs when an accumulated product near or at the end of the pathway inhibits one of the enzymes used in the earlier reaction through a negative feedback mechanism. The end product acts as an allosteric inhibitor.



(b).



According to the theory, an enzyme is a three dimensional organic molecule capable of binding substrate molecule thus speeding up a biochemical reaction. Enzyme has a three dimensional portion whose configuration is complementary to that of the substrate. These are called active sites. Substrate with a complementary configuration binds to the active site of the enzyme the way a key fits in a lock forming an enzyme-substrate complex. At this point, activation energy of the substrates is reduced; and eventually an enzyme-product complex is formed. Being incompatible with the enzyme‘s active site, the product is released from the enzyme; leaving the enzyme free to combine with other substrates.

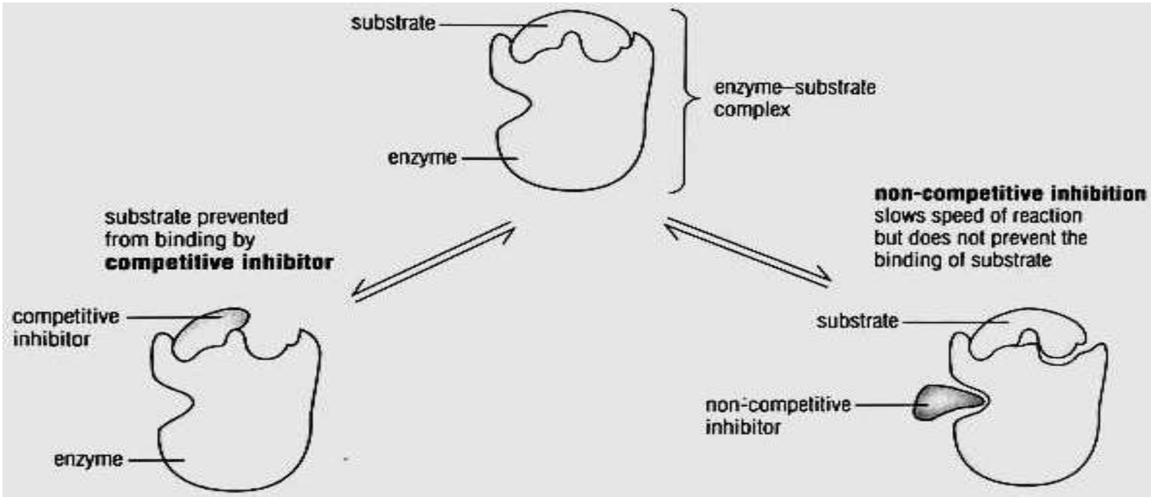
(c).

Similarities

• Both result in loss of the enzyme‘s ability to catalyse biochemical reactions
• For both, increase in inhibitor concentration reduces rate of reaction.

Differences

Competitive inhibition	Non-competitive inhibition
Structural configuration of the inhibitor is complementary to that of enzyme‘s active site	Structural configuration of the inhibitor is not complementary to the enzyme‘s active site.
Inhibitor binds to the active site of the enzyme;	Inhibitor binds to other sites of the enzyme other than the active site (allosteric sites)
Degree of inhibition is inversely proportional to the concentration of the substrate.	Degree of inhibition is independent of concentration of the substrate.
Reversible	Either reversible or non-reversible



Question 14.

(a)Explain the effects of substrate concentration, temperature and pH on the rate of enzyme controlled reactions ***(13 marks)***

(b).How do the following confirm the one gene one enzyme hypothesis

(i).phenylketonuria ***(04 marks)***

(ii).Alkaptonuria ***(03 marks)***

(a).

Effect of substrate concentration on enzyme activity; The rate of enzyme controlled reactions increases with increase in substrate concentration to a maximum; and thereafter remains constant. As substrate concentrations, there are more active sites of the enzyme exposed. Enzyme-substrate interractions increase. At high substrate concentration, the active sites of the enzyme become saturated; any extra substrate molecules will only react after the enzyme-substrate release product to avail more active sites.

Effect of temperature on enzyme activity; Temperature increases the kinetic energy of the substrate & enzyme molecules. At optimum temperature, there is maximum effective collision between the enzyme and the substrate molecules producing products. Below this optimum temperature, the kinetic energy of the molecules is low, the enzyme molecules are said to be inactivated. As temperature is increases from the low value towards the optimum , the kinetic energy of the molecules increase, the enzyme is said to be activated; more affective collisions betwe-en the enzyme and the substrate and hence increase the rate of reaction. When temperature is increased above the optimum, the rate of enzyme of enzyme controlled reaction decreases because the high temperature denatures the secondary and tertiary protein structures. The rate of denaturation increases with increase in temperature.

Effect of pH on enzyme activity; Every enzyme has an optimum range over which it functions most efficiently. Change in pH alters ionic charge of the basic and acidic groups disrupting the precise shape and structure of the active sites. At extremes of pH, the enzyme is denatured and the reaction stops.

(b)(i).

Phenylketonuria is due to inability to convert the amino acid phenylalanine to tyrosine because of the faultiness of a single enzyme (phenylalanine hydroxylase) controlling this reaction. As result phenylalanine accumulates causi-ng nervous and mental damage. It is an autosomal recessive trait characterized by severe mental retardations, tumors, seizures, hypopigmentation of hair, eczema and a mousy odour.

(b)(ii).

Alkaptonuria is an autosomal recessive disorder due to mutation in the gene coding for the enzyme homogentisate 1,2-dioxygenase whose deficiency results in elevated concentration of homogentisic acid. The condition clinically manifests with elevated concentration of homogentisic acid in urine, which darkens on standing or undergoing alkalinization and joint pains (arthritis).

Question 15.

(a)What is meant by the following terms?

(i) A protein? *(02 marks)*
(ii).Tertiary structure of a protein? *(02 marks)*
(b).Discuss with suitable examples, the variety of functions of proteins in organisms. *(10 marks)*
(c).Why are carbohydrates able to form a variety of polysaccharides? *(06 marks)*

(a)(i).

It is a complex organic compound composed of a chain of amino acids linked by peptide bonds to form a three dimension structure of large molecular mass.

(a)(ii).

The polypeptide chain coils extensively forming a compact globular shape; This structure is maintained by interaction; of the four types of bonds i.e. ionic, hydrogen, disulphide bonds and hydrophobic interactions; The hydrophobic interactions are quantitatively the most important and occur when a protein folds to shield the hydrophobic side groups from the aqueous surrounding and at the same time exposing hydrophobic side chains;

(b).

Cellular structures
• Fibrous and globular proteins form component of cell membranes/organelles
• Chromatin; forms structural component of chromosomes

Transport and defence
• Heamoglobin, haemoerythrin and haemocyanin are important pigments for transport of oxygen
• Fibrinogen, prothrombin for blood clotting
• Antibodies for defence

Excretion
• Urease, arginases; important enzymes in ornithine cycle

Movement/locomotion/ support
• Actin/myosin for muscle contraction
• Keratin form components of feathers, claws, nails, scales for protection
• Collagen; offers strength in cartilage and tendons.
• Elastin for flexibility with strength in ligaments
• Mucin for lubrication
• Chitin; an important component of the exoskeleton for protection

Reproduction
• Keratin; structural components like horns/antlers for sexual display

Sensitivity
• Photosensitive pigments like rhodopsin and iodopsin for vision
• Hormones like Insulin, prolactin and vasopressin perform endocrine roles

Nutrition
• Pepsin, amylase, lipases etc perform a digestive role
• Protein in granal lamellae for photosynthesis
• Casein; nutritive protein in milk
• Gluten; for storage protein in seeds

Growth
• Hormones like thyroxine and growth hormone mediate growth.

(c).

• They form both 1,4 and 1,6 glycosidic bonds. This increases the variety of polysaccharides since branching can occur e.g cellulose has only 1,4 while glycogen and starch have both 1,4 and 1,6 glycosidic bonds.
• They use both pentoses and hexoses to form polysaccharides. In some cases one monosaccharide is used while in other cases, two or more different monosaccharides are used in alternating sequences.
• The difference in the level of branching shown by carbohydrate polymers, leads to the formation of different polysaccharides e.g glycogen is more branched than starch.
• The existence of both alpha and beta forms of certain monomers increases the variety of polysaccharides. This causes the difference between starch and cellulose.

• The high chemical reactivity of monomers makes them combine with other groups to form related monomer units. These combine to form different polysaccharides e.g cellulose differs from chitin.
• The existence of both ketoses and aldoses which form both five numbered and 6 numbered rings. This causes the difference in certain polysaccharides e.g insulin is different from starch.
• The high chemical reactivity of monomers makes them combine with other groups to form related monomer units. These combine to form different polysaccharides e.g cellulose differs from chitin.
• The existence of both ketoses and aldoses which form both five numbered and 6 numbered rings. This causes the difference in certain polysaccharides e.g inulin is different from starch.

Question 16.

(a).Explain what is meant by cofactors? ***(01 marks)***
(b).With examples, state roles of various types of cofactors in metabolic pathway ***(07 marks)***
(c).Explain four applications of enzyme inhibitors ***(05 marks)***

(a).

Cofactors are non-protein substances that are needed by enzymes for their efficient activity. They vary from simple inorganic ions to complex organic molecules.

(b).

Enzyme activators; these are inorganic ions whose presence increases the chances of catalysis of some enzymes and substrate reactions e.g the presence of chloride ions increase the activity of salivary amylase.
Prosthetic groups; low molecular weight organic molecules that are tightly and permanently bound to enzymes improving their catalytic activity eg haem contains iron at its centre, also present in many cytochromes and it is important in electron transfer enabling oxygen carrying proteins like haemoglobin and myoglobin function efficiently. It is also present in catalases and peroxidases that decompose hydrogen peroxide.
Co-enzymes; these are organic molecules derived from vitamins and are not permanently attached onto the enzyme but their presence improves catalysis. E.g nicotinamide adenine dinucleotide (NAD); an important electron carrier is derived from niacin (vitamin B_2).

(c).

• Useful in many insecticides and nerve gas that inhibit acetylcholinesterase; cause prolonged muscle contraction that finally cause paralysis due to uncontrolled acetylcholine release.
• The functioning of metabolic poisons like cyanide is based on their non-competitive inhibition of enzymes involved in the respiratory pathway.
• Photorespiration in C_3 plants bases on the ability of O_2 to outcompete CO_2 for the active site of Ribulose bisphosphate (RUBP).
• Studying biochemical pathways e.g those with many reaction pathways; one can be inhibited & another investigated.
• Inhibition controls enzyme activity;
• Balances stimulation of a process; in organisms e.g. in muscle contraction, the impulse will be accompanied by one to prevent muscle contraction of its antagonistic one;
• Regulates metabolism; e.g. in allosteric enzymes where enzymes exist in different shapes;
• Helps in drug action in humans; e.g. antibiotics and sulphonamides are competitive inhibitors;
• Applied in respiratory poisons e.g, cyanides; works by inactivating the enzyme cytochrome oxidase;

Question 17.

(a).Briefly explain the characteristics of proteins. ***(04 marks)***
(b).With examples, describe the different structures of proteins ***(08 marks)***
(c).State the differences between fibrous proteins and globular proteins ***(08 marks)***

(a).

• All proteins in living cells are colloidal.
• Amphoteric properties; All proteins are usually charged positively or negatively
• Large size of molecules; proteins have large molecular weights
• Specificity of proteins;
• Denaturation; all proteins are affected by heat, chemical reagents and radiations
• Hydrolysis of proteins; complete hydrolysis of all proteins yields mixtures of amino acids.

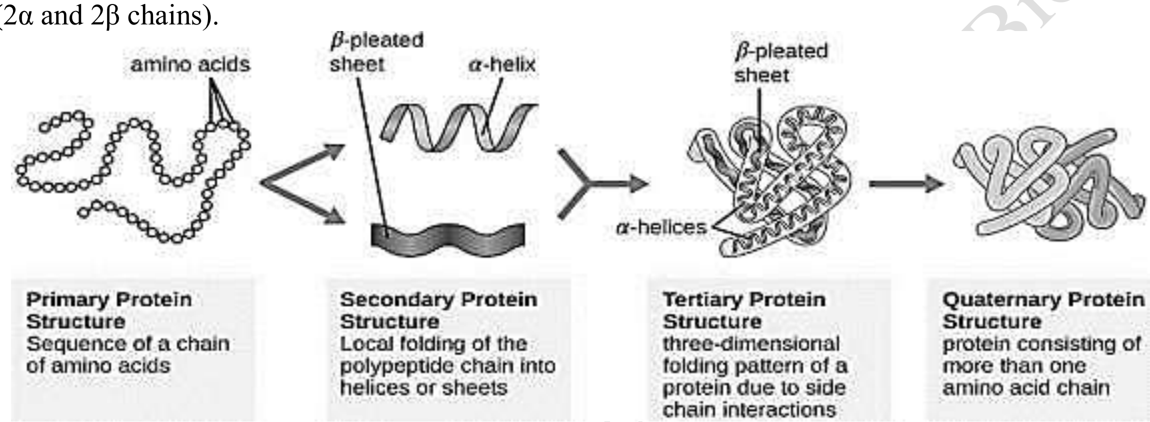
(b).

Primary structure; here a long sequence of amino acids linked by peptide bonds makes up a polypeptide chain. Proteins with a primary structure may be simple or conjugated. Examples include; myoglobin.

Secondary structure; here the polypeptide chain coils to form α helices or folds into β pleated sheets. The shape of the α helices and β pleated sheets is maintained by the regularly spaced hydrogen bonds. A single polypeptide may have some regions coiled into α helices and the others folded into β pleated sheets. Examples of proteins with α helices include; keratin and collagen. Those with β pleated sheets fibroin in silk.

Tertiary structure; here the helically coiled chains bend and twist forming a compact protein with a three dimensional configuration. The compactness is maintained by disulphide, ionic and hydrogen bonds together with hydrophobic interractions.

Quaternary structure; is a complex protein made up of more than one polypeptide; which are held together by hydrophobic interractions, hydrogen bonds and ionic bonds e.g haemoglobin made up of 2 distinct polypeptide chains (2α and 2β chains).



(c).

Fibrous protein	Globular protein
Repetitive regular sequence of amino acids	Irregular amino acid sequence
Amino acid sequence may vary slightly between two similar proteins	Amino acids sequences highly specific and varies between two similar proteins
Polypeptide chains form long parallel strands	Polypeptide chain folded into a spherical shape
Length varies between two same proteins	Length is the same between two same proteins
Stable structure	Relatively unstable structure
Insoluble	Soluble forms, colloidal suspensions
Carry out support and structural functions	Carry out metabolic functions
Examples include collagen and keratin	All enzymes, some hormones like insulin and blood

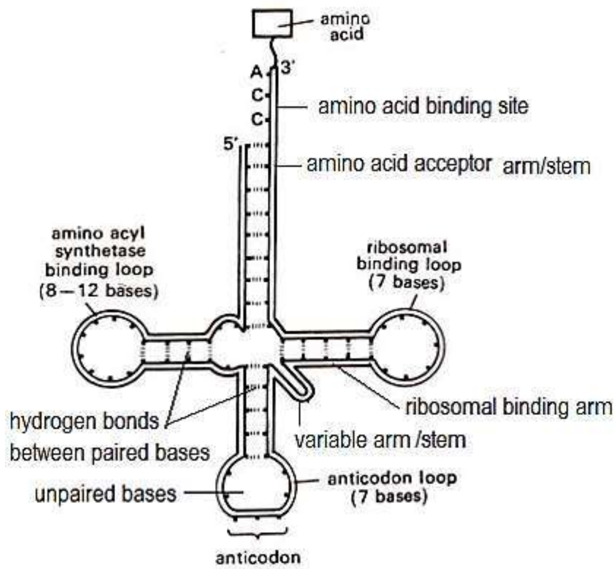
Question 18.

(a).Describe the structure of the transfer RNA molecule ***(09 marks)***

(b).Compare the processes of DNA replication and transcription ***(11 marks)***

(a).

Forms about 15% of the total cell RNA. Primary structure in all tRNAs has sequences of 73 to 93 nucleotides. 3‘ end always terminates with the sequence CCA, where amino acid attaches while the 5‘end terminates in base G. Secondary structure forms a clover leaf shape with 4 hydrogen bonded base-paired stems Cloverleaf contains three non-base-paired loops: Amino acyl synthetase binding loop, anticodon, ribosomal binding loop. Tertiary structure is a compact shape whereby the anticodon stem and acceptor stem form a double helix. Anticodon is a single stranded loop at the bottom. tRNA carries amino acids in the cytoplasm to ribosomes.



(b).

Similarities

- Both involve unwinding the helix
- Both involve separating the two strands
- Both involve breaking hydrogen bonds between bases.
- Both involve complementary base pairing
- Both involve C pairing with G
- Both work in a 5` to 3` direction
- Both involve linking/ polymerization of nucleotides.
- DNA or RNA polymerase require a start signal

Differences

DNA replication	Transcription
Involves DNA nucleotides, where the pentose sugar is deoxyribose, and the base adenine pairs with thymine	Involves RNA nucleotides where the pentose sugar is ribose, and the base adenine pairs with uracil
Both strands are copied	Only one strand copied not both
Ligase enzyme or no Okazaki fragments are involved	No ligase enzyme / no Okazaki fragments
Has multiple starting points	Has only one starting point
replication gives two DNA molecules	Gives mRNA molecule

Question 19.

(a).Explain what is meant by the genetic code *(02 marks)*
(b).Outline the properties of the genetic code *(09 marks)*
(c).Explain briefly the advantages and disadvantages of the universality of the genetic code to humans.

(a).

The genetic code is the set of rules by which information encoded in genetic material (DNA or RNA sequences) is translated into proteins (amino acid sequences) by living cells.

(b).

The code is a triplet codon; the nucleotides of mRNA are arranged as a linear sequence of codons, each codon consisting of three successive nitrogenous bases, i.e., the code is a triplet codon.

The code is non-overlapping; in translating mRNA molecules the codons do not overlap but are read sequentially.
The code is commaless; means that no codon is reserved for punctuations. After one amino acid is coded, the second amino acid will be automatically, coded by the next three letters and that no letters are wasted as the punctuation marks.
The code is non-ambiguous; a particular codon will always code for the same amino acid. The same codon shall never code for two different amino acids.
The code has polarity; the code is always read in a fixed direction, i.e., in the 5‘→3′ direction.
The code is degenerate; more than one codon may specify the same amino acid; For example, except for tryptophan and methionine, which have a single codon each, all other 18 amino acids have more than one codon.
Some codes are start codons; in most organisms, AUG codon is the start or initiation codon, i.e., the polypeptide chain starts either with methionine (eukaryotes)
Some codes are stop codons; three codons UAG, UAA and UGA are the chain stop or termination codons. They do not code for any of the amino acids. These codons are also called nonsense codons, since they do not specify any amino acid.
The code is universal; same genetic code is found valid for all organisms ranging from bacteria to man.

(c).

Advantages

- Genetic material can be transferred between species/ between humans
- One species could use a useful gene from another species
- Bacteria/ yeasts can be genetically engineered to make a useful product

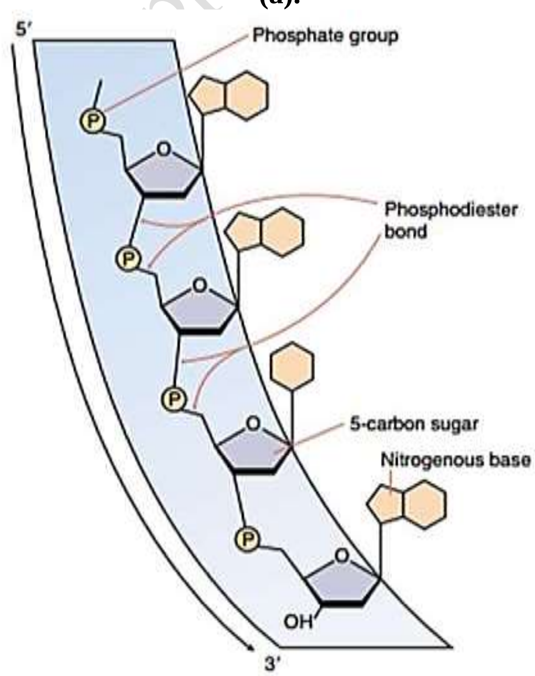
Disadvantages

- Viruses can invade cells and take over their genetic apparatus e.g HIV
- Viruses cause disease

Question 20.

(a)Describe the structure of nucleic acids *(07 marks)*
(b)State the adaptations of DNA to function *(08 marks)*
(c).Describe the role of mRNA in protein synthesis in a cell *(05 marks)*

(a).



Nucleic acids are polymers made of nucleotides. A nucleotide is made up of three molecules Phosphate group; pentose sugar; either Deoxyribose (in DNA) or Ribose (in RNA) & nitrogen base; any purine (Adenine, Guanine) or pyrimidine (Cytosine and either Thymine in DNA or Uracil in RNA). Nucleoside forms when a pentose sugar joins an organic base by condensation reaction (a water molecule is lost). Nucleotide forms when a nucleoside (pentose sugar + organic base) joins a phosphate by loss of second water molecule. The sugar-phosphate-sugar backbone is formed when the 3‘carbon on one sugar joins to the 5‘carbon on the next sugar by phosphodiester bonds repeatedly to form a polynucleotide (long chain of nucleotides) with organic bases protruding sideways from sugars.

(b).

• Sugar-phosphate backbone is held together by strong covalent phosphodiester bonds to provide stability.
• The two sugar-phosphate backbones are antiparallel which enables purine and pyrimidine nitrogen bases to project towards each other for complimentary pairing.
• Sugar-phosphate backbones are two / it is double stranded to provide stability.
• The two sugar-phosphate backbones form a double helix to protect bases/hydrogen bonds.
• Long/large molecule for storage of much information.
• Double helical structure makes the molecule compact to fit in the nucleus.
• Base sequence allows information to be stored.
• Double stranded for replication to occur semi conservatively/ strands can act as templates.
• There is complementary base pairing / A-T and G-C for accurate replication
• Weak hydrogen bonds enable unzipping/separation of strands to occur readily.
• There are many hydrogen bonds which increase stability of DNA molecule.

(c).

mRNA carries genetic information in form of nitrogenous bases from chromosomal DNA in the nucleus to the rRNA in the cytoplasm. It acts as a template for protein synthesis. It is complementary to DNA & carries the same base sequence as found in that part of DNA from which it is transcribed. As a result, mRNA directs synthesis of proteins as directed by the base sequence on the segment of DNA from which it is copied (translation)

Question 21.

(a).Explain what is meant by transcription and state its importances ***(03 marks)***
(b).Describe the series of events that lead to formation of a mRNA in a cell ***(10 marks)***
(c).How does the molecular structure of proteins relate to its functions ***(07 marks)***

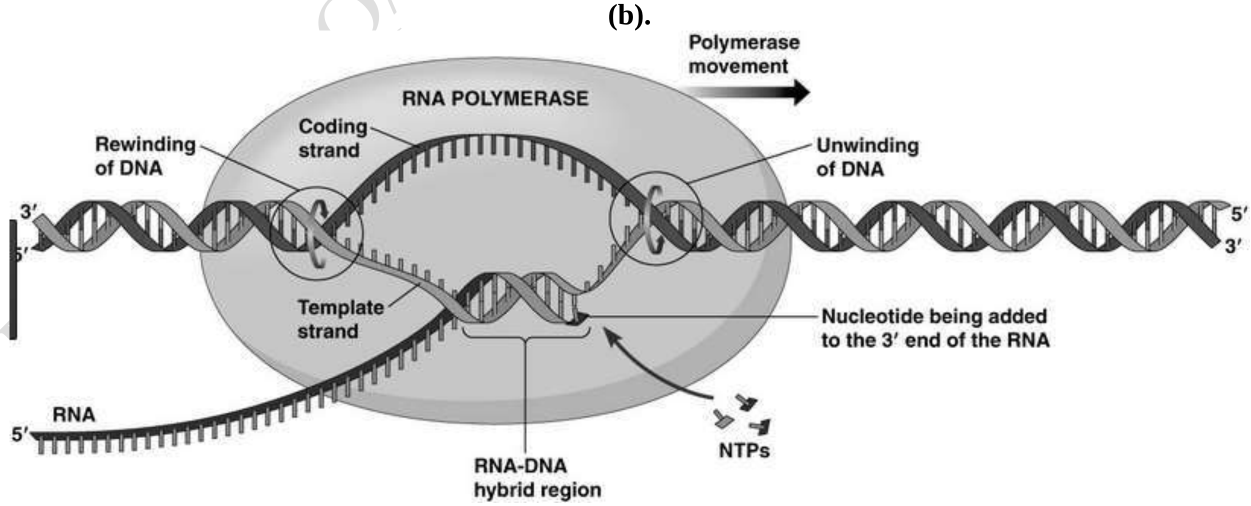
(a).

Transcription is the process whereby the DNA code of a gene is copied to make messenger RNA (mRNA).

Importance of transcription

• DNA is too large to fit through the nuclear pores, yet mRNA being small can readily exit the nucleus.
• DNA contains many codes that aren‘t always needed at a given time, so mRNA only carries that code needed to make specific proteins out of the nucleus to the ribosome.

(b).



Transcription is performed by an enzyme called RNA polymerase and a number of accessory proteins called transcription factors which together form the transcription initiation complex. Transcription is initiated when RNA polymerase enzyme binds to the DNA strand at a promoter. The promoter is the beginning code of DNA on the gene where the RNA polymerase begins reading the DNA code, and is always the 3 letter triplet TAC. Untwists then unzips the two strands of DNA, reads the antisense strand of DNA from 3‘to 5‘(antisense side containing the code to make a polypeptide), matches new nucleotides with their complements on the DNA strand (G with C, A with U) in the 5‘to 3‘direction, then binds these new RNA nucleotides together to form a complimentary copy of the DNA strand (mRNA). The sense strand of DNA is the side of DNA that does not contain a code to make a polypeptide. It is not read by the RNA polymerase. Elongation occurs when the new mRNA strand is lengthened in the 5‘-3‘direction. Transcription stops when the terminator code which is section of DNA is reached. Its code is complementary to the stop codons of m-RNA. The newly created mRNA of eukaryotic cells is edited by removal of non-coding sections, called introns since they remain in the nucleus. The finished mRNA (with exons only) contains the code needed to make the polypeptide leaves via nuclear pores to the ribosome in the cytoplasm for translation.

(c).

Fibrous proteins from a long, tough fibre insoluble thus function as structural and supporting structural and supporting proteins and include; keratin, collagen, elastin etc.

Globular proteins have globular shape but lack contractile properties. They contain polypeptide chains coiled about them. They thus act as regulatory molecules and as food storage in plants. Soluble globular proteins are amphipathic and therefore act as buffers of body fluid pH.

Conjugated proteins consist of a simple protein united with some non-protein substance eg glycoproteins which form mucin of saliva that softens food, chromoproteins combined with a protein such as haemoglobin an oxygen carrying molecule; metallo-proteins which act as enzymes.

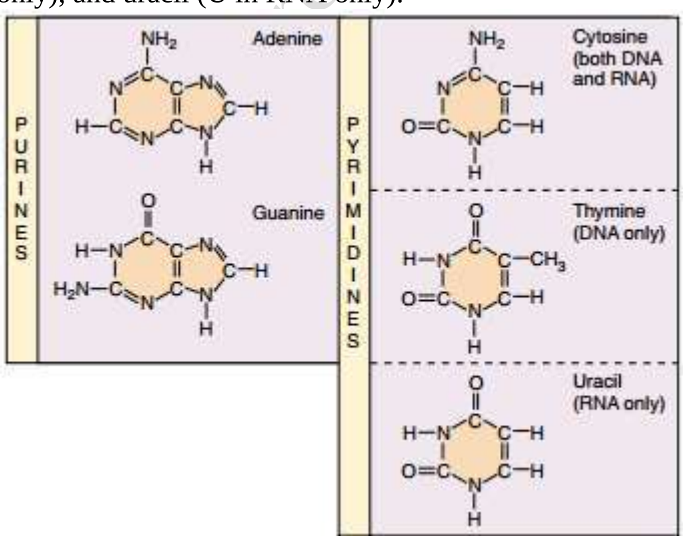
Question 22.

(a). Distinguish between purines and pyrimidines ***(04 marks)***

(b). Explain how enzyme activity is precisely regulated in metabolic pathways ***(16 marks)***

(a).

Purines, are large, double-ring organic nitrogen bases found in both DNA and RNA; they are adenine (A) and guanine (G) while pyrimidines, are smaller, single-ring organic bases; they include cytosine (C, in both DNA and RNA), thymine (T in DNA only), and uracil (U in RNA only).



(b).

Allosteric enzymes have two kinds of binding sites; one an active site for the substrate and one an allosteric site for an allosteric effector. There are two kinds of allosteric effectors:

An allosteric activator binds to the enzyme and induces the enzyme‘s active form.

An allosteric inhibitor binds to the enzyme and induces the enzyme‘s inactive form.

In ***feedback inhibition;*** an end product of a series of reactions acts as an allosteric inhibitor, shutting down one of the enzymes catalyzing the reaction series.

In ***competitive inhibition;*** a substance that mimics the substrate inhibits an enzyme by occupying the active site. The mimic displaces the substrate and prevents the enzyme from catalyzing the substrate.
In ***non-competitive inhibition;*** a substance inhibits the action of an enzyme by binding to the enzyme at a location other than the active site. The inhibitor changes the shape of the enzyme which disables its enzymatic activity. Many toxins and antibiotics are non-competitive inhibitors.
In ***cooperativity;*** an enzyme becomes more receptive to additional substrate molecules after one substrate molecu-le attaches to an active site. This occurs, for example, in enzymes that consist of two or more subunits (quaternary structure), each with its own active site. A common example of this process (though not an enzyme) is hemoglob-in, whose binding capacity to additional oxygen molecules increases after the first oxygen binds to an active site.

Question 23.

(a).With suitable examples, classify enzymes based on the reactions they catalyse ***(09 marks)***
(b).State the general characteristics of the active sites of different enzymes ***(06 marks)***
(c).Describe the mechanism of enzyme action based on the induced fit model ***(05 marks)***

(a).

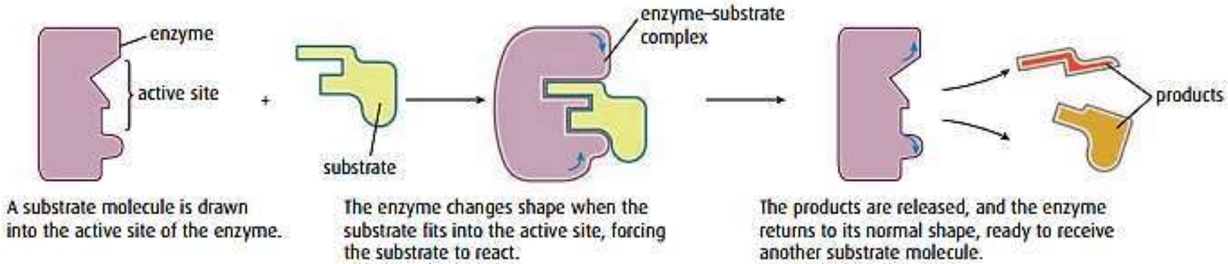
Oxidoreductases; catalyze oxidations and reduction reactions e.g oxidases and dehydrogenases
Transferases; catalyze transfer of chemical groups from one substance to another e.g kinases etc.
Hydrolases; catalyze hydrolysis reactions e.g peptidases, lipases and phosphatases.
Isomerases; catalyze geometric or structural changes within a molecule e.g isomerases and mutases.
Ligases; catalyze bonding of two molecules using energy from hydrolysis of ATP e.g synthetases.
Lyases; catalyze addition or removal of a chemical group other than hydrolysis e.g decarboxylases.

(b).

• The active site is a three-dimensional cleft; formed by different parts of the amino acid sequence.
• The active site takes up a relatively small part of the total volume of an enzyme;
• Active sites are clefts or crevices; in which substrate molecules get bound to.
• Substrates are bound to active sites by multiple weak attractions;
• The configuration of the active site is complementary to the shape of the substrate;
• The specificity of binding depends on the precisely defined arrangement of atoms in an active site.

(c).

Within the enzyme, there is a three dimensional active site with which the substrates readily interact because of the shape or polarity. Enzymes are flexible molecules and that the shapes of their active sites can be markedly mo-dified by the binding of substrate. When a substrate approaches & binds to an enzyme, it induces conformational change analogous to placing a hand (substrate) into a glove (enzyme). An enzyme-substrate complex is formed. At this point, activation energy of the substrates is reduced; and eventually an enzyme-product complex is form-ed. Being incompatible with the enzyme‘s active site, the product is released from the enzyme; freeing the enzyme for further binding with other substrates.



Question 24.

(a).With examples, explain what is meant by cooperativity in line with protein functioning ***(04 marks)***
(b).When you hard-boil an egg, the clear liquid part surrounding the yolk becomes white and solid. Discuss why this happens. ***(04 marks)***
(c).Explain some of the practical uses of enzymes ***(12 marks)***

(a).

In cooperativity, an enzyme becomes more receptive to additional substrate molecules after one substrate molecu-le attaches to an active site. This occurs, for example, in enzymes that consist of two or more subunits (quaternary structure), each with its own active site. A common example of this process (though not an enzyme) is hemoglobin, whose binding capacity to additional oxygen molecules increases after the first oxygen binds to an active site.

(b).

The white of an egg is mostly the protein albumin. When a protein is heated above a critical temperature, it denatures i.e begins to lose its structure. Secondary, tertiary and quaternary structures begin to break down. If temperatures are high enough, and applied for a long enough time, the structure of the protein is permanently destroyed.

(c).

Enzymes are used as biological detergents; proteases degrade coagulated proteins into soluble short chain peptides, lipases degrade fats or oil stains into soluble fatty acids and glycerol and amylase degrades starch into soluble shorter chain polysaccharides and sugars.
Enzymes are used in bakery industry; proteases are used in the breakdown of proteins in flour for production of biscuits, amylase is used in the breakdown of some starch to glucose in flour for making bread, buns and rolls.
Enzymes are used in the medical treatment of diseases; e.g pancreatic enzymes are used in treatment of exocrine pancreatic insufficiency disease, streptokinase for removing blood clots and to clean wounds etc
Fermentation; production of alcohol from sugars is catalysed by enzymes like zymase.
Enzymes used to assist in digestion and metabolism: enzymes aid digestion and metabolism e.g enzymes like papain are administered orally after food for easing digestion in elderly patients.
Enzymes used to assist drug delivery: Some drugs need to penetrate deeper tissues for better action. For this some enzymes are used along with drugs in intramuscular injection forms to help proper penetration of tissues. One of the such enzyme is hyaluronidase.
Enzymes are used to diagnose disorders: Enzymes of liver, kidney, skeletal muscle, heart etc leak into blood during related disorders. Measuring the levels of corresponding enzyme for their presence in high or low levels in blood indicates the specific disorder e.g alanine transferase for liver disease
Enzymes used in manufacture of medicines: Immobilized enzymes are used in manufacture of many drugs. This is possible as enzymes convert the pro-drug molecules to drugs.
Enzymes in food industry: to process carbohydrates, proteins & fats. The chief enzymes in food processing include amylase, lactases, cellulases, Pectinase like enzymes which act on hard pectin is used in fruit juice manufacture Pectinase breaks pectin making juice less viscous.
Applications of enzymes in leather industry: The leather after being removed becomes hard due to denaturation of proteins and also the fats present in it. To obtain smooth and soft leather proteases and lipases are used to remove the hair on the skin and also these proteins and fats in between the leather.
Role of enzymes in cloth or textile industry: Natural cotton fabric are not as smooth and glossy. To give them smoothness and glossy appearance, enzymes like cellulase are used. Further the fabric size or thread thickness is controlled by treating with these amylase enzymes. Catalase is used to remove any hydrogen peroxide residues after bleaching.

Question 25.

(a)What is the significance of the distribution of DNA in eukaryotic cells? ***(03 marks)***
(b).How does the structure of deoxyribonucleic acid suit it for functioning? ***(08 marks)***
(c).Describe the role of Ribonucleic acid in protein synthesis ***(07 marks)***

(a).

Nuclear DNA; Extra-nuclear DNA in mitochondria; and chloroplast; Extra-nuclear DNA codes for a few proteins; not sufficient to cater for the needs of the organelle; which has to depend on proteins coded for by nuclear DNA; Nuclear DNA codes for wide ranging proteins; on which the entire cell depends;

(b).

• Long/large molecule so can store lots of information;
• Helix/coiled so compact;
• Base sequence allows information to be stored/ base sequence codes for amino acids/protein;
• Double stranded so replication can occur semi-conservatively/ strands can act as templates;
• Complementary base pairing / A-T and G-C so accurate replication/identical copies can be made;
• (Weak) hydrogen bonds for replication/ unzipping/strand separation;
• Many hydrogen bonds so stable/strong;

• Sugar-phosphate (backbone)/double stranded/helix so provides strength/stability /protects bases/protects hydrogen bonds;

(c).

Three kinds of RNA molecules perform different but cooperative functions in protein synthesis; ***Messenger RNA (mRNA);*** carries the genetic information copied from DNA in the form of a series of three base code; each of which specifies a particular amino acid; ***Transfer RNA (tRNA);*** has two functions; to be chemically linked to a particular amino acid and to base pair with a codon in mRNA so that the amino acid can be added to a growing peptide chain. Each tRNA molecule is recognized by one and only one of the 20 aminoacyl-tRNA synthetases; Likewise, each of these enzymes links one and only one of the 20 amino acids to a particular tRNA, forming an aminoacyl- tRNA; Once its correct amino acid is attached, a tRNA then recognizes a codon in mRNA, thereby delivering its amino acid to the growing polypeptide; ***Ribosomal RNA (rRNA);*** associates with a set of proteins to form ribosomes, which then physically move along an mRNA molecule, catalyze the assembly of amino acids into protein chains and also bind tRNAs and various accessory molecules necessary for protein synthesis;

Question 26.

(a) Distinguish between replication and transcription. ***(06 marks)***

(b) Explain the relationship between the Watson–Crick DNA structure and its function ***(14 marks)***

(a).

Replication	Transcription
Occurs in the S phase of the cell cycle	Occurs in the G1 and G2 phases of the cell cycle
Catalysed by DNA polymerase	Catalysed by RNA polymerase
Occurs along both strands of DNA	Occurs along one strand of DNA
Involves unwinding and splitting of the entire DNA molecule (chromosome)	Involves unwinding and splitting of only those genes to be transcribed
Involves copying the entire genome	Involves copying of certain individual genes
Two double stranded DNA molecules are formed from one DNA strand	One single stranded RNA molecule is formed from a segment of DNA
Replicated DNA strand remains hydrogen bonded to its template DNA strand	Transcribed RNA strand separates from its DNA template
Products remain within the nucleus	Products pass from the nucleus to the cytoplasm
Products are not degraded	Products are degraded after their function is done
Serves to conserve genome for the next generation of cells and individuals	Serves to form DNA copies of individual genes for immediate use in protein synthesis
Requires RNA primer to start replication	No primer is required to start transcription
Produces normal DNA that do not need any processing	Produces primary RNA transcripts which need processing to acquire final form and size

(b).

• The sugar-phosphate backbone makes the molecule more stable
• DNA coils up into a double helix that is more compact, so lots of information is stored in a small place
• The sequence of bases allows it to carry coded information for making proteins
• It is very long so it stores lots of information
• Complementary base pairing allows the molecule to replicate itself accurately
• The double helix makes it stable as the base pairs are on the inside and so are less likely to get damaged
• The bases are held together by weak hydrogen bonds allowing the molecule to unzip‘(separate) easily when it replicates.

Question 27.

(a).What is meant by a buffer solution? ***(03 marks)***

(b).Explain the general functions of minerals in living systems. ***(12 marks)***

(c).Explain how enzymes catalyse biochemical reactions? ***(05 marks)***

(a).

A buffer solution is an aqueous solution consisting of a mixture of a weak acid and its conjugate base or a weak base and its conjugate acid; capable of resisting changes in pH when small amounts of acid or base is added. Living organisms utilize the bicarbonate, protein, and phosphate buffer.

(b).

- Potassium; a systemic electrolyte and is essential in co-regulating ATP with sodium
- Chlorine; needed for production of hydrochloric acid in the stomach and in cellular pump functions
- Sodium; a systemic electrolyte and is essential in co-regulating ATP with potassium
- Calcium; needed for muscle, heart, builds bone, supports synthesis and function of blood cells
- Phosphorus; A component of bones (see apatite), cells, in energy processing, in DNA and ATP
- Magnesium; required for processing ATP and chlorophylls.
- Iron; required for many proteins and enzymes, notably hemoglobin; aiding oxygen carriage
- Zinc; required for several enzymes such as carboxypeptidase, liver and carbonic anhydrase.
- Manganese; A cofactor in enzyme functions
- Copper; Required component of many redox enzymes, including cytochrome c oxidase
- Iodine; Required for synthesis of thyroid hormones, thyroxine and tri-iodothyronine
- Chromium; Involved in glucose and lipid metabolism
- Molybdenum; co-factory for the oxidases like xanthine oxidase and aldehyde oxidase
- Selenium; essential to activity of antioxidant enzymes like glutathione peroxidase.
- Sulphur; is a component of proteins;

(c).

Enzymes are biological catalysts that speed up reactions by lowering activation energy. Many enzymes change shape when substrates bind by "induced fit" mechanism. The precise orientation of the enzyme required for catalytic activity is induced by the binding of the substrate. Enzymes have active sites where substrates bind. There is a precise substrate interaction that occurs at the active site stabilized by numerous weak interactions (hydrogen bonds, electrostatic interactions, hydrophobic contacts, and van der Waals forces). Enzyme-substrate complex formed; catalyse reactions following lowered activation energy.

Question 28.

(a). State the structural features of carbohydrates that account for the existence of the wide variety of polysaccharides ***(06 marks)***

(b).With examples, outline the chief functions of monosaccharides in living organisms ***(10 marks)***

(c).Explain why cells of poikilothermic animals usually have a higher proportion of unsaturated fatty acids than homeothermic animals ***(04 marks)***

(a).

- Existence of a variety of monosaccharides such as pentoses and hexoses.
- Existence of two linkage types; 1,4 and 1,6-glycosidic bonds permitting branching
- Existence of various lengths of chains and branches; extent of branching varies enormously.
- Existence of alpha and beta forms of monosaccharides
- Existence of a variety of sugars which may be aldoses and ketoses
- The high chemical reactivity of sugars (aldehydes, ketones and hydroxyl groups) that render the sugars highly reactive molecules.

(b).

Trioses like glyceraldehyde and dihydroxyacetone

- Glyceraldehyde and dihydroxyacetone are metabolic intermediates in respiration and photosynthesis.

Pentoses like ribose, deoxyribose and ribulose.

- Synthesis of nucleic acids such as ribose in RNA and deoxyribose in DNA.
- Synthesis of some co-enzymes e.g ribose is used in synthesis of NAD and NADP.
- Synthesis of ATP requires ribose
- Ribulose bisphosphate; a carbondioxide acceptor in photosynthesis is made from a 5C sugar ribulose.

Hexoses like glucose, fructose and galactose

- Sources of energy in respiration; e.g glucose, mannose, fructose etc
- Synthesis of disaccharides; involving linkage of two monosaccharides units

• Synthesis of polysaccharides; involving polymerization of several hexoses.
• Galactose is used in synthesis of lactose.
• Fructose is used in the synthesis of inulin, constituent of nectar, sweetens fruits to attract pollinators and dispersal agents.

(c).

Body temperature of poikilothermic animals becomes lower in cold environment; lipids rich in unsaturated fatty acids (which have lower melting points) generally remain liquid at lower temperatures (below 5ºC) than those rich in saturated fatty acids. This may be necessary if the lipids are to maintain their functions such as constituents of membranes.

Question 29.

(a).With reference to hemoglobin, describe how a tertiary structure differs from a quartenary structure of proteins ***(04 marks)***
(b).State the various ways;
(i). phospholipids differ from triglycerides ***(03 marks)***
(ii) Cellulose differs from glycogen ***(10 marks)***
(iii)Collagen differs from haemoglobin ***(03 marks)***

(a).

Tertiary structures refers to the 3-dimesional shape of each polypeptide chain of haemoglobin while quartenary structure refers to the overall shape formed by the four polypeptide chains of each hemoglobin molecule.

(b)(i).

Phospholipids	**Triglycerides**
Contains two fatty acids	Has three fatty acids
Contains a phosphate group	Lacks a phosphate group
Hydrophilic head and hydrophobic tail	Completely hydrophobic

(b)(ii).

Cellulose	**Glycogen**
Polymer of β-glucose	Polymer of α-glucose
Plays a structural role/ non-storage roles	Plays a storage role/ non-structural role
Monomers rotated alternately at 180^o to each other	No rotation of adjacent monomers
Straight chains with hydrogen bond cross linkings	Branched chains
Has β-1,4-glycosidic linkages	Has α-1,4 and 1,6-glycosic linkages
Found in plants	Found in animals and fungi
Forms microfibrils	Doesnot from microfibrils
Hydroxyl groups project outwards	Hydroxyl groups project inwards
Few organisms can digest cellulose/ cellulase is not a common enzyme	Easily digested/ hydrolysed by many organisms
Used for paper making	Fewer commercial uses.

(b)(iii).

Collagen	**Haemoglobin**
Its fibrous protein	It‘s a globular protein
Entirely helical	Partly helical
Triple helix/ extended helix/ three stranded	Alpha helix
Lacks prosthetic group	Has prosthetic group
Insoluble in water	Soluble in water

Question 30.

(a).Describe how polypeptide chains may be folded to form protein molecules ***(06 marks)***
(b).Explain the effects of temperature on enzyme activity ***(06 marks)***
(c).How does inhibition alter the rate of enzyme controlled reactions either directly or indirectly

(a).

Sequence or position of amino acids determines where the bonds will form/ exactly how the chain will fold. Primary structure/ chain of amino acids is folded into an alpha helix or a beta pleated sheet; to form a secondary structure; held in place by many hydrogen bonds. The secondary structure is then folded again to form the tertiary structure; other types of bonds eg disulphide bonds/ ionic bonds are involved in maintaining the precise shape; quartenary structure if more than one polypeptide chain is incorporated into the structure.

(b).

Increase in temperature increases kinetic energy of the enzyme/ substrate molecules. These then move faster more collisions between the enzymes and the substrate occur; forming more enzyme-substrate complexes; allowing faster catalysis. However at higher temperature above the enzyme‘s optimum temperature, enzyme molecules vibrate more; enzymes bonds like hydrogen bonds break; denaturation occurs; enzyme‘s tertiary structure is altered; shape of the enzyme is altered; substrate no longer fits in the active site and enzyme-substrate complex cannot form any more.

Decrease in temperature decreases kinetic energy of both enzyme and substrates; fewer collisions between the two occur; fewer enzyme-substrate complexes formed. At extremely lower temperatures, the enzyme is inactivated.

(c).

Direct inhibitors are usually competitive inhibitors; have a shape similar the substrate molecule; perfectly fits in the enzyme‘s active site; preventing substrate forming an enzyme-substrate complex; are concentration dependent/ the more inhibitor present, the greater the degree of inhibition since the inhibitor greatly outcompetes the substrate for the enzyme‘s active site.

Indirect inhibitors are usually non-competitive inhibitors; binds to a site on the enzyme away from the active site; effect is to distort the enzyme molecule and hence the active site; substrate molecules nolonger fit in the active site; enzyme-substrate complexes not formed; degree of inhibition is concentration independent.

Question 31.

(a).Outline the reasons why;

(i). glycerol is a suitable energy storage in animals ***(05 marks)***

(ii).water is suitable in transport of substances ***(04 marks)***

(b).State the differences between

(i). monosaccharides and disaccharides ***(03 marks)***

(ii) amylose and amylopectin ***(03 marks)***

(c). Briefly explain the roles of mRNA and tRNA in protein synthesis ***(05 marks)***

(a)(i).

• Insoluble; no osmotic effect, will not dissolve
• Large molecule; will not move out of cell and can store large amounts of energy
• Compact; can store large amounts of energy in small space
• Very branched; easily hydrolysed to release glucose
• Made of alpha glucose and held by 1,4 and 1,6 glycosidic bonds.

(a)(ii).

• Water is a solvent and can dissolve polar solutes /ions
• Water has a dipole nature; can form weak hydrogen bonds
• Water has strong adhesive and cohesive forces
• Water is fluid and can assist mass flow

(b)(i).

Monosaccharides	Disaccharides
Made of 1 sugar	Made up of 2 sugars
No glycosidic bonds	Has glycosidic bonds
$C_nH_{2n}O_n$ is the general formula	General formula is $C_nH_{2n-2}O_{n-1}$

(b)(ii).

Amylose	Amylopectin
Unbranched, helical chain	Branched chain

is coiled/spiral	Not coiled/ spiral
Has 1,4 glycosidic bonds	Has 1,4 & 1,6 glycosidic bonds
Stains deep blue with iodine	Stains red to purple with iodine
Relative molecular mass up to 50,000	Relative molecular mass up to 500,000
200-5000 glucose units/ molecules	5000-10000 glucose units

(c).

mRNA

mRNA transcribe DNA template; is copy of genetic code. mRNA is made up of codons that code for specific amino acids. The mRNA contains the code for the new protein/polypeptide. The mRNA moves out of the nucleus, & binds to the ribosomes and is used in translation [acts as template for translation]

tRNA

tRNA attaches to one specific amino acid (one); amino acids line up on mRNA via complementary base pairing; peptide bonds form via condensation; released by tRNA; tRNA then binds to mRNA; amino acids join via peptide bonds.

Question 32.

(a).Describe the events that take place at the enzyme's active site in order to lower the activation energy
(b).State the property of water that allows each of the following to take place and in each case explain its importance *(06 marks)*
(i).The cooling of the skin during sweating *(05 marks)*
(ii)The transport of glucose and ions in a mammal *(03 marks)*
(iii)Much smaller temperature fluctuations in lakes and oceans than in terrestrial habitat *(02 marks)*
(c).Outline the comparison between α-helices and β-pleats of the same proteins *(06 marks)*

(a).

Temporary binding of the reactants next to each other on an enzyme increases chance of reaction; slight distortion of the reactant molecules as they bind to the enzyme strains the bonds that are to be broken & increases chance that they will break. Reactant are held by the enzyme in such a way that the bonds are exposed to attack. Hydrophobic amino acids create a water free zone in which non-polar reactants may react more easily. Acidic and basic amino acids in the enzyme facilitate the transfer of electrons to and from the reactants.

(b)(i).

Water requires a relatively large amount of heat energy to evaporate i.e water has a high latent heat of vapourisation. Heat energy which is transferred to water molecules in sweat allows them to evaporate from the skin, which cools down, helping to prevent the body from overheating. A relatively large amount of heat can be lost with minimal loss of water from the body.

(b)(ii).

Water is a good solvent. Water is needed for transport by diffusion or active transport into, out of and within cells. Also for circulation in blood so that nutrients can reach the sites where they are needed. Chemical reactions take place in aqueous solution.

(b)(iii).

Water has a high (specific) heat capacity. A more constant environment results, protecting organisms from extremes of temperature which could be harmful.

(b)(iii).

Similarities

• Both are held in place by hydrogen bonding;
• Both form part of secondary structures of proteins;
• In both, all the –NH and –C=O groups of, peptide bonds / polypeptide backbone, are involved;

Differences

β-pleats	α-helices
Polypeptide chains are in a parallel arrangement	Polypeptide chains are helical or spiral
Cannot be stretched	Have some ability to stretch
Have higher tensile strength	Lower tensile strength

Question 33.

(a).Explain why pH affects the activity of the enzyme ***(06 marks)***

(b).Explain the functioning of the –SH groups in proteins and why binding of heavy metals to these groups would inhibit the activity of the enzymes ***(06 marks)***

(c).Describe how starch and glycogen are enzymatically degraded in the digestive system ***(08 marks)***

(a).

pH is a measure of the hydrogen ion concentration; Hydrogen ions being positively charged; can interact with the R groups of amino acids; affects ionic bonding / affects ionization of R groups; affects tertiary structure / affects 3D shape of enzyme; therefore substrate may not fit active site (as precisely);

(b).

–SH groups form disulfide bridges; used to determine tertiary structure; heavy metal would prevent formation of disulfide bridges; could change shape of active site; heavy metal could affect shape either by binding directly in the active site, or by binding at another site which then results in change in shape of the active site; substrate would not be able to fit into active site;

(c).

α-amylase; endoglucosidase that randomly hydrolyses α-1,4 linkages of the side chains of glycogen and amylopectin. It can cleave either side of a branch point except in very highly branched regions.

β-amylase; endoglucosidase that sequentially removes β-maltose from the ends of outer branches but stops cleavage before any branch points are reached.

The structures remaining after hydrolysis by α and β-amylases form limit dextrins that comprise about 3 dozens glucose residues.

Amylo-α-(1,6) glucosidase; a debranching enzyme; catalyses hydrolysis of the α-(1,6) glycosidic linkages of limit dextrins; thereby permitting further breakdown by α and β-amylases.

Question 34.

(a).How is the structure of cellulose and starch related to function in plant cells ***(11 marks)***

(b).With examples, outline the functions of disaccharides in different living organisms ***(09 marks)***

(a).

Structure of Cellulose in relation to function

• Cellulose is made up of β-glucose units held by glycosidic bonds with the hydroxyl groups of the glucose units projecting out wards allowing extensive hydrogen bonding interactions between the adjacent chains; offers greater tensile strength to the plant.

• The β-glucose monomers form straight chained molecules capable of forming cross links to produce a very strong structure.

• The cross linking bind the chains together forming microfibrils which are also arranged in larger bundles to form macrofibrils which offer greater tensile strength (rigidity) and flexibility to the plant cell wall.

• The microfibrils are arranged in several layers offering protection to the plant cell wall from bursting when water enters by osmosis. Cellulose thus offers turgidity to the plant cell wall upon osmotic intake of water and offers support to herbaceous plants.

• Parallel arrangement of cellulose microfibrils permit full permeability to gases, water and solutes.

• The glycosidic bonds holding the β-glucose units can be broken down by cellulase yields free glucose molecules; oxidized on respiration to yield energy.

• Large molecular mass of cellulose prevents them from being lost in solution; effectively function as structural carbohydrates.

Structure of starch in relation to function.

• Starch is a polymer of numerous α-glucose units; offering it a large molecular structure that makes it relatively insoluble in water and hence an ideal storage molecule.

• The α-glucose molecules are held by glycosidic bonds; which can be broken down to free glucose that can be oxidized to yield energy.

• The starch molecules is coiled into a helix with hydroxyl groups projecting inwards making it insoluble in water hence exerts no osmotic effects on cells and is ideal for storage.

• The chains of α-glucose are folded to form starchy granules for easy storage.

(b).

• Sucrose is a respiratory substrate
• Sucrose is a form in which most carbohydrates are translocated in plants
• Sucrose is a storage material in some plants like onions
• Lactose; is respiratory substrate (major carbohydrate source for suckling in breast milk)
• Maltose; is respiratory substrate

Question 35.

(a).Briefly describe the composition of the various polysaccharides in living organisms ***(10 marks)***
(b).With examples, state the functions of;
(i). Polysaccharides in different living organism ***(05 marks)***
(ii).Minerals and ions in biological systems ***(07 marks)***

(a).

Starch (amylose & amylopectin); made of unbranched chain of α-glucose with 1,4-glycosidic links plus branched chains of α-glucose units with 1,4 and 1,6-glycosidic bonds
Glycogen; made up of highly branched short chains of α-glucose units with 1,4-glycosidic links.
Cellulose; made up of unbranched chains of β-glucose units with 1,4-glycosidic links and cross bridges
Inulin; made up of unbranched chains of fructose with 1,2-glycosidic bonds
Chitin; made up of unbranched chain of β-acetylglucosamine units with 1,4-glycosidc links

(b).

• Starch; major storage carbohydrate in plants
• Glycogen; major storage carbohydrate in animals
• Cellulose; gives structural support to cell walls
• Inulin; major storage carbohydrate in some plants like Jerusalem artichoke, Dahlia etc
• Chitin; constituent of exoskeletons of arthropods

(c).

• Components of important molecules; e.g phosphorous in ATP, iodine in thyroid hormones etc
• Constituent of large molecules e.g proteins contain nitrogen and sulphur etc.
• Constituent of important pigments eg chlorophyll contains magnesium and hemoglobin contains iron.
• Maintain cation-anion balance; key in nerve impulse transmission, muscle contraction and translocation.
• Determine osmotic potential and water potential to avoid fluctuations past normal limits.
• Constituent of structures eg phosphorous forms phospholipids, calcium makes up plant cell wall & bone.
• Metabolic activators eg magnesium activates glucose before being broken down in cell, Ca^{2+} activate ATPase during muscular contraction.

Question 36.

(a).How is the distribution of conjugated proteins related to function ***(05 marks)***
(b).Explain some of the applications of the conditions for protein denaturation ***(10 marks)***
(c).State how amino acids are synthesized or formed in both plants and animals ***(05 marks)***

(a).

Haemoglobin; prosthetic group is haem; found in blood; performs oxygen transportation.
Mucin; prosthetic group is a carbohydrate; found in saliva; softens and lubricates food.
Casein; contains phosphoric acid as a prosthetic group; found in milk basis of curd formation.
Nucleoprotein; contain nucleic acids as prosthetic group found in ribosomes used in protein synthesis
Cytochrome oxidase; contains copper(prosthetic group) components of the electron carrier pathway of respiration.

(b).

Coagulation of albumen; (boiling eggs makes the white more fibrous& less soluble) due to heat induced denaturation.
Coagulation of milk proteins; which is acid and alkaline induced denaturation. The souring of milk by acid (e.g lactobacillus produces lactic acid, lowering pH and causing it to denature the casein, making it insoluble and thus forming curds).

Enzyme inhibition; many enzymes are inhibited by being denatured in the presence of certain inorganic ions eg cytochrome oxidase (respiratory enzyme) is inhibited by cyanide.
Sterilization; alcohol denatures certain bacterial proteins; due to organic chemical induced denaturation
Mechanically induced denaturation is utilized in hair styling; Stretching hair breaks hydrogen bonds in the keratin helix. The helix is extended & the hair stretches. If released, hair returns to normal length. If however, it is wetted and then dried under tension, it keeps its new length-the basis of hair styling.

(c).

In plants, the formation of amino acids occurs in mitochondria and chloroplasts in a series of stages;
• Absorption of nitrates from the soil
• Reduction of nitrates to the amino group
• Combination of these amino groups with a carbohydrate skeleton e.g α-ketoglutarate from Krebs cycle
• Transfer of the amino groups from one carbohydrate skeleton to another (transamination)
• Animals obtain their essential amino acids from food they ingest
• Animals then have the ability to synthesize their own non-essential amino acids

Question 37.

(a).What is the importance of water in enzymatic activity *(03 marks)*
(b)Outline the main properties that make water biologically important for life *(12 marks)*
(c).Explain the role of mineral salts in the creation of electric tension (voltage) in a cell *(05 marks)*

(a).

Enzymes depend on water to reach their substrates and bind to them. In addition enzymes depend on optimum pH interval to work and the pH is a consequence of liberation of hydrogen ions and hydroxyl ions by acids and bases in water.

(b).

• Molecular polarity; makes it a solvent for polar solutes
• Thermal stability (elevated specific heat capacity, fusion and vaporization)
• Acid-base neutrality; ensures a neutral pH range
• Small molecular size and low chemical reactivity
• High surface tension; allows floatation of some light organisms
• Being a liquid at room temperature; provides a liquid intracellular environment
• Universal solvent; makes it dissolve more solutes than any other common solvent.
• Stronger adhesive forces of water; permits capillarity in which water moves through narrow channels
• Water being colourless and transparent; enables light infiltration permitting photosynthesis
• Water being denser than air; supports and disperses reproductive structures like larvae.
• Water being incompressible; enable support in plants and maintenance of a hydrostatic skeletons.
• Water being an important metabolite; enable it serve as a raw material in several biochemical reactions
• Water being less viscous; enables allows it freely flow through narrow vessels, can serve as lubricants
• Water having a high tensile strength; allows a continuous water column from the roots high up the stem

(c).

The electrical activity of a cells eg in a neuron depends on the relative concentrations of positive & negative ions between the inner and outer surfaces of the cell membrane. Ions such as sodium ions, potassium ions, chloride ions are responsible for that potential difference (voltage). The cell membrane of a non-excited cells has commonly a negatively inner side and a positive outside whereas the excited one has commonly a positive inner membrane and a negative outside the membrane.

Question 38.

(a).Describe the properties of DNA that allow self-replication to take place *(06 marks)*
(b).the role of proteins in DNA replication *(14 marks)*

(a).

• Purines and pyrimidines that join the two DNA strands pair exclusively with only one other base; ensuring that when DNA strands separate to replicate an exact copy is created;

• Double stranded chain of nucleotides/ pairs of polynucleotides; allows for an identical separation upon unwinding and unzipping; resulting in each half attracting its complementary nucleotides to itself; whose subsequent joining form two identical DNA molecules;

(b).

Protein	Role
Helicase;	Unwinds and separates the parental DNA strands;
Single-strand binding proteins;	Bind to exposed single strands, protecting them from cleavage and from rewinding hence stabilizing the unwound parental strands;
Initiator proteins;	Binds to the replication origin, starting a series of interactions that opens the helix;
DNA polymerase;	Catalyses the formation of complementary sequences on each of the two DNA strands at the same time/ assembling of complementary strands; Removes the primer and fills the gap, as well as the gap between okazaki fragments; Proof reads newly formed DNA against its template;
DNA ligase;	Joins the fragment of polynucleotide chain together;
Primase;	Synthesizes RNA primers, using the parental DNA as a template that initiates replication;
Topoisomerase;	Breaks, swivels, and rejoins the parental DNA ahead of the replication fork, relieving the strain caused by unwinding;

Question 39.

(a).How does a mutation lead to a non-functional enzyme? ***(05 marks)***
(b) Describe the features of a gene which enable it to code for a particular protein? ***(06 marks)***
(c) With reference to the sickle cell allele, explain the term heterozygous advantage. ***(09 marks)***

(a).

Change in base sequence; change in sequence of triplet codes; change in sequence of amino acids change. In primary structure of protein/enzyme; change in hydrogen/ionic/disulfide bonds change in tertiary structure (3D shape); change in active site shape; substrate no longer complementary to active site can no longer form enzyme substrate complex.

(b).

• Gene is a length of DNA/ a sequence of bases/chain of nucleotides that specify a particular protein;
• Triplet base code/read in threes on coding strand. with triplet coding for single amino acid;
• Non ambiguous; a codon specifies a single amino acid;
• Conservative; for degenerate codons; the first two bases are the same
• Degenerate code; several codons may specify/code for the same amino acid;
• Non-overlapping; code is read in threes without overlap
• Punctuated; has a start and stop codon;
• Universal; particular triplet codes for a particular amino acid in all living organisms

(c).

Heterozygous advantage refers to a genetic condition where the heterozygote has a survival advantage over homozygotes of a given character against a certain environmental condition. For sickle cell gene, the heterozygote has a survival advantage against malaria. HbAHbA suffer malaria and their death reduces their frequency since the plasmodia breed efficiently in normal red blood cells with normal haemoglobin. Sicklers HbSHbS suffer the pleiotropic effects of having abnormal haemoglobin and sickle cells eg kidney failure; heart failure; splenomegaly; acute anaemia. HbAHbS have about 40% abnormal Hb; but the larger proportion has normal haemoglobin. These individuals do no suffer malaria since plasmodia do not breed to cause malaria and do not suffer anaemic condition.

Question 40.

(a).Distinguish between collagen and cellulose. ***(07 marks)***
(b).How are each of the following biomolecules adapted for their functions;
(i).Collagen ***(03 marks)***

(ii)Cellulose *(03 marks)*

(c).Explain what is meant by Lactose intolerance? *(05 marks)*

(a).

Cellulose	Collagen
Polysaccharide	Protein
Found in plant cells	Found in animal connective tissues
Made up of repeated units of beta glucose	Made up of variable amino acids sequences
Polymer	Not polymer but a relatively large molecule
Structure of parallel microfibrils interlinked by cross bridges	Triple helical structure
Straight chained microfibrils	Chains coiled/ wrapped around each other
Made of variable chains/ microfibrils joined to form macrofibril	Made of three chains wrapped around each other

(b)(i).

• Thick strong fibres in bundles to provide strength & support/ build tendons/ligaments/ connective tissues;
• Triple helical polypeptide chains to provide strength;
• Polypeptide chains held by covalent bonds to increase tensile strength

(b)(ii).

• Many cellulose chains are cross linked by hydrogen bonds to form microfibrils making it stiff, tough with high tensile strength
• Many microfibrils are cross linked to form macrofibrils for strength;
• Microfibrils are reinforced with hemicellulose and lignin making cellulose rigid for support and enabling plant cell walls withstand turgor pressure due to osmotic influx of water

(c).

Person does not make lactase enzyme; Lactose remains undigested and hence not absorbed leading to diarrhoea, flatulence and excoriation of the perineum/ peri-anal area. Undigested lactose in the lumen of the intestine lowers its water potential, so water enters the lumen by osmosis leading to watery faeces (Diarrhoea). Undigested lactose broken down by microorganisms in large intestine giving oil gas/ flatulence. Faecal contents being acidic excoriates the peri-anal area.

Question 41.

Explain the relationship between the structures and functions of the following proteins

(a). Haemoglobin *(10 marks)*

(b). Collagen *(10 marks)*

(a).

The function of haemoglobin is the transport of oxygen from the lungs to respiring tissues. It is found inside red blood cells.

Solubility; The tertiary structure of haemoglobin makes it soluble. The four polypeptide chains are coiled up so that R groups with small charges on them (hydrophilic groups) are on the outside of the molecule. They therefore form hydrogen bonds with water molecules. Hydrophobic R groups are mostly found inside the molecule.

Ability to combine with oxygen; The haem group contained within each polypeptide chain enables the haemoglobin molecule to combine with oxygen. Oxygen molecules combine with Fe^{2+} in haem group. One oxygen molecule (two oxygen atoms) can combine with each haem group so one haemoglobin molecule can combine with four oxygen molecules (eight oxygen atoms).

Pick-up and release of oxygen; The overall shape of the haemoglobin molecule enables it to pick up oxygen when the oxygen concentration is high, and to release oxygen when the oxygen concentration is low. Small changes in oxygen concentration have a large effect on how much oxygen the haemoglobin molecule can hold. Once one oxygen molecule has combined with one haem group, the whole molecule changes its shape in such a way that it is easier for oxygen to combine with the other three haem groups.

(b).

The function of collagen is to provide support and some elasticity in many different animal tissues, such as human skin, bone and tendons.
Insolubility; collagen molecules are very long and are too large to be able to dissolve in water.
High tensile strength; Three polypeptide chains wind around one another, held together by hydrogen bonds, to form a three-stranded molecule that can withstand quite high pulling forces without breaking. This structure also allows the molecules to stretch slightly when pulled.
Compactness; Every third amino add in each polypeptide is glycine, whose R group is just a single hydrogen molecule. Their small size allows the three polypeptide chains in a molecule to pack very tightly together.
Formation of fibres; There are many lysine molecules in each polypeptide, facing outwards from the three-stranded molecule. This allows covalent bonds to form between the lysine R groups of different collagen molecules, causing them to associate to form fibres.

Question 42.

(a). Why is water an ideal medium for living organisms? ***(16 marks)***
(b). Explain why buffers are important in biological systems? ***(04 marks)***

(a).

Water is a component of intracellular & extracellular fluid & forms the external environment for many organisms
Water molecules are dipolar (have slight negative and slight positive charges)**;** making water an excellent solvent of polar substances**;** enabling components of fluids like blood, sap in xylem and phloem to mix miscibly and be transported throughout the body without separating out by gravity**;**
Water's polarity repels hydrophobic substances**;** which enables cell membranes to create barriers against entry & exit of intracellular solutions**;** hence isolating reactions in organelles/ cells from the interference of surrounding medium**;**
Water has high heat capacity (changes temperature very slowly with changes in heat content)**;** which provides a temperature-stable environment**;** for biological molecules like enzymes to remain stable and regulate metabolic reactions that maintain living systems**;**
Water's high heat of vapourisation**;** enables mammalian bodies to cool during sweating**;** because evaporation of sweat takes out large heat amount**;**
Water's density decreases with decrease in temperature**;** causing ice to float at the surface of water bodies thereby insulating bottom water from further cooling which enables aquatic organisms like fish to survive freezing temperatures**;**
Water has strong cohesion (attraction between like substances) because of hydrogen bonding causing high surface tension**;** firm enough to enable small insects like pond skaters to walk upon without sinking**;**
Water has strong adhesive force (attraction of unlike substances)**;** enabling xylem contents to rise up from roots to leaves**;** without falling**;**
Water's transparency**;** enables sunlight penetration into water bodies to considerable depth**;** to support photosynthesis in water**;**

(b).

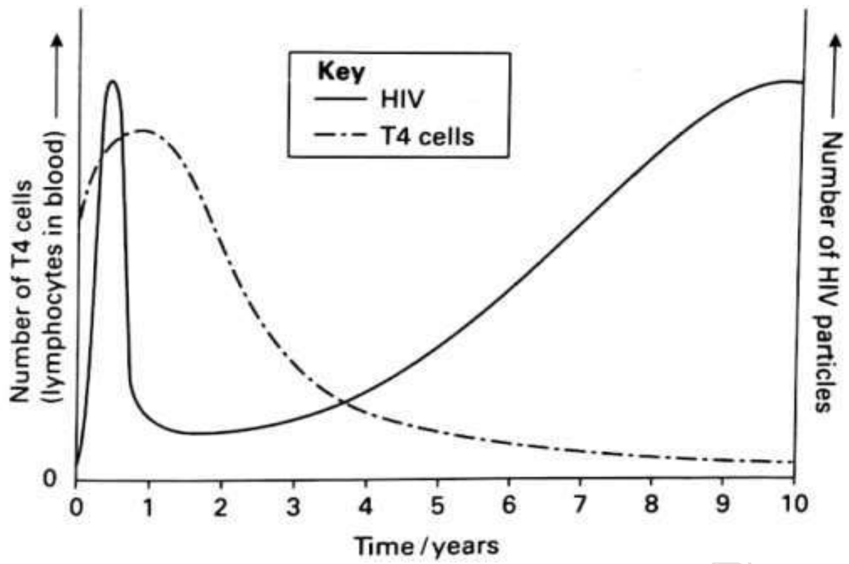
Buffers regulate the pH of body fluids within narrow limits; to allow proteins maintain their physical & chemical structures/ avoid denaturation and inhibition of enzymes; enabling maintenance of biological functioning; which if allowed to occur would cause death;

Chapter 4; TRANSPORT AND DEFENCE IN PLANTS AND ANIMALS

Question 1.

The human immune deficiency virus (HIV) is a retrovirus that suppresses the immune system resulting into Acquired immune Deficiency Syndrome (AIDS). Figure 1 below shows the development of an infection with HIV over a period of 10 years and the changes in the number of T-lymphocytes that active other cells of the immune system Use this information and figure 1 to answer the question that follows.

Fig.1



(a)(i).Describe the Variation in number of HIV particles & T-lymphocytes for 10 years ***(05 marks)***

HIV particles; Number of HIV particles increases rapidly for half a year; to a maximum; then decreased rapidly for the next six months; then falls gradually up to the end of 2nd years; It then rise gradually up to 9th year; then more gradually to a maximum by the 10th year;

T lymphocytes; 0-1 year, number of T-lymphocytes increased rapidly, reaching a peak/ maximum then decreased rapidly to the 3rd year; and falls gradually to the 10th year;

(ii).Explain the relationship between the number of HIV particles and T lymphocytes for the period shown

T-lymphocytes increased rapidly following a rapid increase in HIV particles but later decreased following the resurgence of HIV. T-lymphocytes increased in response to the invading HIV particles more of the HIV particles were killed by the lymphocytes; The remaining T-lymphocytes infected by the virus during the latency period. More T-lymphocytes were killed by the virus as the virus increased gradually reaching a maximum with few remaining T-lymphocytes.

(iii).From the figure what evidence shows that HIV suppresses the immune system? ***(03 marks)***

A rapid increase in T-lymphocytes for less than a year which later decreased to minimum; shows that HIV suppresses the immune response by removing the cells that would produce antibodies against it.

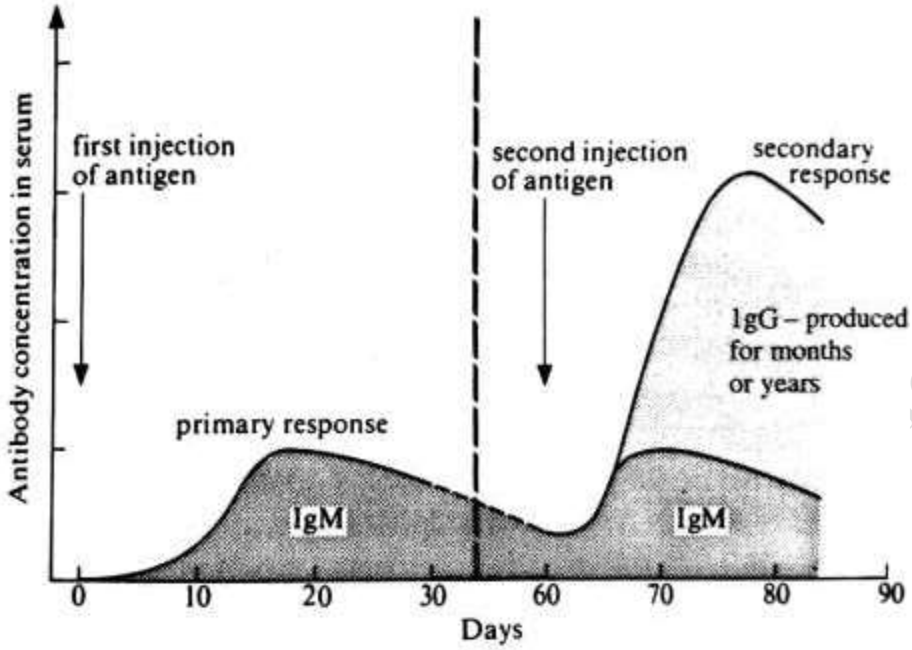
(iv).Predict with a reason what would happen if the development of an infection continued for another five years ***(03 marks)***

Death due to reduction in number of T-lymphocytes which would defend the body against antigen resulting into secondary infection.

(v).Suggest a reason why it has taken to obtain vaccine for HIV. ***(04 marks)***

HIV contains reverse transcriptase enzyme which directs the host cell to synthesize viral DNA on a template of viral RNA which when incorporated into the host DNA acts as a gene.

Figure 2 below shows the companion of antibodies produced to the same antigen during primary and secondary response.



(i). Compare the primary and secondary response ***(03 marks)***

Similarities

• Both have the antibody concentration rise and fall
• Both result in antibody production.

Differences

Primary response	Secondary response
Few antibodies produced	More antibodies produced
Occurs gradually or slowly	Occurs rapidly or at a faster rate

(ii).Explain how each response is being stimulated. ***(08 marks)***

Primary response

One B cell is activated by a specific antigen with complementary shape to the immunoglobulins on cell surface which then divides to produce a clone of cells capable of also producing identical antibodies against the antigen however some of the B-cells from the memory cells.

Secondary response

On being exposed to the same antigen the second time, memory cells formed in the primary response divide to produce large number of B-cell which in turn each produce a clone of B cells that make antibodies to destroy the antigens.

(iii)From figure2, What is the significance of a secondary response in the immune system of an individual

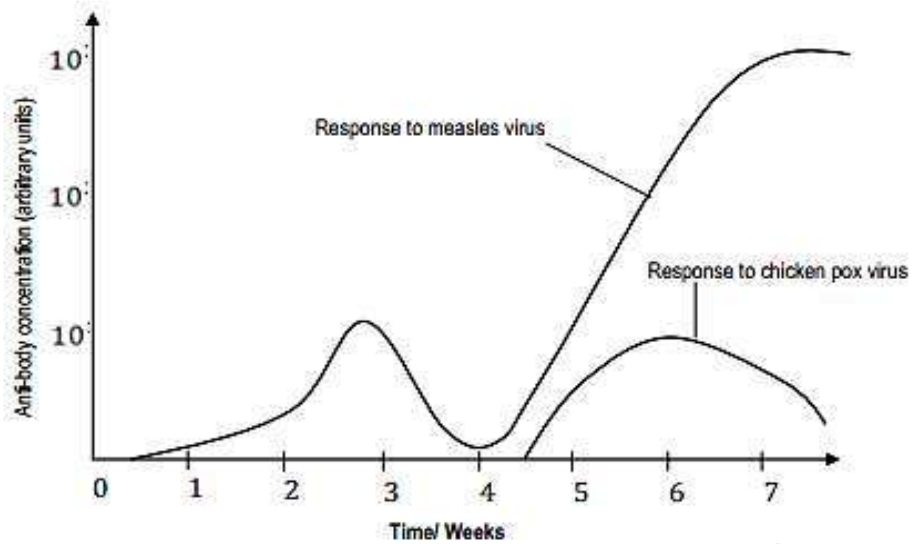
It results in the production of large number of antibodies hence the antigens are moped out /combated quickly before they cause a secondary infection. This brings about efficiency in the immune system.

(iv). Suggest other ways in which the body defends its against diseases causing organisms ***(02 marks)***

• Phagocytosis
• Blood clotting

Question 2.

The concentration of antibodies of a child was measured over a period of eight weeks. The child was exposed to the measles virus at a time 0 weeks when he inhaled droplets from the infected person. At the fourth week, the child was exposed to the measles virus, and at the same time, he was exposed to chicken pox virus. The results are shown in the graph below.



Use the information provided to answer the questions that follow.

(a) Compare the variation in concentration of antibodies during the first and second exposure to the measles virus. ***(06 marks)***

Similarities

• At both first time exposure and re-exposure to the measles virus, a rise in antibody titers is registered.
• In both first time exposure and re-exposure, peak antibody titer/concentration is attained after sometime.
• In both an immediate fall in the antibody titer follows the attainment of the peak antibody concentration.

Differences

Antibody concentration on first exposure	Antibody concentration on re-exposure
Lower peak antibody titer attained	Higher peak antibody titer attained
Initially remains constant for a short period of time after exposure	Antibody titers rises immediately after re-exposure
Rapid decrease in antibody titer immediately after attainment of peak	Slow decrease in the antibody concentration following attainment of the peak
Gradual increase in the antibody titer following exposure	Rapid increase in antibody titer immediately after Exposure

(b).Account for the differences in (a) above. ***(08 marks)***

First time exposure to measles virus evokes a primary immune response; which is a specific humoral response ;in which measles specific B cells had to be synthesized and activated to plasma cells; These plasma cells produced antibodies against measles virus; established immune complexes(antigen-antibody complexes); that were either neutralized; opsonized; agglutinated; lysed or subjected to antibody dependent cellular cytotoxicity; secondary to complement fixation/activation; Gradual increase in the antibody titer registered on first exposure, was due to the progressive/ gradual proliferation of the newly synthesized plasma cellular clones: fewer plasma cells account for the lower peak antibody concentration; However, first time exposure to the measles antigen resulted in formation of memory cells; which are plasma cells of very high specificity to the inducing antigen (measles antigen); remain dormant till re-exposure to the same antigen; Therefore, re-exposure, evokes a secondary immune response involving rapid proliferation of these memory cells into clones; which produce very high titers of antibodies; accounting for the rapid elevation in the antibody concentrations and higher peak concentration

(c) Using the results above, suggest why;

(i). Children who catch measles for the first time suffer symptoms of the disease, but normally recover completely within two to three weeks of being infected. ***(05 marks)***

Before 2-3 weeks after invasion, the immune system is not yet sensitized about the new antigen (measles virus). During that time, B cells specific to measles virus are being synthesized; get differentiated to plasma cell which are active antibody producing cells that proliferate to clonal cells. However, before the end of two weeks, there are fewer B cells specific to measles; and these mount an insufficient immune response/ produce less antibodies; patient therefore gets the symptomatic manifestations of measles.

(ii). A person who has had measles normally is immune for life. ***(05 marks)***

First time exposure to the measles antigen result in formation of memory cells; which are plasma cells of very high specificity to the inducing antigen (measles antigen); remain dormant till re-exposure to the same antigen; Therefore, re-exposure to the measles antigen, evokes a secondary immune response involving rapid proliferation of these memory cells into clones; which produce very high titers of antibodies; accounting for the rapid elevation in the antibody concentrations and higher peak concentration.

(iii). A measles patient is mostly infectious about 8-16 days after first infection. ***(02 marks)***

8-16 days represent the incubation period of the measles virus; beyond which symptoms develop; and the disease becomes very contagious;

(d). How do the results above illustrate about the immune response? ***(01 marks)***

The immune response is specific i.e B cells that can mount an immune response to measles virus; do not mount any response to another antigen e.g chicken pox.

(e). State with reasons the type of immunity illustrated. ***(02 marks)***

Natural active immunity;

Because immunity is provided by antibodies produced by the body after being exposed to particular antigens. After production of the antibodies, the body becomes resistant to the subsequent similar infections.

(f).How have the results of this study been applied by humans in the prevention and control of certain human disease? ***(02 marks)***

• Development of vaccines

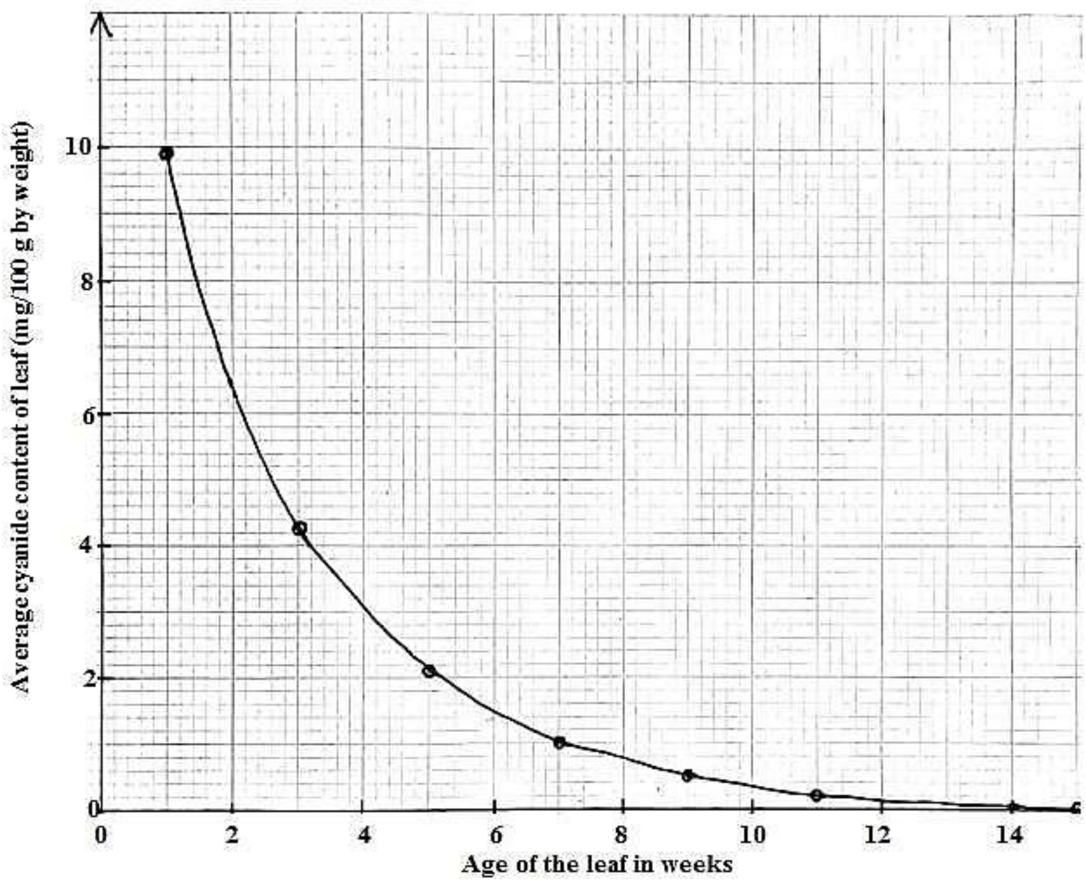
• Vaccination against infectious diseases.

(g). Certain plants called cyanogenic plants use hydrogen cyanide as a defense mechanism against herbivores. The table below shows the average cyanide content of leaves of certain plants of different ages.

Age of leaf (weeks)	Average cyanide content of leaf (mg/100g by weight)
1	9.9
3	4.3
5	2.1
7	1.0
9	0.5
11	0.2
15	0.0

(i). Present the information in the table above graphically. ***(04 marks)***

A graph showing the variation of the average cyanide content of cyanogenic plants with the age of the leaves.



(ii)State the relationship that exists between cyanide concentration and age of the leaf. ***(01 marks)***
Cyanide concentration is inversely proportional to the age of the leaf.
(iii) In what way could this relationship be of survival value to the plant? ***(02 marks)***
• Allows the plant to grow to full maturity with minimal predatory interruption/ pressure.
• Ensures dispersal of plants at maturity; thus efficient colonization of new territories.
• Permits harvest of fully mature/ ripe crops; increase net yield.
(iv). Suggest any other defense mechanisms used by plants. ***(03 marks)***
• Possession of impenetrable barriers like the bark and waxy cuticles.
• Production of toxic metabolites like alkaloids that are poisonous or bitter to herbivores/ predators.
• Produce antimicrobial chemicals, proteins or enzymes that fight pathogens.
• Plant parts modified into defensive devices such as thorns, hard shells, spines, trichomes etc
• Crypsis; in which sensitive plants eg mimosa pudica close their leaves when touched; making them appear unappetizing to predators.
• Release of volatile organic compounds that precipitate physiological reactions that increase concentration of toxic compounds n plants to ward off the enemy.
• Mutualistic associations with defensive organisms; eg some Acassia tree species mutually associate with ants that offer them defence.

In an experiment on transpiration, twelve twigs of approximately the same age, leaf surface area and from the same species of plant were used in the experiment. The twigs were divided into three groups treated simultaneously as follows

Group 1;	twigs completely covered with transparent polyethene bags
Group 2;	twigs fanned with electric fans
Group 3;	twigs placed in still air in the open.

The table below gives the summary of the results of the mean values in cm3 of four readings taken in each group represented on the table as A, B and C.

Time of the day (hours)	Mean of the readings (cm^3)		
	A	B	C
08.00	2.0	2.0	2.0
09.00	3.0	2.4	2.5
10.00	4.2	2.6	3.4
11.00	5.4	2.7	4.4
12.00	7.1	2.8	5.5
13.00	9.6	2.9	7.0
14.00	13.1	2.9	9.5
15.00	16.6	2.9	11.5
16.00	18.1	2.9	13.0
17.00	19.0	3.0	13.6
18.00	19.5	3.1	13.9

(a).Calculate the mean cumulative volume of water lost in each hour by the twigs of group A and B and record them in an appropriate table ***(02 marks)***

Time of the day (hours)	Mean cumulative of water lost (cm^3)	
	A	B
08.00	2.00	2.00
09.00	5.00	4.40
10.00	9.20	7.00
11.00	14.60	9.70
12.00	21.70	12.70
13.00	31.30	15.60
14.00	44.40	18.50
15.00	61.00	21.40
16.00	79.10	24.30
17.00	98.10	27.30
18.00	117.60	30.40

(b). Using suitable scales and the same pair of axes, draw curves to show the relationship between;

(i). the mean cumulative volume of water lost by the twigs of group A and B with time

(ii) the mean volume of water lost per hour by the twigs of group C with time ***(13 marks)***

(c). From the curves drawn, identify the experimental condition to which each group of twigs A, B and C were placed. ***(03 marks)***

- Group A; placed near electric fans
- Group B; placed in still air in the open
- Group C; completely covered with transparent polythene bags

(d). With respect to twigs of groups A and B, give reasons for the observed difference in the two curves drawn ***(05 marks)***

Increased/ higher transpiration in A than group B twigs; because fans create mass flow of air; hence sweeps away the saturated air/ water vapour from the vicinity of the leaves A. Steep diffusion gradient is maintained and this increases transpiration between leaf atmosphere and external atmosphere. Shells of saturated air builds up around leaves of group B; thus reduce diffusion gradient/ transpiration.

(e). Explain why rate of water loss throughout the day varies as shown in curve C above ***(07 marks)***

Transpiration rate increases rapidly from 08.00 to 14.00 hours because more stomata are opening wider; light intensity is increasing; increasing the rate of evaporation of water from the mesophyll cells due to the rising temperature; From 14.00 to 18.00; rate of transpiration is increasing gradually outside the covered leaves; due to gradual decrease in light intensity and temperature;

(f). Why were the twigs of the same age, leaf surface area and same species of plant were used in the investigation? ***(05 marks)***

To eliminate/ exclude/ minimize experimental errors; Transpiration rate is directly proportional to the leaf surface area/ leaf surface area to volume ratio; older leaves have larger surface area than younger leaves. Different plant species have leaves of different sizes/ surface area; hence the rate of transpiration will be different according to leaf ages and plant species.

Suggest:

(i). a hypothesis which this experiment was designed to test. ***(01 marks)***

To test the hypothesis that relative humidity affects transpiration rate of a plant

(ii).the name of the apparatus commonly used in this type of experiment ***(01 marks)***

Potometer

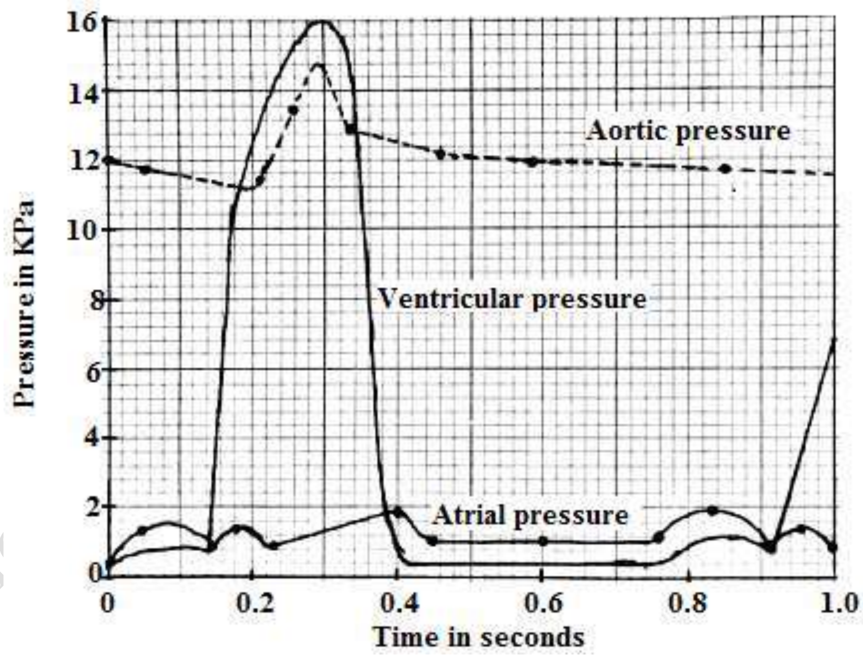
(h).It is observed that a tree canopy with an area of $20m^2$ loses greater amount of water in a given time than a water body with the same surface area. Suggest an explanation for this. ***(04 marks)***

• Water has a higher heat capacity;/ absorbs a lot of heat but with minimal rise in its temperature

• Water has high latent heat vapourisation; thus must absorb alot of heat inorder to evaporate hence less water will evaporate and be lost from a water body. On the other hand, more water will evaporate from a tree canopy of the same surface area.

Question 3.

Figure 1 below shows the changes in the pressure that takes place within the atria, ventricle and aorta during one cardiac cycle. The left atrium and ventricle were used to easily relate their pressure changes with that of the aorta.



(a). Using figure above,

(i). Calculate the heart rate in beats per minute. Show your working. ***(02 marks)***

1 beat takes 0.74seconds;

074 seconds are required to complete 1 beat

60 seconds are required to complete (60/0.74) beats = 81 beats per minute;

(ii). Determine how long is the valve between the left atrium and the left ventricle closed? Explain how you arrived at your answer. ***(02 marks)***

Valve closed when ventricular pressure exceeded atrial pressure at 0.14 seconds; and opened when ventricular pressure decreases below atrial pressure at 0.38 seconds;

Time when valve remained closed = 0.38-0.14 = 0.24 seconds

(iii). Describe the changes in aortic pressure in a single heart beat ***(06 marks)***

From 0 seconds to 0.2 seconds aortic pressure decreases gradually; from 0.2 seconds to 0.28 seconds aortic pressure increases rapidly to the maximum; from 0.28 seconds to 0.34 seconds aortic pressure decrease rapidly; from 0.34 seconds to 0.74 seconds, aortic pressure decreases gradually;

(b). Explain the significance of the differences in the following pressure changes

(i). Atrial pressure and ventricular pressure ***(08 marks)***

Between 0 seconds and 0.14 seconds, atrial pressure is above/higher than ventricular pressure; atrium is contracting, forcing blood into the ventricle; between 0.14 seconds to 0.38 seconds ventricular pressure is above/greater than atrial pressure; ventricles contract; forcing semilunar valves to open; forcing blood into the aorta; between 0.38 seconds and 0.74 seconds atrial pressure is slightly above the ventricular pressure, both atrium and ventricle are relaxed; atrio-ventricular(bicuspid) valves open; blood begins to flow into the ventricle;

(ii). Aortic pressure and ventricular pressure ***(09 marks)***

Between 0 seconds and 0.2 seconds, aortic pressure is higher than ventricular pressure; to keep semilunar valves closed as blood is filling in the ventricles; between 0.2 seconds and 0.36 seconds; ventricular pressure is higher than aortic pressure; ventricles are contracting building pressure to force open the semilunar valves; to allow blood enter into the aorta; Between 0.36 seconds and 0.74 seconds, ventricular pressure is higher than aortic pressure; ventricles relax; while the aorta contract; forcing blood slightly backwards to close the semilunar valves; preventing backflow of blood into the ventricles.

(c). What is the effect of changes in ventricular pressure on the volume of ventricles ***(05 marks)***

From 0 seconds to 0.l4 seconds, slight increase in pressure results into a slight decrease in volume of the ventricles/ volume remains almost constant; from 0.14 seconds to 0.28 seconds, rapid increase in ventricular pressure results in rapid decrease in ventricular volume; to the minimum; from 0.28 seconds to 0.4 seconds rapid decrease in ventricular pressure results into rapid increase in volume of the ventricles back to normal; from 0.4scconds to 0.74 seconds, ventricular pressure remains almost constant resulting into no effect on the volume of ventricles;

(d).Suggest reason(s) for the difference in pressure in the right ventricle and that in the left ventricle of the heart ***(04 marks)***

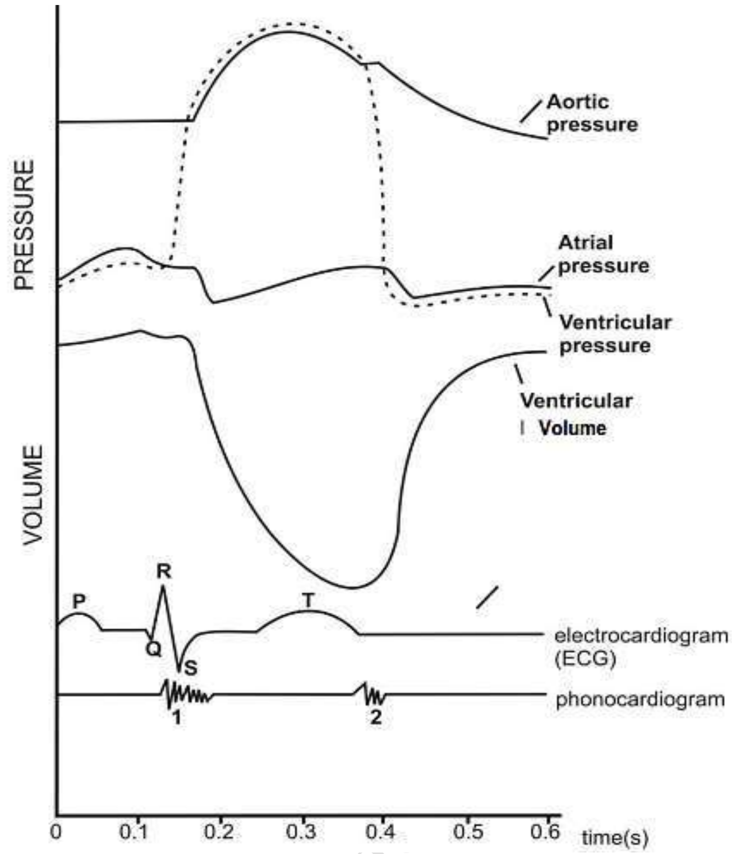
Left ventricle has a higher pressure; its walls are thicker hence more muscular; to pump blood to longer distances (to all parts of the body); whereas the right ventricle wall is thinner; as it pumps blood to shorter distances preventing damage to the thin walls of blood vessels in pulmonary circulation;

(e). State the adaptations of the heart to its function(s) ***(04 marks)***

- Valves; to ensure flow of blood in a single direction;
- Elastic to allow expansion to accommodate the large volume of blood;
- Highly muscular for generation of greater contractile force to pump blood at high pressure;
- Supplied with coronary arteries to supply oxygen and nutrients to the cardiac muscles
- Cardiac muscles have long refractory periods to prevent fatigue;
- SAN generates electrical excitations leading to contraction and relaxation of cardiac muscles;
- AVN spreads out waves of excitation throughout the heart;
- Purkyne tissue to spread waves of excitation to lower apex/ vertex of the ventricles;
- The lining of inner chambers consist of squamous epithelium to allow smooth flow of blood in the heart;
- Surrounded by pericardium to limit expansion of the heart to maintain the internal pressure;
- Septum to separate oxygenated and deoxygenated blood preventing them from mixing;
- Innervated by the vagus nerve (parasympathetic) and sympathetic nerves to control heart rate.
- Valve tendons attached to atria-ventricular walls to support valve preventing them from turning inside out due to changes in heart chambers;

Question 5.

The figure below shows the pressure and volume changes that occur during the mammalian cardiac cycle (of a dog). The pressure changes were measured in the left atrium and ventricle, and the aorta. Volume changes were measured for both ventricles. The electrical activity in the heart wall (electrocardiogram) and heart sounds (phonocardiogram) as recorded in a human subject are also shown.



(a) Describe the changes in:

(i) Atrial pressure. *(07 marks)*

(ii) Ventricular pressure. *(07 marks)*

(b) What are the differences in the changes in ventricular pressure and ventricular volume between 0.1 seconds and 0.5 seconds? *(03 marks)*

(c) Explain the effect of the changes in atrial, aortic and ventricular pressures to blood flow during the cardiac cycle. *(15 marks)*

(d) What is represented by the:

(i) Waves on the electrocardiogram? *(03 marks)*

(ii) Sounds 1 and 2 on the phonocardiogram? *(02 marks)*

(e) Explain three factors that ensure efficient flow of blood within the mammalian heart. *(03 marks)*

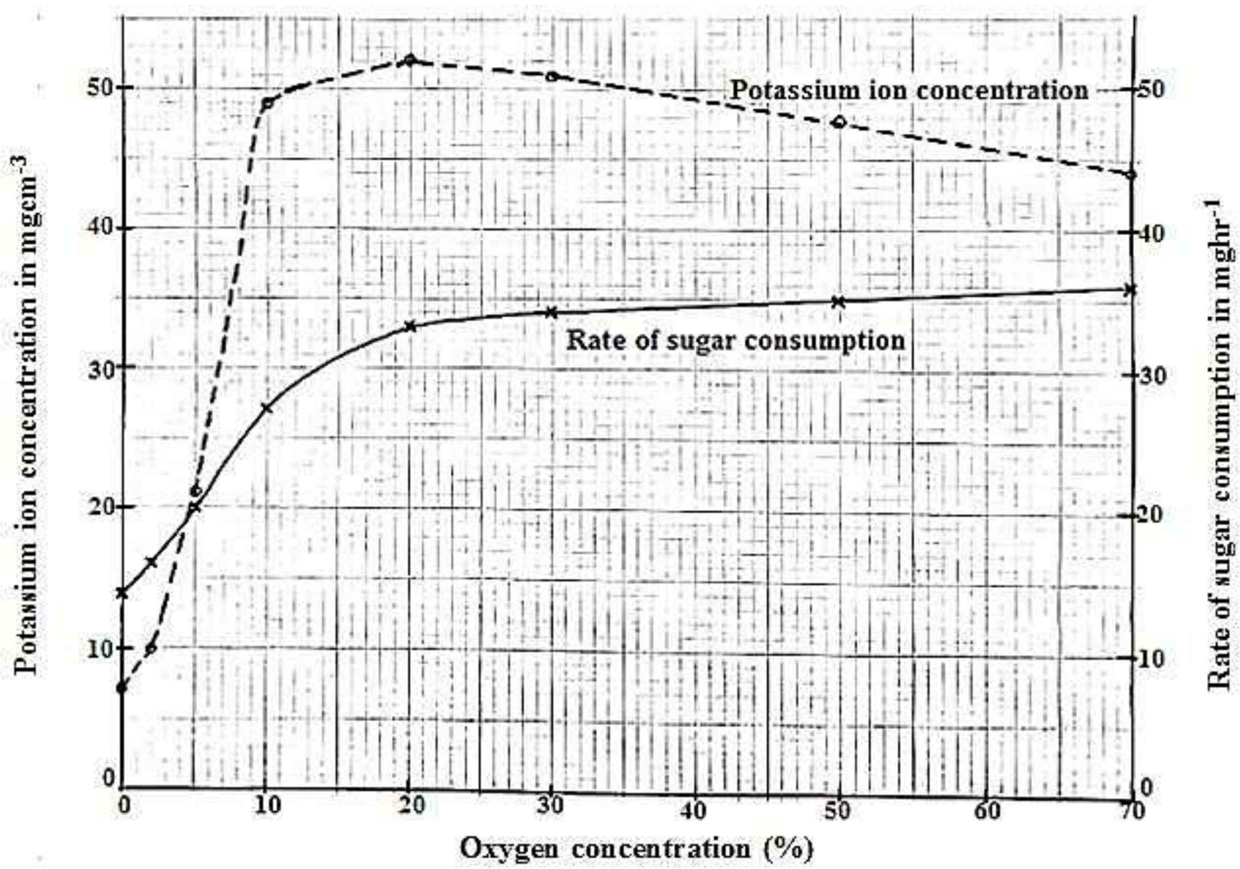
Question 6.

The relationship between potassium ion concentration in the roots and sugar consumption at different oxygen percentage was investigated. The table below shows in ($mgcm^{-3}$) the concentration of potassium ions and the rate of sugar consumption ($mghr^{-1}$) by roots of fleshy uprooted plants when inserted in a bathing fluid, at different oxygen concentrations.

Oxygen concentration (%)	0	2	5	10	20	30	50	70
Potassium ion concentration ($mgcm^{-3}$)	7	10	21	49	52	51	47.7	44
Rate of sugar consumption ($mghr^{-1}$)	14	16	20	27	33	34	35	36

(a).Plot the results in the table graphically, so that you can easily interpret the data. *(05 marks)*

<u>Graph showing the variation of the potassium ion concentration and rate of sugar consumption of the roots of fleshly uprooted plants with percentage oxygen concentration in bathing fluids.</u>



(b)From the graph, state the differences and similarities of the effect of Oxygen percentage on the potassium ion concentration in the roots and rate of sugar consumption.

(i) Differences ***(05 marks)***

• From 0 to 4% oxygen concentration, rate of sugar consumption is higher;/ K^+ concentration is lower.
• From 5% to 70% oxygen concentration, K^+ concentration is higher / rate of sugar consumption is lower.
• 0-10% oxygen concentration; K^+ concentration increases rapidly; rate of sugar consumption increases gradually.
• K^+ concentration is highest at lower oxygen concentration (20%); rate of sugar consumption is highest at higher oxygen concentration (70%)
• K^+ concentration attains peak; rate of sugar consumption does not.
• 20-70% oxygen concentration, K^+ concentration decreases slowly; rate of sugar consumption increases slowly.
• At 70% oxygen concentration; potassium ion concentration is higher than rate of glucose consumption.

(ii) Similarities ***(05 marks)***

• Both K+ concentration and rate of sugar consumption have low values at 0% oxygen concentration.
• Both K+ concentration and rate of sugar consumption at 0% oxygen concentration are above zero.
• 0-10% oxygen concentration, both K+ concentration &rate of sugar consumption rapidly increased.
• At 4.5% oxygen concentration, both K+ concentration &rate of sugar consumption are equal.
• 10-20% oxygen concentration, both K+ concentration &rate of sugar consumption gradually increased.

(c). Give an explanation for each of the following;

(i). Potassium ions are present in the root even at Zero concentration of oxygen. ***(03 marks)***

These potassium ions are absorbed before uprooting the plant; taken up by passive diffusion. Also anaerobic respiration of sugars produces some ATP molecules; that drive active uptake of ions.

(ii).K^+ ion concentration increases rapidly with increasing oxygen concentration up to 20% ***(03 marks)***

Increasing oxygen concentration is associated with increased aerobic breakdown of sugars; more ATP molecules are produced; that drive the process of active uptake of potassium ions from the solution to the root cells.

(iii). K^+ ion concentration begins to fall off after the peak at oxygen concentration of 20% ***(04 marks)***

Possibly translocated from the root to the stem and leaf cells. Essential factors of respiration like sugar concentration, temperature etc besides oxygen concentration may be limiting factors. This eventually results in reduced ATP production; associated with reduced uptake of potassium ions.

(iv)The rate of sugar consumption continues with increase in oxygen concentration throughout the range shown above. ***(03 marks)***

As the concentration of oxygen increases, aerobic respiration proceeds with continuous production of more ATP molecules; facilitating active uptake of salts/ ions

(d).State the two other factors other than oxygen concentration that affect the rate of potassium ion uptake by roots. ***(04 marks)***

- Temperature
- Concentration of sugars
- Respiratory poisons like cyanide
- pH
- Presence of mycorrhiza

(e). Briefly explain the uptake of minerals from soil up to the mesophyll cells of the plant. ***(08 marks)***

Ions taken up from the soil into the root hairs by active transport. Ions then move by diffusion or mass flow via cortical cells through the apoplast, vacuolar and symplast pathways. The casparian strip of the endodermis; being suberized and thus impermeable to water cuts off the apoplast and vacuolar pathways; thus channeling the ions to only the symplast pathway; The ions are then actively taken up into the root xylem. The ions and water then moves up the stem xylem by mass flow and transpiration pull. Mesophyll cells take up the ions by active transport and diffusion.

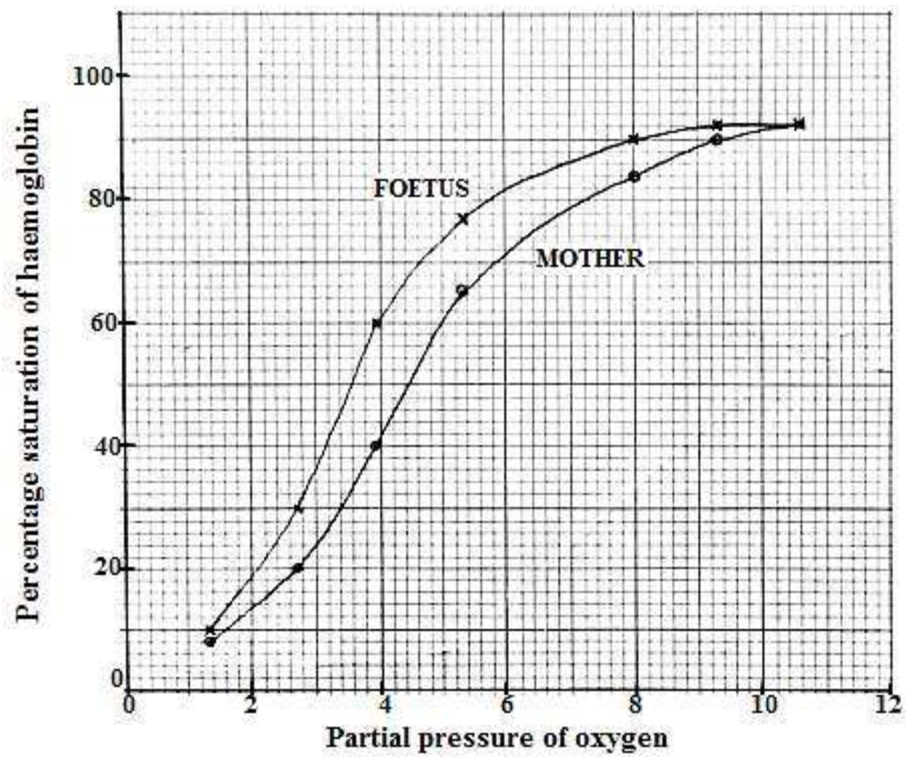
Question 7.

The table below shows the difference in percentage saturation of blood with oxygen at varying partial pressures of oxygen between a pregnant woman and that of a foetus developing in her uterus.

Partial pressure of oxygen in mmHg	**Percentage saturation of blood with oxygen**	
	Mother	**Foetus**
1.3	8	10
2.7	20	30
3.9	40	60
5.3	65	77
6.6	77	85
8.0	84	90
9.3	90	92
10.6	92	92

(a).Plot the results in a suitable graphical form. ***(05 marks)***

<u>Graph showing the percentage saturation of blood with oxygen with partial pressure of oxygen for a pregnant mother and the developing foetus in the uterus</u>



(b)(i). Compare the percentage saturation of blood for the mother and that of the fetus. ***(07 marks)***

Similarities

Both percentage saturation of mother and the foetus;

- Generally display a sigmoid pattern with increasing PPO2
- Generally increase with increasing partial pressure of oxygen.
- Have equal maximum percentage saturation of haemoglobin with oxygen at 10.6 mmHg PPO2
- Have initially slow increase in percentage saturation at low partial pressures of oxygen.
- Have rapidly increasing partial pressure of oxygen for moderate ranges of oxygen partial pressures.
- Have slow and almost leveling off percentage saturation of haemoglobin at high ranges of PPO2

Differences

Foetal percentage saturation of blood	Maternal percentage saturation of blood
Oxygen dissociation curve lies to the left of the mother	Oxygen dissociation curve lies to the right of that of the foetus.
Generally higher except at 10.6 mmHg	Generally lower except at 10.6 mmHg
Increases gradually for 1.3-2.7 mmHg PPO_2	Increases slowly for 1.3-2.7 mmHg PPO_2
Remains constant for 9.3-10.6 mmHg PPO_2	Increases slowly for 9.3-10.6 mmHg PPO_2
Reaches maximum at lower PPO_2	Reaches maximum at higher PPO_2

(b)(ii). Explain the differences if any that were identified in (b)(i) above ***(08 marks)***

Generally the percentage saturation of maternal haemoglobin with oxygen is lower than that of the foetus and is shifted to the right of the foetal curve; because the mother, being exposed to an environment of ambient/ higher PPO2 renders her haemoglobin a lower affinity for oxygen but has higher dissociation to readily supply the actively metabolising tissues as well as to the foetus. Foetus on the other hand is only exposed to maternal oxygen whose partial pressure is very low compared to that present in the mother's environment. Therefore the foetal haemoglobin develops a higher affinity for the little oxygen exposed to it; but compromises dissociation due to its relatively low metabolic profile.

(c). Account fully for the sigmoid shape of the maternal curve. ***(10 marks)***

The maternal curve is sigmoid because of the positive co-operative effect in which oxygenation of the first heme increases affinity for the 2nd,3rd and the 4th in turn. The percentage saturation of haemoglobin with oxygen betw-een

1.3-2.7 PPO_2 described by the lower left tail of the curve rises slowly as hemoglobin loads more oxygen at increasing (but still low) ambient tissue partial pressure of oxygen. But as each heme group binds an oxygen molecule, this changes the shape of globin in a way that facilitates the binding of the next oxygen, then that further facilitates the third, and that one the fourth. Thus, there is a positive feedback effect in which oxygen loading accelerates the loading of more O2, accounting for the rapidly rising mid portion of the curve between 2.7 to 9.3 PPO_2. Towards the upper right, at high ambient PPO_2, the curve plateaus as the haemoglobin approaches approximately full saturation/ most binding sites of haemoglobin are occupied by oxygen and can't load any more.

(d).Explain the physiological significance of the position of the fetal curve. ***(03 marks)***

Foetal oxygen dissociation curve shifted to the left of the maternal curve; implies increased affinity for oxygen; ensures that enough oxygen is obtained by diffusion via the placenta; permits fat ATP synthesis for rapid growth and development.

(e). Explain the effect of increasing the following on the two curves suggesting its importance

(i). Temperature ***(03 marks)***

Rise in temperature reduces the affinity of haemoglobin but increases dissociation of oxygen. Thus the dissociation curve is shifted to the right. This is physiologically important as more oxygen is delivered to the active tissues.

(ii). Carbondioxide partial pressure ***(04 marks)***

There will be reduced affinity of Hb to oxygen but increases the dissociation of oxy-haemoglobin. This is physiologically important because in metabolically active tissues such as muscle, a high concentration of carbondioxide is generated, pH lowers, saturation of haemoglobin with oxygen lowers; encouraging dissociation of oxy-haemoglobin to release oxygen; allowing for enhanced uploading of oxygen in these metabolically active tissues; preventing hypoxia (low oxygen supply to tissues).

Question 8.

The table below shows the percentage saturation of haemoglobin with oxygen at varying partial pressures of oxygen in man. The experiment was carried out at two different partial pressures of carbondioxide.

Partial pressure of oxygen/kPa	**Percentage saturation of haemoglobin with oxygen**	
	At 3 kPa partial pressure of carbon dioxide	At 6 kPa partial pressure of carbon dioxide
0	0	0
1	10	4
2	38	8
4	90	35
6	96	60
7	100	70
11	100	83
13	100	85

(a). Using the same axes, plot the results in a suitable graphical form. ***(08 marks)***

(b) Account fully for the shape of the curve at 3 kPa partial pressure of carbon dioxide. ***(16 marks)***

(c).Explain the position of curve at 6 kPa with respect to that at 3 kPa partial pressure of CO_2 ***(08 marks)***

(d).Use the graph to explain why human haemoglobin:

(i) is saturated with oxygen in the lungs. ***(04 marks)***

(ii) releases oxygen when it reaches the tissues. ***(04 marks)***

Question 9.

The data below was obtained from experiments using plant materials treated as shown below. Figure I shows the uptake of potassium ions in an aerated solution by young cereal roots which had previously been thoroughly washed in pure water. After 90 minutes, potassium cyanide was added to the solutions.

Figure I:

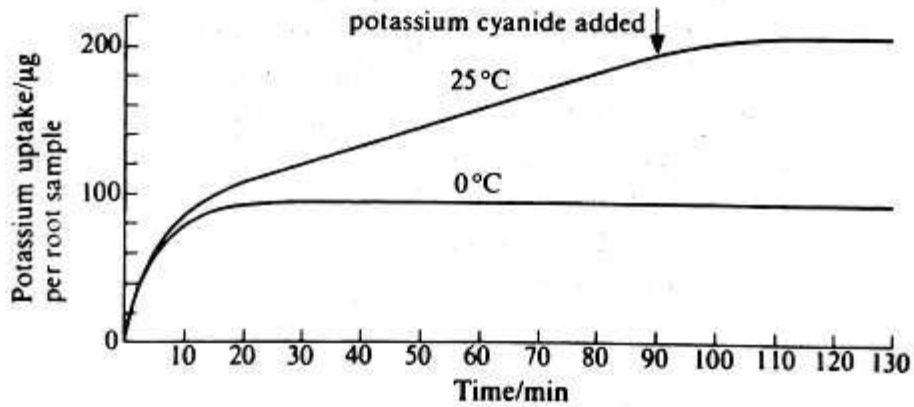
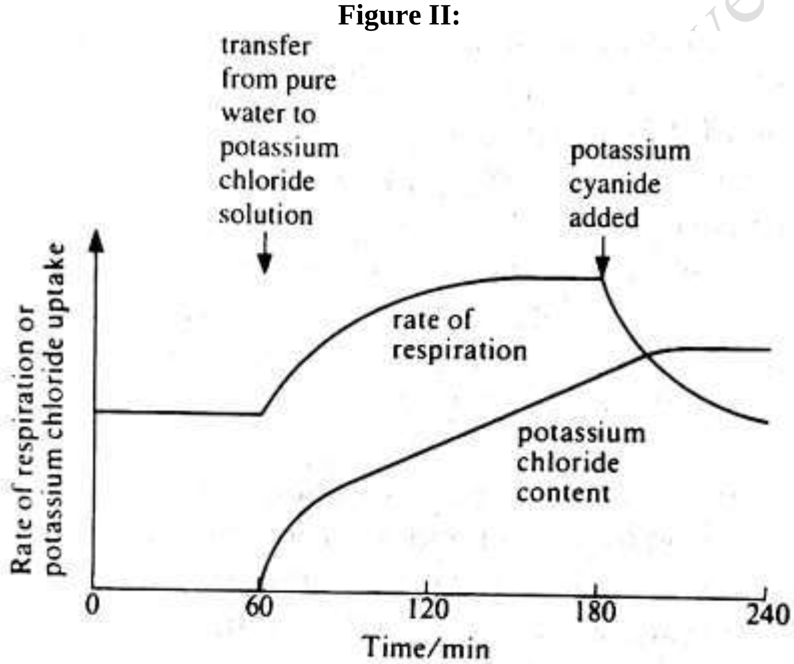


Figure II shows the rate of respiration and uptake of potassium chloride by young carrot discs. The carrot discs had previously been thoroughly washed in pure water and transferred to potassium chloride solution after 60 minutes. Potassium cyanide was added to the solution after 180 minutes.

Figure II:



With reference to figure I:

(a)(i) Compare the change in uptake of potassium ions at 0ºC and 25ºC. ***(05 marks)***

(ii) Explain fully the trend of uptake of potassium ions at 0ºC. ***(06 marks)***

(b) Explain why:

(i) The same rapid uptake of potassium ions occurred in the first few minutes of the experiment at both temperatures. ***(02 marks)***

(ii) uptake of potassium ions at the two temperatures greatly differs for much of the experiment. ***(06 marks)***

(iii) Potassium cyanide has the effect it does at each temperature. ***(03 marks)***

(iv) The cereal roots were washed before placing them in a solution containing potassium ions. ***(01 marks)***

(v) In a similar experiment, but involving phosphate uptake, 16% of the phosphate taken up by barley roots over a short period could be washed out after transferring to pure water again. ***(02 marks)***

(vi) Ions cannot reach the xylem entirely by means of the apoplast pathway. ***(03 marks)***

With reference to Figure II:

(c) Explain the trend in rate of respiration:

(i) Before addition of potassium cyanide. ***(09 marks)***

(ii) After addition of potassium cyanide. ***(03 marks)***

Question 10.

In an experiment, constant volumes of a mammalian blood were used to determine the percentage saturation of its haemoglobin with oxygen and how this saturation is influenced by different conditions of oxygen partial pressures ,pH, and excess carbondioxide. The table below shows the results. Study it carefully and use it to answer the questions which follow;

Table

Oxygen partial pressure (mm. Hg)	**Percentage hemoglobin saturation with oxygen**			
	pH 7.0	**pH 7.4**	**pH 7.8**	**Excess CO_2**
0	0.0	0.0	0.0	0.0
25	32.0	41.5	59.5	24.5
50	64.5	68.5	80.5	51.0
75	76.0	82.0	88.0	62.5
100	81.0	87.5	92.0	68.0
125	88.5	92.0	97.5	70.5
150	93.5	95.5	100.0	71.0
200	95.0	100.0	100.0	72.5

(a).Using the same axes and suitable scales, reflect the above results graphically to show the variations in percentage saturation of haemoglobin at different pH, and in excess carbon dioxide as partial pressure of oxygen varies.
(b)(i).Describe how percentage haemoglobin saturation with oxygen changes with PH, and carbon dioxide concentration.
(b)(ii).Explain why the presence of excess carbon dioxide in the experiment stimulates low PH.
(c)(i).Explain how the above conditions favour gaseous exchanges in
(c)(ii).The mammalian lungs
(c)(ii).The internal tissues of an insect
(d).An athlete who lives at low attitude is trained at high attitude before major competitions. Comment on the:-
(i). The respiratory changes he would get during training.
(ii).The importance of the acquired changes.

Question 11.

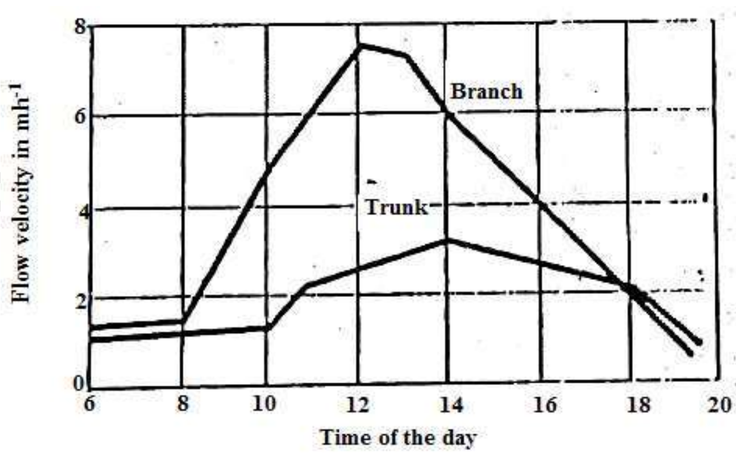
The rate of transpiration of maize plants was compared with the rate of evaporation of water from a porous pot atnometer over a 24 hour period. The following results were obtained.

Period in hours	**Water lost per hour in cm^3**	
	Porous pot	**Maize leaves per m^2**
7-9	3.8	91
9-11	6.6	160
11-13	8.1	218
13-15	9.5	248
15-17	9.4	195
17-19	9.0	179
19-21	6.6	12.1
21-23	3.8	08
23-1	3.4	18
1-3	1.5	18
3-5	0.7	13
5-7	0.9	23

(a)(i). Present the above data on a suitable graph. ***(07 marks)***
(ii). Describe and explain the rate of transpiration in maize plant over the study period. ***(15 marks)***

From 7 hours to l5 hours; the rate of transpiration increased rapidly; to a maximum of 248cm; From l5 hours to 19 hours; the rate of transpiration decreased gradually; From 19 hours to 23hours, the rate of transpiration decreased rapidly; to a minimum of 8cm; From 23 hours to 3hours, the rate of transpiration remained constant; From 3 hours to 7 hours, the rate transpiration increased gradually;
The rate of transpiration increased rapidly between 7 to 15 hours; because the sun had risen which provided increased light intensity that indirectly caused opening of stomata; as well as heat energy; to facilitate evaporation of water; from the leaves at 15 hours the light intensity was high; which favoured a high evaporation rate;
The rate of evaporation decreased from l5 hours to 23 hours; because the sun was setting; and as such there was reduced light intensity; leading to gradual decrease in stomatal opening; and little heat energy; to facilitate evapo-transpiration; until it was dark. At 23hours it was dark;
The increase in the rate of evaporation between 23 to 7 hours; was that the sun was rising; thus there was both an increases in light intensity; and heat energy; to facilitate evaporation of water from the leaves;
(iii). Account for observed differences in water loss from the maize plant and porous pot. ***(05 marks)***
The rate of transpiration of water from the maize leaves is far much higher compared to the rate of evaporation from the porous pot because;
The maize leaves have a much higher surface area exposed over which transpirations takes whereas the porous pots surface area which is low thus little evaporation.
Transport mechanism within the plant also aid the movement of water up the plant and its consequent loss which needs to be replaced also contribute to high transpiration rate within the maize plant yet the porous pot such mechanisms are not there.
In the porous pot, evaporation is only due to heat increase but in the plant there are added factors such as increased stomatal opening with more light intensity, root pressure and increased temperature which lead to more evaporation compared to the porous pot.
The porous pot has a high specific heat capacity compared to the maize plant thus raising its temperature to facilitate evaporation requires a lot of heat energy whereas for the plant little heat energy is required to cause evaporation.

(b). In another experiment the linear velocity of flow of sap through the xylem of a tree was measured in M/h in the trunk and in one of the small branches at the top of the tree. Measurements were taken at two hourly intervals on a sunny day. The results are shown in the figure below.
<u>Changes in the linear velocity of flow of sap through the xylem in the trunk and in one of the small branches at the top of a tree.</u>



(i). Describe the velocity flow in the trunk. ***(03 marks)***
The flow velocity is almost constant from 6 hours to10 hours; the velocity then increases rapidly from 10 hours to 11 hours: from 11 hours to l4 hours the velocity increases gradually; up to a maximum of 3mh^{-1}; beyond which the velocity decreases gradually up to 18 hours. Beyond 18hrs the flow velocity decreases rapidly to a minimum;
(ii). Explain the velocity flow in the branch as compared to that in the trunk over time ***(05 marks)***

The velocity flow in the branch increases and decreases more rapidly; This is because the branch is near leaves where water is lost; and thus water has to be replaced quickly; compared to the trunk which is further away thus it doesnot experience pronounced transpiration pull; The xylems within the branch is so small and have narrower diameters; such that small velocity changes can easily be detected. If the same volume of water is withdrawn compared to the xylem in the trunk which are large; and have wide diameters thus changes cannot easily be detected.

(iii). What difference would you expect in the circumference of the trunk measured at l4:00 hours when compared with that measured at 18:00 hours. Explain your answer. ***(03 marks)***

The circumference of the trunk at l4.00hrs would be larger/high compared to that at 18.00 hour. This is so because the velocity in the trunk at l4hrs is greater than that at l8.00 hours which places the trunk under some degree of pressure; that may cause widening in diameter of the trunk during times of high transpiration;

(iv). What do these results show about the mechanism by which water passes up the tree? ***(02 marks)***

Water passes up the tree as a result of the transpiration pull; brought about as a result of water loss by transpiration.

Question 12.

The figures (a), (b) and (c) show the different factors affecting uptake of mineral ions by Valonia a plant growing in water

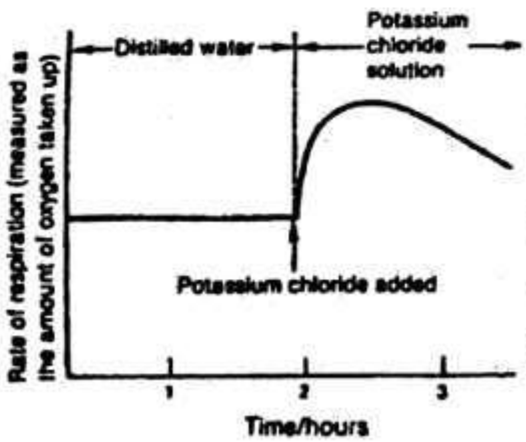


Fig 1 (a)

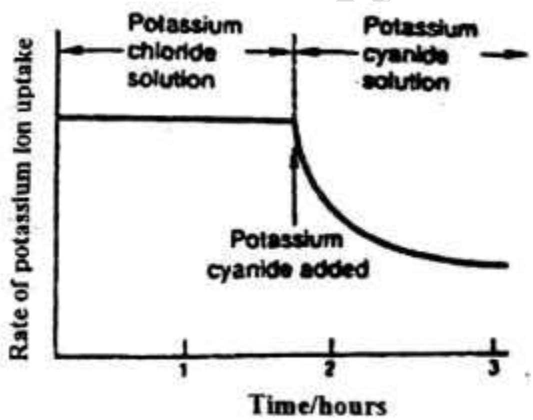


Fig 1 (b)

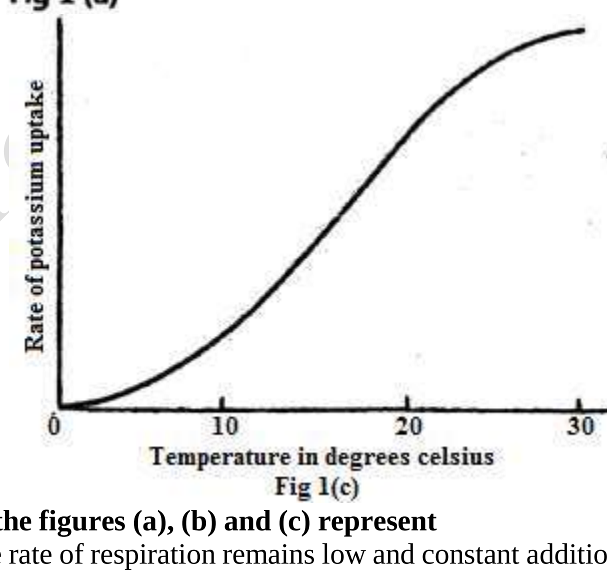


Fig 1(c)

(a)(i).Describe what each of the figures (a), (b) and (c) represent ***(09 marks)***

Fig 1(a); in distilled water, the rate of respiration remains low and constant addition of KCl at 2 hours increases the rate of respiration to the maximum at 2.5 hours the water decreases gradually

Fig 1(b); In potassium chloride solution, rate of potassium uptake remains high and constant; addition of KCN at about 1-8 hours decreases potassium ion uptake rapidly and then increased generally

Fig 1(c); Below 10°C rate of potassium uptake increases gradually then increases rapidly up to 20°C then gradually increases from 20°C to 30°C

(b).Explain the shapes of each of the graphs in figures (a), (b) and (c) above ***(14 marks)***

Fig (a); In distilled water a small and constant amount of oxygen is taken up for metabolism of cells carrying out body processes; in potassium chloride solution; Valonia plant roots take up K^+ ion rapidly by active transport; requiring more energy in form of ATP produced during respiration requiring more uptake of oxygen from the water. After 2.5 hours, most of the ions have been absorbed from the solution reducing the rate of active uptake of the remaining ion

Fig (b); In potassium chloride solution. K^+ ions are taken up from the surrounding solution by both diffusion and active transport; addition of KCN at 1-8 hours which is a respiratory inhibitor inhibits energy synthesis by respiraation reducing amount of energy available for active uptake of K^+ ion from solution limiting uptake of K^+ ion to passive process such as diffusion which are slow.

Fig (c); Below 10°C, few enzymes are active/ most are inactive, low rate of respiration; less energy availed for active uptake of K^+ ions; most of the uptake is passive(diffusion) between 10°C to 30°C, optimum temperature provided for activation of enzymes rapid catalysis of respiration; more energy in form of ATP provided for rapid active uptake of K^+ ions from the surrounding solution.

(c). Suggest reasons why the rate of respiration in figure (a) is above zero in the first two hours of experiment

Oxygen is being attracted from water for cellular metabolism of root cells and cells of the entire plant to ensure their survival.

(d)(i). What would happen to the rate of respiration and the rate of uptake of potassium ions in figure (a) and (b) respectively if the investigation was allowed to run for more 3 hours ***(02 marks)***

In fig (a); rate of respiration would decrease up to the original rate in distilled water as all the K^+ ion would be depleted from the oohitron requiring no more energy for their active uptake.

In fig (b); rate of potassium uptake would decrease and later remain constant as the roots would continue taking up ion by passive means

(ii). Give reasons for your observations in (d)(i) above ***(04 marks)***

(e).Describe

(i).The role of ATP in the uptake of potassium ions by a water plant ***(03 marks)***

ATP consists of three high energy bonds upon their hydrolysis release energy about 30.8 $kgmol^{-1}$ for the first two bonds; this changes the configuration of the carrier protein to which the K^+ is attached bringing the K^+ ion into the cell.

(ii). How potassium ions absorbed may find their way to the xylem of a plant ***(03 marks)***

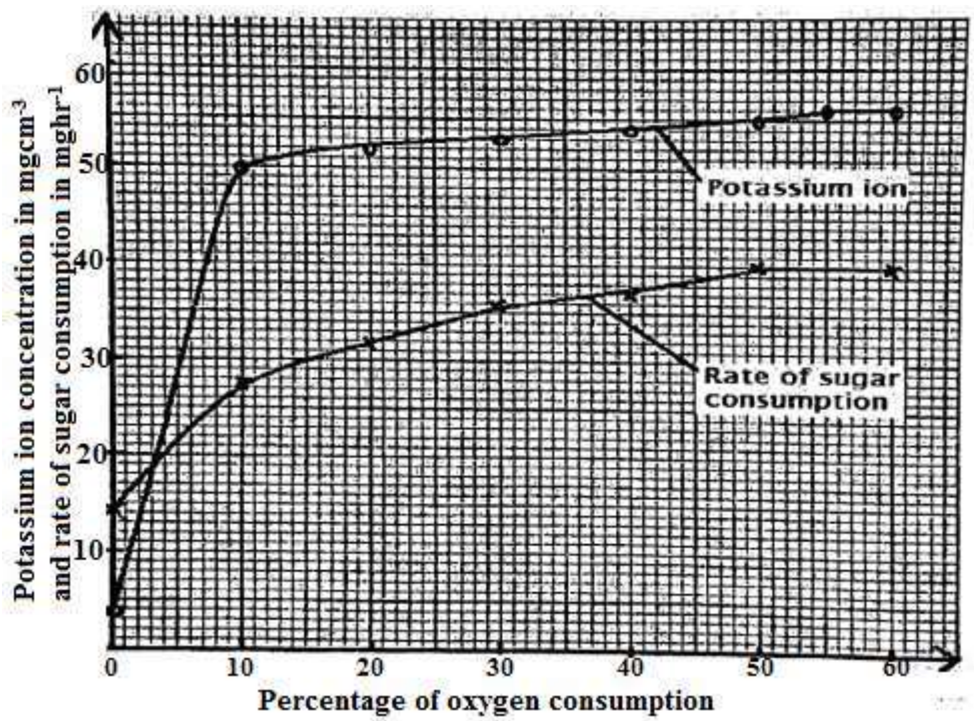
Absorbed ion move by way of apoplast pathway, symplast and vacuolar pathway together with absorbed water apoplast uptake occurs up to the endodermis where, the casparian strip prevents further uptake thus the ions pass by either diffusion or active transport through the cell surface membrane of endodermis cells; joining the symplast and vacuolar pathway into the xylem.

(f). State three factors that increase uptake of mineral ions by the Valonia plant ***(03 marks)***

- Optimum temperature
- Absence of respiratory inhibitors.
- High surface area of the roots (plants having numerous root hairs)

Question 13.

The relationship between potassium ion concentration in the roots and sugar consumption at different oxygen concentration was investigated. Figure 1below shows concentration of potassium ions ($mgcm^{-3}$) and the rate of sugar consumption ($mghr^{-1}$) by roots of freshly uprooted plant when inserted in a bathing fluid at different oxygen concentration.



(a).Compare the effects of oxygen concentration on potassium ion concentration in the roots and the rate of sugar consumption. ***(07 marks)***

Similarities

Both potassium ion concentration and sugar consumption in roots;

• Increased up to the maximum
• Increased rapidly up to 10% oxygen concentration and then gradually up to 50% oxygen consumption
• Remain constant from 55% to 60% oxygen concentration
• Were at their lowest values at 0% oxygen concentration.
• Have the same value at 5% oxygen concentration.

Differences

• Rate of sugar consumption is higher while potassium ion concentration is lower from 0 up to 5% O_2 concentration
• K^+ concentration is higher while rate of sugar consumption is lower from 5% up to 60% oxygen concentration
• Potassium ion concentration increased more rapidly while rate of sugar consumption increased rapidly from 0 up to 10% oxygen concentration
• Potassium ion concentration increased more gradually while rate of sugar consumption remained constant from 50 up to 55% oxygen concentration.
• Maximum potassium ion concentration reached is higher than maximum reached by rate of sugar consumption
• Rate of sugar consumption reached peak at a relatively lower percentage of oxygen concentration of 50% while Potassium ion concentration reached peak at relatively higher percentage of oxygen concentration of 55%

(b). Explain the;

(i). Presence of potassium ion concentration in the roots without oxygen ***(06 marks)***

Some little potassium ions were passively absorbed from the solution by diffusion and mass flow; due to potassium ion concentration gradient that exists; anaerobic respiration occurred; producing small amounts of energy in form of ATP; which was used for some active uptake of small amounts of potassium ions; root hair cells containned some small amounts of potassium ions before being uprooted;

(ii). Relationship between potassium ion concentration and oxygen consumption ***(12 marks)***

At 0% oxygen concentration; potassium ion concentration is low; because uptake of small amounts of potassium ions into the root hair cells is only by passive diffusion; anaerobic respiration produced small amount of energy inform of ATP which was used for active uptake of small amounts of potassium ions

From 0% to 10% oxygen concentration, potassium ion concentration increased rapidly; because of plenty of oxygen: aerobic respiration occurred rapidly; large amounts of energy in form of ATP formed; used for active uptake of large uptake of potassium ions; From 10%to 50%, potassium ion concentration increased gradually; sugars which are the respiratory substrates are getting depleted; resulting into slow aerobic respiration; less energy inform of ATP is produced; reducing on the active uptake of potassium ions, from 55%to 60 %. Potassium ion concentration remained constant; no ATP produced from either aerobic or anaerobic respiration due to complete depletion of sugars; no active uptake 01'Potassium ion by the root cells occurs;

(iii). Effect of increasing percentage of oxygen consumed on rate of sugar consumption ***(07 marks)***

Increasing percentage of oxygen concentration from 0 up to10% causes a rapid increase in the rate of sugar consumption; sugar is a metabolite for respiration; oxidative aerobic break down of sugars increases due to availability of oxygen allowing respiration to occur at a higher rate;

Increasing percentage of oxygen concentration from 10 up to 55% causes a gradual increase in the rate of sugar consumption; sugar is getting depleted; and enzymes catalyzing aerobic respiration of sugars are getting denatured; by low pH and Oxygen poisoning; little or no respiration of sugars occurs; Increasing percentage of oxygen concentration from 55 up to 60% causes the rate of sugar consumption to remain constant; sugars are completely depleted; enzymes are completely denatured; no further break down of sugars;

(c). Predict change in concentration of potassium ions in the roots and rate of sugar consumption if the experiment was to continue for some time up to 90% oxygen consumption.

Suggest reasons for your answer ***(05 marks)***

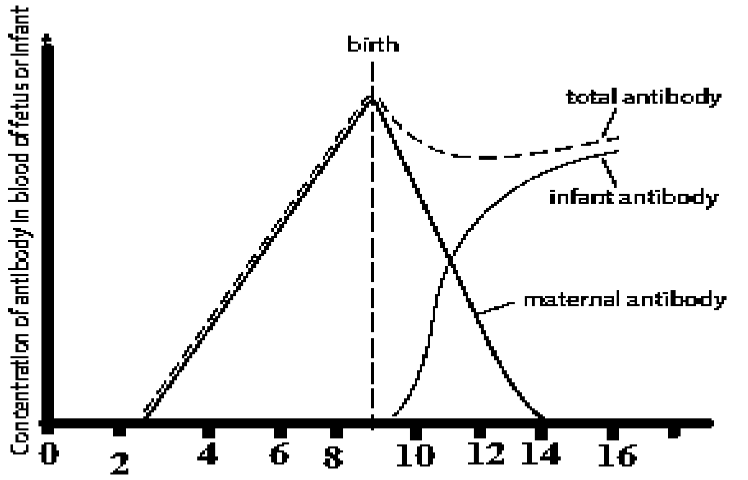
Potassium ion concentration in the root cells will decrease until the concentration; remains constant a very low values; because there is no more energy for active uptake of ions; yet potassium ions in the root hair cells are transported away through the xylem vessels and tracheid to other regions of the plant where the ions will be utilized for protein synthesis/ building up new tissues; concentration of proteins remain constant when the ions are depleted in the bathing solution or no more active uptake of ions into the root cells. Rate of sugar consumption will remain constant; sugar molecules in the solution are depleted and enzymes have all been denatured thus no further metabolism of glucose will take place.

(d). State three factors other than oxygen concentration that could affect the rate of potassium ion uptake by roots. ***(03 marks)***

- Low or high temperature below or above the optimum
- Concentration of potassium ions in the solution
- Surface area of root hairs.
- Presence of inhibitors or metabolic poisons
- pH levels

Question 13.

In an investigation, the concentration of antibody of a human fetus was followed from the time it was conceived in the mother (fetus) through birth up to when the baby was 8 months old (infant), the results obtained are represented in figure 1 below.



(a)(i). Identify the type of immunity shown by the fetus ***(01 marks)***

Natural passive immunity;

(ii). How is the immunity in a(i) above of importance in the fetus? ***(02 marks)***

Protects the fetus against diseases which are endemic; and which the mother has caught or been vaccinated against;

(iii). Outline the differences between the type of immunity of fetus and active immunity

Passive	Active
No immunological memory	Immunological memory developed
Short lived	Long lasting
Brings about immune response immediately	Immune response is delayed

(b).Comment on the concentration of total antibody in blood of both fetus and infant observed in figure 1 above

From 3 months to birth increased rapidly reaching a peak; From 9 months to 12 months of infant decreased rapidly; and then increased gradually; Total antibody concentration in fetus increases rapidly as maternal antibody also crosses rapidly into fetus; decreases rapidly as maternal antibody is being broken down with little infant antibody produced; Increases gradually; when some little maternal antibody is supplemented by increased production of infant antibody by infant; Total antibody concentration is higher than both maternal and infant antibody throughout the investigation;

(c). Explain the observed concentration of antibody in the blood of the fetus and infant over the period of investigation

(i).Maternal antibody ***(10 marks)***

From 0 month to 3 months; no maternal antibody; placenta had not yet developed; for maternal antibody to cross from mother to fetus; from 3 months to birth (9 months) concentration increases rapidly; the placenta has developped fully; maternal antibodies cross by diffusion across the placenta from the mother to the fetus; from birth to 6 months of infant concentration decreases rapidly; maternal antibodies are being broken down in the spleen and liver; removing them from circulation;

(ii).Infant antibody ***(06 marks)***

Absent in fetus; the fetus has no any mature B or T cells; and develops in a sterile / germless environment thus does not produced its own antibodies; from 9 months to 16 months concentration increases; infant is living in a new environment where it encounters infection; the infection/pathogen trigger the mature B and T cells to produce infant antibodies; to resist infection;

(d).What would be the effect of injecting the infant with an immunosuppressing agent after six months from birth ***(01 marks)***

Antibody production will be blocked; the infant becomes more susceptible to all different kinds of infection; as it would not respond to the antigens of invading pathogenic microorganisms;

(e). Suggest the different ways an adult mammal is protected from infections ***(10 marks)***

- B cell production of antibodies;
- T cell destruction of foreign or infected cells;
- Immunization /vaccination;
- Phagocytic action of neutrophils of blood and macrophages all over the body;
- By commensal flora of microorganisms on skin in gut that out compete pathogen;
- Clotting of blood when the circulation is breached;
- Lysozymes in nose, tears, saliva and urine;
- Mucus of the trachea, bronchi and lungs by the acid/ enzyme barrier in the stomach;
- The physical barrier of the skin;

Question 15.

The table below shows data obtained from a study of the leaves of a tree.

Time	Percentage of open stomata	Relative amount of starch in guard cells	Relative intensity of light
08.00am	42	70	0
10.00am	100	30	5
12.00noon	100	13	50
02.00pm	100	18	61
04.00pm	80	30	76
06.00pm	28	68	20
08.00pm	0	100	0

(a) Using the same axes, plot graphs for this data ***(13 marks)***

(b) Describe the nature of the graphs ***(08 marks)***

(c) What are the interrelationships between?

(i).Stomatal opening and relative amount of starch in guard cells ***(01 marks)***

(ii).Stomata opening and relative intensity of sunlight ***(01 marks)***

(iii).Percentage of open stomata and time of the day. ***(01 marks)***

(d).Explain these interrelationships. ***(16 marks)***

Question 16.

The table below shows the diurnal variation in the sucrose content of leaves and the phloem in stems.

Time in hours	Sucrose concentration in percentage dry weight	
	Leaves	Phloem
4.00am (night)	0.9	0.4
6.00am	0.6	0.3
8.00am	0.9	0.4
10.00am	1.8	0.6
12.00 noon	2.6	0.9
2.00pm	3.0	1.0
4.00pm	1.4	0.8
6.00pm	1.2	0.6

(a) Represent the results in a suitable graphical form. (08 marks)

(b).Using your graph in(a) above, compare the sucrose concentration of leaves and phloem. (07 marks)

(c) Explain the variation in patterns of sucrose with time of;

(i). Leaves. (11 marks)

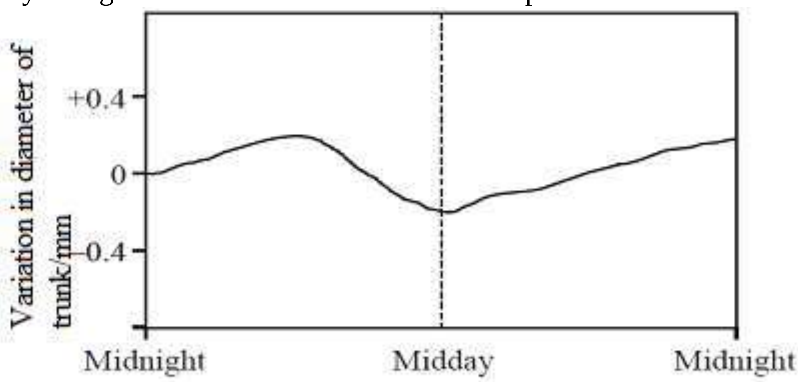
(ii).Phloem (09 marks)

(d).State any two environmental factors that can affect the levels of sucrose in the leaves. (02 marks)

(c) From the graphs in (a), explain the evidence that sucrose in the leaves is transported in the phloem of the stem. (03marks)

Question 16.

The graph shows the daily changes in the diameter of the trunk of a pine tree.



(a) Explain why the diameter of the trunk is smallest at midday. ***(08 marks)***

At midday there was highest light intensity that caused most stomata to open providing largest surface area for water toss; and highest air temperatures provided much heat of vaporization; thus highest rate of water evaporation/loss by transpiration from mesophyll/ airspace/stomata; causing water to move across leaf by osmosis; Transpiration/evaporation exerts force causing tension/ pulling force in water column: due to transpiration pull; hydrogen bonding between molecules/ cohesion holds water columns together in a continuous non-breaking column; there is bonding/ adhesion between walls of Xylem vessels and water molecules; thus at midday there was highest tension/pulling in water column and highest adhesion between walls of xylem vessels and water molecules that caused collapsing of xylem inwards; making diameter smallest;

(b) Describe the adaptations of xylem and phloem to their functions.

Xylem: Vessels have no end walls / hollow/ no cytoplasm allowing unrestricted flow of water. Lignification or cellulose sidewalls provides support/ strength/ impermeability; Bordered pits allow lateral transport; Tracheids with porous end walls/ long cells/ tubes with no end walls for continuous water columns; no cytoplasm/ no organelles to impede/obstruct flow/ allows easier water flow thickening/lignin; support/ withstand tension / waterproof/ keeps water in cells; Tracheids joined end to end to allow continuous flow at water

Phloem; Companion cells metabolically active to load sugars into sieve tube elements; cytoplasmic filaments for cytoplasmic streaming; Sieve pores to allow mass flow; sieve tube joined end to end to allow continuous flow; Companion cells with numerous mitochondria to generate energy to load sugars into sieve tube; metabolically active cells to cause changes that generate hydrostatic pressure gradient.

(c) Discuss the role of each of the following in plants;

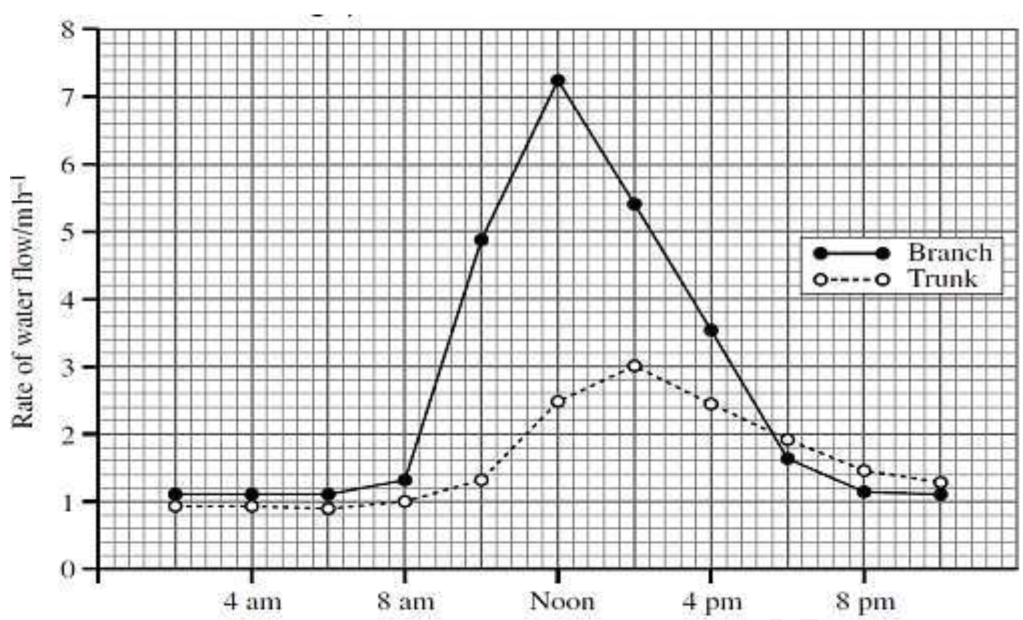
(i). hydathodes

Hydathodes: Modified pores in epidermis of leaf that exudes drops of water. Abundant in leaves of submerged aquatic plants eg water lettuce, water hyacinth and of herbaceous plants. Pores connect to the plant vascular system by vascular bundle; are made of living cells with numerous intercellular airspaces filled with water leading to an open pore; involved in guttation in which positive xylem pressure/ root pressure causes water to exude from of the water pores. Halophyte actively secrete salts in the glandular trichomes epidermal cells/margins of leaves causing loss of water actively across the hydathodes;

(ii).casparian strip

Casparian strip: impervious cylindrical layer in cell wall of endodermal cells; made of suberin which renders it impermeable to water. It blocks cellwall/ apoplastic transport across endodermis; diverting water into the cytoplasmic/symplastic route. Endodermis also actively secretes salts/ ions from cortex into xylem; these ions are prevented from leaking out xylem by the casparian strip; maintaining large water potential gradient forcing water uptake via the symplast of endodermal cells (root pressure).

(d) The rate of water flowing through a branch of a tree and the tree trunk was measured over a 24-hour period. The results are shown in the graph below.



(i) Compare the rate of water flow through the trunk and branch.

Similarities

From 2am and 6am both rates of water flow were constant;
From 6pm and 10pm both rates of water flow decreased gradually; From 6am and 8am, both rates of water flow increased slightly/slowly;
Both rates of water flow were high during daytime;
Both rates of water flow were low during nighttime;
Both rates of water flow reached one maximum/peak;
At 5:36pm. the rate of water flow was the same in both the trunk and branch

Differences

Water flow through the branch	Water flow through the trunk
Reached a higher maximum	Reached a lower maximum
Reached maximum at an earlier time of the day	Reached maximum at a later time of the day
From 2am to before 5:36pm, rate was higher	Rate was lower during this time
After 5:36pm, rate was lower	Rate was higher at that time
From 8am to noon, rate increased rapidly/ steeply	Rate increased gradually
From 2pm and 6pm, rate decreased rapidly	Rate decreased gradually during this time

(ii) Explain the changes in the rate of water flow in the branch over the 24-hour period.

From 2am to 6am, rate of water flow was low and constant; due to very low light intensity and temperatures; resulting in low rate of photosynthesis; low concentration of sugars in guard cells; low ATP production (light stage); potassium ions diffuse out of guard cells causing stomatal closure/low aperture; leading to a very low/ transpiration pull. From 6am to 8am, rate of water flow increased slightly due to slight increase in light intensity that led to slight increase in aperture and number of stomata that opened due to more photosynthesis; more sugar production more ATP and more pumping of K^+ions into guard cells; increasing surface area over which transpiration occurred and slight increase in air temperatures which provided heat of vaporization increasing rate of loss of water vapour across surfaces such as stomata and lenticels; which led to a rise in transpiration which in turn increases the transpiration pull. From 8am to noon rate of water flow increased rapidly; due to fast increase in light intensity that led to rapid increase in aperture and number of stomata that opened due to much photosynthesis; much sugar production; more ATP and more pumping of K^+ ions into guard cells; Increasing surface area over which transpiration occurred and rapid increase in air temperatures which provided much heat of vaporization increasing rate of loss of water vapour across surfaces such as stomata and lenticels; which led to much rise in transpiration; which in turn much increases transpiration pull.

From noon to 6 pm, rate of water flow decrease rapidly; due to fast decrease in light intensity that led to rapid decrease in aperture and number of stomata that opened due to reducing photosynthesis; reducing sugar production; less ATP and less pumping of K^+ ions into guard cells; decreasing surface area over which transpiration occurred; and rapid decrease in air temperatures which provided less heat of vaporization decreasing rate of loss of water vapour across surfaces such as stomata and lenticels which led to fall in transpiration; which in turn decreased in transpiration pull.

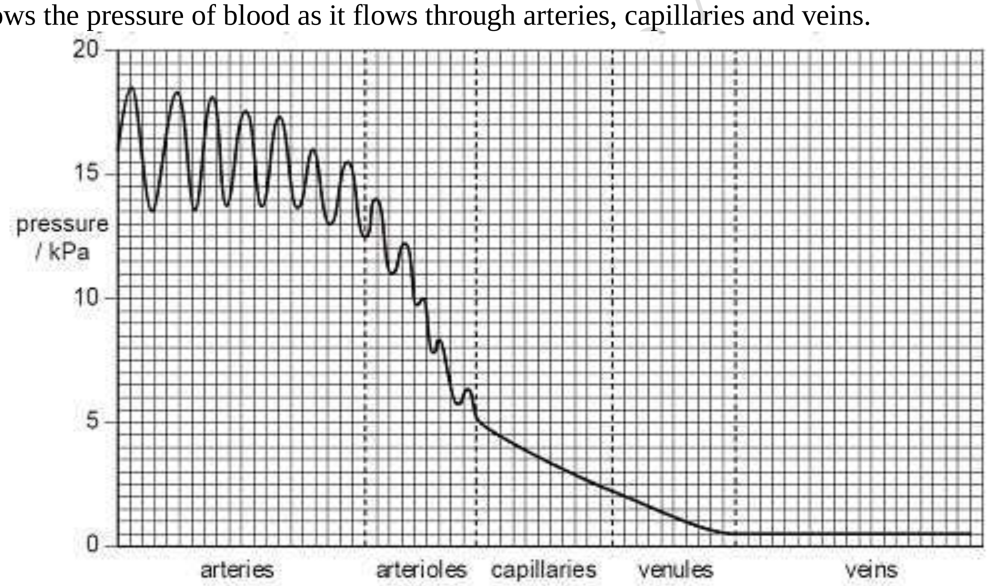
From 6 pm to 10pm rate of water flow decreased gradually; due to much decrease in the already low light intensity that led to further decrease in aperture and number of stomata that opened due to reducing photosynthesis; reducing sugar production; less ATP and less pumping of K+ ions into guard cells; further decreasing surface area over which transpiration occurred; and further decrease in air temperatures which provided less heat of vaporization decreasing rate of loss of water vapour across surface such as stomata and lenticels; which led to fall in transpiration; which in turn decreased in transpiration pull

(iii) Explain the difference in the rate of water flow in the branch and in the tree trunk.

Rate of water loss in branch is higher than in the tree trunk from 2am to just before 5:36pm; because the branch is smaller than the trunk thus has larger surface area to volume ratio, loses more water as compared to size by transpiration thus a greater transpiration pull; its xylem vessels are narrower hence generate greater capillarity for water flow. The branch has photosynthesizing leaves unlike the trunk thus experiences highest transpiration pull and trunk being further away; experiences less transpiration pull. After 5:36 pm, rate of flow in the branch fell below that of trunk because of a greater drop in transpiration trunk and higher root pressure in the trunk than branch.

Question 17.

The graph shows the pressure of blood as it flows through arteries, capillaries and veins.



(a).Describe the changes in the pressure of the blood as it flows through the vessels.

As blood flows along the arteries, blood pressure is high but falls gradually. As blood flows along the arterioles, blood pressure falls rapidly. As blood flows from arterioles to capillaries, blood pressure falls very rapidly. As blood flows along the capillaries to venules, blood pressure falls gradually. As blood flows along the veins, blood pressure is low and constant Along arteries and arterioles; blood pressure fluctuates (continues to rise and fall).

(b) Explain what causes the rise and fall in pressure across arteries.

The heart/ ventricle/ cardiac muscles are involved; peaks coincide with systole/ contraction; troughs with diastole/ relaxation (stretch-recoil effect of the heart muscles)

(c) What causes the drop in blood pressure as it flows from arteries to veins?

With increasing distance from heart; blood pressure falls due to a drop in blood volume; increasing friction / resistance to blood flow; less/ no stretch-recoil effect increasing volume/surface area of arterioles/ capillaries; large capillary bed; branching nature of large blood vessels into many smaller vessels.

(d) Explain why it is important that the pressure is lower by the time blood reaches the capillaries?

To stop damage to capillaries/ stop their bursting as they can't withstand high pressure; they lack of much elasticity due to the fact they are thin/ delicate/ one cell thick; lack collagen and muscle:
-Slow flow rate allows time for exchange materials e.g amino acids.
-Also prevent oedema risk since high pressure might force out more tissue fluid

(e).Venous pressure seems too low. How is blood able to flow along the venous system?

Valves prevent backflow: Action of skeletal muscle propels blood in veins by constricting them: large lumen of vein provides little resistance; negative pressure in chest/ thorax/ heart; gravity effect from areas above the heart.

(f) The table below shows the blood flow to various organs while a person is at rest and during strenuous exercise.

Organ	Blood flow at rest /cm^3 min^{-1}	Blood flow during strenuous exercise /cm^3 min^{-1}
Skeletal muscle	1200	12 500
Skin	500	1900
Kidneys	1100	600
Intestine	1400	600
Other	1600	1900
Total	5800	17 500

(i).With reference to the functioning of arteries, explain how blood flow to organs such as the kidneys is decreased during strenuous exercise.

Because the body needs to get more blood to the muscles; it diverts blood flow from non-exercising tissue like kidneys, intestines. Muscles need more blood to account for the new oxygen demand The sympathetic nervous system causes vasoconstriction of the organs got needed and then sends more blood to the muscles

(ii).Suggest explanations for the pattern of changes in the blood flow to the organs during strenuous exercise.

Blood flow to the skeletal muscles increases during exercise to supply more nutrients like oxygen and glucose to the muscle cells to provide energy for contractions and also elimination of wastes like carbondioxide. Blood flow to the skin increases to eliminate the excess heat and wastes accumulated due to exercise so there is vasoconstriction of the blood vessels. Blood flow to the kidneys and intestines decreases inorder to supply more blood to the muscles as these organs do not have immediate needs for energy, less urine output is needed during exercise and there is need to increase blood pressure to pump more blood to skeletal muscles. Generally, the total amount of blood increases during exercise inorder to supply more nutrients to the actively respiring cells and drain wastes for if they accumulate can damage the cells

(iii) The skeletal muscle respires much more rapidly during strenuous exercise. Explain how this results in oxyhaemoglobin unloading more oxygen to the tissue.

More heat in exercising muscle/ increase in body temperature; as respiration releases some energy as heat ATP to ADP releases some energy as heat; muscle temperature rises. above normal body temperature so more oxygen release (from haemoglobin/RBCs);

(g).What is the significance of red blood cells being impermeable to cations?

Protons/ H+ ions accumulate; increasing acidity following dissociation of carbonic acid; leading to Bohr effect. Oxyhaemoglobin releases more oxygen/ has lower affinity for oxygen/ has lower saturation of oxygen at a certain partial pressure of oxygen; Protons buffered by haemoglobin forming haemoglobinic acid.

Question 18.

A study was conducted on the effect of development of no infection with human immunodeficiency virus (HIV) on the number of type of T_4 lymphocyte (T-lymphocyte). The results are presented in the figure 1 below. Study the figure and answer the question that follow

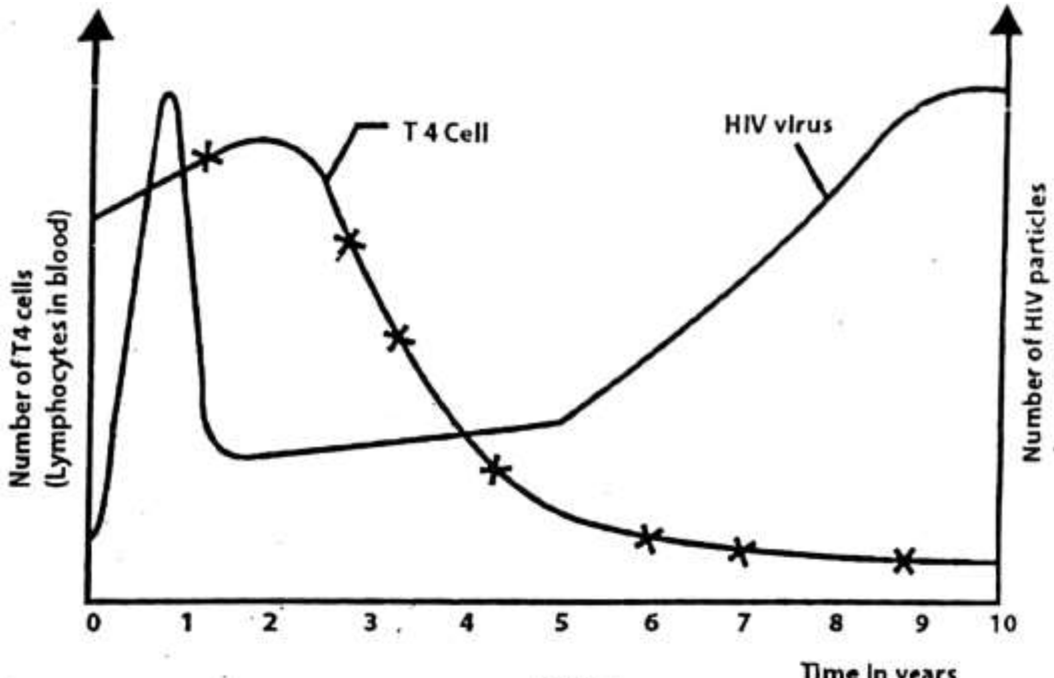
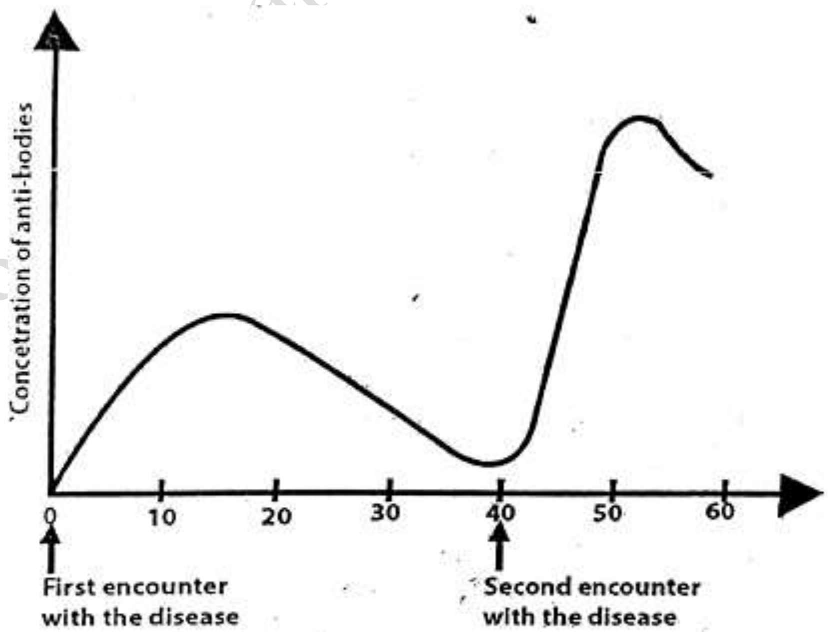


Figure 1

(a). Describe the effect of HIV infection on the variation of number of T4 cells in blood for the period of 10 years
(b) Explain,
(i).The relationship between number of HIV particles and number of T4 cells in blood over the 10 years.*(12 marks)*
(ii)The role played by T-Lymphocytes in the immune response. *(06 marks)*
(c).Suggest important areas of treatment that medical researchers must consider in order to prevent spread of HIV infections. *(03 marks)*
In another experiment, the quantities of antibodies produced in the first infection & second infections by the same disease was studied and the results are shown in figure 2 below. Study the figure 2 and answer the questions that follow.



(d).Explain the differences in the changes and peaks in the concentrations of the antibodies in the first and second encounters with the disease. *(09 marks)* (e).Explain how the changes in the concentrations of the antibodies under the two conditions exhibited in the figure 2 can be made useful in providing immunity artificially to humans. *(04 marks)*

Question 19.

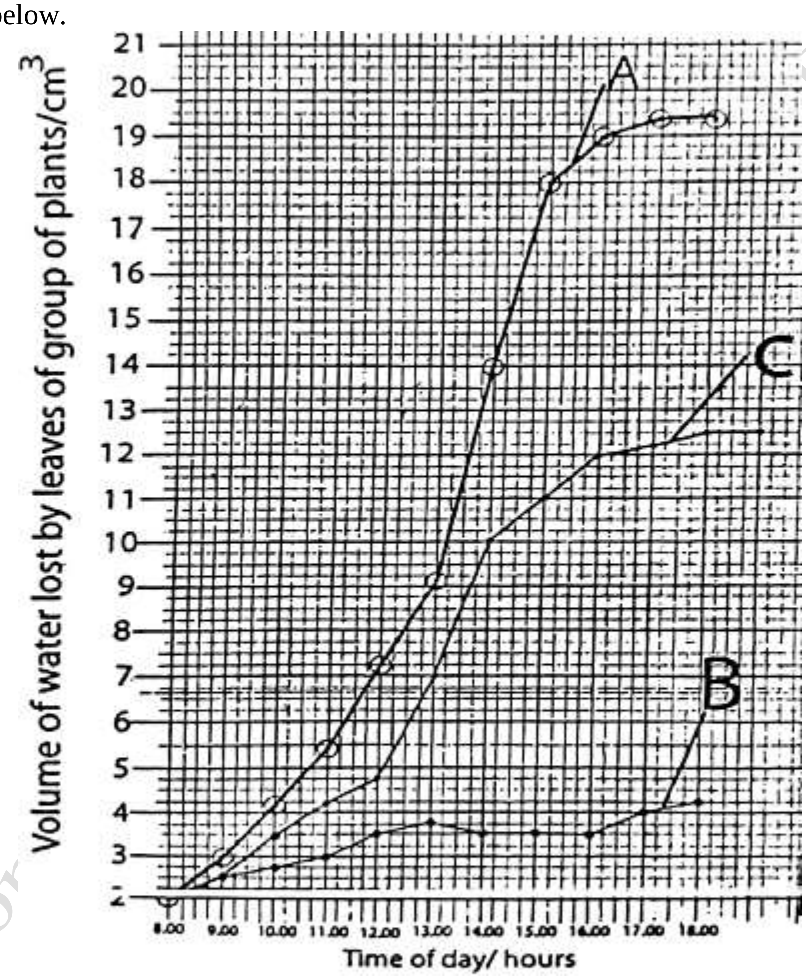
An experiment was carried out to investigate the rate of water loss by three groups of leafy plants under different conditions. Twelve leafy plants of approximately the same age, leaf surface area and same species were placed in each group and treated simultaneously as follows:

Group 1; Plants completely covered with transparent polythene bags.

Group 2; Plants fanned with an electric fan.

Group 3; Plants placed in still air in the open

The figure below shows the results of the experiments and the mean volume in cubic centimetres of water lost through evaporation over the leaf surfaces of groups of plants recorded. Each group of plants is represented as A, B and C in the figure 1 below.



(a).Compare the volume of water lost by the leaves of different groups of plants shown in figure 1 above.*(08 marks)*

(b)(i) From the curves drawn, identify the experimental conditions to which each group of plants A, B and C were placed. *(03 marks)*

(ii).With respect to group of plants A and B, suggest reasons for the observed difference in the two curves drawn.

(c) Why were the plants of the same age, leaf surface area and same species used in the experiment? *(05 marks)*

(d) Suggest

(i) the name of the apparatus commonly used in this type of experiment. *(01 marks)*

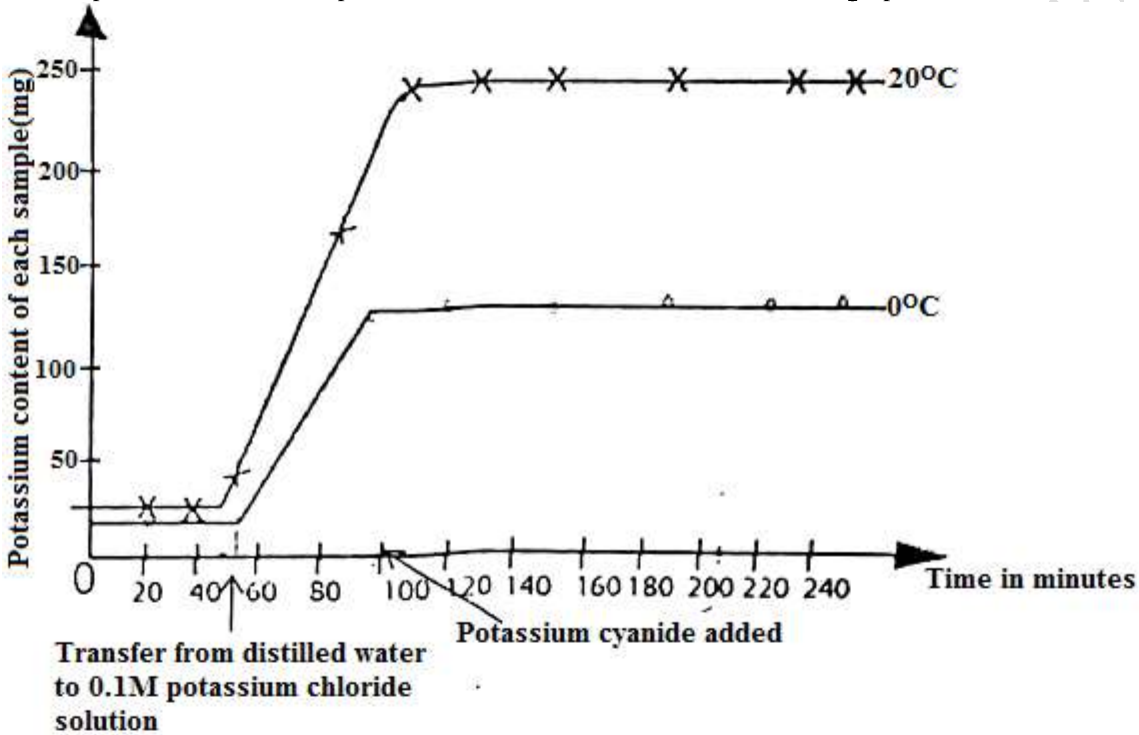
(i) a hypothesis which this experiment was designed to test. *(01 marks)*

(e).It is observed that a tree canopy with an area $30m^2$ loses greater amount of water in a given time duration than a water body with the same surface area. Suggest an explanation for this observation. *(04 marks)* (f)(i).Calculate the rate of water loss over the leaf surfaces by evaporation in group C between the time of the day 12:00-14:00 hours and 16:00-18 hours. *(03 marks)*

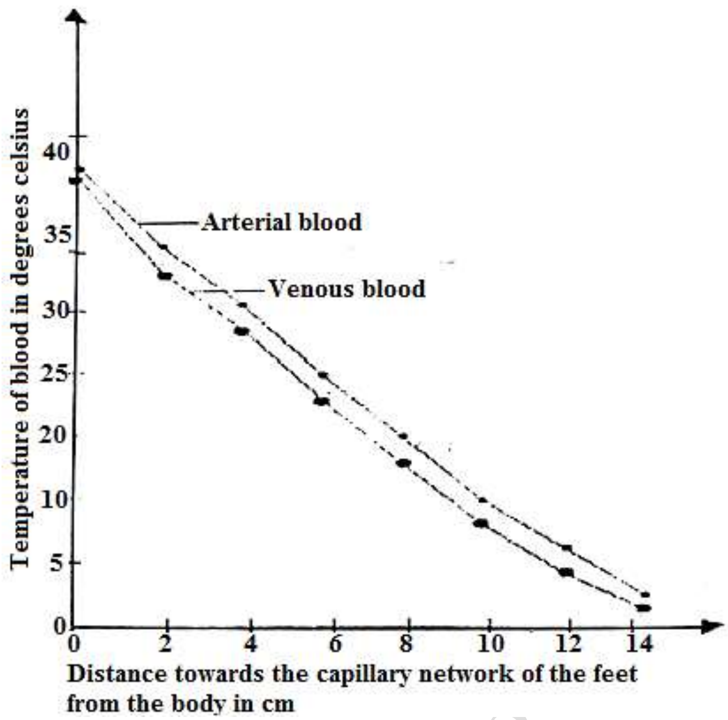
(ii) Explain the difference in the rate of water loss by the same group of plants at various times of the day *(08 marks)*

Question 20.

In an experiment to investigate absorption of minerals by plant's roots, young maize seedlings were placed in distilled water for 12 hours. Samples of equal mass were then taken periodically and the amount of potassium they contained was estimated. After 45 minutes. the seedlings were then transferred from distilled water to a 0.1 M solution of potassium chloride and equal mass samples were again taken and measured for their potassium content. Two hours later some potassium cyanide solution was added to the remaining seedli1ngs before they in tum were sampled. The experiment was then repeated at 0ºC. The results are shown in the graph below.



In another experiment. the temperatures of the arterial blood flowing towards the capillary network of the feet and venous blood flowing from the capillary network back to the body of an arctic mammal was measured. The two blood vessels are very close and parallel to each other. The arctic mammal was living in extreme cold conditions whose external environmental temperatures kept at 1ºC. Also determined was a very low critical temperature of the mammal. The temperatures of the arterial and venous blood were measured along the 14 centimeters (cm) length of the feet from the body to the capillary network of the long feet. The results obtained were represented as shown on graph in figure 2 below. Study it and answer the questions that follow.



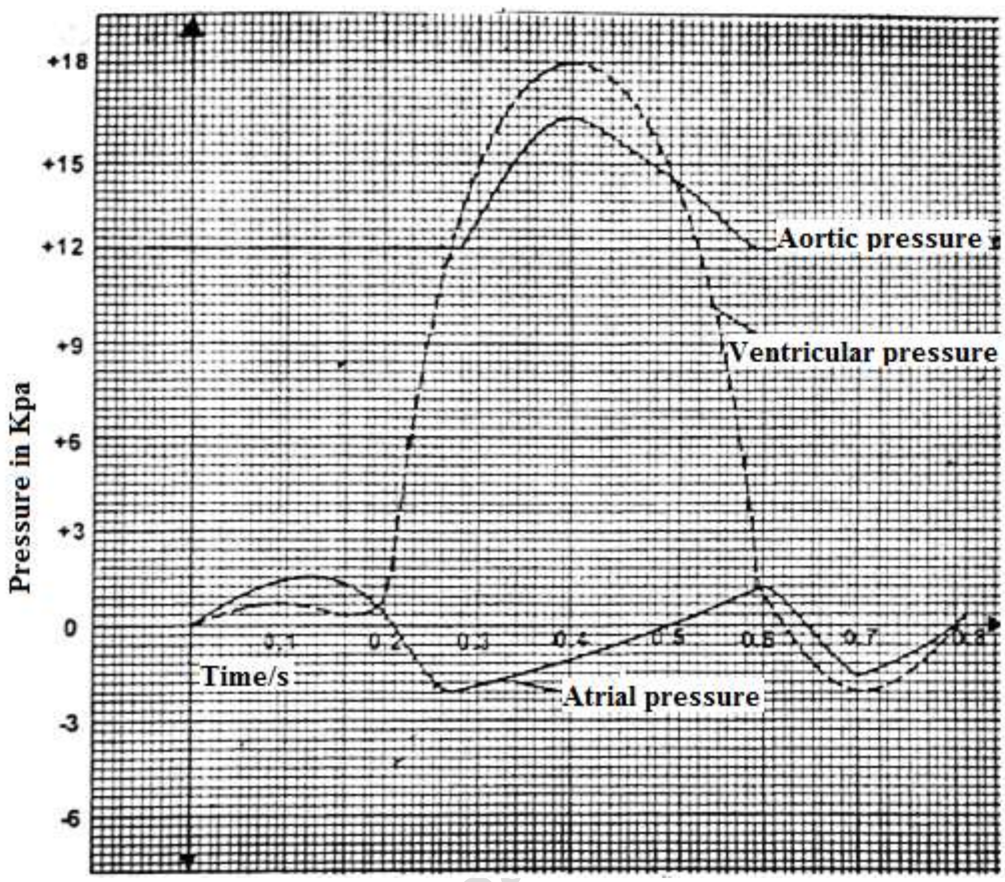
(e)(i). Using a suitable table, show the temperatures of the two different blood vessels at 1cm and 13cm distances towards the capillary network in the feet of the arctic mammal. *(02 marks)*

(ii).Briefly explain the significance of the differences in the temperatures of the two blood vessels. *(03 marks)*

(f).Give any three structural features of the arctic mammal that enables it to survive in its environment. *(03 marks)*

Question 21.

The graphs below show changes in pressure within the atria, ventricle and aorta during one cardiac cycle. The left atrium and ventricle were used to easily relate their pressure changes with that of the aorta



Study the information carefully and answer the following questions:

(a) Compare the changes in pressure during the cycle for each of the following

(i) atrium and ventricle *(06 marks)*

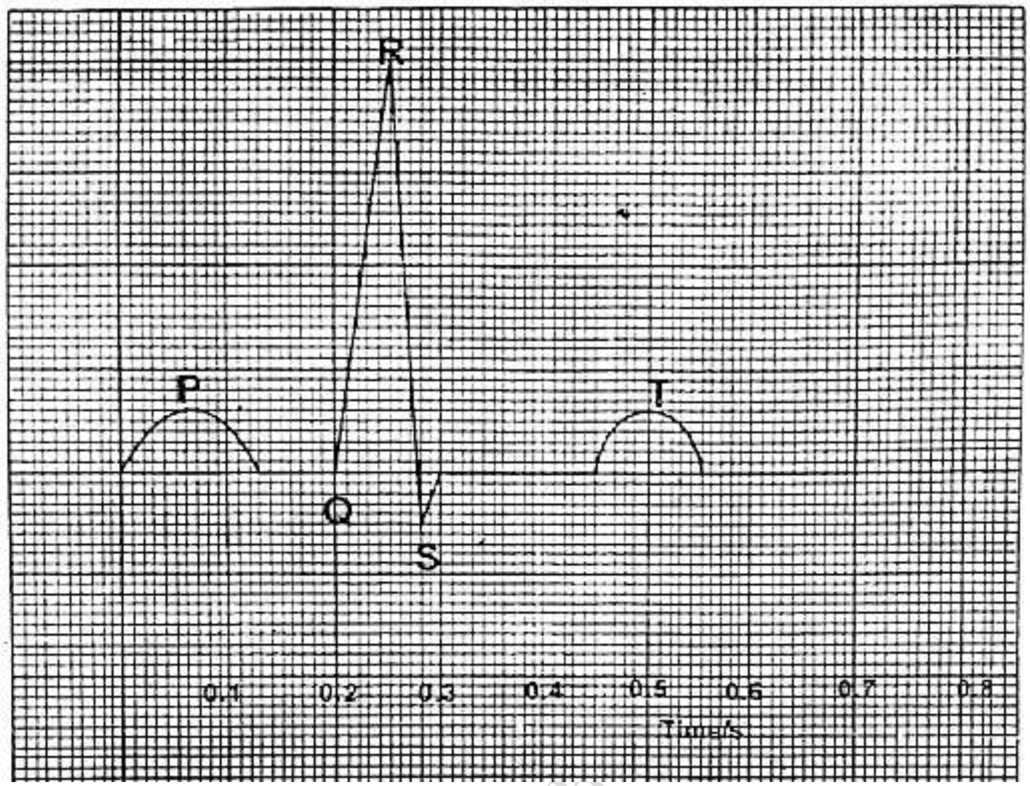
(ii) aorta and ventricle *(06 marks)*

(b) Explain the changes in pressure during the cycle for the;

(i) atrium and ventricle *(08 marks)*

(ii) aorta and ventricle *(08 marks)*

The figure below is for the electrocardiogram, of a health human being at rest



(c). Describe the changes in the heart during its excitation that lead to the following;
(i) P wave
(ii) QRS complex
(iii) T wave *(08 marks)*
(d).Explain the statement "heart muscle contraction is myogenic" and point out the significance of this in heart transplantation surgery *(04 marks)*

Question 1.

(a). Compare the transport systems found in mammals and flowering plants ***(12 marks)***
(b).Discuss the importance of transport systems in flowering plants ***(08 marks)***

(a).

Similarities

• Both take place via specialised tissues called tubes/ vessels
• Both carry materials in the circulatory fluid
• Both are facilitated by some pumping forces.
• Both are involved in transport of materials e.g food, wastes, carbondioxide and hormones.
• Both are involved in regulation of body temperatures
• Both systems have high tensile strength so that the tubes do not collapse
• Both systems form a continuous flow and connect or link all body cells.

Differences

Transport system in plants	Transport system in mammals
Lack contractile tissues such as muscles	Powered by contractile tissues like muscles
Movement is mainly by passive means	Movement is mainly by active means
Transport may occur in dead vessels.	Transport restricted to living tissues only
Transport systems lack valves	Possess valves that prevents back flow
Lack a pumping organ	Possess a pumping device
Lack pigments for carriage of respiratory gases	Have pigments for transportation of gases

Gaseous exchange surface is the stomata	Gaseous exchange surface are the lungs
Single circulation eg transport of water from roots to leaves and out	They have double circulation

(b).

Translocation of organic substances; newly synthesized organic molecules are moved to the phloem from the leaves to the stems and roots for storage or to the growing parts of the plants for immediate use.
Transport of water and minerals; water and mineral salts/ nutrients dissolved in it are absorbed from the soil by the root hairs and then move into the xylem to the leaves where they are required for photosynthesis.
Cooling of plants; through the evaporation, water inform of vapour is lost from the plant and causes cooling.
Movement of waste products; such as toxic minerals, excess water and acids are transported from their sources to places where they can be eliminated e.g leaves and fruits.
Support in herbaceous plants; continuous osmotic intake of water creates turgidity in herbaceous plants which is the basis for support in such plants.

Question 2.

(a).How does the variation in osmotic potential in the soil surrounding the root hair cells affect mechanical support ***(10 marks)***
(b).Explain how plant hormones are transported. ***(10 marks)***

(a).

Lower osmotic potential of the surrounding soil solution; relative to the sap of the root hairs; permits osmotic uptake of water into the root hairs along the concentration gradient; vacuoles of the surrounding cells take up water by osmosis; turgidity builds up till maximum turgor pressure gets achieved at maximum cellular stretch; and this keeps the plant erect; Higher osmotic potential of the surrounding soil solution; relative to the sap of the root hairs; leads to osmotic loss of water from the root hairs along the concentration gradient; vacuoles and sap of the surrounding cells lose water; cells becomes plasmolysed /flaccid and maximum flaccidity/ plasmolysis achieved at maximum cellular shrinkage; this keeps the plant flaccid; mechanical support lost;

(b).

Hormones can diffuse from the source to the target site; or translocated through the phloem with other organic solutes by mass flow; In the phloem, energy from ATP hydrolysis in the companion cells; leads to active loading of hormones and other organic solutes from the source (site of production) into the sieve elements; this lowers the water potential in the sap; water enters the sieve elements down a water potential gradient by osmosis; a corresponding buildup of hydrostatic pressure in the sieve elements; creates a pressure difference/ gradient between the source(site of hormonal production) and the sink (target site); causes mass flow of water, phytohormones and other organic solutes; from source to target site (sink);

Question 3.

(a).Describe the structure and functioning of the lymphatic system ***(06 marks)***

(b).Briefly explain how lymph is formed ***(03 marks)***
(c).State the;
(i). Functions of the lymphatic system ***(05 marks)***
(ii).Main differences between blood circulatory system and lymphatic system ***(06 marks)***

(a).

The lymphatic system is a one-way system of vessels that return excessive tissue fluid to the blood circulatory system. The system begins with lymphatic capillaries that lie near the blood capillaries. It collects excessive tissue fluid which leaks out of the blood capillaries. The small lymphatic capillaries gradually join up to form larger lymphatic vessels, which carry the lymph to the subclavian veins through several lymph nodes. Lymph nodes small ovoid/ spherical structures made up of lymphoid tissues that produce lymphocytes. Another type of lymph vessels are the lacteals that are present within the intestinal villi. Lymph vessels have no pump but it has valves to ensure unidirectional flow of lymph.

(b).

Capillary walls permeable to water; high blood pressure at the arterial end of capillary; forces water plus small solutes and ions out of the capillary into the interstitial spaces; to form tissue fluid; not all tissue fluid returns to capillaries; higher pressure in the tissue fluid than lymph; excess drains into lymphatic vessels; now called lymph; fats added; lymph node products/ antibodies added.

(c)(i).

- Drains excessive tissue fluid from the extracellular compartment back into circulation.
- Serve as temporary fluid stores; releases fluids gradually; reducing workload on the kidneys.
- Carry proteins and other large molecules; generates sufficient oncotic pressure.
- Main route for absorption of fats from the gastro-intestinal system into the blood stream.
- Form part of the reticulo-endothelial system; defends the body against disease.

(c)(ii).

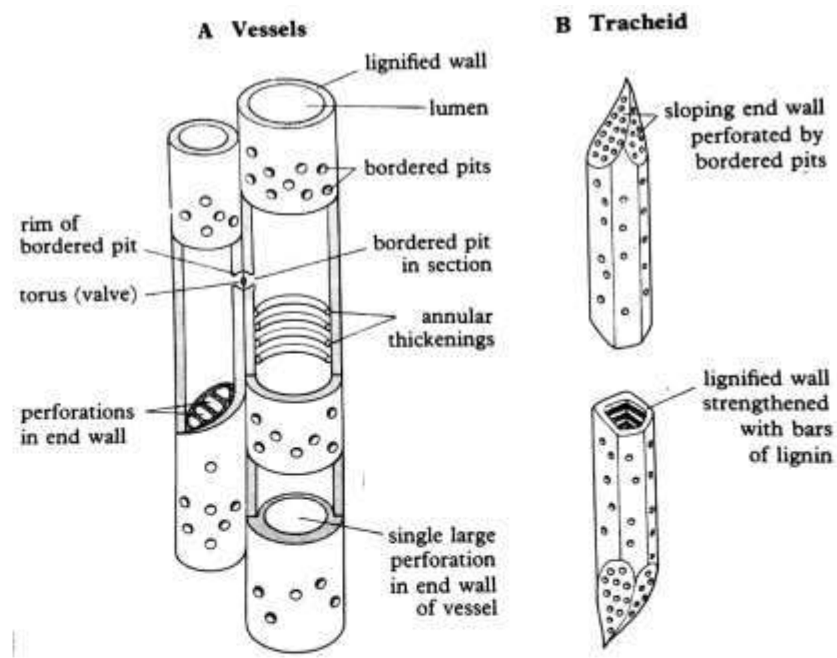
Lymphatic system	Circulatory system
Transports lymphatic fluid	Transports blood
Lymph is transported in lymph vessels	Blood is transported in blood vessels
Has tiny end capillaries that extend in almost all body tissues	Has tiny continous capillaries in all tissues of the body
Lacks a pump (heart) but has valves to ensure unidirectional flow of materials	Has both valves and pump to ensure unidirectional flow
Produce lymphocytes important in immunity	Only carries lymphocytes but not producing them.
Moves only in one direction from the body tissues to the heart	Moves in two directions; to and from the heart
Lymph flow is under low pressure and speed	Blood flow is under high pressure and speed
Lymphatic vessels are of the same diameter	Vessels are of variable diameters

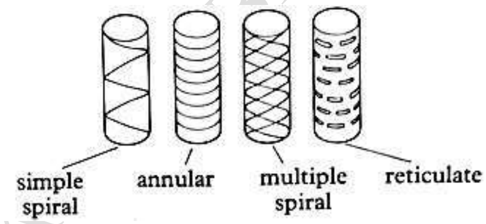
Question 4.

(a). Describe the structure of xylem tissue in a plant ***(11 marks)***
(b).How is xylem tissue adapted to its functions? ***(09 marks)***

(a)

Xylem tissue consists of two main conducting elements; tracheids and vessels. Tracheids have pointed/ tapering ends with 5 or 6 sides in cross section. Vessels on the other hand are long, cylindrical and open at each end. All xylem tissues are impregnated with lignin with lost cellular components so the tissue is dead (wood). The lignified walls are perforated with bordered pits which are areas on no lignin deposition. Bordered pits in conifers have torus a plug like structure, that controls water passage in adjacent vessels. Inner walls of vessels have lignified ribs which extend through the lumen to give various thickenings; thickenings may be annular, simple spiral, multiple spiral or reticulate.





(b).

- Bordered pits, ensure lateral exchange of water between adjacent cells of xylem tissue
- Broken end walls; ensure continuity of flow of water.
- Lignin exerts high adhesive forces with water; allows continuous capillary flow of water
- Narrow lumen; ensures rapid water movement up the plant by capillarity
- Long tubes; ensure long distance transport of water in a plant.
- Elongated vessels that create enough capillarity force
- Vessels are placed end to end with no cross barrier between them permitting continuous flow.
- Various lignin thickenings like reticulate, spiral, annular etc; lignin having a higher tensile strength increase mechanical strength of tissue; important in support of the plant
- Mature xylem is dead; lacks living protoplasm; which would otherwise offer viscous resistance to water flow; reducing the speed of water transport.

Question 5.

(a) Describe the methods of transport of each of the following substances between various regions

(i) Mineral salts from the soil into xylem vessels ***(07 marks)***

(ii)Sugars across a sieve plate ***(04 marks)***

(b)Explain how changes in pH play a role in transport of carbon dioxide in mammals ***(09 marks)***

(a)(i).

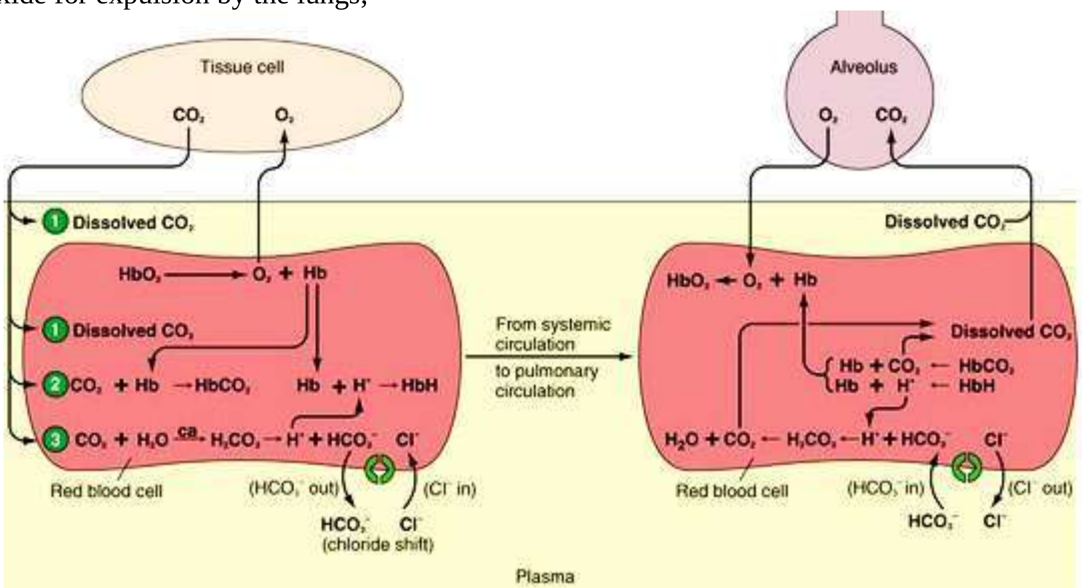
Mineral salts dissolve in water; and then are absorbed initially by diffusion; then by active transport; they are transported across the parenchyma of the cortex ; where they pass from one parenchyma of the cortex to the next vial the cellulose cell wall (apoplast) and cytoplasm (symplast); the movement is by diffusion and mass flow; until endodermis is reached where apoplast pathway is prevented/inhibited the mineral salts then are actively transported into the xylem vessels and tracheids of the roots;

(a)(ii)

The passage of polar water molecules occurs across electrically charged sieve plates; by electro-osmosis; the polar water molecules are swept along with the streams of ions through the sieve pores by the potential difference; as the ions pass through the sieve pores they carry with them sugars across the sieve plate

(b).

Large amount of carbon dioxide is transported in the blood plasma as sodium bicarbonate ions; low PH is maintained in the red blood cells by retention of high levels of protons/hydrogen ions obtained from dissociation of carbonic acid; the hydrogen ions combine with haemoglobin to form haemoglobinic acid (HHb^+); when blood reaches the capillaries of the alveoli, oxygen diffuses into the red blood cells and combines with the haemoglobinic acid; releasing hydrogen ions (H^+) and oxyhaemoglobin is formed; low pH condition is maintained in the RBC causing some few hydrogen carbonate ions (HCO_3^-) in the RBC to combine with the hydrogen ions; to form carbon dioxide and water; carbon dioxide diffuses out of the red blood cells into the alveoli and expired out of the body; this causes a negative ion deficit in the red blood cells causing more hydrogen carbonate ions to diffuse into the red blood cells from the plasma; more carbonic acid molecules are formed and continuously dissociates to release more carbon dioxide for expulsion by the lungs;



Question 6.

(a).Explain the lack of vascular systems in specific organisms ***(03 marks)***

(b).Using illustrations, describe the different types of thickening found in vessels of the xylem. ***(03 marks)***

(c).Explain how materials are transported in the xylem. ***(14 marks)***

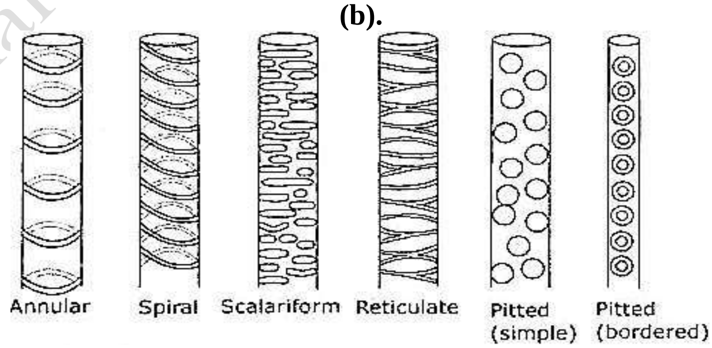
(a).

• Protists eg amoeba are unicellular hence too small and having a large surface area to volume; increasing the rate at which materials diffuse to reach the different parts of the organism;

• Flat bodied organisms eg tape worms, liver flukes have flattened bodies to increase surface area to volume ratio for faster diffusion of materials.

• Hollow bodied organisms eg hydra depend on diffusion alone for circulation of essential materials; because a hollow body increases their surface area to volume ratio.

(b).



(c).

• Due to gradient of water potential; through the whole plant; being highest in soil; surrounding the roots and lowest in the atmosphere outside the leaves; continuous flow of water through the plant is created;

• Root pressure; also contribute towards the ascent of water;

• Once inside the vessels and tracheids minerals/ salts/ ions and water are carried up the stem by transpiration stream;

• Adhesion; between water molecules comprising the material lining the vessels; made possible by narrowness of vessels and cohesion between water molecules which prevents the water column breaking the two forces are demonstrated by capillarity; which is the rise of a liquid in a capillary tube;

(c).

• Cools the leaves in hot conditions;
• Transpiration stream makeup for the water lost in transpiration; acc. water absorption.
• Provides pathway through which mineral contents are transported in the plant;

Question 7.

(a) Describe the events of the cardiac cycle. ***(10 marks)***
(b) Explain how the heart action is controlled. ***(07 marks)***
(c) Explain what will happen to the heart when the vagus nerve is cut ***(03 marks)***

(a).

Atrial systole	Ventricular systole	Atrial & ventricular diastole
		

Atrial systole; Both atria contract; small amount of remaining blood forced into the relaxed ventricles via the open AV valves; Ventricular systole; both ventricles contract; The atrio-ventricular valves are pushed shut by the pressurized blood in the ventricles; Heart sound I (lub) produced; Ventricular pressure being greater than arterial pressure forces semilunar valves open; Blood ejected from the ventricles into the arteries; Atrial and ventricular diastole; Ventricles and atria relax; ventricular pressure drops; blood flows back against the cusps of semilunar valves; forcing them closed; 2nd heart sound(Dub) produced; Blood then flows from the veins through the relaxed atria into the ventricles; which fill passively and the cycle continues

(b).

Intrinsically the heart rate is controlled by a set of specialised cardiac cells which initiate and distribute electrical signals myogenically throughout the heart; The SAN as the pacemaker; spreads electrical excitations to atria; making them contract; excitation wave then reaches the AVN; which delays and relays signals through purkyne tissue; and the bundle of His; to the ventricles; which then contract. Extrinsically the heart rate is controlled by the autonomic nervous system; Sympathetic nervous system releases noradrenaline; facilitates depolarization of cardiac muscles; increases cardiac activity; Parasympathetic nervous system (vagus nerve); releases acetylcholine; hyperpolarizes cardiac tissue; decrease cardiac activity; Other extrinsic controls include; baroreceptor activity, hormones like thyroxine, age, exercise and body temperature.

(c).

Heart rate will increase. Cutting the vagus nerve cuts off the parasympathetic innervation of the heart. The is therefore unopposed sympathetic nervous system activity; causing rise in nodal conduction, and hence an overall rise in heart rate.

Question 8.

(a)(i). Explain what is meant by mass flow ***(01 marks)***
(a)(ii).Describe how materials are moved by mass flow in the sieve tube elements. ***(10 marks)***
(b).What evidence supports the phloem as the channel for sugars and dissolved mineral salts? ***(09 marks)***

(a)(i).

Mass flow is the bulk movement of substances from one area to another due to differences in pressure.

(a)(ii).

By mass flow, materials move from leaves (source) where there is a high concentration of sugars to the roots (sinks) where there is a low concentration of sugars. In the leaves, accumulation of sugars lowers the water potential; causing an osmotic influx of water; this continues into the sieve tubes of the leaves resulting in buildup of a pressure potential. In the roots, sugars are used up / stored in insoluble forms; lowering their concentration, less water is absorbed by osmosis reducing the pressure potential. Therefore materials move from a region of high pressure potential (source) to the region of low pressure potential (sinks) along the pressure potential gradient by bulk/ mass flow.

(b).

Ringing experiments/ Classic girdling experiments; results of stripping off a ring of the back from a tree trunk revealed that the leaf did not wilt but growth below the ring greatly reduced. This was due to increase in sugar concentration above the ring and decrease below it; indicating that downward movement of the sugars is blocked at that point.

Radio-tracer studies; microautoradiography of stem sections from plants fed with $^{14}CO_2$ revealed radioactivity in the phloem

Mass spectrometry studies; Non-radioactive isotope of carbon ^{13}C was introduced into the plant as $^{13}CO_2$ and detected by mass spectrometry. The ring of phloem was killed with a fine jet of steam and translocation of ^{13}C labeled sucrose though this section was shown to be prevented.

Aphid study experiments; aphids have needle like mouth parts to obtain sugars from the phloem. Immobilizing the aphids by CO_2 induced anesthesia; cutting its proboscis at the site close to the head and leaving the proboscis sticking with the plant for some time reveals fluid exudation at the cut end. On analysis, exudates are found loaded with concentrated sugars and amino acids Electron microscopy of the cut section of the stem/ leaf from revealed the tip of the proboscis pierced within a single sieve tube element.

Other evidences

• Diurnal variations in the sugar concentration, the amount of sugars in the leaves at one time is equal to the amount of sugars in the phloem any change in the environmental factors lead to change in the sugar content of the leaves and hence in the phloem.

• Sucrose distribution using autoradiography studies reveals highest concentration of sucrose in the bark and these are reflected in the phloem sieve tube elements.

• Effect by metabolic poisons; Metabolic poisons do prevent organic matter translocation; metabolic poisons were found to prevent organic matter translocation suggesting phloem as a living tissue.

Question 9.

(a).Outline the features that ensure efficient flow of blood within the mammalian body ***(10 marks)***

(b).Explain the significance of Bohr effect in transport dynamics of vertebrates ***(05 marks)***

(c).State the reasons why the double circulatory system is advantageous compared to single circulation

(a)

• Pumping action of the heart; generates a strong propulsive force that pumps blood.

• Smooth muscles in arteries; generate wave like contraction and recoils; keep blood flow in the arteries.

• Muscular contraction; squeeze thin walled veins; increase pressure within them; facilitate venous return.

• Inspiratory movements; reduce intrathoracic pressure; aid venous return of blood to the heart.

• Gravity; aids venous return from areas of the body above the heart

• Residual heart pressure usually -10mmHg or less allows venous return.

• Pocket valves; Prevent retrograde blood flow/ back flow; augments unidirectional blood flow.

• Narrow lumen of the arteries; maintains high pressure of forward flow of blood.

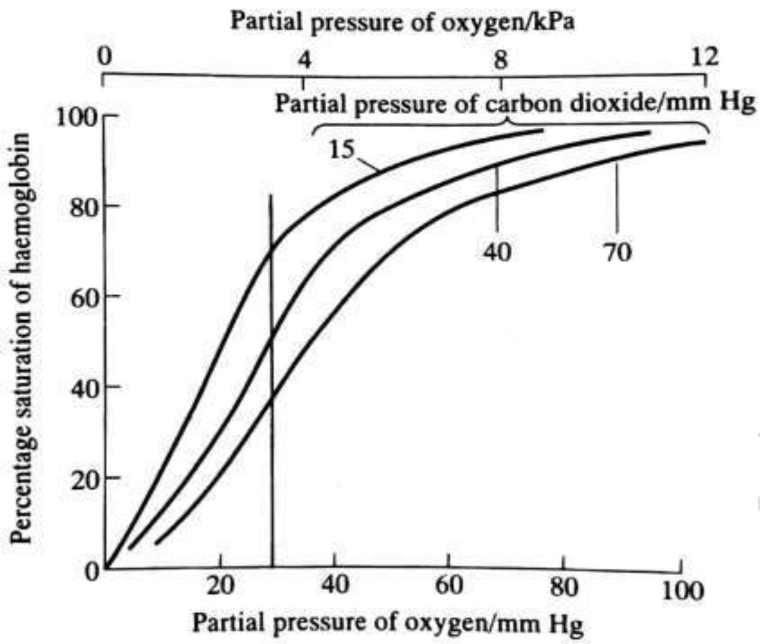
• Wider lumen of veins; reduce resistance to blood flow such that unidirectional flow is maintained.

• Effect of hydrostatic pressure generated at the arterial end of the capillary bed.

(b).

Bohr effect (reduced affinity of haemoglobin to oxygen; due to increased blood CO_2 or decreased pH).

Significance; In metabolically active tissues such as muscle, a high concentration of carbondioxide is generated, pH lowers, saturation of haemoglobin with oxygen lowers; encouraging dissociation of oxy-haemoglobin to release oxygen; this allows for enhanced uploading of oxygen in these metabolically active tissues; preventing hypoxia (low oxygen supply to tissues).



(c).

- Blood flows at a higher pressure and at a faster speed ensuring a high metabolic activity of tissues.
- Blood can flow at a lower pressure/slower into the lungs less damage to the lungs
- Closed circulation ensures adjustments in heart rate, blood pressure according to the body requirements.
- Organisms with closed circulation are more metabolically active compared to those with single circulation

Question 10.

(a).Compare open circulation and closed circulation *(07 marks)*
(b).Describe the functioning of the circulatory system in an insect. *(08 marks)*
(c).Describe how the myogenic contractions of the heart are generated. *(05 marks)*

(a).

Similarity

- In both, circulation is powered by the pumping actions of the contractile device; the heart.

Differences

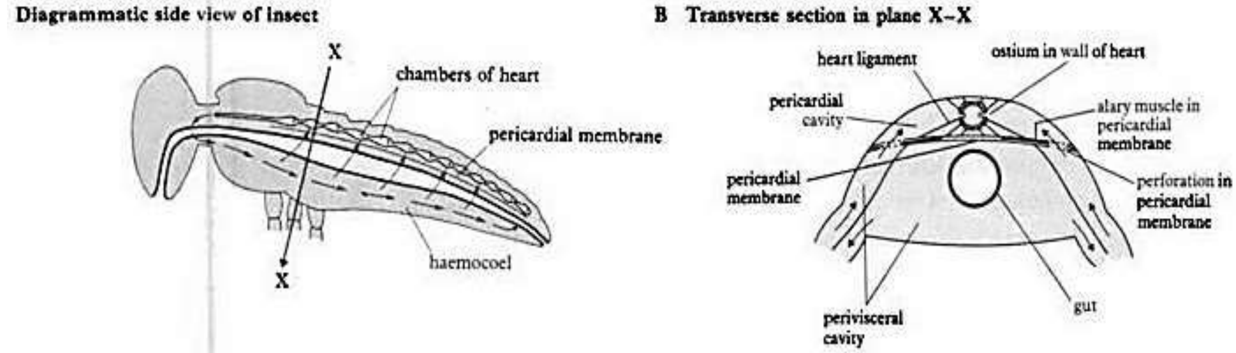
Open circulation	Closed circulation
Blood flows through open body cavities called lacunae and sinuses	Blood flows through enclosed blood vessels.
Blood flow velocity is lower	Blood flow velocity is higher
Blood pumped at a lower pressure	Blood is pumped at a higher pressure
Blood flow, pressure and heart beat cannot be regulated	Blood flow, blood pressure and heart beat can be regulated
Internal organs directly bathed by blood	Internal organs/tissues indirectly bathed by blood
Mainly found in lower animals with lower metabolic rate; process is less energy intensive	Found in higher animals with higher metabolic rate; process is highly energy intensive.

(b).

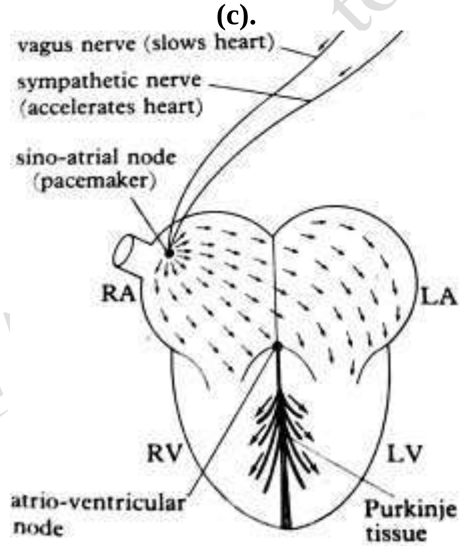
Circulation is by single open circulation. For blood to be drawn into the heart from the haemocoel of the pericard-ial cavity; alary muscles contract to pull the pericardial membrane down wards; tension in the heart ligaments is created and the hearts expand; internal pressure within the hearts is reduced below the external pressures; blood enters into the hearts via the ostia; blood also flows from the perivisceral cavity into the pericardial cavity due to higher pressures in the perivisceral cavity than pericardial membrane. Relaxation of the alary muscles causes the tension in the heart ligaments to be eased; the heart contracts; pressures in the heart increases above the external pressures; causing blood to flow from the heart via the aorta into the haemocoel.

OR.

Blood is propelled forward by waves of contraction beginning from the posterior end of abdomen towards the thorax. When heart muscles contract (systole), alary muscles relax; tension in the heart ligaments fades and pull the heart chambers inwards; intra-cardiac pressure (pressure in the heart) increases. Also pericardial membrane moves upwards; volume of the pericardial cavity decreases, pressure within exceeds that in the peri-visceral cavity, forcing blood out of the heart through the aorta into the body cavity where it bathes the tissues. When heart muscles relax (during diastole), alary muscles contract; tension in the ligaments increases; pulls the heart chambers outwards; ostium widely opens. Contraction of the alary muscles also causes the pericardial membrane to displace downwards; volume of the pericardial cavity increases pressure within decreases and goes below that in peri-visceral cavity, blood flows back to the heart through the widely open ostium. Valves around the ostium prevent retrograde blood flow backflow ensuring unidirectional flow.



(c).



Heart contractions are rhythmic and intrinsic i.e originate from within the cardiac muscle itself; (myogenic). Excitations are initiated within the heart by the Sino-Atrial Node (SAN) in the right atrium, then spread to both atria; cause atria contract; Excitations converge to the Atrio-ventricular node (AVN), located at the base of the right atrium along the interventricular septum. AV nodal conductions spreads the excitations to the ventricles via the purkinje tissues and the Bundle of His which then distributes the excitations to the ventricles. Contractions are then initiated from the base of the ventricles; spreading up wards (from the base to the ria).

Question 11.

(a). Describe how B cells defend the body against infections ***(08 marks)***

(b).Compare primary and secondary humoral immune responses to an infection ***(05 marks)***

(c).Explain the changes that occur to the bitten part of a human body by a wasp ***(07 marks)***

(a).

B lymphocytes perform humoral immune response. Detection of the antigen; causes rapid mitotic proliferation of the B cells; form clones. These cells differentiate into plasma cells; which synthesize and secrete antibodies (immunoglobulins).Antibodies defend the body by;
Neutralization; antibodies bind to toxic substances produced by the antigen, neutralize its effect.
Agglutination; antigens get clumped together, made susceptible to attack by phagocytes.
Precipitation; antibodies bind to soluble antigens, larger units precipitated, easily phagocytosed by macrophages.
Complement activation; cascade of immune reactions; leads to formation of membrane attack complex (MAC) that elicits an inflammatory reaction
Opsonization; some of the proteins of the complement system, act as opsonins that tag the antigen; rendering them easily identifiable by phagocytes
Antibody dependent cellular cytotoxicity (ADCC) done by antigen presenting cells like dendritic cells, giant cells.
Lysis; lytic enzymes are released; digest the antigen.

(b).

Similarities

- Both involve B cell activity
- In both, antibodies are the main defensive tool

Differences

Primary humoral response	Secondary humoral response
Occurs on first time exposure to the antigen.	Proceeds multiple exposures to the same antigen/virus
Slow response	Rapid response
Fewer B cells are involved	More B cells involved
Powered by plasma cells of lower specificity to the antigen	Powered by memory cells; which are plasma cells with higher specificity
Lower antibody titers	Higher antibody titers
Infection is symptomatic	Infection is asymptomatic

(c).

Upon tissue injury, local tissue inflammation; a primary body immune response results; cardinal signs being increased redness, tenderness (pain), heat generation, swelling and loss of function of the bitten part. It begins with cytokine and nitric oxide mediated activation of leucocytes (neutrophils and monocytes); which heavily infiltrate the bitten site; phagocytose bacteria; Inflammatory mediators like histamine, prostaglandins, bradykinin etc are also produced at the site; provokes an inflammatory process.
Increased redness (erythema); due to dilation of the small blood vessels within the damaged tissues; mediated by chemical substances such as prostaglandins.
Increased hotness at the injured site; cytokine mediated, other mediators like prostaglandins also causes it.
Swelling (localized edema); due to accumulation of fluids in the extravascular space; due to increased vascular permeability; caused by mediators like histamine, serotonin and prostaglandins.
Pain; due to stretch & tissue destruction following inflammatory edema, pyogenic pressure (pressure due to pus);
Loss of function; inflamed area is inhibited by pain; severe swelling also immobilizes the tissue.

Question 12.

(a).Explain the functions of the thymus gland in a mammalian immunity ***(04 marks)***
(b).Distinguish between
(i) Active and passive immunity ***(06 marks)***
(ii)Internal defence of invertebrates and vertebrates ***(03 marks)***
(c).Explain how vaccination protects against a serious case of a disease ***(07 marks)***

(a).

The thymus confers immunological competence upon T-lymphocytes. Within the thymus, these cells develop the ability to differentiate into cells that can respond to specific antigens.

The thymus gland also stimulates the release of the hormone thymosin which stimulates T cells after leaving the thymus gland to complete differentiation and become immunologically active

(b)(i).

Active immunity	Passive immunity
Follows exposure to antigens	An individual receives antibodies actively produced by another organism
Induced by immunization with a vaccine containing a weak or dead disease organisms	Artificially induced by injection with gamma globulins
Naturally induced by pathogens entering the body natural encounters like inhaling aerosols	Naturally passed on through passing on antibodies via the placenta or breast milk
Involves memory cells	No memory cell involvement
Produces antibodies specific to the pathogen	Non-specific antibodies are introduced
Offers long term immunity	Offers short term immunity

(b)(ii).

Internal defence in invertebrates	Internal defence in vertebrates
Make non-specific responses like phagocytosis	Both specific and non-specific responses
Lymphatic system not involved	Lymphatic system is involved
Few involve the immunological memory cells	Majority involves memory cells
Non-specific disease fighting substance are contained mainly in the hemolymph	Non-specific disease fighting substance are contained mainly in blood.

(c).

Vaccination causes a primary immune response against a harmless form of disease-causing antigen so that the body is sensitized by conserving memory cells specific to the antigen such that the body poses a more effective secondary response in case of a re-exposure to the same antigen. Once re-exposed, the specific memory cells made in the primary immune response proliferate rapidly; cause production of greater amounts of antibodies that mount a more effective secondary response. The disease therefore remains asymptomatic.

Question 13.

(a).Describe how water moves from the soil into the roots of a plant ***(09 marks)***

(b).Explain how structure of cardiac muscle tissue is related to physiological function ***(07 marks)***

(a).

Higher water potential in the soil because of fewer solutes and the lower water potential in the root hair cells due to the higher concentration of solutes; permits osmotic entry of water into the root hairs down the water potential gradient. Water crosses the cellwall into the cytoplasm of the root hairs/ epidermal cells; root hairs increase surface area for water uptake; water travels along cell walls/ apoplastic route; through cytoplasm/ symplastic route; via vacuolar route; apoplast pathway most important; Suberin/ casparian strip in the endodermal cells; prevents the apoplastic movement and forces the symplastic route; endodermis secretes ions into the xylem; lower water potential in the xylem due to lower/ more negative solute potential; due to water moving up the xylem; setting up tension in the xylem and thus lowering the water potential of its sap; water moves up the xylem down the water potential gradient.

(b).

Cardiac muscle tissue is made up of numerous cardiac myocytes (muscle cells) that are short, cylindrical and branched; joined end to end by intercalated discs; to form a lattice-like network; which allows extensive propagation of electrical excitations from one cell to another; so that the linked cells may contract simultaneously as a single unit (syncytium). Cardiac myofibrils contain a regular arrangement of myofilaments; actin and myosin giving cross striations; whose sliding movements allow contractions and relaxations of the muscle. Sarcoplasm enclosed by the sarcolemma contains numerous mitochondria which are the ATP generators, and several nuclei that control all the metabolic reactions in the myocytes. Within the muscle tissue are several blood capillaries that supply blood to meet the high oxygen and nutrient requirements of the tissues as well as removing CO_2.

Question 14.

(a).Describe how the cohesive and adhesive forces ensure a continuous water column up the xylem vessels

(b)Explain how photosynthesis may influence stomatal opening in a plant *(08 marks)*
(c)How is the rate of transpiration regulated in terrestrial plants *(04 marks)*
(d).Explain why plants do not use a circulatory system in executing transport activities *(04 marks)*

(a).

Cohesive forces prevent breakage of the water column; ensure continuity of the water column.
Adhesive forces hold the water molecules on the walls of the xylem vessels; and this prevents back flow of water column ensuring continuous flow of water in the xylem.

(b).

Photosynthesis leads to accumulation of sugars in the guard cells; this lowers the water potential/ increases the osmotic potential of the guard cells hence water enters the guard cells by osmosis. Guard cells then become turgid causing the stomata to open. During photosynthesis, carbondioxide is absorbed from the intercellular spaces of the leaf; this increases the pH in the guard cells due to the low levels of carbonic acid; encouraging conversion of starch to glucose; raising the solute potential in the guard cells; water enters by osmosis; become turgid and stomata opens.

(c).

The rate of transpiration is regulated by regulating the stomatal rhythm by controlling the size of the stomatal pores. The pores are surrounded by guard cells whose inner cells are thinner while the outer cells are thicker and are adjacent to the epidermal cells from which they absorb water become turgid and then open. On the other hand, loss of water from the guard cells makes them flaccid; and this closes the stomata.

(d).

- They utilize CO2 produced by the plant cells for photosynthesis thus preventing accumulation.
- Plants produce oxygen as a by-product of photosynthesis which is then used in respiration.
- Plants have numerous stomata and lenticels that favour fast gaseous exchange.
- They have large intercellular spaces that favour fast circulation of gases without blood.
- They have low demand for oxygen due to their low metabolic rate because they are less active since they are immobile.

Question 15.

(a).Discuss the factors that may alter the rate of heart beat in mammals *(10 marks)*
(b).What is the physiology of Bohr effect in animals? *(08 marks)*
(c).Explain why according to the mass flow hypothesis, translocation can only take place in living phloem

(a).

Environmental emperature; increases metabolic rate; heart beat is faster when the external temperature is high.
Level of activity/ exercise; increased muscular activities result in increased carbondioxide in the body which results in a higher heart rate.
Effect of hormones; hormones like adrenaline increases heart rate to prepare for escape.
Effect of neurotransmitters; acetylcholine inhibits heart beat while noradrenaline increases heartbeat.
Effect of drugs/ poisons; some drugs inhibit while others accelerate heart rate
State of health; heart rate is faster in diseased organisms due to increased carbondioxide & temperature.
Body size; Small organisms have a higher heart rate than larger ones due to their higher metabolic rate**;**
Age; Young organisms have higher metabolic rate due to rapid growth and hence higher heart rate**;**
Environmental temperature; Increase in temperature increases metabolic/respiratory rate leading increase in heart rate to eliminate excess carbon dioxide and to supply metabolites**;**
State of emotion; increase heart beat causing supply of more nutrients to tissues**;**
Sex; heart rate is higher in males than females since males are poorly insulated leading to higher metabolic rate**;**

(b).

Bohr effect is the shifting of the oxygen dissociation curve downwards and to the right due to increase in the partial pressure of carbondioxide in the blood. A high carbondioxide concentration/ low pH in the tissues reduces the ability of haemoglobin to associate with oxygen/ reduce the affinity of haemoglobin for oxygen thus the oxyhaemoglobin will dissociate faster into oxygen and haemoglobin. Bohr effect is due to the reduction in pH caused by dissolution of carbondioxide in water forming weak carbonic acid; which partially dissociate into hydrogen ions and hydrogen carbonate ions. The dissociation curve shifts to the right as the oxy haemoglobin dissociates to release oxygen to the tissues; High pH or low partial pressure of carbondioxide; increases hemoglobin's ability to associate with oxygen.

(c).

Loading and unloading the sieve tube elements is an active process; carried out by living companion cells.

Question 16.

(a).Explain the

(i). necessity of blood circulation in animals ***(07 marks)***

(ii) the lack of vascular systems in specific organisms ***(06 marks)***

(b).Describe the physiological adaptations of a mammalian heart to carry out its function ***(07 marks)***

(a)(i).

Many higher animals are multicellular, complex and are of large sizes. Their surface area to volume ratio being reduced renders transport of materials in and out of the organisms by passive means such as diffusion very inefficient. The long distance between organs that synthesized materials and where these materials are utilized/excreted prompts the use of a well-developed transport system made up of vessels and a pumping device (heart). Efficient defence of the body and homeostatic roles of blood require a well-developed vascular system.

(a)(ii).

• Protists eg amoeba are unicellular hence too small and having a large surface area to volume ratio; increasing the rate at which materials diffuse to reach the different parts of the organisms
• Flat bodied organisms; eg tapeworms liver flukes have flattened bodies to increase surface area to volume ratio for faster diffusion of materials.
• Hollow bodies organisms eg hydra; depend on diffusion alone for circulation of essential materials because a hollow body increases their surface area to volume ratio.

(b).

• Myogenicity; enabling the heart work independent of the central and autonomic nervous system
• Cardiac rhythmicity; enable the heart to pump blood throughout life.
• Rich calcium ion stores in the sarcoplasmic reticula; sufficiently sustain cardiac contractions.
• Sino-atrial nodal conductions; serves as the pacemakers for the heart contractions.
• Conductions of AV nodes and purkinje tissues ensure spread of excitations to the ventricles;
• Long refractory periods; permits sustained cardiac activity without fatigue.
• Innervated by autonomic nervous system; permit automatic control of cardiac activities.
• Rich blood supply by the coronary vessels; maintains a steep gradients for nutrients, gases etc.
• Patent baro-chemoreceptor reflexes; for automatic control of blood pressure and CO2 levels.
• Auto regulated blood flow of the heart through the cardiac microcirculation maintains an efficient oxygen delivery facilitating a high metabolic rate;
• Syncytial behaviour of the heart (contract as a single unit) creates strongest pumping force that propels blood.
• Free ion exchanges along the cardiac tissue tight junctions (intercalated discs) allow continuous propagation of the action potential throughout the cardiac
• Increased surface area for rapid spread of excitations through the heart by cross striations of the cardiac muscle tissues.
• High vascularity and with large numbers of mitochondria reflect the high metabolic requirements of cardiac muscle fibers

Question 17.

(a).Describe the structure of guard cells in a plant leaf ***(06 marks)***

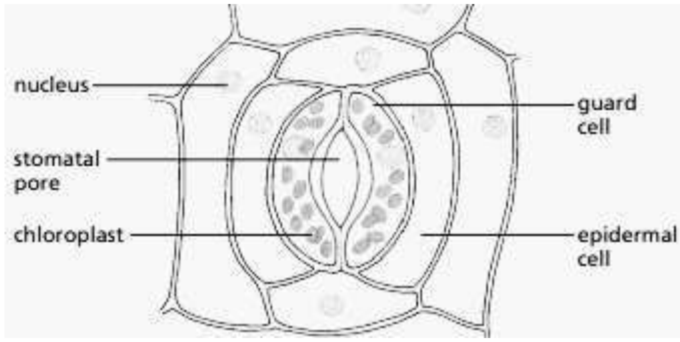
(b).Explain how stomatal opening occur according to;

(i). Starch-sugar inter-conversions ***(08 marks)***

(ii).Photosynthetic theory ***(06 marks)***

(c).Explain how blood capillaries exchange materials within cells of the body ***(04 marks)***

(a).



Guard cells are two kidney shaped cell enclosing stomata on the inside. The guard cells are bordered by epidermal cells on the outside. Guard cells have thinner outer cellulose walls and a thicker inner cell wall. Guard cells have chloroplasts; a central sap vacuole and a peripheral nucleus.

(b)(i).

According to the starch-interconversion theory, the enzymes that convert sugars to starch are favoured by low pH while the conversion of starch to sugars is favoured by high pH. During the day, most of the carbondioxide is used in photosynthesis; hence low formation of hydrogen ions from carbonic acid. Thus any starch present is converted into sugars; which raises the osmotic potential of the guard cells; these take up water by osmosis; become turgid and the stomata opens. However, at night when photosynthesis is low, carbondioxide in the guard cells combines with water to form carbonic acid; this acid dissociates to release hydrogen ions; offering an acidic pH that favours conversion of sugars into starch; thus lowering the osmotic potential of the guard cells; guard cells lose water by osmosis; become flaccid; and the stomata close.

(b)(ii).

This supposes that, during the day, guard cells carry out photosynthesis and manufacture sugars; which raise the osmotic potential of the guard cells; therefore guard cells take up the water by osmosis; become turgid and the stomata open. However, at night, little sugars are manufactured due to absence of light; thus the osmotic potential of the guard cells is lowered, consequently losing water by osmosis; become flaccid and the stomata close.

(c).

Capillaries have a single layer of endothelial cells; small gaps between these cells make wall permeable to water, small molecules and ions; capillary network runs close to cells; slow blood flow through capillaries allows time for materials to exchange; material exchange down concentration gradient. Tissue fluid formation transports materials out of capillaries at the arterial end of the capillary network; increased solute concentration/ more negative solute potential of the blood at the venous end of the capillary bed; draws tissue fluid back into the capillaries.

Question 18.

(a).Describe the adaptations of terrestrial animals living in the following environmental conditions

(i). Extreme oxygen tensions ***(02 marks)***

(ii).High altitudes ***(10 marks)***

(b).Explain how each of the following affects the dissociation of haemoglobin in the mammalian blood, suggesting in each case the physiological advantage of the effect

(i).Increased body temperature ***(04 marks)***

(ii).Small body size ***(04 marks)***

(a)(i).

• Haemoglobin has a relatively lower affinity and a higher dissociation to deliver oxygen more readily to the tissues.
• Fewer red blood cells;

(a)(ii).

• Increased red blood cell count; to increase oxygen carriage to the tissues.
• Increased haemoglobin concentration; to increase oxygen carrying capacity.
• Haemoglobin develops a higher affinity for oxygen; capture the little oxygen available
• Increased erythropoietin release from the kidney; increase red cell synthesis in the bone marrow.
• Increased pulmonary ventilation; blow off the large excesses of carbondioxide and take up oxygen.
• Increased cardiac output; to meet tissue demands using the little available oxygen.

• Angiogenesis (growth of many new blood vessels); increase blood supply to tissues.
• Increasing diffusing capacity at the respiratory surface; due to increased pulmonary capillary blood.
• Hirsute chest increase thoracic volume; allows intake of plenty of oxygen & expulsion of CO_2 per single breath.

(b)(i).

Increased body temperature is as a result of increased metabolic activity thus provides a reduction in the affinity of haemoglobin for oxygen; and increased dissociation of haemoglobin to release oxygen to the active tissues of the body.

(b)(ii).

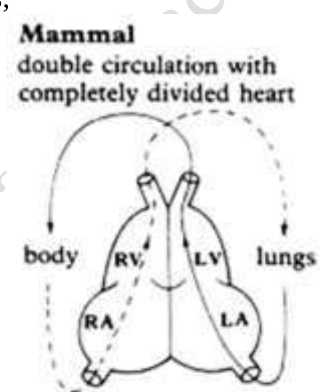
Small mammals have a larger surface area to volume ratio; and thus have a higher metabolic rate than big mammals; so small mammals have their haemoglobin having a lower affinity for oxygen; and a higher dissociation inorder to release oxygen more readily to the tissues.

Question 19.

(a) Describe the double closed circulation system in animal. ***(06 marks)***
(b) Explain briefly the role of the following in promoting venous circulation
(i) The skeletal muscles. ***(02 marks)***
(ii) Structure of the veins. ***(02 marks)***
(iii)Ventricular diastole ***(04 marks)***
(c).Account for the greater efficiency of the double closed circulatory system when contrasted with the open system. ***(06 marks)***

(a).

Circulation/ blood flow confined to a four-chamber heart and blood vessels /arteries and veins. Blood flows through the heart twice in a single cycle; each cycle consists of pulmonary and systemic circulation. Blood flows rapidly through artery from heart/ right ventricle to lungs for oxygenation and back through a vein in pulmonary circulation. Blood flows through arteries from hearts/ left ventricle to body tissues for oxygen delivery in a systematic circulation, and back to heart through veins;



(b)(i).

Most veins lie between skeletal muscles whose contractions squeeze the veins and thus permit venous return of blood to the heart.

(b)(ii).

Wide lumen of the veins offer less resistance to blood flow; permitting efficient venous return.
Valves on the venous walls prevent backflow of blood thus permit unidirectional blood flow only towards the heart.

(b)(iii).

Ventricular diastole increases volume of the ventricle; thus decrease the pressure in the ventricles.
Blood leaving the atria create a suction effect; which pulls blood towards the heart from the veins;

(c).

• Unlike in open circulation blood volume, blood flow and distribution in closed circulation are controlled by the body.
• Closed circulation transports both nutrients and respiratory gases unlike in open circulation where only nutrients are transported.

• Blood flow in closed circulation is faster and under high pressure compared to that in open circulation which is sluggish and is under low pressure.
• Closed circulation is associated with faster delivery of nutrient and oxygen to tissues.
• Circulating blood in closed circulation has oxygen carrying pigments like haemoglobin; which increase the efficiency of oxygen transportation.
• Presence of a capillary network in closed systems permits faster exchange of materials between the blood and tissues.

Question 20.

(a). State the ways by which flowering plants obtain nutrients and water ***(05 marks)***
(b).Describe the pathways and mechanisms by which water moves right from roots to the leaves ***(15 marks)***

(a).

Water
• Sources include; available soil water, metabolic by-products.
• Hydrotropism
• Taken in by root hairs from the soil solution; by osmosis along the concentration gradient

Nutrients
• Uptake by diffusion and active transport form the soil solution via the root hairs.
• Mycorrhiza association; plant roots symbiotically associate with the fungi; facilitating absorption of nutrients.
• Association with nitrogen fixing bacteria.
• Nitrifying bacteria facilitate absorption of nitrates by absorbing them from ammonium compounds.
• Parasitic and carnivorous/ insectivorous feeding interractions.

(b).

Symplastic pathway; Water enters the cytoplasm by osmosis through the partially permeable cell surface membrane. Water moves into the sap in the vacuole, through the tonoplast by osmosis or from cell to cell through the plasmodesmata or through adjacent cell surface membranes and cell walls.
Apoplastic pathway; Water enters and moves through the cell wall then either directly from one cell wall to another or through the intercellular spaces.
Vacuolar pathway; here water is osmotically drawn from sap vacuole of one cell to that of another adjacent cell along the osmotic gradient. Pathway provides some resistance to movement of water.

Mechanism

Root endodermis actively pumps salts from the cortex into the xylem vessels of the root. Casparian strip prevents leaching out of the ions back to the cortex. Water potential in the xylem tubes thus gets lowered and a water potential gradient is created which forces an osmotic influx of water from the endodermal cells to the root xylem via the symplast pathway. Accumulation of water in the root xylem creates a root pressure reduced only by water moving up the stem. Water therefore moves up the stem xylem under the influence of transpiration pull, capillarity, cohesion and adhesion. Flow through the stem xylem is continuous since the xylem vessels have no end walls to restrict flow. Water enters the leaf xylem following an osmotic gradient created when water is lost into the atmosphere either through stomatal transpiration or evaporation. Movement across the cortex and the leaf may also be through cell walls alone and plasmodesmata by the apoplast and symplast pathways.

Question 21.

(a)(i).How does collenchyma tissue differ from the sclerenchyma tissue? ***(03 marks)***
(a)(ii).Explain the evidences that show that xylem transports water in a plant ***(08 marks)***
(b).How are plants adapted to reproduce on land? ***(09 marks)***

(a)(i).

Collenchyma tissues consists of living cells with corners of each cell reinforced by extra cellulose whereas mature sclerenchyma tissues consists of dead cells impregnated with a thick layer of lignin.

(a)(ii).

• The sharp end of the shoot is placed in a solution containing a metabolic poison, uptake of solution continues as normal; meaning that the uptake of this solution is passive and since the xylem cells are dead; it is therefore the probable site for this transport.

• If a leaf's shoot is cut under water containing a coloured dye, left for some time and then observed under a microscope, it is found that only the xylem contained the dye.
• A plant shoot made to draw a fatty solution wilted. On examination, it was observed that the fats blocked the lumen of xylem impeding water movement.
• Removing the back of the woody stem doesnot affect flow of water up the stem proving that water movement doesnot occur in the in the phloem rather in the xylem.

(b).

• Some plants reproduce by spores which are resistant to adverse conditions of the environment.
• Spores are light and can easily be dispersed.
• Some exhibit seed dormancy for until conditions become favourable for germination.
• In some, the seeds are indigestible so they pass through the alimentary canal for dispersal.
• In some the fruits are freshy, brightly coloured and nice scented easing dispersal by animals.
• Some use explosive mechanism when dry to release seeds after developing tension.
• Many plants produce light pollen grains that are easily carried by wind for pollination
• Pollen grains are smooth so they can float in air with minimum resistance.
• Some produce numerous pollen gains hence increasing the chances of survival and fertilisation.
• Some produce spiky pollen grains which attaches on the body of the pollinators
• Some produce pollen grains; attach on the body of the pollinator.
• Some have brightly coloured petals; that attract pollinators.
• Double fertilisation; successful and very efficient mode of reproduction.
• Some exhibit alternation of generations.

Question 22.

(a).What is meant by water stress? *(01 marks)*
(b).Outline the effects of water stress *(05 marks)*
(c).With examples, explain how plants survive conditions of water stress *(14 marks)*

(a).

This is the state when supply of water to the plant/ amount of water absorbed is less than that lost by transpiration.

(b).

• It leads to wilting
• Secretion of Abscissic acid to counter water stress.
• Stomatal closure
• Reduction in the photosynthetic rate.
• Reduction in the respiratory rate
• Decrease in the physical size of the plant following reduced productivity.
• Evolutionary development of the C_4 metabolism and crassulacean acid metabolism

(c).

• Xerophytes like cacti, creosote and yucca trees possess thick cuticle which block plant pores trapping moisture; reduce water loss by transpiration.
• Xerophytes like cacti utilize crassulacean acid metabolism in which they reverse stomatal rhythms; minimize water loss during day.
• Plants like piggyback plant, primrose plant and desert brittle bush demonstrate pubescence (possess hairy leaf laminae); insulate against water losses through transpiration.
• Drought evading plants like cheese weed and brittlebush do stem photosynthesis at the expense of leaf photosynthesis during the dry season since stems lose less water compared to leaves.
• Drought deciduous plants do periodic shed off of leaves during the dry season; reduce rate of transpiration.
• Drought enduring plants like desert brittle bush possess glandular trichomes which secretes a resin that coats the leaf surface thus limiting water loss through transpiration.
• Phreatophytes like mesquites have an extensive root system; which either spread over the surface soil or penetrate deeper layers; to absorb water.
• Xerophytes like cacti are succulent; for reservoir water storage.

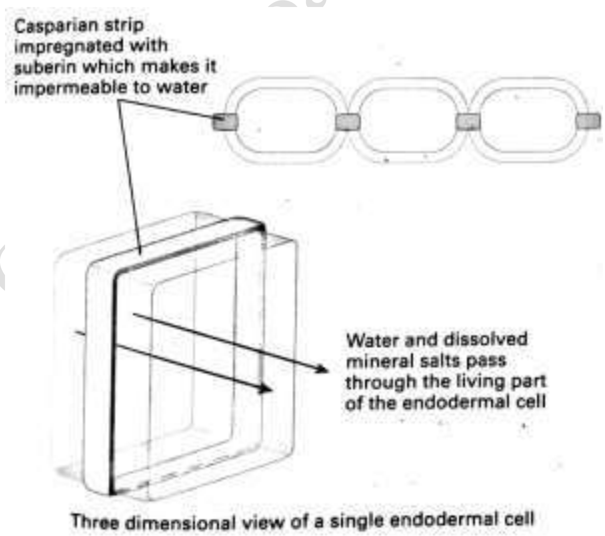
• Shallow and superficial roots of the desert succulents allowing quick responses of the plant to light rainfalls increasing water intake.
• Possession of waxy stems and leaves by drought succulents reduce cuticular water loss
• Leaves of some desert plants such as cacti are reduced to spines; reducing surface area for water loss through transpiration.
• Drought enduring plants like cacti and creosote have steeper leaf angles parallel to solar radiations reducing direct exposure to the sun; thus reducing water loss through transpiration.
• Some xerophytes possess leaves that are folded/ rolled/ curled in; reduce area exposed to sunlight thus minimizng water loss through transpiration.
• Produce Abscissic acid; cause stomatal closure; counteracting water stress by reducing transpiration
• Small size of the leaves reduce surface area exposed to light
• Shiny foliage possessed by plants such as reflective desert brittlebush and Hawaiian silver sword; increase the plant‘s reflectance of light; reducing water loss via transpiration.
• Sunken stomata of xerophytes reduce water loss through transpiration.

Question 23.

(a).Explain the role of the casparian strip in plant nutrient and water uptake ***(08 marks)***
(b).Why does transpiration occur mainly via leaves other than other parts of the plants? ***(07 marks)***
(c). How does variation in pH of the mammalian blood affect the ability of haemoglobin to associate with oxygen? ***(05 marks)***

(a).

The casparian strip is found in the cell wall of endodermal cells. It is made up of suberin which is hydrophobic (water repellant) such that when water reaches the endodermis, the apoplast pathway is prevented and water is diverted to the symplast and vacuolar pathway. Since salts are transported along with water, diversion of water also causes accumulation of salts in the endodermis; these are actively pumped into the root xylem; reducing its water potential. Water thus follows the salts osmotically building up a hydrostatic pressure which pushes water some distance up the plant.



Three dimensional view of a single endodermal cell

(b).

• Leaves are many; creating a greater surface area for plentiful water loss
• Each leaf contains several stomata; increasing water loss per leaf surface area.
• Leaves are thin hence readily facilitating easy diffusion of water vapour out of plants.
• Transpiration pull, root pressure, osmosis and capillary forces generate sufficient force that propel water high up the most terminal sites which are the leaves
• The position of leaves on the plants is terminal; hence transpiration pull allows continous flow of water to be more efficiently lost through the leaves.

• Other aerial parts of the plants except the stomata possess a waxy cuticle which is hydrophobic prompting more stomatal transpiration than cuticular transpiration.
• Secondary tissues; have greatly suberized layers that are impervious to water except at the fewer sites that form lenticels. This limits lenticular transpiration.
• Air spaces in spongy mesophyll cells in leaves create a very steep diffusion gradient for transpiration to occur.
• The terminal end of xylem vessels of leaf veins facilitates evaporation of water from leaves.

(c).

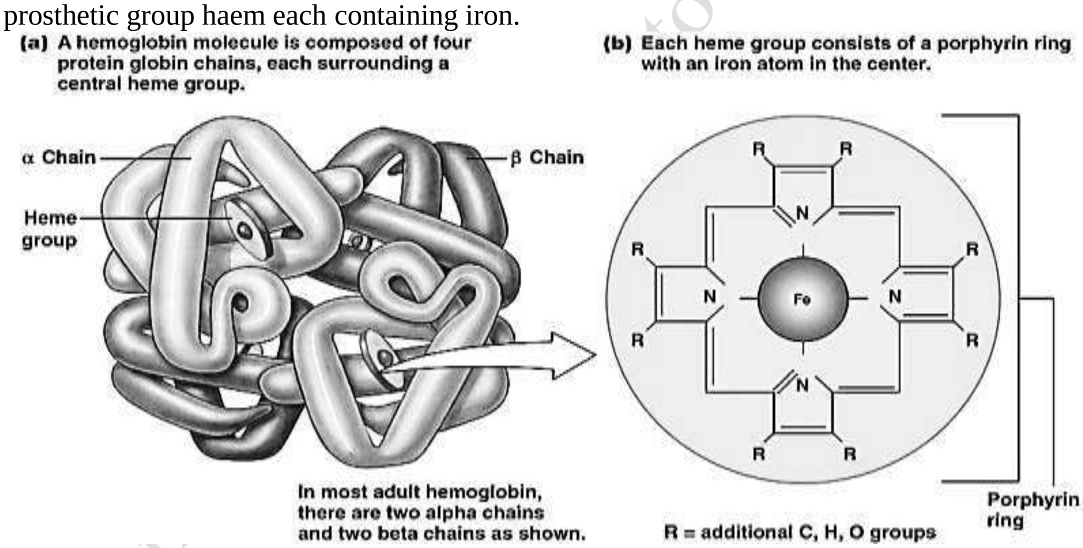
Decreasing pH makes haemoglobin increase its dissociation as its affinity for oxygen is getting decreased therefore shifts the oxygen dissociation curve to the right.
Increasing pH of blood decreases the dissociation of haemoglobin as its affinity increases. This shifts the oxygen the oxygen dissociation curve to the left.

Question 24.

(a).Describe the structure of haemoglobin molecule ***(04 marks)***
(b).Explain why the affinity of haemoglobin for oxygen increases when it already possess oxygen molecule.
(c).State how the oxygen dissociation curve for myoglobin is related to that of haemoglobin and point out the physiological significance of this relationship ***(05 marks)***
(d).Describe the essential features of the mammalian blood vascular system ***(07 marks)***

(a).

Haemoglobin has a quaternary structure consisting of four polypeptide chains. Each chain is itself a protein known as globin and is of two types i.e alpha globin (α-globin) and beta-globin (β-globin). The polypeptide chains are globular with the hydrophobic side chain pointing in wards to the centre of the molecule. Each globin chain is attached to a prosthetic group haem each containing iron.



(b).

Binding of the first oxygen molecule to the iron of the first haem group; alters the position of the polypeptide chain which distorts the shape of the haemoglobin molecule which exposes the iron atoms of the remaining haem groups hence the subsequent oxygen molecule are added more easily; quickening uptake of oxygen molecules.

(c).

Oxygen dissociation curve for myoglobin is displaced to the left of that of haemoglobin.

Physiological significance

In a resting muscle, the oxygen supply may exceed oxygen demands. Thus myoglobin unloads the oxy haemoglobin picking up oxygen from it and forming oxy-myoglobin thus myoglobin acts as a store for oxygen in resting muscle. In active muscle, the oxygen supply from haemoglobin may not meet the oxygen demands. When all the oxy-haemoglobin is exhausted, oxy-myoglobin releases oxygen to enrich with the muscle with more oxygen molecules.

(d).

Consists of a four chambered heart which pumps blood in a closed system of vessels; Double circulation of blood flow through the heart occurs i.e blood flows through the heart twice in a single circulation. Blood is pumped from the heart to the lungs then back to the heart in the pulmonary circulation. Blood is then pumped from the heart to other body parts through arteries. Blood is further supplied to peripheral tissues through miniature vessels called arterioles. Venules pick de-oxygenated blood from tissues; drain to veins which drain blood back to the heart. Capillaries interlink the arteries to veins.

Question 25.

(a).Explain what is meant by a chloride shift ***(02 marks)***

(b).Describe the main biochemical changes that occur when carbondioxide from a respiring cell diffuses through plasma into a red blood cell ***(07 marks)***

(c).Outline the adaptations of red blood cells to their function ***(08 marks)***

(d).Explain why mouth to mouth breathing together with chest pressing is the classical first aid for drowning

(a).

Chloride shift is the entrance of chloride ions from plasma into the red blood cells to restore electroneutrality.

(b).

Carbondioxide diffuses from plasma into red blood cells. Carbondioxide combines with water forming carbonic acid. This acid partially dissociates releasing hydrogen ions and hydrogen carbonate ions. Hydrogen ions combine with haemoglobin forming haemoglobinic acid, which cause release of oxygen. The red cell membrane is permeable to hydrogen carbonate ions therefore these ions diffuse out of the membrane leaving a net positive charge in the RBC therefore chloride ions from dissociation of NaCl enter the RBC to restore electroneutrality.

(c).

• Contains haemoglobin; an efficient oxygen transporting pigment
• Lack a nucleus & other membrane organelles; increase surface area for accommodation of haemoglobin.
• Biconcave shape; increase surface area for gaseous exchange.
• Thin membrane of the red blood cell; reduce diffusion distance for the gases.
• Red blood cells are pliable; enable them to squeeze through the capillary networks without hemolysing.
• Contain enzyme carbonic anhydrase; catalyse combination of carbondioxide with water.
• Numerous in numbers; increasing the net amounts of gases exchanged per unit time.
• Entirely depend on ATP molecules of the glycolytic pathway; thus remain functional for a long period of time even in anaerobic conditions.

(d).

Mouth to mouth breathing ensures that the drowned individual is supplied with sufficient carbondioxide which acts as a stimulus to increase the respiratory drive. Pressing the chest, allows intake of atmospheric air which contains more oxygen and less carbondioxide. Also increases the intrathoracic pressure that pushes water out of lungs.

Question 26.

(a).Outline the characteristics of the xylem and phloem tissues ***(09 marks)***

(b).Compare the transport systems in the xylem and phloem ***(07 marks)***

(c).Outline the importance of transpiration in plants ***(04 marks)***

(a).

Characteristics of the xylem tissues

• Consist of dead tubes
• They are hollow
• Its walls are lignified
• Have no protein filaments
• Has no cytoplasm
• Transports water and salts
• Transports water and mineral salts in one direction

Characteristics of phloem tissues/ sieve tube elements

• Consist of living cells
• Have a thin cytoplasm
• Associated with companion cells

• Consist of sieve cross walls
• Consist of protein filaments
• Transport food materials
• Transport materials in opposite direction.

(b).

Similarities

• In both, materials are transported in solution form.
• In both, transport involves use of energy e.g. in xylem, transpiration pull depend on solar energy and in phloem it depends on respiratory energy.

Differences:

Xylem transport	Transport in phloem
Occur in one direction i.e. up the plant	Occur in two directions i.e. up and down.
Depend on transpiration pull/ solar energy	Depend on respiratory energy.
Transport water and dissolved minerals.	Manufactured food and auxins
Occur in dead cells	Occur in living cells
Both tracheids and vessels are used	Only sieve tubes are used
Occurs in cells with lignified walls	Not lignified cells

(c).

Positive importances

• Results in the absorption of water and its movement up the plant to aid processes like photosynthesis.
• Contribution to maintenance of continuous stream of water throughout the plant.
• Transported water keeps the plant cells turgid and cools the plant.
• Results in the movement of mineral salts up the plants to where they are needed.

Negative importances

• Excessive water loss from the plant may lead to wilting, drying and even death of the plant.
• Water may lead to over cooling which affect metabolic activities
• Over absorption of mineral salts with water lead to soil exhaustion.

Question 27.

(a).Describe the different types of transpiration in plants ***(06 marks)***
(b).Explain the factors affecting rate of transpiration in plants ***(14 marks)***

(a).

Stomatal transpiration; this is the loss of water vapour to the atmosphere through the stomatal pores of the leaves. This contributes 90% of the total water loss from a leafy shoot. This is because leaves contain a large number of stomata for gaseous exchange where this water vapour can pass and also there is little resistance to the movement of water vapour through the stomatal pores. In addition, leaves also have a large surface area over which water vapour can evaporate rapidly to the atmosphere.
Cuticular transpiration; This is the loss of water vapour to the atmosphere directly through the epidermis coated with a cuticle layer. It contributes 5% to the total water loss from the leafy shoot. This is because the cuticle is hard, waxy and less permeable to most diffusing molecules including water vapour molecules.
Lenticular transpiration; This is the loss of water vapour through a mass of loosely packed cells known as lenticels found scattered on the stems. It also contributes 5% of the total water loss to the atmosphere in a leafy shoot. It is because the lenticels are usually few in number and not directly exposed to environmental conditions. Lenticular transpiration is the main source of water loss from deciduous plants after shading off their leaves. Because there are more stomata on the leaves than elsewhere in the shoot system, it is evidence that most of the water vapour is lost from the leaves.

(b).

Temperature; Increase in temperature increases the rate of transpiration. This is because high temperatures provide latent heat of vaporization which increases the evaporation of the water leading to more water to be lost. Temperatures also increase the kinetic energy of the air molecules around the leaf which causes them to move further apart and this increases rate of diffusion from the leaf.

Relative humidity; Humidity is the amount of water vapour in the atmosphere. As humidity increases, the rate of transpiration decreases. This is because the environment becomes saturated with the water vapour. The water then can be absorbed from the plant decrease which reduces the rate of transpiration.
Prevailing winds; rate of transpiration is higher in windy air than in still air. This is because wind helps/ assists to remove water vapour in the air around the leaf and creates more spaces that can take up more water vapour. However, if the wind speed becomes too high transpiration stops due to mechanical closure of the stomata and the cooling effect the wind has on the leaf.
Light intensity; rate of transpiration is high during the presence of light and low in the dark because high light intensity result in high rate of photosynthesis which increase the sugar concentration in the guard cells which lead to wide opening of the stomata leading to more evaporation from the plant (also light provide heat which increase evaporation from the leaf stomata.
Availability of water; This affects the turgidity of the guard cells i.e. more water more turgidity which leads to opening of stomata and enable more water loss and to high transpiration rate.
Atmospheric pressure; humidity decreases with decrease in atmospheric pressure. Hence decrease in atmospheric pressure greatly increases the rate of transpiration due to decreased humidity.
Distribution of stomata; The rate of transpiration is low when more stomata are on the lower side and is higher when more stomata are on the upper side of the leaf.
Number of stomata; the greater the number of stomata, the higher the rate of transpiration because more water vapour is lost through the stomata.
Surface area for transpiration; plants with wide/broad leaves have a larger surface for transpiration thus they experience a higher rate of transpiration. But that with small leaves e.g. desert plants have a small surface area hence low rate of transpiration.
Thickness of the plant cuticle; the rate of transpiration decreases with increase in thickness of the cuticle. For that reason, plants found in deserts have extremely thick cuticle than those in tropical regions.

Question 28.

(a)(i)Distinguish between plasma and serum *(01 marks)*
(a)(ii).Describe the different forms of immunity exhibited by humans *(08 marks)*
(b).List three characteristics of an immune response. *(03 marks)*
(c).Describe the functions and mechanism of blood clotting in animal. *(08 marks)*

(a)(i).

Plasma is the fluid portion of blood including proteins, whereas serum is fluid portion of blood or plasma without proteins especially fibrinogen.

(a)(ii).

Inborn or innate immunity; This is the type of resistance to diseases that one is born with.
Acquired immunity; This is the type of immunity developed by the body during its life towards various diseases. It is divided into: natural acquired immunity and artificial acquired immunity
Natural acquired immunity; This is the immunity provided by antibodies which are naturally acquired. It is further divided into 2 types; natural active immunity and natural passive immunity
Natural active immunity; immunity is provided by antibodies produced by the body after being exposed to a particular disease. After production of the antibodies, the body becomes resistant to the subsequent similar infections e.g. contracting flu and recovering from it without using any drugs.
Natural passive immunity; immunity is provided by antibodies acquired from another individual of the same species. It is a temporary type of immunity e.g. the body obtains antibodies from the mother through breast feeding colostrum.
Artificial acquired immunity; Is the type of immunity provided by antibodies injected artificially from either the organisms of the same species or artificially made. It is divided into;
Artificial active immunity; is a product of inducing the body to produce antibodies by artificially injecting one with a vaccine (weakened/attenuated pathogenic organism). This process is called vaccination or immunization.
Artificial passive immunity; is the immunity provided by antibodies artificially injected into an individual. It is temporary and the body is not induced to produce its own antibodies.

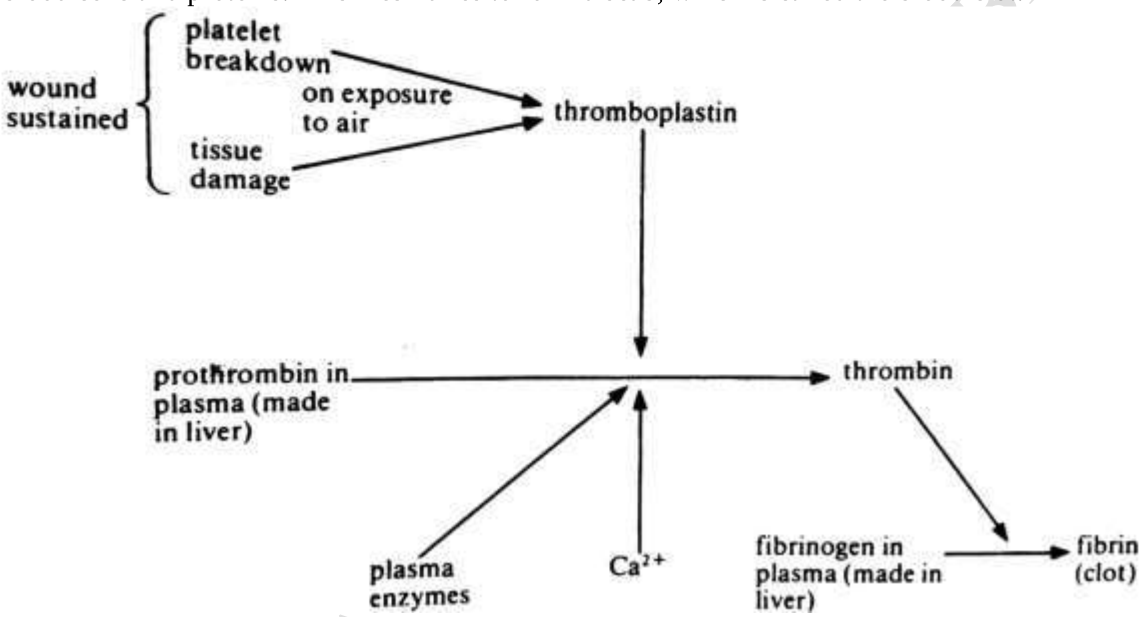
(b).

• They are specific
• They can recognise foreign bodies
• They have memory life.
• It is a prerequisite for the healing of a wound
• Prevents over breeding.
• Blocks entry of germs into body.

(c).

Mechanism

When blood is exposed to air as a result of a cut or wound, the platelets in the blood at the damaged tissue stimulate the release of a chemical called thromboplastin (thrombokinase). In the presence of calcium ions and vitamin K, thromboplastin stimulates the conversion of prothrombin to thrombin enzyme. Thrombin then catalyses the conversion of soluble blood protein fibrinogen to the insoluble form fibrin. Fibrin forms fibers, which form a mesh and trap blood cells and proteins. This mesh dries to form a scab, which is called the blood clot.



Question 29

(a).Describe the structure of an antibody *(05 marks)*
(b).Explain the physiology behind blood transfusion based on the ABO system *(09 marks)*
(c).Why is it relevant to ascertain the rhesus status of any expectant mother *(06 marks)*

(a).

An antibody/ immunoglobulin is composed of four polypeptide chains linked together by disulphide bonds. Two chains are long and slightly bent at the hinge and are referred to as the heavy chains while the two other polypeptide chains are short poly polypeptide chains. Each polypeptide chain is composed of a constant and a variable region whereby the constant region is the one composed of the same amino acid sequence in all different molecules of antibodies while at the variable region, the amino acid sequence varies with different molecules of antibodies. At one end, the two linked heavy and light chains is an antigen binding site where a specific antigen becomes attached.

(b).

Blood group A has antigen A on the surface of its red blood cells and antibody b in the blood plasma of that person. Blood group B has antigen B on the surface of its red blood cells and antibody a in the blood plasma of that person. Blood group AB has antigen B and A on the surface of its red blood cells and no antibody in the blood plasma of that person. Blood group O has no antigen on the surface of its red blood cells and both antibody b and a in the blood plasma of that person. During transfusion, the recipient‘s antibody reacts with the corresponding antigen in the donor‘s blood. Whenever the antigen of the donor corresponds with the antibody of the recipient‘s blood group, an antibody-antigen reaction occurs, leading to agglutination. Individuals with blood group O are called universal donors because they lack antigens which would react with the corresponding antibodies in the recipient's blood and individuals with blood group AB are universal recipients because they lack antibodies in their blood plasma which would have reacted with the corresponding antigens in the donor's blood.

Table of compatibility

universal donor → O ab (donor); universal recipient → AB o (recipient)

donor \ recipient	O ab	A b	B a	AB o
O ab	–	–	–	–
A b	+	–	+	–
B a	+	+	–	–
AB o	+	+	+	–

(c).

When an expectant mother who is Rh- bears the foetus with which is Rh+, some foetal erythrocytes with D-antigens cross the placenta and enter maternal circulation towards the end of the gestation period (pregnancy). The D-antigens that have entered the mother's blood circulation stimulate the maternal body to manufacture corresponding antibodies (anti-D antibodies); hence getting sensitized to rhesus antigens. The first pregnancy is usually safe but with the subsequent pregnancies of other Rh+ foeti, the maternal anti-D antibodies cross the placenta and enter the foetal blood circulation where they attack and agglutinate with the D-antigens of the foetal red blood cells, causing red cell breakdown, a condition called erythroblastosis foetalis (Haemolytic disease of the new born). This disease results into acute anaemia which can lead to death of the foetus. It is thus worthwhile to give any rhesus negative mother bearing a Rh+ foetus anti-D vaccine 72 hours to delivery; to render her immune system insensitive towards the D-antigen.

Question 30.

(a).Outline the differences between the major blood vessels in the body ***(10 marks)***
(b).State the adaptations of each of the blood vessels to facilitate blood flow ***(10 marks)***
(c).Why is the thickness of a blood vessel not a good indicator of whether it is an artery or vein? ***(02 marks)***

(a).

Structural differences

Artery	Veins	Capillaries
Have thick walls with smooth muscles	have thin walls with smooth muscles	Have thinner walls with smooth muscles
have more elastic fibres	Have few elastic fibres	Do not have elastic fibres
Have smaller lumen relative to diameter	Have a wider lumen relative to diameter	Have largest lumen relative diameter
Have no valves except at the base of aorta	Have valves throughout their length	Have no valves
Can constrict	Can't constrict	Can't constrict
Walls not permeable	Walls not permeable	Walls permeable

Functional differences

Artery	Vein	Capillaries
Carry blood away from the heart	Carry blood towards the heart	Carry blood to and from the heart
Carry oxygenated blood except pulmonary artery and umbilical artery	Carry deoxygenated blood except pulmonary vein and umbilical vein	Carry both oxygenated and deoxygenated blood

Blood flow at high pressure(flow in pulse)	Blood flow at low pressure	Blood flow at intermediate pressure
Blood flow in pulse	Blood does not flow in pulse	Blood does not flow in pulses

(b).

Adaptations of veins

• They have wide lumen to encourage flow of blood at low pressure.
• They have thinner walls than arteries which are adequate to withstand low pressure.
• They have valves at intervals along their length which prevent blood from flowing backwards / maintain flow of blood in one direction.
• They are not capable of constricting.
• They transport deoxygenated blood except the pulmonary vein and umbilical vein.
• They have less elastic muscles.
• They are found near the body surface.

Adaptations of arteries

• Has three layered wall; strong to withstand the higher pressure as resulting from the pumping action of the heart.
• They have fibrous outer wall so as to withstand high pressure
• They are found deeply in the body; for protection against mechanical damage.
• They have a pulse beat corresponding to the heart beat; to permit rhythmic blood flow.
• Their walls are elastic to allow stretching due to high blood pressure.
• They have no valves except at the base of the pulmonary artery and aorta.
• They have narrow lumen than veins which maintains blood flow at high pressure.
• They carry oxygenated blood except the pulmonary artery and umbilical artery.
• They all carry blood from the heart to other parts of the body.

Adaptations of capillaries

• They have a large surface area for exchange of materials.
• They have very thin walls for faster diffusion of materials.
• They have a high diffusion gradient leading to rapid diffusion of materials.
• Slow movement of blood in capillaries makes exchange of materials efficient.

(c).

Although an artery has a thicker wall than a vein of the same size, the absolute thickness of a vessel depends on its absolute size. A smaller artery may have a thinner wall than a larger vein.

Question 31.

(a). With examples, describe the different leaf varieties adopted by plants to suit in various environments
(b). Describe the non-specific and specific mechanisms utilized by the human body to fight against invading pathogens ***(09 marks)***

(a).

Floral leaves (bracts); Poinsettias and dogwoods have relatively inconspicuous, small, greenish-yellow flowers. However, both plants produce large modified leaves, called bracts. These bracts surround the true flowers and perform the same function as showy petals

Spines; The leaves of many cacti, barberries and other plants are modified as spines; reduces water loss and also may deter predators.

Reproductive leaves; Several plants, notably Kalanchoë, produce tiny but complete plantlets along their margins. Each plantlet, when separated from the leaf, is capable of growing independently into a full sized plant. The walk-ng fern (Asplenium rhizophyllum) produces new plantlets at the tips of its fronds.

Window leaves; Several genera of plants growing in arid regions produce succulent, cone-shaped leaves with tra-nsparent tips that admit entry of light allowing photosynthesis to take place beneath the surface of the ground.

Shade leaves; Leaves produced where they receive significant amounts of shade tend to be larger in surface area, but thinner and with less mesophyll than leaves on the same tree receiving more direct light.

Insectivorous leaves; Are modified to trap insects, with some digesting their soft parts. Plants with insectivorous leaves often grow in acidic swamps deficient in needed elements, or containing elements in forms not readily available to the plants; this inhibits the plants' capacities to maintain metabolic processes sufficient to meet their growth requirements. Their needs are, however, met by the supplementary absorption of nutrients from the animal kingdom.

(b).

Non-specific defence mechanisms

- Skin is a physical and hostile barrier covered with oily and acidic (pH from 3 to 5) secretions from sweat glands.
- Antimicrobial proteins (such as lysozyme, which breaks down the cell walls of bacteria) are contained in saliva, tears, and other secretions found on mucous membranes.
- Cilia that line the lungs serve to sweep invaders out of the lungs.
- Gastric juice of the stomach kills most microbes.
- Symbiotic bacteria found in the digestive tract and vagina outcompete other organisms that could cause damage.
- The inflammatory response in response to pathogens.

Specific defence mechanisms

- Phagocytes (neutrophils and monocytes) that engulf pathogens by phagocytosis.
- Natural killer cells (NK cells) attack abnormal body cells (such as tumors) or pathogen-infected body cells.
- Complement system; These proteins help attract phagocytes to foreign cells and help destroy foreign cells by promoting cell lysis (breaking open the cell).
- Interferons; secreted by cells invaded by viruses that stimulate neighboring cells to produce proteins that help them defend against the viruses.

Question 32.

(a).Discuss how the human body responds to a viral infection ***(15 marks)***

(b).What difficulties does the human body have in defending against HIV that causes AIDS (acquired immunodeficiency syndrome)? ***(05 marks)***

(a).

When a virus enters the body, various leukocytes (white blood cells) will recognize the virus as an antigen. Antigens circulating in body fluids stimulate the humoral immune response. Specific B cells that recognize an antigen proliferate (a process called clonal selection), producing two kinds of B cells: plasma cells and memory cells. The plasma cells release antibodies, proteins that bind with and inactivate antigens (the virus in this case). Memory cells provide protection against future invasions of the same virus. In addition to the humoral immune response, non specific white blood cells, such as neutrophils, phagocytic macrophages, and natural killer cells, also attack the virus. They are responsible for attacking and removing antigens inactivated by antibodies. The humoral immune response responds to viruses that are circulating in body fluids. If, however, some viruses infect body cells, the cell-mediated immune response is activated. A normal, uninfected cell is identified as a self-cell by special molecular markers called the histocompatibility complex, or MHC. However, when a virus is actively replicating inside a cell, both self and non-self markers are displayed. Specific T cells recognize these markers, proliferate by clonal selection, and produce killer T cells and helper T cells. The killer T cells destroy the infected cells. Helper T cells in cooperation with macrophages (that attack and engulf the infected cells), produce chemical signals called interleukins that stimulate the proliferation of B cells and more T cells. In addition, special proteins (complement) proteins destroy the infected cells by puncturing holes in them (lysis).

(b).

HIV is different from most other viruses because it attacks helper T cells. When T cells become infected, the cell mediated response is activated. This response stimulates the production of helper T cells, killer T cells, and B cell. As helper T cells increase in number, however, more and more of them become infected. Eventually, most T cells are destroyed, allowing the proliferation of opportunistic diseases such as pneumonia and skin cancer (Kaposi's sarcoma). Eventually, these opportunistic diseases kill the infected person. In addition, some HIV may begin a lysogenic cycle in which the virus remains hidden and temporarily inactive within the DNA of the host cell. These host cells do not display non-self markers and cannot be detected as abnormal by T cells. In addition, HIV undergoes mutations making antibodies produced earlier by the immune system obsolete.

Question 33.

(a).What is meant by

(i).Pressure potential ***(02 marks)***

(ii).Solute potential *(02 marks)*
(b).What is the effect of lowering the solute potential on the
(i). Water potential of a plant tissue *(03 marks)*
(ii).Mechanical support in herbaceous plants *(03 marks)*
(c).Explain the significance of a transport system in organisms *(10 marks)*

(a)(i).

Pressure potential is the pressure exerted by the cell wall against the protoplasmic contents preventing further expansion of the cell. Pressure potential is maximum at full turgidity and is a positive component of water potential.

(a)(ii).

Solute potential is the component of water potential due to presence of solutes in the system. It is a negative component of water potential.

(b)(i).

Provided pressure potential is constant; lowering solute potential also lowers water potential because a solution with a low solute potential has a high solute concentration which makes water potential more negative.

(b)(ii).

Lowering solute potential increases solute concentration hence lowering the water potential; osmotic intake of water is increased raising turgidity of the cells; hence increasing mechanical support in herbaceous plants.

(c).

In plants

• Translocation of organic substances; newly synthesized organic molecules are moved to the phloem from the leaves to the stems and roots for storage or to the growing parts of the plants for immediate use.
• Transport of water and minerals; water and mineral nutrients dissolved in it are absorbed from the soil by the root hairs and then move into the xylem to the leaves where they are required for photosynthesis.
• Cooling of plants; through the evaporation, water inform of vapour is lost from the plant and causes cooling.
• Movement of waste products; such as toxic minerals, excess water and acids are transported from their sources to places where they can be eliminated eg leaves and fruits.
• Support in herbaceous plants; continuous osmotic intake of water creates turgidity in herbaceous plants which is the basis for support in such plants.

In animals

• Transport systems ensure oxygen delivery from the lungs to all parts of the body.
• Transport systems ensure distribution of hormones from their site of production to their target sites
• Transport systems ensure distribution of heat in the body and aids in temperature control.
• Transport systems prevents infection by transportation of white blood cells.
• Movement of waste products; such as toxic minerals, excess water & acids, carbondioxide are transported from their sources to places where they can be eliminated
• Transport systems ensure transportation of digested food from the digestive system to other parts of the body for use.

Question 34.

(a).Compare the circulatory systems of fish and mammals *(06 marks)*
(b)(i)Distinguish between plasma cells and memory cells *(03 marks)*
(b)(ii)Explain how T lymphocytes achieve immunity against diseases in humans *(11 marks)*

(a).

Similarities

Both have closed circulation
Both utilize the heart as the contractile pumping device

Differences

Circulatory system in fish	Circulatory system in mammals
Has single circulation	Has double circulation
Heart divided into two chambers	Heart divided into four chambers
Septum is absent	Septum is present

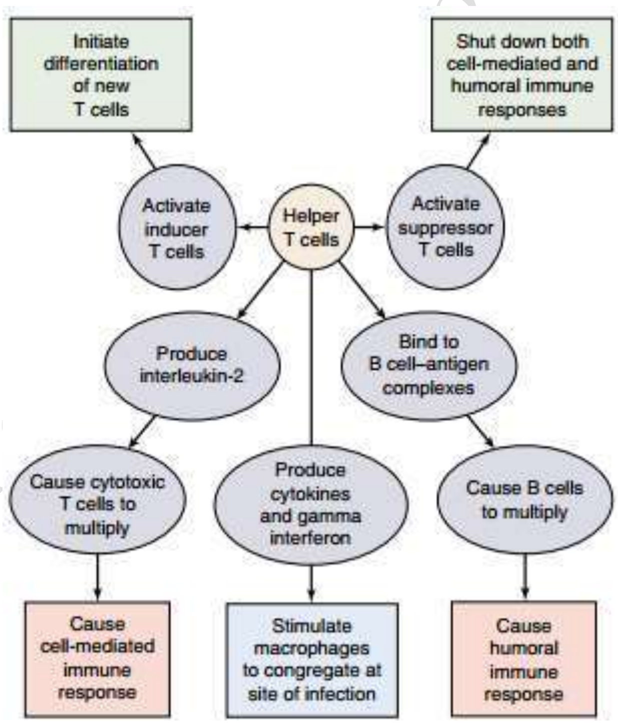
Deoxygenated blood flows from heart to gills	Deoxygenated blood flows from heart to lungs
Oxygenated blood flows from gills to body cells.	Oxygenated blood flows from lungs to body cells.

(b)(i).

Plasma cells	Memory cells
Short lived antigen specific B cells	Long-lived antigen B cells
Release antibodies in response to the immediate antigen invasion	Release antibodies to eliminate any *subsequent* invasion by the same antigen
Provides immunity to first time occurrence of the disease.	Provides immunity to many diseases after the first occurrence of the disease.

(b)(ii).

The cell-mediated response uses mostly T cells and responds to any non self-cell including cells invaded by pathogens. When a nonself cell (viral infected cells, cancer cells or transplant tissue cells) binds to a T cell, the T cell undergoes clonal selection, initiating the following chain of events. T cells produce cytotoxic T cells. These cells destroy non-self cells by lysis. T cells produce helper T cells; which bind to macrophages. Macrophages that have engulfed pathogens display aberrant plasma membrane markers which Helper T cells identify as non-self and bind Helper T cells then produce interleukins to stimulate a proliferation of T cells and B cells. When helper T cells bind with macrophages, they release interleukins, or communication chemicals between leukocytes. The interleukins initiate a sequence of positive feedback events that result in the proliferation of more interleukins, promote inflammation and stimulate B cells to produce antibodies against antigens. Once adequate immune response has been evoked and the non self cells have been clear, the T-suppressor cells proliferate to terminate the immune response.



Question 35.

(a).Outline the main adjustments that occur to the heart and the circulatory system just before, during and after a 100m race ***(12 marks)***

(b).When an animal is wounded, its overall blood pressure rises but the area in the vicinity of the wound swells as a result of local vasodilation. Explain the significance of this ***(04 marks)***

(c).Explain the advantages of supplying systemic circulation with blood of higher pressure and the pulmonary circulation with blood at lower pressure ***(04 marks)***

(a).

Before the race; adrenaline is secreted in anticipation of the race. This stimulates vasoconstriction throughout the body in all but the most vital organs; hence blood pressure is raised. Heart rate is also increased; thereby raising the cardiac output (extra blood is also passed to the general circulation from the spleen.

During the race; increased metabolic activity takes place during the race, especially in the skeletal muscles. Increased carbondioxide levels in these regions promote local vasodilation. The increased body temperature further enhances vasodilation. The general increase in carbondioxide level in blood is noted by chemoreceptors of the aorta and carotid bodies which in turn stimulate the vasomotor centre to promote vasoconstriction. This increases blood pressure and hence speeds up blood flow. Heart rate is increased and a more complete emptying of the ventricles occurs. Towards the end of the race, the muscles will be respiring anaerobically producing lactic acid. Strong contractions of the muscle squeeze the veins and promote faster venous return of blood to the heart.

Recovery; oxygen debt is paid off and the lactic acid removed from blood system. Tissues subside in activity and the carbondioxide levels decreases. Consequently, there is return to normal of the heart beat and blood pressure.

(b).

Local vasodilation in the wounded area enables more blood carrying oxygen and nutrients to arrive there and speed up the process of repair and replacement. Likewise the waste products of metabolism are cleared from the injured site at a faster rate. Increased body blood pressure prepares the body of the animal to respond to any further stress more readily and efficiently.

(c).

The oxygenated blood of the systemic circulation reaches blood capillaries at a much higher pressure. This is essential for the efficient functioning of organs and tissue fluid formation as well as permitting a high metabolic rate and a higher body temperature to be maintained. It is essential that a much lower pressure is developed in the pulmonary artery inorder to prevent rupture of the delicate pulmonary capillaries.

Question 36.

(a).Describe how carbondioxide in blood is expelled as gaseous carbondioxide in lungs ***(08 marks)***

(b).Explain the following observations

(i). Rise in temperature affects the dissociation of haemoglobin and is physiologically advantageous to survival of the organisms ***(03 marks)***

(ii).The oxygen dissociation curve of small mammals is displaced to the right of that of humans ***(02 marks)***

(iii).The oxygen dissociation of the fetus is to the left of its mother ***(04 marks)***

(iv).The oxygen dissociation curve of high altitude mammals is to the left of that of most other mammals

(a).

Carboxyhaemoglobin reaches the lungs and takes up oxygen to from oxyhaemoglobin which has a lower affinity for H+ ions than haemoglobin and hence releases H^+. H^+ combines with hydrogen carbonate ions in the red blood cell forming carbonic acid. Carbonic acid dissociates to carbondioxide and water catalysed by carbonic anhydrase. As a result of loss of hydrogen carbonate ions from the red blood cell, further hydrogen carbonate ions diffuse into the red blood cell from the plasma. More carbonic acid is formed and dissociates into more carbondioxide and water. Carbondioxide diffuses out of the RBC; dissolves in the fluid lining of the alveolus and eventually get excreted from the body via the lungs.

(b)(i).

Rise in temperature reduces the affinity of haemoglobin and an increased dissociation of oxygen. Thus the dissociation curve is shifted to the right. This is physiologically important as more oxygen is delivered to the active regions/ tissues.

(b)(ii).

Small mammals possess a large surface area to volume ratio; thus possess a much higher metabolic rate to generate more heat than the humans. Therefore it is appropriate that oxygen should be released much more readily.

(b)(iii).

The position of the curve of the foetus relative to the that of its mother means that its blood has a greater affinity for oxygen than the maternal blood. This is because the foetus must obtain all its oxygen from the mother at the placenta. Therefore at any given oxygen partial pressure, the foetal blood will take up oxygen from the maternal blood and will always be more saturated with oxygen than the maternal blood.

(b)(iv).

Blood has a high affinity for oxygen and is able to combine with it at low oxygen tensions experienced at low altitudes.

Question 37.

(a) State three (3) ways how flow of blood is maintained in a mammal *(03 marks)*
(b).Of what significance is blood circulation system to living organisms? *(10 marks)*
(c).Explain how each of the following affects the efficiency of oxygen transport in living organisms
(i). Increasing carbon dioxide tension *(04 marks)*
(ii). Increasing carbon monoxide concentration *(03 marks)*

(a).

• The heart pumps blood under high pressure through the aorta to all parts of the body
• Contraction of muscles all over the body aids venous blood circulation
• Inspiratory movements aids venous blood flow from abdomen into the thorax and back to the heart
• The hormones adrenaline and vasopressin (ADH) increase blood pressure
• Gravity causes return /flow of blood from regions of the head back to the heart

(b).

• Blood platelets important in causing blood clot; preventing excessive blood lose in case of injuries;
• White blood cells/ lymphocytes produce antibodies; for defence against diseases;
• Maintenance of constant pH, through maintenance and circulation of the plasma proteins;
• Growth, development and coordination, by transport of hormones and other regulatory substances from the endocrine glands to all parts including the target organs
• Important in homeostasis by delivering normal levels of all essential materials to the tissue fluid needed for metabolism
• Blood pigments like haemoglobin; transport oxygen needed for respiration from lungs to the respiratory tissues; also transports carbon dioxide from respiring tissues to the lungs for expulsion out of the body;
• Transports waste products of metabolism from cells, tissues, organs producing them to respective excretory organs that excrete them out of the body;
• Transports soluble products of digestion from the intestine to organs like liver, muscles where they are used or stored;
• Distributes heat generated from metabolism to all body parts for maintenance of internal body temperature constant/ temperature regulation;
• It is a communication medium, where it carries hormones from endocrine glands to target cells/ organs to cause response;

(c)(i).

Decreases the affinity of haemoglobin for oxygen/ shifts the oxygen dissociation curve to the left; carbon dioxide dissolves to release carbonic acid which dissociates to release more hydrogen ions; lowering pH stimulating rapid break down of oxyhaemoglobin; bringing about rapid delivery of oxygen to respiring tissues;

(c)(ii).

Carbonmonoxide combines irreversibly with haemoglobin forming carboxyhaemoglobin which does not dissociates; few haemoglobin molecules are available for carriage of oxygen; reducing the capacity of red blood cells to transport oxygen to respiring tissues;

Question 38.

(a).Briefly describe how dissolved blood carbon dioxide is expelled in gaseous form by the lungs. *(10 marks)*
(b).Describe the structures involved in the translocation of organic solutes between the different parts of a flowering plant. *(10 marks)*

(a).

The carbon dioxide in pulmonary capillaries mainly in bicarbonate (HCO_3^-) form; Reacts with hydrogen ions (H^+) to form carbonic acid (H_2CO_3); Carbonic acid dissociates into water (H_2O) and carbondioxide gas(CO_2); Carbondioxide diffuse into alveoli; thoracic pressure increases above atmospheric pressure; Due to contraction of internal intercostal muscles, lowering of the rib cage, doming of diaphragm and reduced thoracic volume; All of which result in Carbon dioxide exiting (being expelled from) the lungs;

(b).

The transportation of organic solutes usually from leaves to other parts of the flowering plant occurs in phloem tissue; Phloem is made up of sieve tube elements, companion cells; phloem parenchyma and phloem fibres. Sieve-tube elements; are long tube-like structures; arranged longitudinally; and are associated with the companion cells; Their end walls are perforated in a sieve-like manner to form the sieve plates; A mature sieve element possesses a peripheral cytoplasm and a large vacuole but lacks a nucleus; Companion cells are specialized parenchymal cells, which are closely associated with sieve tube elements; The sieve tube elements and companion cells are connected by pit fields present between their common longitudinal walls; Phloem parenchyma; is made up of elongated; tapering; cylindrical cells; which have dense cytoplasm and nucleus; The cell wall is composed of cellulose and has pits through which plasmodesmatal connections exist between the cells; Phloem fibres (bast fibres) are made up of sclerenchymal cells; These are much elongated; unbranched; and have tapered apices; The cell wall of phloem fibres is quite thick; At maturity, the fibres lose their protoplasm and die;

Question 39.

Explain

(a).The law of limiting factors. ***(06 marks)***

(b).Why oxygen dissociation curve of haemoglobin has a sigmoid shape. ***(10 marks)***

(c).Compare the efficiency of a sigmoid oxygen dissociation curve of an animal as compared to non-sigmoid one ***(04 marks)***

(a).

The law of limiting factors states that when a chemical process is affected by more than one factor, its rate is limited by that factor which is nearest to its minimum value;

A limiting factor is a resource or environmental condition which limits the growth, distribution or abundance of an organism or population within an ecosystem. These can be either physical or biological factors which can be identified through a response of increased or decreased growth, abundance, or distribution of a population, when the factor is changed and when the other factors necessary to life are not.

(b).

The curve is sigmoid because of the positive co-operative effect in which oxygenation of the first heme increases affinity for the 2^{nd},3^{rd} and the 4^{th} in turn. The lower left tail of the curve rises slowly as hemoglobin loads more oxygen at increasing (but still low) ambient tissue partial pressure of oxygen. But as each heme group binds an oxygen molecule, this changes the shape of globin in a way that facilitates the binding of the next oxygen, then that further facilitates the third, and that one the fourth. Thus, there is a positive feedback effect in which oxygen loading accelerates the loading of more O_2, accounting for the rapidly rising mid portion of the curve. Toward the upper right, at high ambient PO_2, the curve plateaus as the haemoglobin approaches approximately 100% saturation and can't load any more.

(c).

With a sigmoid oxygen dissociation curve, there is efficient loading and unloading of oxygen precisely where needed in the quantities required, by passively following local concentration gradients. Without the sigmoid shape of the hemoglobin oxygen-saturation curve, oxygen would be less readily taken up in the alveoli and less readily unloaded peripherally.

Question 40.

(a).Explain what is meant by a cardiovascular Disease (CVD)? ***(01 marks)***

(b).Cardiovascular diseases and their complications such as stroke are on a rise. Outline some of the risk factors for cardiovascular disease and their effects ***(05 marks)***

(c)(i). How does a diet of high fat and inactivity leads to risk of cardiovascular disease ***(05 marks)***

(c)(ii).Explain why a diet high in carbohydrates can lead to obesity ***(03 marks)***

(d).Outline the events that result in a stroke following formation of an internal blood clot ***(06 marks)***

(a).

Disease of heart or blood vessels eg atherosclerosis that leads to narrowing of lumen of blood vessels

(b).

- Smoking; makes platelets sticky & reduces oxygen carrying capacity of haemoglobin
- Inactivity (sedentary lifestyle); leads to energy imbalance and weight gain
- Obesity; raises the circulating levels of cholesterols that end up lodging in blood vessels

• Diet high in salt and fats; raises blood pressure and circulating cholesterols.
• Diabetes mellitus; excess sugars can be converted to lipids which can lodge in blood vessels
• High blood pressure; increase risk of vascular rupture.

(c)(i).

• Leads to energy imbalance; can cause weight gain/obesity
• Leads to diabetes; risk factor for cardiovascular disease
• Increase of blood pressure; increases risk of damage/rupture
• Higher chance of atherosclerosis; narrowing of lumen
• Higher low density lipoproteins to high density lipoprotein level; linked with CVD

(c)(ii).

Carbohydrates are a source of a high amount of energy; If the energy input (carbohydrates) is greater than the output excess carbohydrates are converted into fat resulting in weight gain/ energy imbalance;

(d).

Blood clot leads to reduced blood flow; less/no oxygen reaches heart/brain; less aerobic respiration; no ATP produced; Brain/heart needs a lot of ATP to function; Lactic acid produced from anaerobic respiration; inhibits enzymes/is toxic;

Question 41.

(a).The heart forces blood at the same rate but at different pressures along the two systems of double circulation. Explain how the mechanism that controls each heart beat and the structure of the heart enables it to do so ***(08 marks)***
(b).Describe the part played by hormones and nervous system in controlling heart rate ***(08 marks)***
(c).Describe how lymph is formed ***(04 marks)***

(a).

Sinoatrial node/ pacemaker initiates heart beat; wave of excitation spreads across both atria causing virtually simultaneous contraction; wave reaches atrioventricular node; bundle of His/ purkyne tissue; spreads down the ventricles at same time; to the base/ apex; from where it radiates upwards; ventricles contract simultaneously from the base upwards/ both will beat/ contract at the rate. Nerves (vagus nerve and sympathetic nerves) act on the sinoatrial node to alter the rate; pressure produced by the contraction of the cardiac muscle; blood ejected from the left ventricle at higher pressure/ converse for the right ventricle.

(b).

Chemoreceptors in aorta/ carotid artery; detect changes in blood carbondioxide; stretch/ pressure receptors in main blood vessels; send impulses to control centre (cardiac inhibitory centre or excitatory center) in the medulla; impulses from the aorta/ carotid bodies decrease heart rate. Impulses from vena cava increases heart rate; parasympathetic/ vagus nerves decrease heart rate; sympathetic nerves take nerve impulses from excitatory centre to sinoatrial node increasing activity of sinoatrial node; parasympathetic impulses are transmitted from the inhibitory centre to the sinoatrial node; decreasing activity of the sinoatrial node. Adrenaline from the adrenal glands, noradrenaline, thyroxine increase heart rate; and bind to their receptors at the sinoatrial node.

(c).

Capillary walls permeable to water; high blood pressure at the arterial end of capillary; forces water plus small solutes and ions out of the capillary; to form tissue fluid; not all tissue fluid returns to capillaries; higher pressure in the tissue fluid than lymph; excess drains into lymphatic vessels; now called lymph; fats added; lymph node products/ antibodies added.

Question 42.

(a).Outline the significance of the different components of the blood plasma ***(08 marks)***
(b).Describe fully how mammalian blood picks up and transports respiratory gases ***(12 marks)***

(a).

Chemical component of plasma	Function
Water	Solvent for many materials; transport medium; regulates blood volume/ pressure
Carbondioxide / HCO_3^-	Waste product of respiration

Proteins/ albumins/ globulins	Enzymes; transport of hormones, fat soluble vitamins, iron, calcium, cholesterol; antibodies, blood clotting; buffers
Hormones	Control of blood sugars, body water content; growth; metabolic rate
Sugars	Respiratory substrates; synthesis of other compounds
Fatty acids	Respiratory substrates; synthesis of compounds
Glycerol	Synthesis of other compounds like lipids
Amino acids	Synthesis of proteins; buffers
Urea/ other excretory products	Removal of excess nitrogen
Vitamins	Required in small amounts for good health
Mineral ions	Regulation of solute potential, pH level in blood; clotting factors

(b).

Oxygen diffuses into the alveolar capillaries; down a concentration gradient; across the capillary endothelium / plasma; combines with haemoglobin in the red blood cells; iron atoms within haemoglobin combine with oxygen; in areas of high oxygen concentration/ lung; each haemoglobin molecules can combine with 4 oxygen molecules; amount of oxygen that can combine with haemoglobin determined by the partial pressure/ concentration of oxygen saturation of haemoglobin at different partial pressures of oxygen shown by the oxygen dissociation curve. Carbondioxide from the cells diffuses across the tissue fluid/ capillary endothelium/plasma down a concentration gradient; some carbondioxide transported in solution; as carbonic acid; more carbondioxide transported combined with proteins as carbaminohaemoglobin; amount carried this way depends on the amount of oxygen being carried/ the less oxygen being carried, the more carbondioxide can be carried; most carbondioxide transported as hydrogen carbonate; carbondioxide combines with water inside red blood cells to form carbonic acid; catalysed by carbonic anhydrase; carbonic acid dissociates into hydrogen ions and hydrogen carbonate ions. Hydrogen ions displace oxygen from haemoglobin; haemoglobinic acid formed; buffering action of haemoglobin; allows large quantities of carbonic acid to be transported to lungs without large shifts into blood pH. The negatively charged bicarbonate ions diffuse from the red blood cells to plasma; form sodium hydrogen carbonate; positively charged red blood cells attract negatively charged chloride ions from plasma/ chloride shift.

Question 43.

(a). Give an illustrated account of the structure and function of the stomata, describing the theories put forward to explain their opening& closure ***(16 marks)***

(b).Explain how the transport of water from soil to the root xylem aid transportation of nitrogen from the soil throughout the plant ***(04 marks)***

(a).

Structure; stomata are pores surrounded by two banana or kidney shaped guard cells; Guard cells contain chloroplasts; thicker/ less elastic cellwall on the side nearest to the pore; and is thinner/ more elastic wall away from the pore; cellulose microfibrils of the cell wall run across the width of the cell; forcing cell to elongate rather than expand sideways when turgor increases.

Functions; gaseous exchange; for respiration/photosynthesis; transpiration via stomata aids water transport up the xylem evaporation of water helps cool plants; enable plant regulate balance between the need to obtain carbondioxide and to conserve water.

Theories; potassium ions accumulate in the guard cells in response to light; pumped in by active transport; light may activate ATPase; positive ions balanced electrically by negative ions/ malate from starch stored in guard cells or by negative chloride ions entering with potassium ions; or hydrogen ions may be pumped out and potassium ions may then enter to balance charge; or sugar accumulates as a photosynthetic product within guard cells; water moves in down a water potential gradient by osmosis from adjacent cells; as guard cells increase turgidity, only thinner wall can stretch causing cells to assume a semicircular shape, creating open pore between the pair of guard cells;

Theory for closure of stomata; abscissic acid concentration increases when loss is high triggers potassium ion pump which acts to pump theses ions out of the guard cells; turgor reduced/ stomata close; darkness, potassium ions leak out of the guard cells; water potential increases and water moves out of the guard cells which become flaccid and the stomata close.

(b).

Active transport of nitrogen as nitrates; require ATP; passive uptake occurs by diffusion in which the nitrates are taken in solution; ions move through the apoplast only until endodermis; then cross cell surface membrane to enter cytoplasm of endodermal cells; membrane allows selection of which ions reach the xylem.

Question 44.

(a).How are root hairs adapted to function ***(06 marks)***
(b).State the forces that prevent the column of water in the xylem from breaking apart when it is pulled upwards in the trunk of a tall tree ***(04 marks)***
(c).Explain the role of transpiration in the transport of water from the soil to leaf cells of a tree. ***(10 marks)***

(a).

• Lacks a cuticle and a suberized cell wall; creates a thin membrane over which water easily permeates.
• Root hairs are slender and flexible for easy penetration through soil.
• Root hairs are numerous to increase surface area for absorption.
• Contain numerous mitochondria; generate enough ATP that powers active uptake of mineral salts.
• They lack the cuticle which would otherwise restrict water absorption.
• Centre of the root hair is a vascular tissue; transports water and mineral salts to the rest of the plant.
• They are long and narrow; increases surface area to volume ratio that increases rate of water absorption.
• Cell sap within root hairs has more negative water potential / higher solute potential than the available soil water ;allows water to move into them by osmosis.

(b).

• Tensile strength of water column
• Adhesion between water molecules and the walls of the xylem vessels
• Cohesion forces between one water molecule and another.
• Transpiration pull.

(c).

Loss of water from the open stomata by transpiration causes withdrawal of water from the sub-stomatal airspaces which in turn withdraw water from the surrounding cells (mesophyll and epidermal cells). These cells develop a negative water potential as a result of loss of turgidity; developing a tension. To overcome the tension, they draw water from the leaf xylem; which in turn develops a tension and draws water from the stem xylem; this tension created is transmitted to the root xylem; which in turn draws water from the cortical cells of the roots and eventually from the surrounding soil solution. The stream of water is maintained unbroken from the roots to the leaves by the transpiration pull due to high cohesive forces between water molecules and the strong adhesive forces between the walls of the xylem & water molecules.

Question 45.

(a). Describe the structure of the vascular system in higher plants ***(07 marks)***
(b). How is the system described in (a) above adapted to its functions ***(13 marks)***

(a).

Vascular system in plants is made up of phloem and xylem. The xylem is made up of tracheids; xylem vessels; parenchyma cells and fibres. The phloem is made up of sieve tube elements; companion cells; parenchyma cells; fibres and sclerenchyma pores. Both tissues occur throughout the plant body. Primary xylem have thickening i.e annular/ spiral/ reticular etc

(b).

• End walls of the vessel elements break down; during development so that a continuous tube is made
• Cell walls of vessels are impregnated with lignin; increase adhesion for upward movement of water
• Tracheids and xylem vessels are placed end to end; to allow continuity of flow.
• Broken end walls of the xylem vessels; permit continuity of water flow.
• Xylem vessel is hollow; allows water to move freely without any obstruction
• Xylem vessels are woody; enables them provide support.
• The side walls of vessels & tracheids are perforated to allow side way movement of water between cells
• Tracheids tapering/ elongated ends with bordered pits; to allow water pass from one cell to another.
• Elongated and narrow tubes of tracheids increase capillarity

• The fibres are dead at maturity; provide strength and support
• Sieve tube elements are joined end to end; have perforated end walls; forming a sieve plate; that allows flow of materials from one cell to another.
• Sieve tube elements lack nuclei; cytoplasm pushed to the periphery; creates enough room for mass flow
• They are connected by the plasmodesmata to companion cells which are metabolically active cells
• Sclerenchyma/ sclereids are lignified for support.

Question 46.

(a).Describe the causes, effects and risk factors of Coronary Heart Diseases and Outline the risk factors of Coronary Heart Disease. ***(10 marks)***
(b)(i) How is tissue fluid formed and returned to circulatory system?
(ii) Describe any factors that may cause accumulation of tissue fluid.

(a).

High blood pressure damages lining of coronary artery; fatty deposits/cholesterol builds up beneath the lining in the wall (atheroma). The atheroma breaks through the lining forming a plaque on the lining of the lumen and this cause turbulent blood flow, a blood clot (thrombus) forms. This blocks the coronary artery therefore less blood flow to the heart muscle less glucose and oxygen delivered the heart muscle cannot respire so it dies (myocardial infarction).

Risk factors for coronary artery disease
Age, gender and ethnicity
Saturated fats (increases low density lipoproteins; deposits cholesterol in the arteries to forrn atheroma) Salts (increases blood pressure; lowers water potential of blood so it holds the water)
Smoking (nicotine increase heart rate and makes platelets more sticky blood clot.
Obesity and sedentary life style

(b)(i).

At the start of the capillary (arterial end) there is a buildup of hydrostatic pressure; this pushes fluid out of the capillary via the capillary pores; the fluid carries the nutrients with it; the fluid surrounds the cells and this is tissue fluid. At the other end of the capillary (venous end); the fluid moves back in by osmosis; the capillary has a low water potential due to the presence of proteins (too large to move out of capillaries); any excess tissue fluid is picked up by the lymphatic system and deposited in the venous system.

(b)(ii).

High blood pressure; increases hydrostatic pressure so more tissue fluid is formed than what is drained
Diet low in protein; reduces oncotic pressure; less tissue fluid thus drains back into the venous end of the capillary system;
Lymphatic obstruction; prevents venous drainage

Question 47.

(a)(i).Discuss the benefit of fetal haemoglobin having high affinity. ***(04 marks)***
(ii).Why do adults not keep with fetal haemoglobin? ***(02 marks)***
(b).Compare the circulatory systems of fish and mammals. ***(05 marks)***
(c). Explain how T-lymphocytes achieve immunity against diseases in humans. ***(06 marks)***

(a)(i).

Fetus gains all its oxygen from the mother across placenta. Fetal haemoglobin's ODC ties to the left. It has high affinity so the oxygen dissociates from the mother's haemoglobin and associates with the fetal haemoglobin at the low partial pressures of oxygen in the placenta so it has enough oxygen for its needs. Fetal Hb thus has a high saturation of oxygen even at low partial pressures of oxygen.

(a)(ii).

Oxygen would not be released readily enough because affinity of fetal haemoglobin would be very high; as the high partial pressure of oxygen in the lungs allows loading with haemoglobin of lower affinity.

(b).

In both blood flows in closed blood vessels.
In both blood is pumped by contractions of the heart.
In both blood is oxygenated and supplied to the respiring tissues of various parts of the body
In both blood leaving respiring tissues is deoxygenated.

In both respiratory gases and soluble products area transported/ blood contains pigments
In both blood flow is unidirectional

Differences

Blood flow in fish	Blood flow in mammals
Blood in the heart flows through one atrium and one ventricle.	Blood in the heart flows through two atria and two ventricles
The heart contains and pumps only deoxygenated blood	The heart contains and pumps both oxygenated and deoxygenated blood
Deoxygenated blood leaves the heart via the aorta	Oxygenated blood leaves the heart via aorta
Single blood circulation	Double blood circulation
Blood flows under low pressure and speed	Blood flows under high pressure and speed;
Oxygenation of blood occurs in the gill lamellae	Oxygenation of blood occurs in the lungs capillaries
Blood flows through sinuses between body tissues	Blood flows in blood capillaries between body tissues

(c).

T-Lymphocytes develop an immune system in humans known as cell mediated immune response; microorganisms bind onto receptor molecules on the surface membrane of the T-lymphocytes. They divide repeatedly (proliferate) to form many T_4-cells (helper cells) and T_8 cells (T_8 molecules); T_4 helper cells produce large amounts of lymphokinase; which destroy the micro-organisms/stimulate T-cells to multiply and produce more lymphokinase which stimulates B-cells to produce antibodies; T_8 cells are of 2 types, the killer cells that produce smaller amounts of lymphokinase which kill/destroys body cells infected with viruses/ kill cancer cells/destroy transplanted organs; suppressor cells secrete lymphokinase which decrease the activities of T-cells/white blood cells and phagocytes.

Question 48.

(a).Discuss the internal factors that affect the rate of transpiration ***(06 marks)***
(b).Explain the importance of transpiration in plants ***(14 marks)***

(a).

Root-Leaf Ratio: If the number and total surface area of leaves become much less in comparison with root region (absorption region) the rate of transpiration will reduce.
Leaf area: The greater the leaf area, greater will be the rate of transpiration, and lesser the leaf area the lesser the rate of transpiration.
Internal surface of leaf: Thin cuticle, thin cell walls, exposed stomata and well-developed spongy parenchyma favour transpiration. On the other hand leaves those possesses thick cuticle, thick cell walls, well-developed pallisade parenchyma, sunken stomata etc. will reduced the rate of transpirations.

(b).

Ascent of water and cell sap; Transpiration creates a pull on the water column in the xylem vessel (transpiration pull); as a result, the water absorbed by the root and cell sap goes upwards.
Conduction of water and minerals to leaves: water and minerals conducted to the leaves by transpiration pull. So water, necessary for photosynthesis and Mg, necessary for production of chlorophyll, conducted to leaves by transpiration. So it can be said that transpiration plays an indirect role on manufacturing food by photosynthesis.
Maintaining proper temperature and release of energy in leaf: Leaves are taking energy from the sun every moment. Only 1% of this energy is utilized in different reactions. The rest of the heat energy released by transpiration. If the temperature in leaf does not remain in optimum condition, all the organic activities would have been seized.
Cell division and physical growth: Transpiration indirectly maintains osmosis and thus keeps all the cells rigid. As a result it enhance cell division and development of the organ.
Resistance to Fungal infection: Due to transpiration, there are deposits of certain hygroscopic salts on the leaf surface, which resists fungal infection.
Absorption of CO_2 for photosynthesis: Spongy mesophyll cells of leaves receive CO_2 from air present in the air spaces, by diffusion. For this the outer layer of the spongy mesophyll should always be wet. The air inside the air spaces absorbs water from here and transpires through stomata.

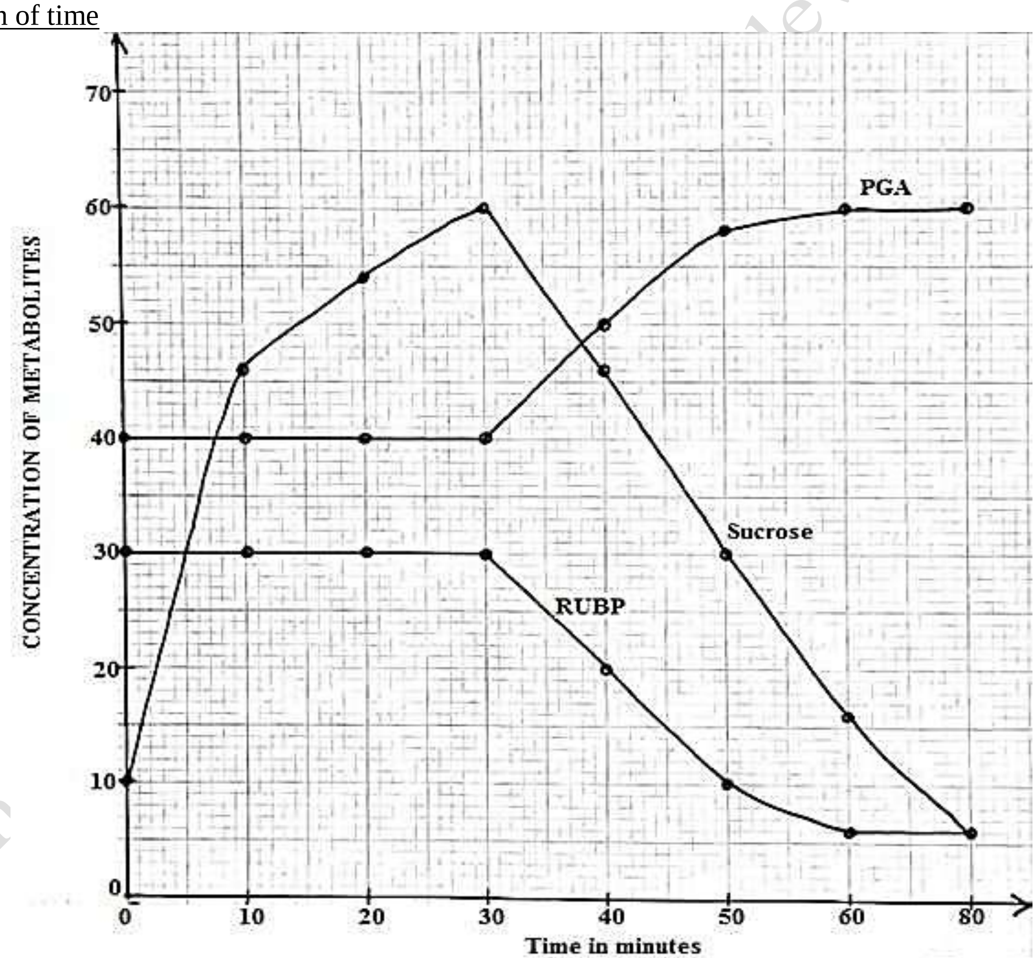
Chapter 5; NUTRITION IN LIVING ORGANISMS

In an investigation to study the effect of light on the physiology and spirogyra, its amount of phosphoglyceric acid (PGA), ribulose by-phosphate (RuBP) and sucrose were measured at different intervals of time in the presence of light. At the 30th minute, light was removed completely. The results obtained are shown in the table below. Study it and answer the questions that follow:

Time in minutes	Amount of metabolites		
	PGA	**RUBP**	**Sucrose**
0	40	30	10
10	40	30	46
20	40	30	54
30	40	30	60
40	50	20	46
50	58	10	30
60	60	06	16
70	60	06	06

(a).Plot the results in a suitable graph. ***(10 marks)***

A graph showing the variation of the concentration of the photosynthetic metabolites (PGA, Sucrose and RUBP) with duration of time



(b). Compare the changes in the amount of PGA and RuBP with time. ***(04 marks)***

From 0 minute to 30 minutes, there is no change in the amount of PGA and RuBP with time; From 30 minutes to 50 minutes, amount of PGA increases rapidly whereas amount of RuBP decreases rapidly; From 50 minutes to 60 minutes, amount of PGA increases gradually whereas amount of RuBP decreases gradually; From 60 minutes to 70 minutes amount of PGA remains constant at its maximum amount whereas amount of RuBP remains constant at its minimum amount;

(c) Explain the changes in the amount of the following with time.

(i) PGA ***(05 marks)***

There is no change in the amount of PGA from 0 minute to 30 minutes; due to presence of light; When light is present, RuBP accepts carbon dioxide, catalyzed by RuBP carboxylase to form PGA; which is reduced to triose phosphate using NADPH and ATP; this ensures that the level of PGA remains constant. From 30 minutes to 60 minutes, amount of PGA increases; because when light was removed, RuBP continues to accept carbondioxide forming PGA; which accumulates due to absence of NADPH and ATP as there is no light; to make them. Presence of NADPH and ATP would reduce PGA to TP; From 60 minutes to 70 minutes, there is no change; in amount of PGA. When amount of RuBP falls so low, carbondioxide fixation stops; and therefore amount of PGA remains constant.

(ii) RuBP ***(05 marks)***

Amount of RuBP does not change from 0 minute to 30 minutes; because RuBP continues to be decarboxylated by Carbon dioxide to PGA; then reduced to TP. Some of the TP is then reconverted back to RuBP in the presence of light thus maintaining constant levels of RuBP. From 30 minutes to 60 minutes, amount of RuBP decreases; because it was being decarboxylated to PGA by RuBP carboxylase; its regeneration also stopped because of absence of NADPH and ATP as a result of the removal of light; From 60 minutes to 70 minutes, there is no change in amount of RuBP. When amount of RuBP falls so low, carbondioxide fixation stops and therefore amount of RuBP remains constant;

(iii) Sucrose ***(06 marks)***

From 0 minutes to 30 minutes, amount of sucrose increases rapidly; Presence of light excites chlorophyll molecules to emit electrons; these electrons pass through electron transport system generating ATP from ADP and an inorganic phosphate; Light splits water molecules to produce protons which are used to reduce NADP to NADPH; NADPH and ATP are then used to reduce PGA to TP; some TP is then converted to sucrose; hence its rapid increase. From 30 minutes to 70 minutes, amount of sucrose decreases rapidly; because light was removed; In absence of light, no further sucrose is synthesized due to absence of ATP and NADPH; That one present is used up in metabolic processes such as respiration to provide energy for growth;

(d) Explain how carbon dioxide is fixed by C4 plants. ***(05 marks)***

In the cytoplasm of the mesophyll cells, Phosphoenol pyruvate (PEP) combines with carbon dioxide; catalyzed by PEP carboxylase to form oxaloacetic acid; which is converted to malic acid; Malic acid is then shunted to the chloroplast of the bundle sheath cells; and converted to pyruvate and carbon dioxide; The carbon dioxide then combines with RuBP to form GPA;

(e) Give the various ways in which C3 plants differ from C4 plants. ***(05 marks)***

C_3 plants	C_4 plants
Lack Kraanz anatomy	Exhibit Kraanz anatomy
First CO_2 acceptor is a 5-Carbon RuBP	First CO_2 acceptor is a 3-Carbon PEP
CO_2 fixation occurs once	CO_2 fixation occurs twice
Photorespiration occurs	No photorespiration
Less photosynthetically efficient	More photosynthetically efficient
GPA/GP is the first stable organic product	OAA is the first stable organic product
Enzymes are more efficient at lower temperatures	Enzymes are more efficient at high temperatures
Only RuBP carboxylase enzyme is used	RuBP carboxylase and PEP carboxylase enzymes are used.
Compensation point is attained at higher CO_2 concentration	Compensation point is attained at lower CO_2 concentration
All chloroplasts have identical structure	Chloroplasts are dimorphic (are in two forms e.g. those of palisade cells have grana yet are lacking in those of the bundle sheath cells.

Question 2.

In an experiment to determine factors affecting photosynthesis, seedlings of a plant were divided into two groups and grown under different light intensities. One group of seedlings was grown at constant high light intensity (25 arbitrary units), and another group grown at a constant low light intensity (3 arbitrary units). When the plants were mature, their apparent rates of photosynthesis n milligrams of oxygen released per unit leaf area per hour, were measured over a range of different light intensities. Fig 1 shows the results of the experiment. In addition, some characteristics of the two groups of plants were recorded as indicated in table 1

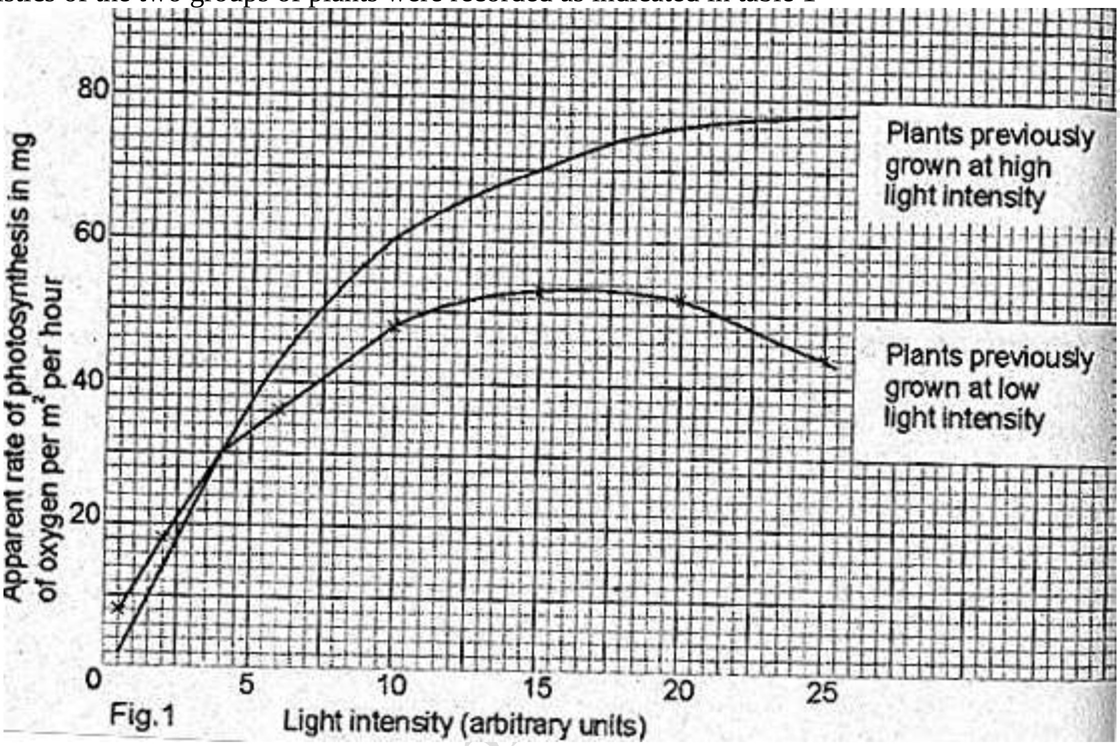


Fig.1

Table 1

Group of plants	Characteristics
Plants grown at high light intensity	Big, dark green leaves with short internodes
Plants grown low light intensity	Small, pale yellow leaves with long internodes

(a). From the graph, state the

(i). differences in the effect of light intensity on the two groups of plants. ***(08 marks)***

Plants grown at high light intensity	Plants grown at low light intensity
At light intensity less than 4 arbitrary units, the rate of photosynthesis is lower	At the same light intensity, rate of photosynthesis is higher
At light intensity above 4 arbitrary units, rate of photosynthesis is higher	At the same light intensity, rate of photosynthesis is lower
Maximum rate of photosynthesis is higher	Maximum rate of photosynthesis is lower
Maximum rate of photosynthesis is attained at a higher light intensity	Maximum rate of photosynthesis is attained at a lower light intensity
Rate of photosynthesis attained a maximum then remained almost constant/ maintained.	Rate of photosynthesis attained a maximum and then declined.
At 15 arbitrary units of light intensity, rate of photosynthesis was still increasing	At the same intensity, rate of photosynthesis attained a maximum
Initial rate of photosynthesis is lower	Initial rate of photosynthesis is higher
At 24 units of light intensity, rate of photosynthesis was at maximum which was maintained	At the same light intensity and beyond, rate of photosynthesis had declined.

(ii). similarities in the effect of light intensity on the two groups of plants. ***(03 marks)***

• Rate of photosynthesis in both groups of plants increases with increase in light intensity (limiting factor); but up to a certain point/ quantity of light intensity.
• At 4 arbitrary units, both groups of plants have equal/ same rate of photosynthesis
• Rate of photosynthesis started at 0.5 arbitrary units of light intensity.

(b). Suggest explanations for the differences you have stated in a(i). above ***(08 marks)***

At light intensity less than 4 arbitrary units, rate of photosynthesis is higher in plants grown at low light intensity because photosynthetic enzymes are more activated than those in plants grown at light intensity. At light intensity above 4 arbitrary units, photosynthetic enzymes in plants grown in higher light intensity are activated; because these plants have better/ greater ability/ more adapted to utilize bright light. Maximum rate of photosynthesis in plants grown in lower light intensity is lower because their metabolic requirements are lower; than those in plants grown in higher light intensity.

(c). Explain the pattern of the curve for plants grown in low light intensity ***(06 marks)***

The rate of photosynthesis increases with increase in light intensity because light is the limiting factor up to 15 arbitrary units of light intensity. Between 15 to 18 arbitrary units of light intensity, the rate of photosynthesis is constant; because the saturation point/ maximum under this condition has been reached/ other factors other than light begin limiting the rate of photosynthesis. Beyond 18 arbitrary units; the rate of photosynthesis begins to fall because light intensity is affecting photosynthesis negatively; bleaching chlorophyll.

(d). Explain the observed characteristics of the two groups of plants as shown in Table l. ***(09 marks)***

Leaf colour

Strong light stimulates production of chlorophyll than weak light intensity; hence more chlorophyll in plants grown in higher light intensity than those grown in low light intensity.

Internode length

Internode is longer in low light intensity because of etiolation/ competition for light. In higher light intensity, the internode is shorter due to less etiolation/ lack of competition for light.

Leaf size

Bigger size in higher light intensity is because of production of enough carbohydrates due to a higher rate of photosynthesis.

(e). Suggest why:

(i). seedlings of the same plant were used in the experiment. ***(02 marks)***

To ensure uniformity/ accuracy in the results; and avoid other factors that could affect the rate of photosynthesis.

(ii) the rate of release of oxygen was used to measure the rate of photosynthesis. ***(02 marks)***

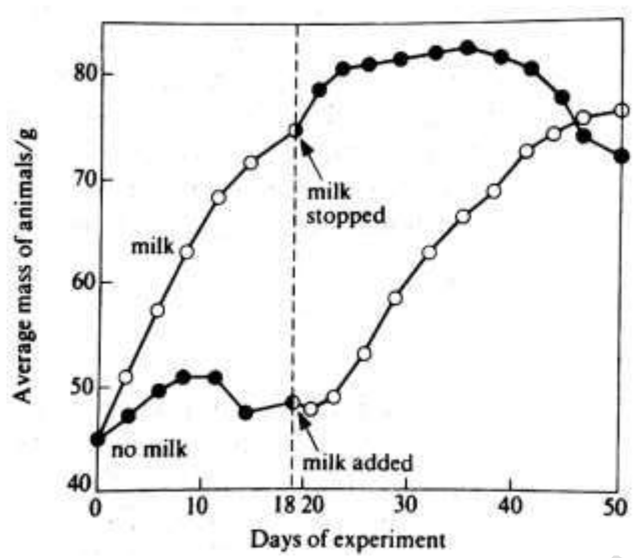
When photosynthesis proceeds, oxygen is released as a byproduct therefore the rate of oxygen release is a good indicator of the rate of photosynthesis.

(f).Name two factors that may limit the rate of photosynthesis of plants previously grown in high light intensity, if subjected to light intensity above 25 arbitrary units. ***(02 marks)***

• Water content
• Temperature
• Carbondioxide concentration

Question 3.

The following feeding experiments were done to illustrate the importance of vitamins in normal dietaries. Two groups of young rats were used. Group A were fed on a diet of purified casein, starch, glucose, lard, minerals and water only for the first 18 days. Group B were fed on a diet of purified casein, starch, glucose, lard, minerals and water plus an extra of 3cm^3 of milk daily for the first 18 days. After 18 days milk was given to group A rats and removed from group B's diet. The graph below shows the variation in the average mass of rats with time.



(a)(i).Describe the variation in the average mass of rats of group A and B with time ***(05 marks)***

Group A rats; increased in mass gradually from 0 day to 10 days, mass decreased gradually until about 12 days, mass remained relatively constant up to 22 days, then mass increased rapidly from about 22 days to 50 days. Group **B rats;** increased rapidly in mass from 0 day to 18 days, then gradually increased in mass from 18 days to about 23 days, stopped growing from about 23 days to 40 days and gradually decreased in mass /lost weight thereafter.

(ii).Explain the variations in average mass for both groups of rats ***(03 marks)***

Group A rats resumed growth and increased in weight after 18 days while group B rats stopped growing and lost weight after 18 days. While the 3cm^3 of milk had an insignificant food value in terms of carbohydrate, fat, protein and minerals, the milk contains an extra nutrient which the rats needed to be able to grow and develop.

(iii)Why it was necessary to transfer milk from group B to group A half way through experiment*(04 marks)*

To ensure that all groups of rats are subjected to identical conditions e.g. feeding them on identical food so as to establish the effect of milk on growth while eliminating the possibility of other factors being responsible the observed differences in results e.g. choice of rats in one group (group A) may have been more sickly than those in group B etc.

(iv). Why feeding rats on one type of protein (casein), not a variety is ruled out as a possible cause of growth stoppage and weight loss? ***(03 marks)***

Although proteins are essential for growth and there are different types, proteins are hydrolysed in the body into different amino acids, and the body is able to make some amino acids for itself. Therefore even though the rats were only getting casein this was enough to not have an effect on growth.

(v). Why while a diet of protein alone is sufficient for young animals, it is inadequate for adults? ***(02 marks)***

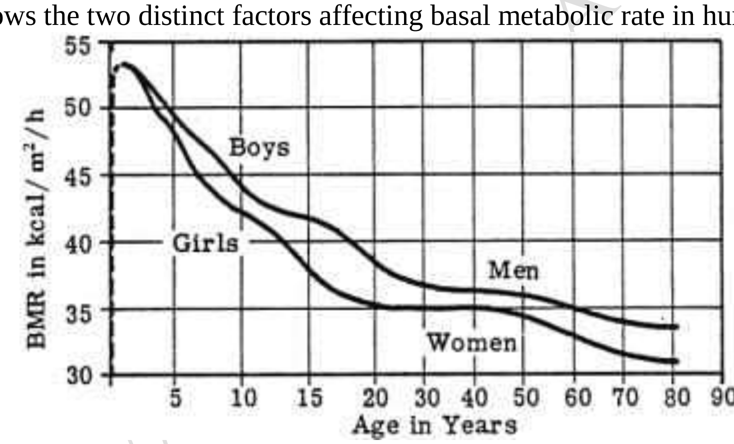
Much as milk contains all the nutritional requirements eg protein, carbohydrates (lactose), lipids, mineral salts, vitamins and water, some amounts may be nutritionally insufficient to meet the metabolic demands of adults. Some people who are lactose intolerant can‘t digest the main sugar (lactose) in milk. In normal humans, production of lactase enzyme that digests lactose stops between ages of two and five years, which would result in insufficient ATP production. Milk is also deficient of iron, vitamin B and rouphages.

In another experiment, a group of rats were encouraged to over eat by feeding them with unlimited supplies of processed foods such as chocolate and cakes over a three-week period. These rats were called cafetarian rats. Over the same period, another group of control rats fed on unlimited supplies of their natural food.

	Average over 21 days	
	Cafetarian rats	**Control rats**
Energy content of food eaten (KJ)	11670	6480
Gain in the body mass (g)	131	103
Gain in body fat (g)	66	40

Energy used (KJ)	9440	4690

(i).What was the effect of feeding the rats on food other than their natural food? ***(01½ marks)***
They gained more body mass, fat and energy
(ii).Determine the average gain in mass of cafetarian rats over the control rats during the 21 days
Average gain in mass =gain in body mass of cafeterian – gain in body mass of control rats
Average gain in mass = 131 – 103 = **28g**
(iii) State three features of the two groups of rats which should be kept the same ***(01½ marks)***
Age, sex, species
(iv).Which chemical of life in the rats is responsible for most of the gain in mass? ***(0½ marks)***
Body fat
(v).Explain the observation that some people eat enormous amounts of foods without putting on weight where as others become over-weight on quite small food intake ***(01 marks)***
Weight gain does not only depend on food intake, but on other factors like genetic makeup.
(vi).Using evidence from the data, explain why cafetarian rats were able to gain more weight than control rats. ***(02 marks)***
The difference between the energy content of food and energy used is higher in cafetarian rats so unused food had to be converted to fat
(vii). Why were control rats necessary in this experiment? ***(01 marks)***
For comparison of results
(c). The graph below shows the two distinct factors affecting basal metabolic rate in humans.



(i).Outline the factors shown in the graph, which affect BMR ***(02 marks)***
Age
Sex
(ii). Using the graph above, explain how the above factors affect basal metabolic rate ***(10 marks)***

Variation in BMR with sex

At about 2.5 years and below, BMR in males is equivalent to BMR in females because infants have basically identical composition of carbohydrates, fats and protein. From about 2.5 years throughout life, BMR is slightly higher in males than in females because males usually have more body muscle than females while females usually have more fat than males per unit body mass and surface area. The more muscle tissue in the body, the more energy the body needs just to function e.g. to conduct impulses and biosynthesis compared to fat cells that largely store fat, with little biosynthesis.

Variation in BMR with age

Infants and children have relatively high BMR than old-aged adults because at infancy and childhood much of the energy consumed is used in biosynthesis of cellular components required for growth. At adulthood, biosynthesis is greatly reduced since growth has stopped. From the age BMR was first determined to about 20 years of age, BMR decreases rapidly, then remains constant up to about 50 years of age and thereafter decreases slowly. From infancy to maturity at 20 years of age, biosynthesis of cellular components required for growth decreases rapidly, then remains constant by middle age until 50 years of age and thereafter decreases slowly, partly because of loss of muscle tissue & also because of hormonal and neurological changes. Only repair and replacement of worn out cells occurs at slow rate by adulthood.

(iii). Explain how the other factors not shown in the graph, may affect BMR ***(10 marks)***

Muscle mass (amount of muscle tissue in the body); Muscle requires more energy to function than fat. The more muscle tissue in the body, the more energy the body needs just to exist.

Body size: Larger bodies tend to have a higher BMR because they usually have larger internal organs and fluid volume to maintain. Taller people have a larger skin surface, therefore have higher metabolism to maintain a constant temperature.

Genetics: Genotypes and genetic disorders determine the rate of BMR.

Physical activity: Regular exercise increases muscle mass and causes the body to burn kilojoules at a faster rate, even when at rest.

Hormonal factors (e.g. during pregnancy and lactation): Hormonal imbalances caused by certain conditions, including hypo- and hyperthyroidism, can affect the metabolism. Expectant and lactating mothers require more energy to support foetal and baby growth respectively.

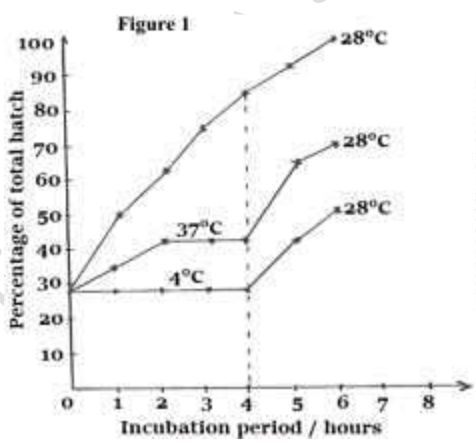
Environmental factors (e.g. temperature): Weather can also have an effect on body metabolism; if it is very cold or very hot, the body works harder to maintain its normal temperature and that increases the metabolic rate.

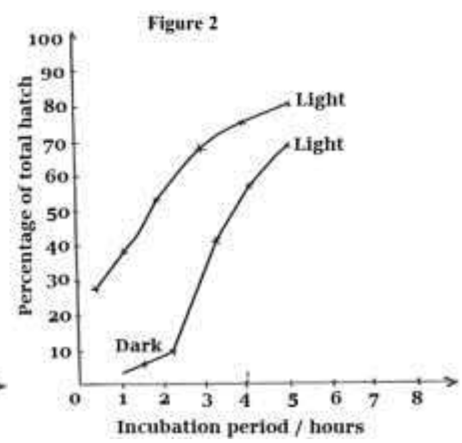
Drug content in the body: Caffeine and nicotine can increase your metabolic rate, while medications including some antidepressants and anabolic steroids can contribute to weight gain regardless of what you eat.

Diet: Certain aspects of one's diet can also affect metabolism e.g. inadequate intake of iodine for optimal thyroid function can slow down body metabolism.

Question 4.

The blood fluke, Schistosoma mansoni is an important helminth parasite that resides within the mesenteric veins of its definite host. Experiments were done and the graphs in figures 1,2 and 3 below show the effect of temperature, light and salinity on the hatching of the eggs of Schistosoma mansoni. At hourly intervals, the number of eggs hatching was determined and expressed as a percentage of total hatch. Figure 1 shows the effect of temperature on hatching. After 4 hours of treatment at the temperatures shown, the samples were incubated for a further two hours at 28oC at constant light and salinity. Figure 2 shows the effect of light on hatching. One sample was kept in light for 6 hours while a second sample was first kept in the dark for 3 hours, then transferred to light for 3 hours at constant temperature and salinity. Figure 3 shows the effect of salinity on hatching after treatment for 6 hours at constant temperature and light (percentage of total hatch is expressed as a % of number of eggs hatching in 0% saline)





The eggs kept in 0.8% saline for 6 hours as in figure 3 above were removed, divided equally into four lots and placed in a range of saline solutions for a further 6 hours. The results are as shown in table 1 below:

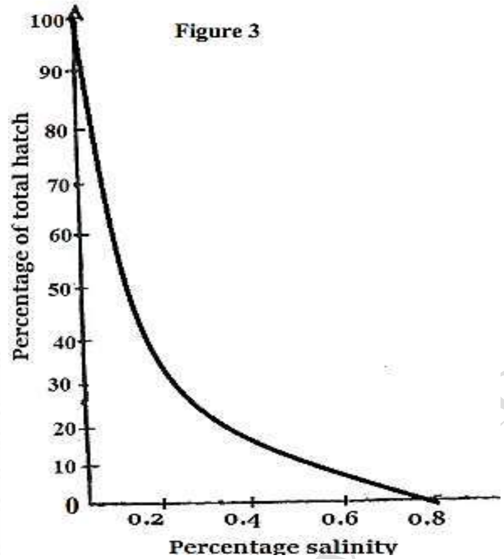


Table 1

Salinity (%)	Total hatch after 6 hours (%)
0.0	100
0.2	40
0.4	20
0.6	8

(a).Comment on the effect of temperature on hatching of Schistosoma mansoni eggs ***(07 marks)***

- At constant light, salinity and temperature of 280C; eggs hatched rapidly; to completion;
- At higher temperature of 37ºC & lower temperature of 40C hatching is just slightly stimulated (greatly inhibited)
- Restoring temperature from 37ºC and 40ºC to 28ºC; stimulates rapid hatching;

(b) Explain the effect of light on percentage hatch of eggs. ***(06 marks)***

The lots of eggs exposed to light hatch rapidly to completion; because light stimulates / activates a hatching substance/enzyme; which digests/breaks down the egg membranes to enable emergence of larvae; Darkness generally inhibits hatching; because the hatching substance is inactive; however in this case a little hatching occurred in the dark probably due to experimental errors which resulted in some illumination of eggs;

(c). What is the effect of salinity on percentage hatch of the eggs? ***(04 marks)***

In fresh water (at 0% salinity) all eggs hatched; at 0.8% salinity no eggs hatched (hatching was inhibited); increase in salinity; causes a rapid decrease in hatching;

(d).From the data presented and restricting yourself to egg stage only, discuss adaptations of S.mansoni to its mode of life. ***(10 marks)***

In the mesenteric veins of the main host of Schistosoma mansoni; there is total darkness and temperature is about 37ºC; both of which prevent hatching of eggs into miracidia (larvae) in man; because they would die; When faeces with eggs reach fresh water bodies; where there is much illumination (light), lower temperature and very low salinity; all of which favour rapid hatching of eggs; many larvae (miracidia) are formed; which infect water snails; (intermediate host) and form more larvae (cercariae) that infect man;

(e)(i). Name the disease caused by this blood fluke to man ***(01 marks)***

Bilharzia (Schistosomiasis);

(ii) Explain how the spread of disease can be controlled ***(04 marks)***

- Disposal of faeces in latrines/toilets to avoid their contact with fresh water bodies;
- Deworming to kill adult worms in humans;
- Wearing gear (boots/shoes) that shield/protect feet from larvae (cercaria) infection;
- Use molluscides to kill larvae‘s (miracidia) intermediate hosts (adult snails) in water;
- Biological control in which some fish and ducks are introduced in water to feed on larvae /snails;

(f)(i) Explain the physiological challenges facing human endo-parasites & how they are overcome ***(06 marks)***

Challenge	Solution to the challenge
Digestion by the host‘s enzymes;	Development of thick cuticle/secretion of inhibitory substances /mucus
Osmotic changes in the habitat;	Increased chemo-sensitivity in order to equilibrate with host
Inhibitory chemical environment;	Secretion of anti-inhibitory substances;
Anaerobic conditions;	Ability to respire anaerobically;

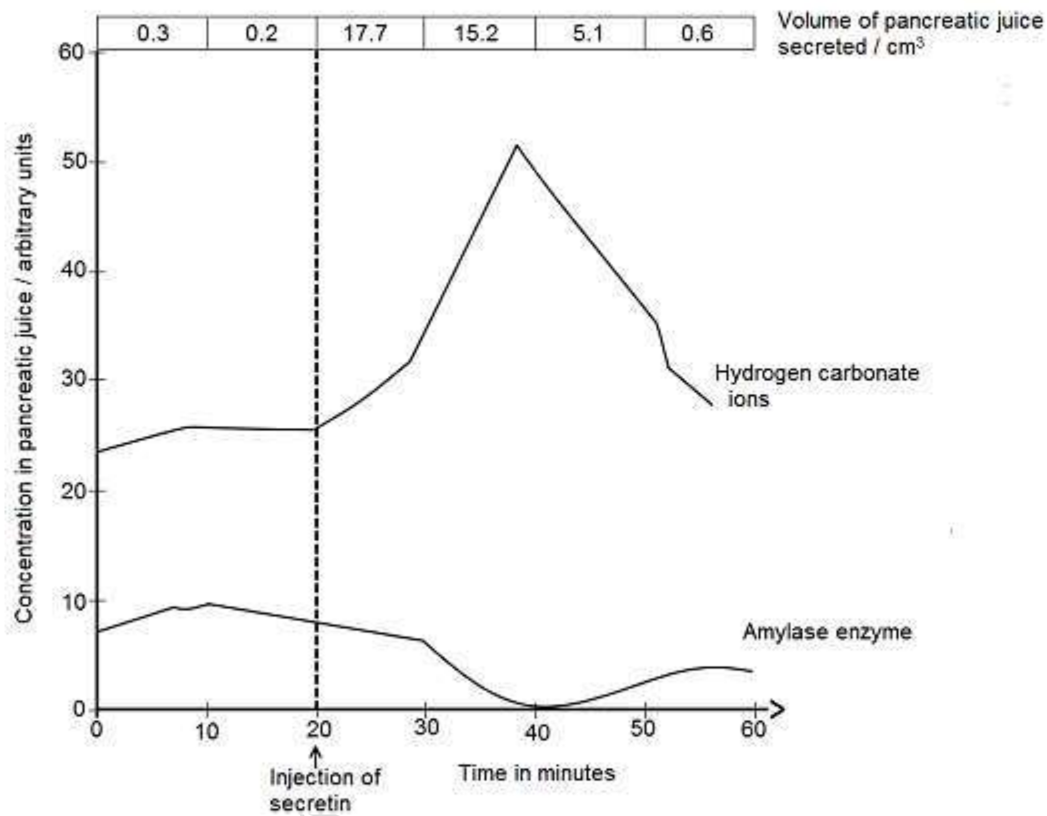
Attack by host's immune	Development of protective structures against the host's immune attack

(ii).What are the benefits of parasitic nutrition to organisms that exhibit it? ***(02 marks)***

A variety of nutrients required for growth, development and body maintenance may be obtained from one meal
Less development of digestive system since most nutrients obtained are fully /partially digested.

Question 5.

The graph in figure 1 shows how an injection of secretin affects secretion of pancreatic juice by the pancreas.



(a).Use the graph to explain the effect of secretin on pancreatic secretion. ***(20 marks)***

Secretin injection causes a rapid increase in volume of pancreatic juice from 20 minutes to 30 minutes followed by gradual decrease to 40 minutes; then a rapid decrease to 60 minutes; Secretin injection causes gradual increase in the concentration of bicarbonate ions from 20 minutes to 30 minutes; followed by rapid increase to a peak at 40 minutes; then rapid decrease until 60 minutes; Secretin injection causes gradual decrease in concentration of amylase from 20 minutes to 30 minutes; followed by rapid decrease to a minimum at 40 minutes; then gradual increase until 55 minutes and thereafter remains constant until 60 minutes; Upon injection into blood, secretin hormone circulates to reach the pancreas and liver, first in low concentration from 20 minutes to 30 minutes; gradually stimulating pancreatic secretion of watery hydrogen carbonate ions from acinar cells and gradually stimulating secretion of somatostatin hormone which gradually inhibits secretion of pancreatic amylase enzyme. From 30 minutes to 40 minutes, there is now much secretin concentration in blood circulation; which rapidly stimulates pancreatic acinar cells to rapidly secrete hydrogen carbonate ions and also greatly stimulates secretion of somatostatin hormone which rapidly inhibits secretion of pancreatic amylase enzyme; From 40 minutes to 60 minutes, high PH (alkalinity) due to hydrogen carbonate ions inhibits the working of secretin hormone; causing less stimulation of acinar cells hence rapid decrease in secretion of hydrogen carbonate ions. Somatostatin hormone secretion decreases hence decreasing the inhibition of pancreatic exocrine cells causing increased amylase enzyme secretion;

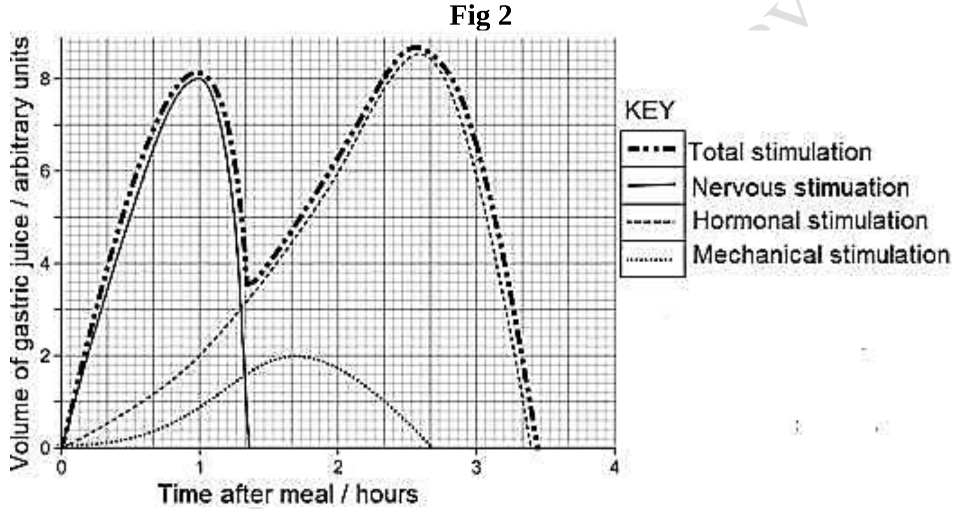
(b)(i) From the graph, comment on the composition of pancreatic juice. ***(02 marks)***

Pancreatic juice is mainly composed of substances (like water), hydrogen carbonate ions and small amounts of enzymes like amylase.

(ii). State any other digestive secretion stimulated by secretin. ***(02 marks)***
Secretion of bile in liver cells, stored in the gall bladder which when released in the duodenum emulsifies fats into droplets, which is physical digestion.
(c). Certain types of ulcers are thought of to be made worse by the production of too much acid from the stomach. Medical doctors have used several methods to treat such ulcers.
Suggest how each of the following treatments might reduce the amount of acid secreted by the stomach:
(i).Cutting the gastric vagus nerve. ***(04 marks)***
Conditioned reflexes from vagal centre in the brain fail to stimulate secretion of acetylcholine, no secretion of gastrin hormone, no secretion of gastric juice (HCl) during the cephalic phase (before food reaches the stomach) hence the stomach wall will be less irritated.
(ii). Blocking the action of acetylcholine by giving the patient atropine. ***(02 marks)***
Blocking the action of acetylcholine using atropine inhibits the secretion of gastrin hormone; hence secretion of gastric juice (HCl) is inhibited

Figure 2 below shows the variations in volume of gastric juice produced by nervous, hormonal and mechanical stimulations with time after eating food

Fig 2



(d).Explain the variations in acid production in response to the various forms of stimulation ***(10 marks)***
Volume of gastric juice produced during nervous stimulation increases rapidly from 0 hour to a maximum at 1 hour, then decreases rapidly and ceases at 1.5 hours. Nervous secretion is shorter lasting instantly rapid as compared to hormonal and mechanical phases. Volume of gastric juice produced during hormonal stimulation increases gradually from 0 hour to 1 hour, then increases rapidly to a maximum at about 2.5 hours, then decreases rapidly and ceases at about 3.3 hours. Therefore, hormonal secretion is: longer las- ting and initially gradual as compared to the cephalic phase. Volume of gastric juice produced during mechanical stimulation (food stretching stomach and duodenal wall increases gradually from 0 hour to 0.7 hours, then increases rapidly to a maximum at about 1.6 hours, then decreases rapidly and ceases at about 2.6 hours.

Question 6.

The figure below shows the changes in leaf area index (ratio of leaf surface to soil surface) of two species of clover, Trifolium repens and Trifolium fragiferum, growing in a pure and mixed stand.

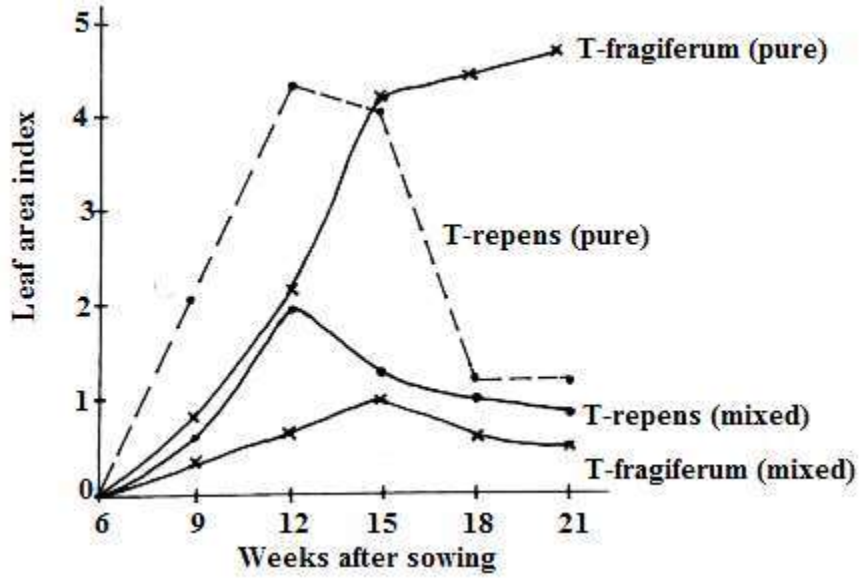


Table 1 shows the characteristics of the petioles and leaf size of the two species of clover.

	T. fragiferum	T. repens
Petiole length	Long	Short
Leaf size	Large	Small

Use the formation in the figure and the table to answer the questions that follow

(a).Compare the leaf area index of T. repens and T fragiferum in the;

(i).Pure stands ***(06 marks)***

Similarities

At 15 weeks after sowing, leaf area index of both T-fragiferum and T repens is equal.
From 6 to 12 weeks after sowing, both T-fragiferum and T repens register an increasing leaf area index.

Differences

Weeks after sowing in the pure stands	Leaf area index of T repens	Leaf area index of T fragiferum
6-15 weeks	Generally higher	Generally lower
15-21weeks	Generally lower	Generally higher
12-15 weeks	Decreases slowly/gradually	Increases rapidly
6-12 weeks	Much more Rapid increase	Less rapid increase.
15-18 weeks	Decreases rapidly	Increases slowly/gradually
18-21 weeks	Constant	increases slowly/ gradually
	Attains a peak at 12 weeks	No peak attained

(ii).mixed stands ***(06 marks)***

Similarities

From 6-12 weeks after sowing, leaf area index of both species increase. Both species attain peak leaf area indices at a particular time after sowing.
From 15-21 weeks after sowing, leaf area indices of both species decreases

Differences

Weeks after sowing in the mixed stands	Leaf area index of T repens	Leaf area index of T fragiferum
Throughout the entire weeks after sowing	Generally higher	Generally lower
	Attains a higher peak	Attains a lower peak
	Peak attained earlier after	Peak attained later after sowing(15
	sowing(at 12 weeks)	weeks)

9-12 weeks	Increases rapidly	Increases gradually/slowly
12-15 weeks	Decreases rapidly	Increases slowly

(b). Explain the trend in leaf area index of Trifolium repens in the pure stands ***(10 marks)***

DESCRIPTION OF THE LAI	EXPLANATION
Rapid increase between the 6th and 12th week**;**	faster early rate of leaf production**;**
Maximum/optimum/peak LAI attained on the 12th week**;**	Maximum number of fresh leaves**;** with the greatest photosynthetic capacity**;**
Leaf area index declines/reduces slowly/ gradually between the 12th and 15th week**;**	Onset of senescence with associated defoliation**;** Senescence greater than new leaf production**;**
Rapid decrease in LAI between 15th -18th week**;**	Higher proportion of old leaves with decreased photosynthetic capacity**;** significantly defoliate.
Constantly low between 18th and 21st week	Rate of defoliation equal to that of leaf production**;**

(c).Explain the difference in the growth rate of the two species in mixed stands ***(04 marks)***

T fragiferum despite having larger seeds and starts growth with greater embryonic capital; has a greater portion of its seeds having harder seed coats; than for T repens. More seeds of T repens thus germinate with more foliage production outcompeting T fragiferum; T repens also has a higher relative growth rate; and produces new leaves at a faster rate than T fragiferum; The hypocotyls of T repens elongate more sensitively in response to shading; thus in a mixed culture, hypocotyls of T repens elongate to carry the small cotyledons of the species to the top of the developing canopy; intercept most of the incident light; Leaf area index of T repens increases at a faster rate thus T fragiferum remains in a position underneath the main canopy.

(d).Explain why Trifolium fragiferum continues to grow after the peak of Trifolium repens ***(04 marks)***

T fragiferum is capable of vertical stem growth; in contrast to T repens that is wholly stoloniferous; T fragiferum thus exhibits greater petiole extension than T repens; eventually overtops T repens in the canopy; Its large leaves then intercept most of the incident light; further increase the leaf area index past the peak of T repens.

(e). What conclusion can you draw from the results in the mixed stands ***(04 marks)***

Differential growth of two closely related species in a mixed stand; involving cotyledon size; hypocotyl length; petiole or stem length; Once one form is in ascendancy, its domination is likely to lead to the monopolistic trapping of light;

(f). What other factors are likely to have caused the difference in growth rate of the two species in mixed stand? ***(03 marks)***

Embryonic capital of the seeds/ size of the seeds
Plasticity of the hypocotyl and petiole
Size of the cotyledons.
Differential rate of nutrient uptake.

Question 8.

Two groups of maize seeds were germinated and grown in different culture solutions. Group A were provided with a complete nutrient solution while Group B were provided with a solution lacking magnesium. An extract of photosynthetic pigments was made from leaves of each group of seedlings at the end of three Weeks. Figure l is the absorption spectra obtained from the extracts.

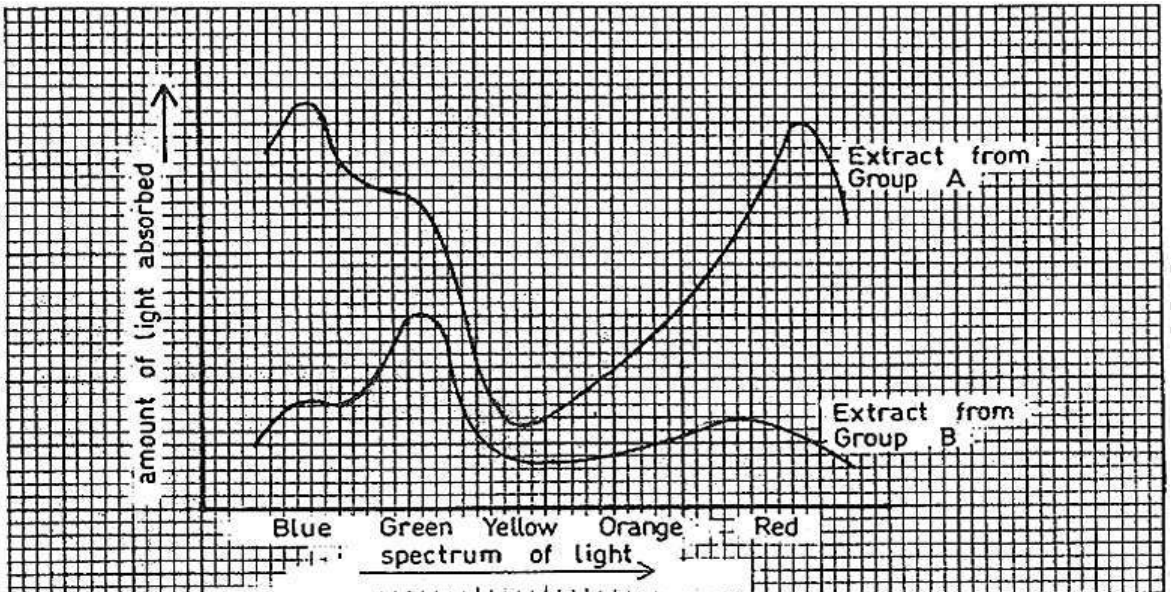


Fig. 1

In another experiment, six identical shoots were placed in separate test tubes of pond water in which a dilute solution of sodium hydrogen carbonate had been added. Each test tube was then exposed to light which had passed through a different coloured filter. The light in all cases was from a 40 watt bulb, placed 40 cm from the test tube. The time taken for 20 bubbles to leave the cut end of each shoot was recorded three times and the average results are recorded in table 1 below.

Table 1

Colour of the filter	Average time taken to release 20 bubbles in seconds	Number of bubbles released per minute
Violet	58	
Blue	40	
Blue-green	62	
Green	132	
Yellow	96	
Orange-red	70	

Use the information to answer the questions that follow:

(a).Compare the light absorption by extract from Group A and that from Group B across the light spectrum. ***(08 marks)***

The absorption spectrum for both extract A and B shown a similar trend. However, the absorption spectrum of extract B is lower than that of extract A; throughout the spectrum. Highest absorption for both extracts is in the blue and red ranges/ regions. The lowest absorption for both extracts is in the yellow region; although in this region, extract A absorbs more light than extract B. For extract B, maximum absorption is observed in the green region; There is a big difference in the absorption n the blue; and red; regions between extract A and B.

(b). Explain the light absorption across the light spectrum for each extract. ***(09 marks)***

Extract A had a complete nutrient solution; so absorbed highly in the red and blue regions. Little light was absorbed in the yellow regions by both extracts because this wavelength s not useful in photosynthesis; however for extract A was still higher possibly because of the presence of chlorophyll.

Extract B was supplied with a solution lacking magnesium; which is necessary in the formation of chlorophyll & therefore this extract had very little chlorophyll; thus the big difference; between the absorption of the extract

(c). How does a coloured filter affect light passing through it? ***(01 marks)***

It absorbs all other colours and allows only the expected colour to pass through/ reflects the colour of the filter.

(d)(i). Copy and complete Table l, by calculating the number of bubbles released by each shoot per minute.

Colour of the filter	Average time taken to release 20 bubbles in seconds	Number of bubbles released per minute
Blue	40	30
Blue-green	62	19.4
Green	132	9.1
Yellow	96	12.5
Orange-red	70	17.
Violet	58	20.7

(ii).Plot a graph to show the relationship between colour of the filter and the rate at which bubbles are rele-ased. ***(06 marks)***

(e)(i) Compare your graph with figure1, and state the relationship between the two ***(02 marks)***
The two graphs are similar; In the blue region for both graphs is where there is highest absorption and highest number of bubbles released.
(ii)What conclusion can you draw from the relationship? ***(02 marks)***
Light from the blue region is one most required for photosynthesis
(f).State what would be observed if the distance between the bulb and the test tubes was gradually reduced. Explain your answer. ***(04 marks)***
The number of bubbles released per minute would increase; and then become constant. This is because reducing the distance increases light intensity which increases rate of photosynthesis until other factors such as carbondioxide concentration becomes limiting factor.
(g). Explain why
(i).the type of bulb and the distance of the bulb from the test tubes were kept constant. ***(01 marks)***
So that the light intensity should remain constant for each of the test tubes.
(ii). dilute solution of sodium hydrogen carbonate was added to pond water in test tubes. ***(02 marks)***
To release carbondioxide; one of the key substrates needed for photosynthesis
(iii).there were three measurements made on each shoot rather than a single one ***(01 marks)***
So as to get the average measurement which is more correct/ accurate
(iv). measuring the rate of photosynthesis by counting bubbles is not an accurate method. ***(01 marks)***
The bubbles may come out at a fast rate so that they cannot be counted accurately or the bubbles maynot be of the same size.

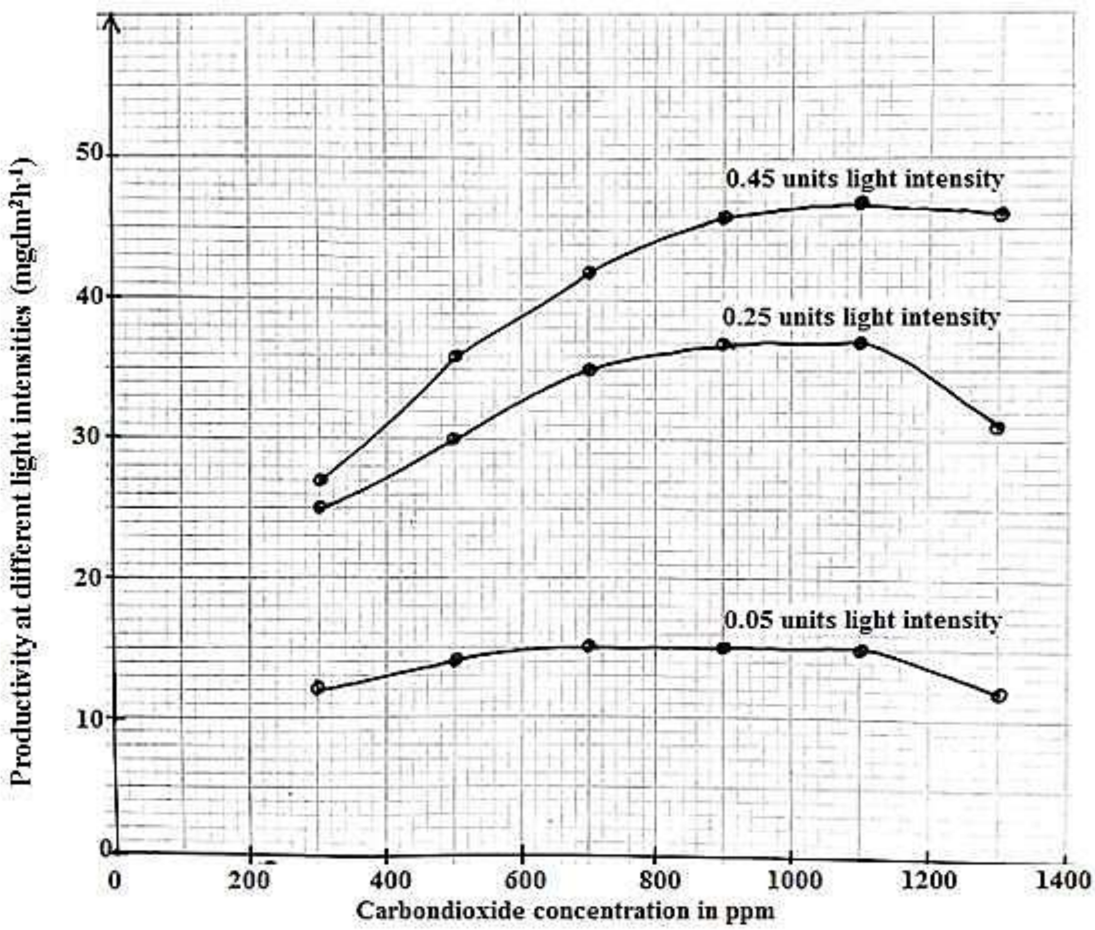
Question 9.

An investigation was made to determine the effect of carbondioxide concentration and light intensity on the productivity of a plant in a greenhouse. The productivity was determined by measuring the rate of carbondioxide fixation in milligrams per dm^2 leaf area per hour. The investigation was conducted at three different light intensities: 0.05, 0.25 and 0.45 (arbitrary units), the highest approximating to full light. A constant temperature of 22°C was maintained throughout. The results are indicated in table 1

Table 1

Carbondioxide concentration (ppm)	Productivity at different light intensities($mgdm^2h^{-1}$)		
	At 0.05 units light intensity	At 0.25 units light intensity	At 0.45 units light intensity
300	12	25	27
500	14	30	36
700	15	35	42
900	15	37	46
110	15	37	47
130	12	31	46

(a). Using the same axes, graphically represent the information in table 1
<u>The graph showing the relationship between the productivity at different light intensity of a plant in a greenhouse with various carbondioxide concentration.</u>



(b).For the experiment at 0.25 units light intensity

(i).What is the effect of increasing carbondioxide concentration on the productivity of the plant?

Increasing carbondioxide concentration increases the productivity of the plant; From 300-700 pm CO_2 concentration, productivity increases rapidly; then productivity increases gradually up to 900 ppm; remain constant between 900-1100 ppm; finally decreases rapidly from 1100 to 1300 ppm CO_2 concentration;

(ii) Explain the effect of increasing carbondioxide concentration on the productivity of the plant

Carbondioxide is a raw material for photosynthesis; Initially increase in CO_2 concentration is the limiting factor; other factors like temperature and light are optimum; The carbondioxide concentration from 900 to1100 ppm is the optimum concentration for maximum rate of photosynthesis at 0.25 units of light intensity; hence rate remains constant and carbondioxide is not a limiting factor; Beyond 1100 ppm concentration of carbondioxide, rate decreases as other factors, limit the rate of photosynthesis.

(c)(i). Carbondioxide concentration of 300 ppm is equivalent to that of the atmosphere. For each of the three light intensities, work out the maximum increase in productivity that was obtained as compared with that at 300ppm.

For plants grown at 0.05 units light intensity

Productivity at 300ppm =12 mgdm^{-2} h^{-1}

Maximum productivity recorded =15 mgdm^{-2} h^{-1}

Maximum increase in productivity =15-12 = 3 mgdm^{-2} h^{-1}

For plants grown at 0.25 units light intensity

Maximum productivity recorded = 37 mgdm^{-2} h^{-1}

Productivity at 300pm= 25 mgdm^{-2} h^{-1}

Maximum increase in productivity =(37- 25) = 12 mgdm^{-2} h^{-1}

For plants grown at 0.45 units light intensity

Maximum productivity recorded =47 $mgdm^{-2}\ h^{-1}$
Productivity at300pm=27 $mgdm^{-2}\ h^{-1}$
Maximum increase in productivity =(47-27) =20 $mgdm^{-2}\ h^{-1}$

(ii). Comment on the effect of changing light intensity on productivity.

• Increasing light intensity increases productivity while decrease in light intensity decreases productivity of the plants.
• Light is the source of energy required for photosynthesis to proceed; High light intensity provides more light energy hence high productivity from increased photosynthesis;
• At higher light intensities; productivity is limited by other factors; or light starts to bleach the chlorophyll molecules.

(d). Why was the temperature kept constant during the experiment ?

The temperature was kept constant during the experiment because temperature affects the activity of enzymes; & is a limiting factor hence would interfere with the results.

(e).From the experiment, state the optimum conditions for the productivity of the plan at 22°C

The optimum conditions for the productivity of the plant at 22°C. Carbondioxide concentration of 1100 ppm; light intensity of 0.45 units;

(f). Suggest other ways in which productivity could have been determined other than measuring the rate of carbondioxide fixation per unit area of a leaf

• Measuringthe gain in dry weight of the plants
• Measuring the rate of oxygen production
• Measuringthe rate of water uptake;

(g).Suggest why even with artificial lighting, glass house crops generally need to have more carbondioxide added when temperatures are low, than when temperatures are high.

Increase in temperature increases kinetic energy of gas molecules; At low temperature, kinetic energy of gas molecules is low; hence more carbondioxide as added to increase the rate of diffusion; and hence increase the rate of photosynthesis; At high temperature kinetic energy of gas molecules is high; carbondioxide diffuses faster into the leaves;

(h). Give adaptations of plants to capturing maximum light

• Cells in the upper layers of the leaves possess numerous chloroplasts; to trap as much light as possible
• Broad leaves present a large surface area to trap as much light as possible
• Some plants grow taller than others to expose their leaves to trap maximum light;
• Some plants climb other plants to expose their leaves to trap maximum light
• Leaves arrange on the stem in such a way as to expose their upper leaf surfaces to trap maximum light.

Question 10.

An investigation was carried out by a scientist on two plant species; Spartina anglica and Spartina martina which live in different habitats. The net carbon dioxide absorption by each species was measured in arbitrary units at various light intensities measured as a mean percentage of noon sunlight keeping other factor constant. The results of this investigation are shown in the tables below.

Table 1; results for Spartina anglica

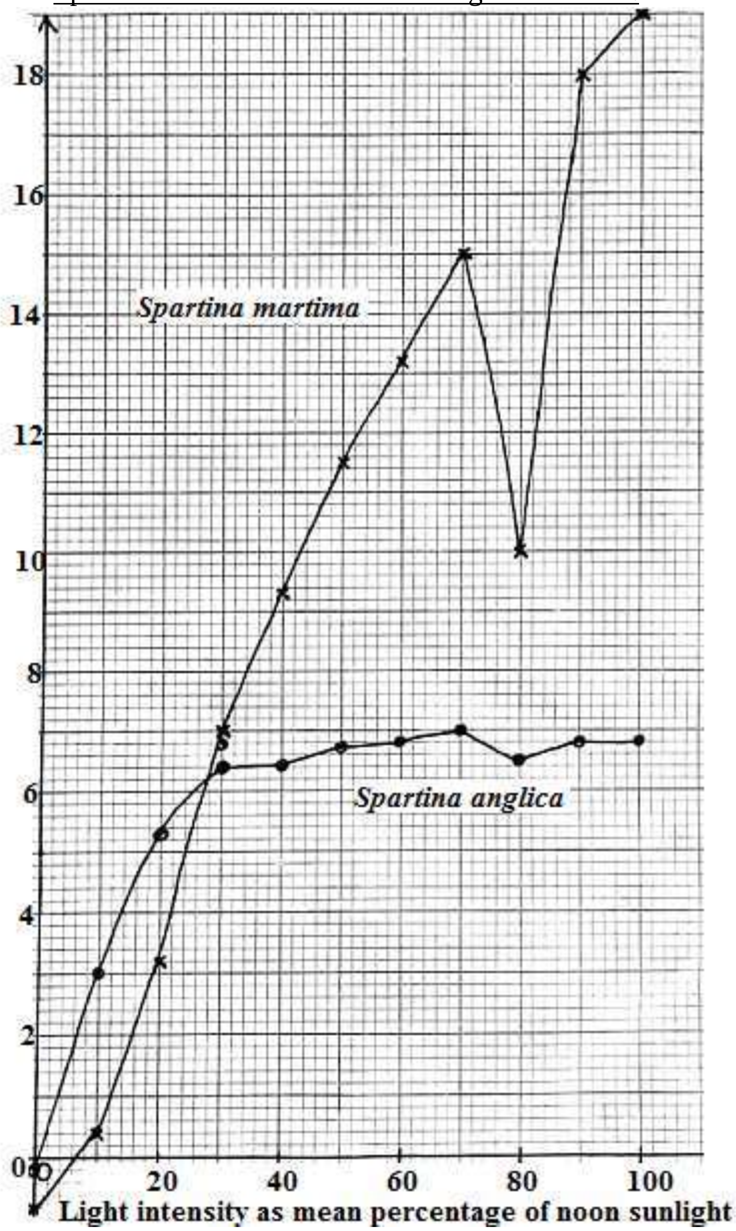
Net CO_2 absorption / arbitrary units	-0.2	3.0	5.3	6.4	6.4	6.7	6.8	7.0	6.5	6.8	6.8
Light intensity as mean percentage of noon sun light	0	10	20	30	40	50	60	70	80	90	100

Table 1 results for Spartina martima

Net CO_2 absorption / arbitrary units	-0.8	0.4	3.2	7.0	9.3	11.5	13.2	15.0	10.0	18.0	19.0
Light intensity as mean percentage of noon sun light	0	10	20	30	40	50	60	70	80	90	100

(a).Plot a graph to represent the data in the above two tables on the same axes. ***(06 marks)***

A graph showing the variation of the carbondioxide concentration of two plant species Spartina anglica and Spartina martina with the various light intensities.



(b). Describe the shape of the curves drawn in (a) above ***(08 marks)***

Spartina anglica

Net carbondioxide absorbed increases rapidly up to 20% light intensity then increases gradually up to 30% light intensity, remains constant between 30-40 % light intensity. Net carbondioxide absorbed then slowly increases to a maximum of 7.0 arbitrary units at 70% light intensity. There after carbondioxide absorbed, decreases between 70-80% light intensity and finally increases slowly with further increase in percentage light intensity.

Spartina martima

Net carbondioxide absorbed gradually increases up to 10% light intensity, rapidly increases up to 30% light intensity then increases less rapidly up to 70 % light intensity. Between 70 to 80% light intensity carbondioxide, absorption decreases rapidly, there after it increases rapidly to a maximum by 100% light intensity.

(c). Explain the shape of the curves in (a) above. ***(14 marks)***

At 0% light intensity, no photosynthesis occurs since there is no light instead carbondioxide is released due to respiration by the plant cells. As light intensity increases photosynthesis takes place, and hence more carbondioxide is absorbed for photosynthesis than carbondioxide released in respiration. At 2% and 6% light intensity, Spartina anglica and Spartina martima respectively rate of photosynthesis is equal to the rate of respiration hence no net carbondioxide exchange occurs. Above 2% and 6% light intensity the two species; Spartina anglica and Spartina martima respectively are provided with enough light more photosynthesis occurs than respiration hence more carbondioxide is absorbed than released. Maximum rate of photosynthesis for Spartina anglica and for Spartina martima is at 70% and 100% light intensity respectively. Spartina anglica has chlorophyll more adapted to absorb light below 28% light intensity; hence, it carries out more photosynthesis than Spartina martima. Above 28% light intensity Spartina martima carries out more photosynthesis, because its chlorophyll absorbs more carbondioxide than the chlorophyll of Spartina anglica. Between 70-80% light intensity there is a decrease in carbondioxide absorption for both species due to increased respiration as a result of increase in temperature as light intensity increases. Also, increase in light intensity causes bleaching of chlorophyll molecules.

(d). Suggest what would happen if the two species where to grow in the same habitat ***(05 marks)***

In the same habitat, the two species would compete for carbondioxide. At light intensity below 28%, Spartina anglica would have a competitive advantage carrying out more photosynthesis than Spartina martima. Subsequently Spartina anglica would grow more rapidly than Spartina martima would be gradually eliminated. Above 28% than Spartina anglica would be outcompeted by Spartina martima which has a higher rate of photosynthesis. At 28%, light intensity the two species compete favourable for carbondioxide and the competitive advantage would be determined by other factors which if kept constant then the two can survive in the same habitat.

(e). State any other two factors, which would affect the results of this investigation ***(04 marks)***

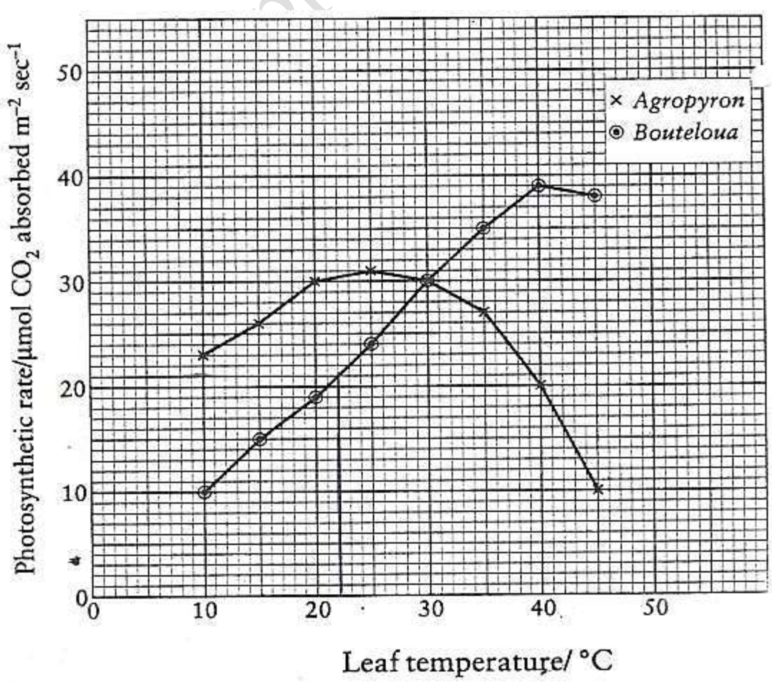
- Light quality.
- Chlorophyll concentration
- Oxygen concentration.
- Relative humidity

(f). Determine the compensation point for each species ***(02 marks)***

- The compensation point for Spartina anglica is at 2% light intensity.
- The compensation point for Spartina martima, at 6% light intensity.

Question 11.

The graph below shows the effect of temperature on the rate of photosynthesis in two grasses, Agropyron and Bouteloua



(a) Compare the effect of changes in leaf temperature on the photosynthetic rate of the two plants

(b) Account for the rate of photosynthesis of Agropyron from:

(i). 10-25ºC. ***(10 marks)***
(ii).25-45ºC. ***(04 marks)***
(c) (i) Describe the photosynthetic mechanism which is likely to occur in the cytoplasm of the mesophyll cells of Bouteloua. ***(05 marks)***
(ii) Explain the physiological significance of the mechanism described in (e) (i) above. ***(04 marks)***
(d) Basing on the data provided, outline the physiological and ecological advantages of Bouteloua over Agropyron. ***(06 marks)***
(e) Briefly discuss the photosynthesis of CAM plants . ***(05 marks)***

Question 12.

Scientists investigated effects of temperature and light intensity on the rate of photosynthesis in creeping azalea plant. They investigated the effect of temperature on the net rate of photosynthesis at three different light intensities. They also investigated the effect of temperature on the rate of respiration. Figure 1 shows the results.

Figure 1

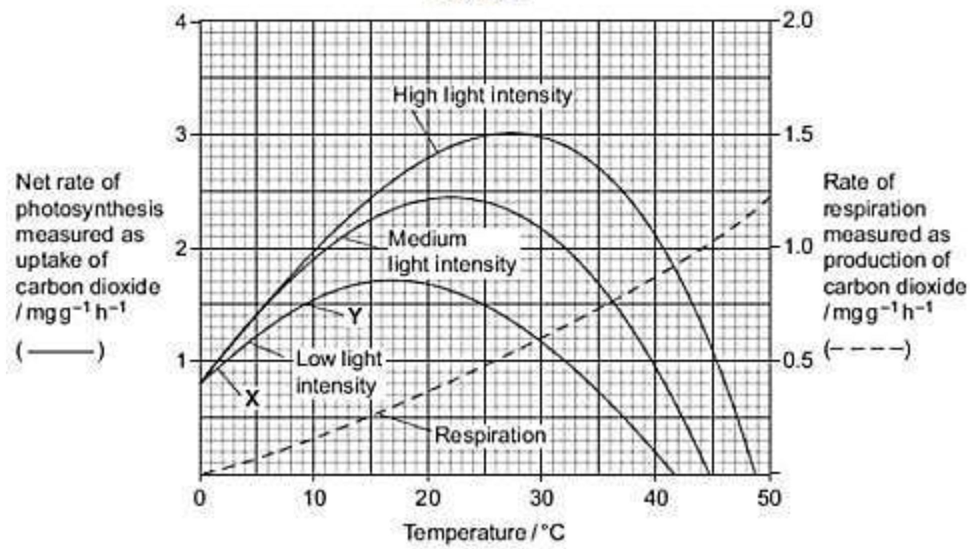
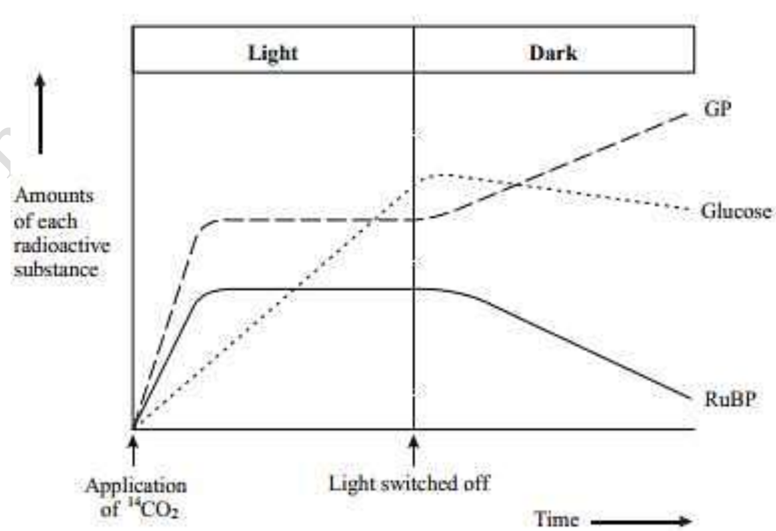


Figure 2 shows the results of an experiment in which photosynthesizing cells were kept in the light and then in darkness.

Figure 2



Using figure 1:
(a) What is meant by net rate of photosynthesis? ***(01 marks)***

(b)(i). Explain the factors that limited the rate of photosynthesis from point marked X to Y. ***(06 marks)***
(ii). Comment on the photosynthetic efficiency of azalea plant at different light intensities. ***(07 marks)***
(c). Compare respiration and photosynthesis at high light intensity. ***(05 marks)***
(d). Explain the rate of respiration as shown in the graph. ***(05 marks)***
Using figure 2:
(e). Explain the effect of varying illumination cycles on amounts of each radioactive substance ***(16 marks)***

Question 13.

The dye reduction technique was used in a controlled experiment conducted to analyze the effects of different conditions on the photosynthetic rate of incubated chloroplast suspensions. Each chloroplast suspension was mixed with Dichlorophenol indophenol (DCPIP), an electron acceptor that changes from blue to colourless when it is reduced. Each sample was placed individually in a spectrophotometer and the percentage transmittance was recorded. The three samples used were prepared as follows:

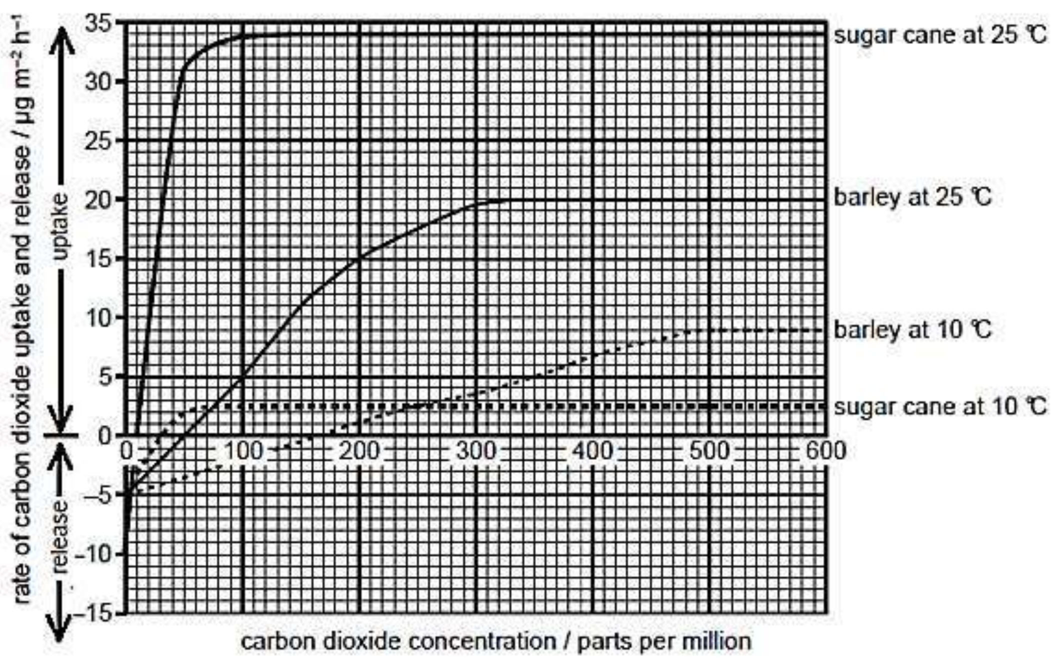
- Sample 1 — chloroplast suspension + DCPIP
- Sample 2 — chloroplast suspension surrounded by black foil wrap + DCPIP
- Sample 3 — chloroplast suspension that has been boiled + DCPIP

Table 1

Time (Minutes)	Transmittance (%)		
	Sample 1	Sample 2	Sample 3
0	28.8	29.2	28.8
5	48.7	30.1	29.2
10	57.8	31.2	29.4
15	62.5	32.4	28.7
20	66.7	31.8	28.5

(a) On the same axes, present the results in table 1 graphically. ***(07 marks)***
(b) From your graph, explain the difference in transmittance for the three samples of results. ***(08 marks)***

In another investigation on photosynthesis using a carbondioxide analyser, the rate of carbon dioxide absorption by undetached leaves of two plants, barley and sugar cane was measured. The leaves enclosed by a carbondioxide analyser were provided with air, moving at a constant rate. Light intensity was kept constant and high, equivalent to full sunlight. The results of the investigation

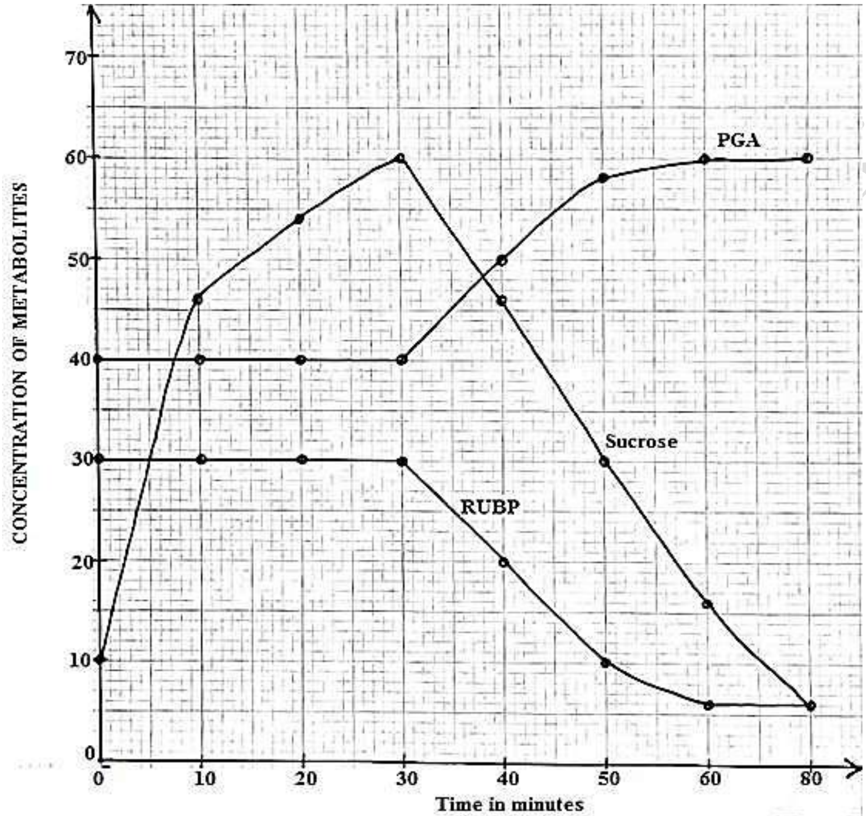


(c) Explain the observed carbondioxide uptake / release in the two species at the different temperatures.
(d) Explain the necessity of:
(i) Measurements being made at the same and high light intensity. ***(02 marks)***

(ii) Leaves remaining attached to the plant during the experiment. ***(02 marks)***

(e) Compare the response of the two species, sugar cane and barley to differences in carbondioxide concentration and temperature. ***(06 marks)***

In an investigation to study the effect of light intensity on the physiology of Spirogyra, its amount of Phosphoglyceric acid (PGA), Ribulose bisphosphate (RuBP), and Sucrose, were determined at different intervals of time in presence of light. At the 35th minute, light was removed completely. The graph below shows the variation of the amount of PGA, RuBP and Sucrose with time:



Study the graph carefully and answer the following questions:

(a). Compare the changes in the amounts of PGA and RUBP with time. ***(03 marks)***

(b). Account for the changes in the amount of:

(i).PGA, ***(07 marks)***

(ii).RuBP, ***(07 marks)***

(iii).Sucrose, with time ***(07 marks)***

(c).Draw a sketch graph for the changes in the amount of PGA and RuBP with time, if carbondioxide had been used in the experiment instead of sunlight. ***(02 marks)***

(d).Explain the changes in the amount of:

(i).PGA, ***(07 marks)***

(ii).RuBP, on the sketch graph with time. ***(07 marks)***

Question 14.

The rate of photosynthesis of Digitaria bipartite & atropa belladonna, a C3 plant was investigated under different intracellular carbondioxide concentrations.

The results are shown in table 1 below.

Table 1

CO_2 concentration ($mldm^{-3}$)	Rate of photosynthesis (mol of CO_2 assimilated per m^2 of leaf area per second)	
	Digitaria bipartite	*Atropa belladonna*
0	0.0	0.0
25	12.5	0.0
50	35.0	5.0
75	37.5	14.0
100	37.5	25.0
150	37.5	40.0
200	37.5	47.5

In a separate experiment, the rate of synthesis of Atropa belladonna under different temperatures was investigated. The results are shown in figure 1 below.

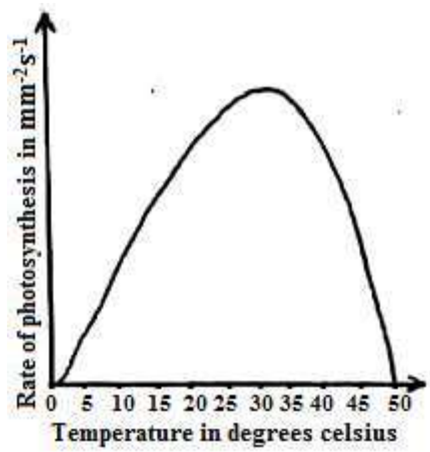
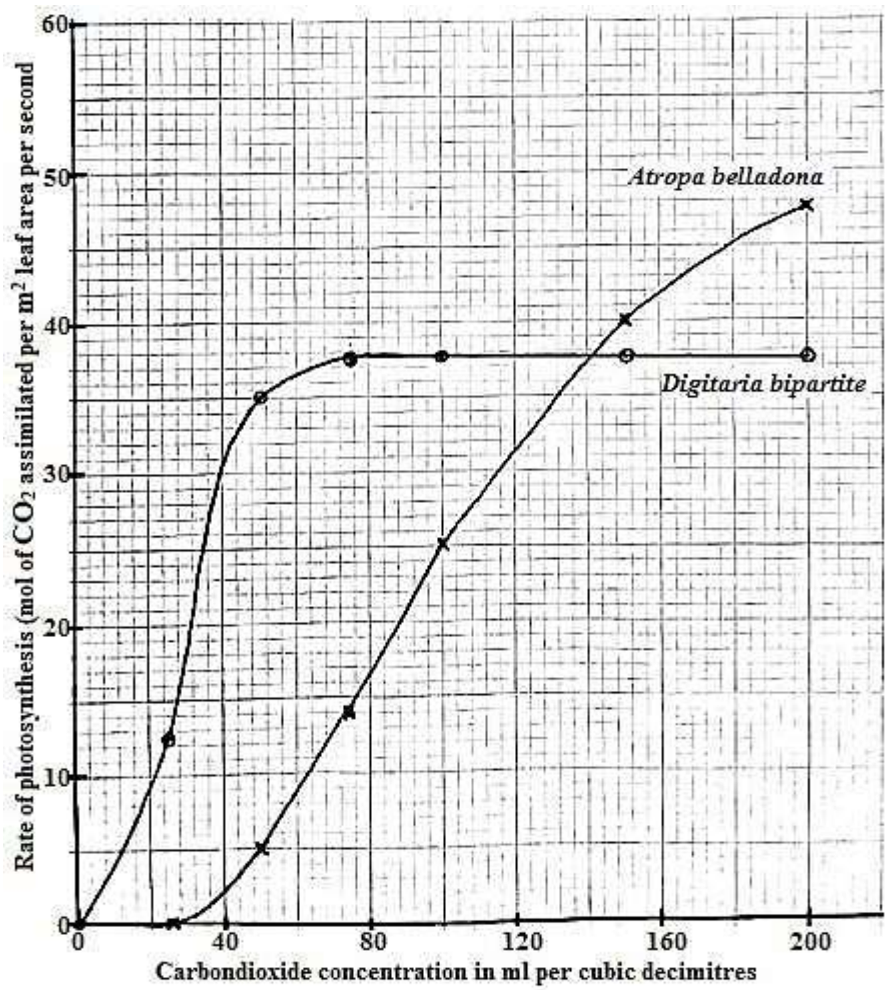


Fig 1.

Study the information provided and answer the questions that follow:

(a).Present the data provide in table 1 graphically *(07 marks)*

<u>A graph showing the variation of the rate of photosynthesis of Digitaria bipartite and Atropa belladonna with carbondioxide concentration.</u>



(b).Compare the rates of photosynthesis of two plants at the carbondioxide concentrations in (a) above.

Similarities

- At 138 ml per dm3 of carbondioxide concentration, rate of photosynthesis is the same for both species.
- Below 75ml per dm3of carbondioxide concentration, rate of photosynthesis for both plants increases with increase in carbondioxide concentration .
- Both donot photosynthesize in the absence of carbondioxide(at 0 ml per dm3)

Differences

- Between 0 and 138 ml per dm^3 carbondioxide concentration, the rate of photosynthesis of Digitaria bipartite is higher than that Atropa belladonna
- Beyond 138 ml per dm^3, of carbondioxide concentration, the rate of photosynthesis of Atropa belladonna is higher than that of Digitaria bipartite.
- From 0 to25 ml per dm^3 of carbondioxide concentration, there is no photosynthesis taking place in Atropa belladonna whereas in Digitaria bipartite photosynthesis is taking place
- Beyond 75 ml per dm^3 of carbondioxide concentration there is no net increase in photosynthesis by Digitaria bipartite whereas for Atropa belladonna rate of photosynthesis increases.

(c). Explain your answer in(b) above. ***(08 marks)***

C_4 plant (Digitaria bipartite) uses an efficient enzyme; PEP carboxylase; catalyses the combination of PEP with carbondioxide even at very low concentrations of CO_2; thus CO_2 fixation is rapid even at very low concentrations of CO_2 until the enzyme reaches the saturation point at low carbon dioxide concentration and other factors such as the high energy consumption of the C4 transport system start limiting the rate of photosynthesis; The C_4 pathway

has an active transport system efficient at concentrating CO_2 in bundle sheath cells; even when environmental concentrations are very low thus preventing photorespiration.
C_3 plant (Atropa belladonna) uses an inefficient enzyme; RUBP carboxylase; which catalyses the combination of CO_2 with RUBP; This enzyme has a lower affinity for CO_2 and at low concentrations no photosynthesis occurs; At very low concentration of CO_2, RUBP can combine with oxygen. This prevents fixation of carbondioxide. However an increase in carbondioxide concentration causes an increase in rate of photosynthesis because there is more carbondioxide than oxygen; and the efficiency of the enzyme becomes high at high carbondioxide concentrations.

(d). Explain the nature of the graph in figure 1 ***(08 marks)***

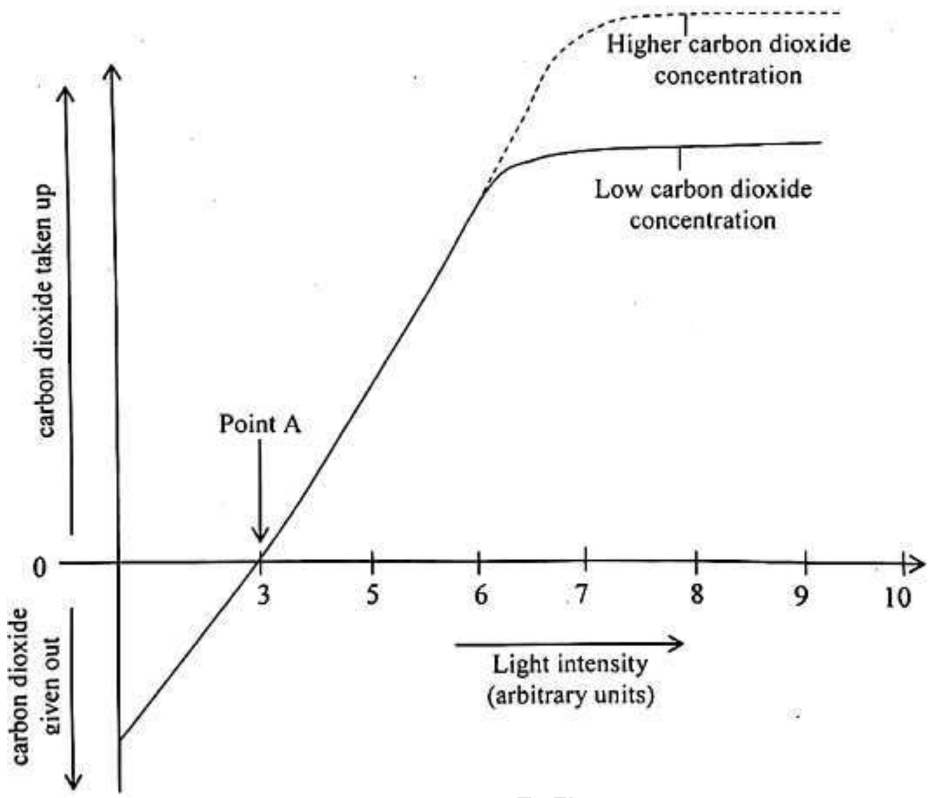
Rate of photosynthesis is low at low temperature; because photosynthesis is controlled by enzymes which are made inactive at low temperatures; lowering rate of photosynthesis. An increase in temperature increases the kinetic energy of the enzyme molecule; becoming activated; this increases the rate of photosynthesis until the optimum temperature of about 25°C is where maximum activation of the enzyme occurs; and the maximum rate of photosynthesis occurs; Beyond 25°C, there is a gradual decrease in the rate of photosynthesis because the high temperatures make the enzyme molecules move more vigorously: the vibrations break the bonds that maintain the shape of the active site; causing the enzymes to denature; hence unable to bind any carbondioxide.
High temperatures also increase oxygenase activity of RUBISCO more rapidly than the carboxylase activity; reducing carbondioxide fixation at very high temperatures. Excessive evaporation of water; due to high temperatures can cause loss of water; an important metabolite /raw material for photosynthesis.

(e). Explain in biochemical terms the distribution of C_3, C_4 and CAM plants in their environments.

Plant	Environment	Biochemical explanation
C_3 plants	Cool moist plants environments	Primarily use the Calvin cycle to fix carbondioxide; so cannot survive in hotter environments as photorespiration will dominate
C_4 plants	Hot dry environments	The enzyme PEP carboxylase fixes carbondioxide in the mesophyll cells by catalyzing the attachment of carbondioxide to PEP to form the 4 carbon acid OAA which is then converted to malate. This 4 carbon acid enters bundle sheath cells through cell to cell connections called plasmodesmata. Here the malate molecules are decarboxylated releasing carbon dioxide prior to a secondary fixation by RUBISCO where the carbondioxide enters the Calvin cycle. This prevents photorespiration when temperatures get high
CAM Plants	Hot, dry and desert environments	Stomata open at night so that plants can take in carbondioxide and incorporate it into organic acids and close during day to allow organic the organic acids release CO_2 molecules that enter the C_3(Calvin cycle) to be fixed into carbohydrates.

Question 15.

The graph in figure1 below represents the rate of photosynthesis as measured by the amount of carbondioxide exchanged at low carbondioxide concentration and at higher carbondioxide concentration with varying light intensity. Study it and use it to answer the questions that follow



(a)(i).Describe the rate of photosynthesis at low carbondioxide concentration ***(08 marks)***
From 0 to 3 arbitrary units light intensity; carbondioxide given out decreases rapidly; becomes zero at 3 arbitrary units of light intensity. From 3 to 6.2 arbitrary units of light intensity; carbondioxide taken up increases rapidly. From 6.2 to 7 arbitrary units of light intensity; carbondioxide taken up increases slowly; attaining maximum carbondioxide uptake at 7 arbitrary units of light intensity. From 7 to 9 arbitrary units light intensity, carbondioxide taken up remains constant.
(ii). Explain your description above. ***(12 marks)***
As light intensity increases; photosynthesis begins as carbondioxide from respiration is being utilized as a photosynthetic substrate. As light intensity increases from 0 to 3 arbitrary units; rate of photosynthesis increases although rate of respiration is still greater than that of photosynthesis. Carbondioxide given out from respiration thus decreases rapidly; as photosynthesis increases. With the continuing increase in light intensity; a point is reached where carbondioxide is neither evolved nor absorbed i.e carbondioxide produced in respiration exactly balances with that used in photosynthesis. Further increase in light intensity result in a proportional rise in the rate of photosynthesis until light saturation is reached. Rate of photosynthesis being greater than that of respiration implies increasing carbondioxide taken up. Beyond the light saturation point; further increases in light intensity have no effect on the rate of photosynthesis as carbondioxide concentration is limiting the photosynthetic process.
(b).Give one difference between higher carbondioxide concentration and low carbondioxide concentration.
At higher carbondioxide concentration, light saturation is attained at a higher light intensity while for lower carbondioxide concentration, light saturation is attained at lower light intensity.
(c).Use the graph above to explain why environmentalists recommend afforestation as a mode of reducing global warming ***(04 marks)***
Low atmospheric carbondioxide concentration is a major limiting factor to photosynthesis. The core cause of global warming, being a planetary rise in carbondioxide concentration implies that introduction of vegetation cover through afforestation would increase rate of photosynthesis in the presence of a higher carbondioxide concentration. The overall effect is a reduction in atmospheric carbondioxide.
(d)(i).Name point marked A on the graph and explain what occurs at this point. ***(02 marks)***
Compensation point

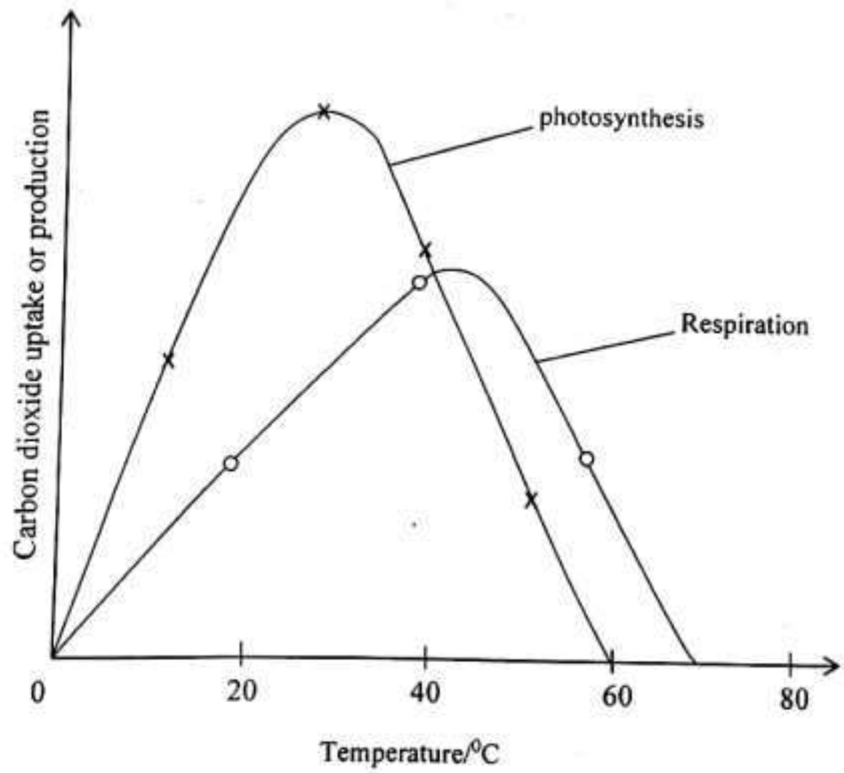
Carbondioxide released during respiration equals that taken up during photosynthesis.

(ii). Suggest & explain what would happen to a point A if instead a shade plant was used ***(03 marks)***

Point A will be reached at a lower light intensity/ lower compensation point; because shade plants have lower respiratory rates and can absorb light of low intensity more efficiently; permitting higher photosynthetic rate in light of lower intensity;

(e). Figure 2 below is a graph showing effect of temperature on the rate of photosynthesis and respiration in well illuminated leaves. (light and other variables kept constant)

Fig. 2



(i).Compare the effect of temperature on the rate of photosynthesis and respiration. ***(05 marks)***

Similarities

- For both CO_2 production in respiration and CO_2 uptake in photosynthesis, increase from 0 to 28°C
- Both CO_2 production in respiration & CO_2 uptake in photosynthesis attain peak at some temperature
- At 40°C, CO_2 production in respiration & CO_2 uptake in photosynthesis are equal.
- For both CO_2 production in respiration and CO_2 uptake in photosynthesis, increase from 44 to 60°C

Differences

Carbondioxide uptake in photosynthesis	Carbondioxide production in respiration
Generally higher between 0 to 40°C	Generally lower between 0 to 40°C
Generally lower between 40 and 60°C	Generally higher between 40 to 60°C
Increase rapidly between 0 and 29°C	Increase gradually between 0 and 29°C
Attains higher peak	Attains a lower peak
Peaks at a lower temperature	Peaks at a higher temperature
Zero between 60 to 70°C	Reduce rapidly to zero between 60 to 70°C

(ii). Suggest a possible reason why the rate of respiration is less affected by temperatures above 40°C than the rate of photosynthesis. ***(03 marks)***

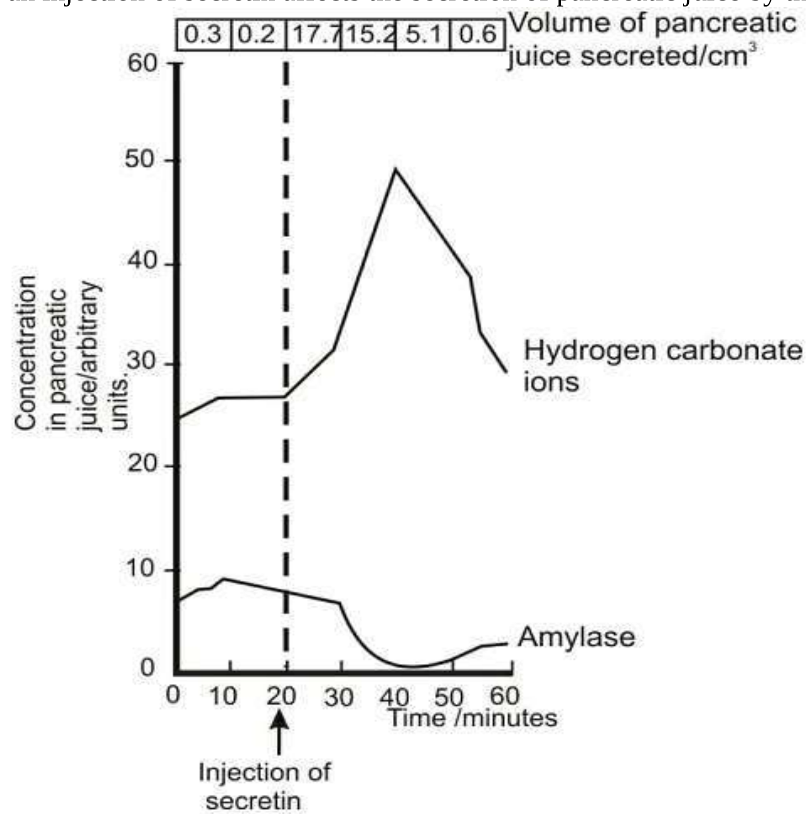
Besides denaturation of the photosynthetic enzymes, there is a possibility of photorespiration that increases with increase in temperature for C_3 plants. A high temperature favours a more rapid increase in the oxygenase activity of Ribulose bisphosphate carboxylase (RUBISCO) than the carboxylase activity. Photorespiration antagonises photosynthesis and reduces its rate.

(iii).What would be the effect of rise in temperatures on the rate of photosynthesis if the intensity of light falling on the leaf was very low. ***(03 marks)***

Rate of photosynthesis will level off and finally reduce because the low light intensity limits the process of photosynthesis;

Question 16.

The graph shows how an injection of secretin affects the secretion of pancreatic juice by the pancreas.



(a)(i). Use the graph to describe the effect of secretin on the pancreas. ***(04 marks)***

Secretin rapidly increases the volume of pancreatic juice in the first immediate 20 to 30 minutes, after its injection Injection of secretin causes a gradual increase in the concentration of hydrogen carbonate ions in the first 10 minutes; and thereafter secretin causes a rapid increase in the concentration of hydrogen carbonate ions in the pancreatic juice to a maximum/peak in the next 10/30-40.

(ii) Explain why concentration of amylase in the pancreatic juice decreased shortly after the injection of secretin. ***(03 marks)***

After 10 minutes of secretin injection, the concentration of amylase in pancreatic juice decreases gradually/ slowly; then from 30-40 minutes; amylase concentration decreases rapidly to attain minimum concentration at the 40th minute; Secretin rapidly increases the concentration of hydrogen carbonate ions; in the pancreatic juice without any effect on the amount of amylase secreted; As a result the concentration of amylase in a pancreatic juice rapidly decreases due to accumulation of hydrogen carbonate ions;

(b). What other digestive secretion is stimulated by secretin. ***(02 marks)***

Bile containing hydrogen carbonate ions; and bile salt of sodium glycocholate and sodium taurocholate;

(c). Certain types of ulcers are thought of to be made worse by the production of too much acid from the stomach. Doctors have used a number of different methods to treat these ulcers. Suggest how the following treatments might reduce the amount of acid secreted by the stomach.

(i). Cutting the vagus nerve to the stomach. ***(06 marks)***

Cutting vagus nerve to the stomach stops transmission of secretary impulses to the stomach walls; which impulses depolarize the stomach walls and stimulates the release of gastric hormone; which stimulates the gastric glands to release gastric juice containing hydrochloric acid; the vagus nerve once cut stops the peristalsis and churning movements of the stomach walls which movements would stimulate release of more hydrochloric acid.

(ii).Giving the patient atropine, which blocks the action of acetylcholine ***(06 marks)***

Since the atropine blocks acetylcholine, the neurotransmitter substance produced by the vagus nerve, the stomach walls are not depolarized to stimulate gastric production and consequent gastric juice release containing the hydrochloric acid; Administration of atropine also stops impulses for the churning & peristaltic movements of the stomach walls which would otherwise stimulate hydrochloric acid secretion by stomach wall depolarization.

(d). Giving examples, explain how organisms are able to utilize cellulose in their diet. ***(10 marks)***

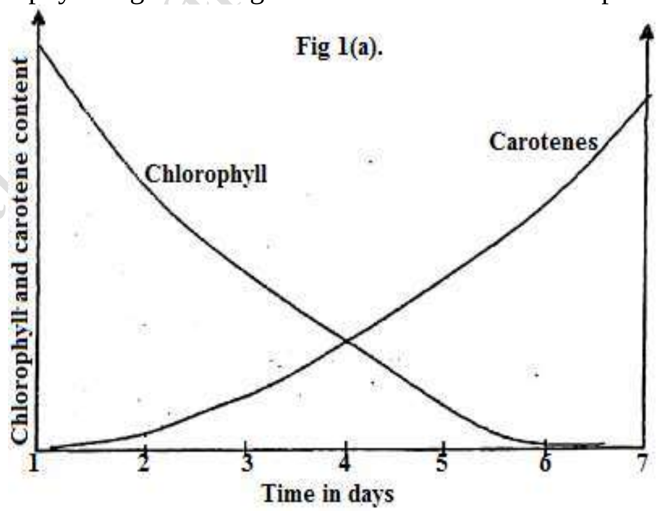
Ruminants harbor cellulose bacteria in the rumen which produce cellulase enzyme which catalyses digestion of cellulose to glucose like cows, goats etc. Other organisms like wood eating termites, harbor flagellates in their gut vacuoles which produce cellulose enzyme catalyzing the hydrolysis of cellulose to glucose units. Other organisms like rabbits practice coprophagy involving eating of own faeces so as to absorb the soluble produce of cellulose digestion which occurs in the lower gut regions way past absorption areas. Some herbivores like cows, goats, and sheep among others possess wide molar and premolar teeth for crushing and grinding plant materials hence increasing the surface area for enzyme action on the cellulose Possession of a diastema in some herbivores increases gap for manipulation which increases chewing capacity of plant materials and consequent surface area for cellulose digestion. Etc

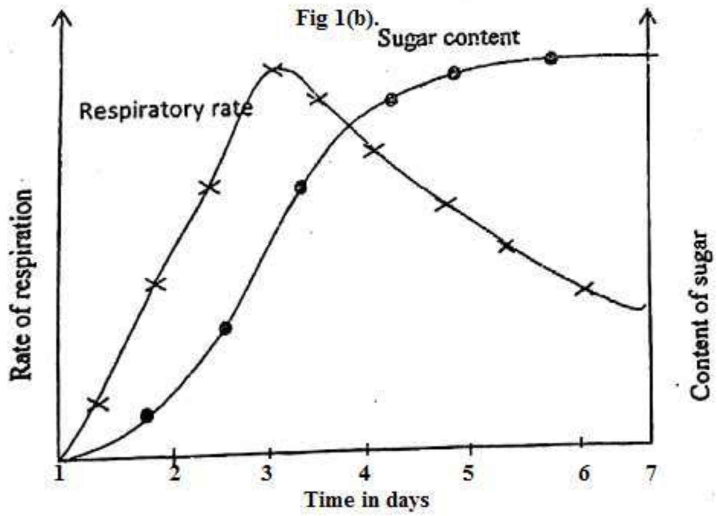
(e).In what ways are saprophytes important to man? ***(09 marks)***

- Decomposition of dead organic matter unlocks mineral elements allowing nutrient recycling.
- Breakdown products of organic matter eg CO_2 is used in brewing, baking, cheese and yorghurt making.
- Important in decomposition of sewage;
- Pathogenic saprophytes cause diseases.
- They are cultured for research for example E coli
- Cause food spoilage; rendering it inedible for human consumption.
- Important in enzyme production;
- Used in the manufacture of antibiotics eg penicillins.
- Sources of food in symbiotic relationship e.g symbiotic bacteria in human gut; are involved in production of nutrients like vitamin B_{12} complex.

Question 17.

Figures 1(a) and 1(b) show the physiological changes that occur in a fruit as it ripens





(a). Describe how each of the following variables changes with time:

(i) Respiratory rate ***(05 marks)***

Respiratory rate increases rapidly reaching a peak; around the 3rd day; then gradually reduces; up to the 7th day.

(ii) Sugar content ***(06 marks)***

Between 1 to 2.5 days; the sugar content increases rapidly between 3.5 to5 days; the sugar content increases gradually between 5 to7days, the sugar content remains constant;

(b). Explain the variations in each of the following

(i). Respiratory rate ***(05 marks)***

The rate of respiration rises rapidly inorder to generate energy required for the process of ripening. Then gradually decreases because the process of ripening is almost complete; so the energy demand of the fruit reduces

(ii).Sugar content ***(05 marks)***

The sugar content increases because the starch is being broken down into sugars. Gradual increase is due to slow conversion of starch to sugars. Sugar content remains constant because fruit ripening is complete.

(c). Explain the relationship between the content of chlorophyll and carotenes. ***(08 marks)***

The chlorophyll content of the fruit reduces while the carotene content increases; chlorophyll content decreases because it is being broken down to allow fruit ripening to occur. Content of carotenes increases because they are being synthesized so that the fruit attains an attractive colour and smell which is important in fruit dispersal.

(d). What is the ecological significance of each of the changes depicted on the figures? ***(05 marks)***

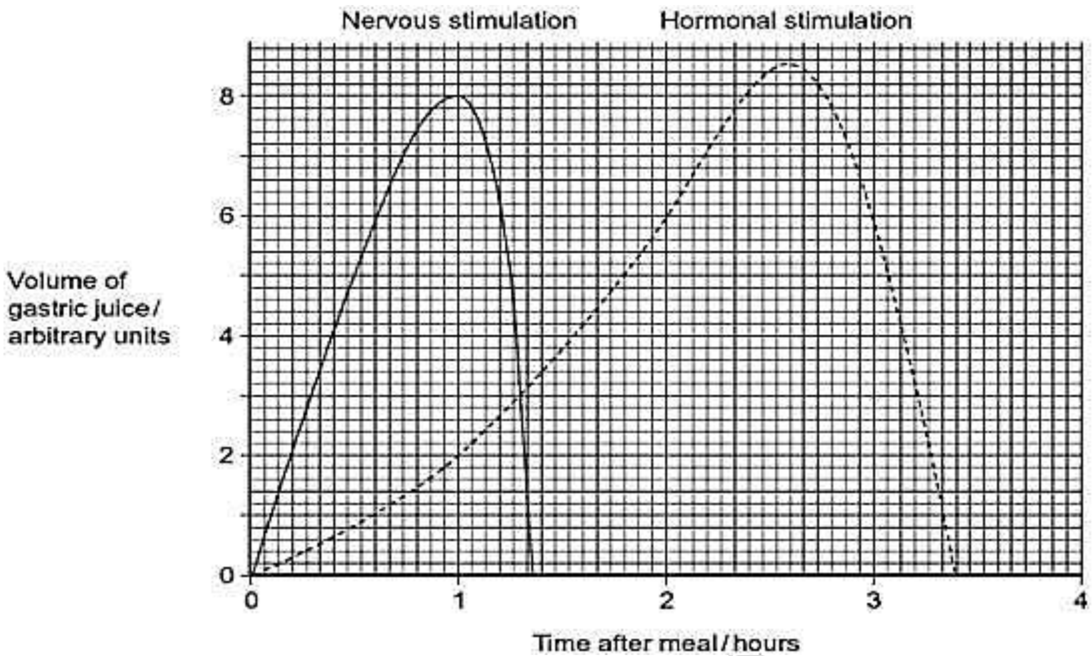
The rate of respiration increases to facilitate fruit ripening. Sugar content increases to make the fruit palatable to consumers which leads to its dispersal. Chlorophyll content decreases to allow fruits to ripen. Content of carotenes increases to give the fruit an attractive colour important in dispersal

(e).Outline other changes which occur in a fruit as it ripens. In each case, give the importance of each of the change. ***(06 marks)***

The cell wall becomes degraded to soften the fruit. The concentration of ethene increases to speed up the Process of ripening & also cause fruit fall. The vitamin C content of the fruit increases to increase on its nutritional value.

Question 18.

Cells in the stomach wall release gastric juice after a meal. The graph shows how the volumes of gastric juice produced by nervous stimulation and by hormonal stimulation change after a meal.



(a)(i).Compare the changes in volume of gastric juice shown by the two curves.

Similarities

• No gastric juice release at both stimulation conditions before meal at 0 hours
• Gastric juice levels were the same at 0 hours and 01:45 hours at both stimulations
• Both stimulations caused a rise to a peak/ maximum in gastric juice secretions
• Both stimulations caused a rise in gastric juice volume just after the meal
• From 0hours to1hour, volume of gastric juice was increasing at both stimulation conditions.

Differences

Nervous stimulation	**Hormonal stimulation**
For one hour just after a meal, volume of gastric juice rose rapidly	Volume of gastric acid rose gradually
Gastric juice release lasted a shorter time (1.5 hours after the meal)	Lasted longer time(3.4 hours after the meal)
Reached a lower peak	Reached a higher peak
Volume of gastric juice reached peak in one hour after a meal (after a shorter time)	Reached peak in 2.5 hours after meal (after a longer time)
From 1 hour to 1.4 hours, volume of gastric juice fell very rapidly	Volume of gastric juice had a gradual rise

(ii). Describe the evidence from the graph that curve A represents the volume of gastric juice produced by nervous stimulation.

Volume of gastric juice increased rapidly just after a meal; Gastric juice secretion lasted a very short time. The release of gastric juice by the nervous stimulation is more rapid/ very test/immediate; and decreases rapidly just like nervous communication whereas hormonal stimulation is slower/ gradual; then increases rapidly after sometime, long lived and then decreases rapidly.

(iii) How are the changes shown by the graph brought about?

Nervous reflexes

(b). The table summarizes mechanisms of control of release of digestive secretions along different parts of the gut.

Part of gut	**Control mechanism**
Mouth	Nervous only
Stomach	Both nervous and hormonal

Ileum	Hormonal control only

(i).Discuss the variation in the trend of control of release of digestive secretions.

Mouth; nervous is rapid since food reaches mouth in the shortest time and short lived since digestion in mouth lasts a very short time

Stomach; nervous since food rapidly reaches stomach following the swallowing reflexes; and hormones whose effect is long lived since the stomach is large thus temporarily stores food for a relatively longer time ensuring digestion of proteins occur

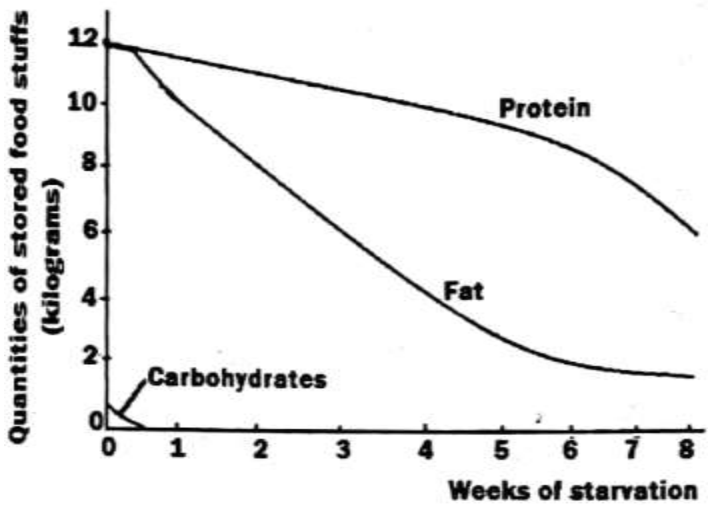
Ileum; hormonal (slow but long lived effect); food takes long to reach ileum thus needs a mechanism that is so slow but lasts a very long time in the ileum and thus requires hormonal mechanism whose effect is long lived.

(c).Explain why release of digestive secretions in man should be controlled.

- Prevent wasteful use of energy in release of secretions without digestive work to be done
- Increase efficiency by ensuring release of secretions in presence of food to be digested
- Prevents waste of materials eg secretions in case there is no food
- Prevents self/ auto-digestion of gut walls (made of proteins) by proteolytic enzymes
- Prevents development of gastric ulcers due to acid release in absence of food; which neutralizes acid effect on gut walls.

Question 19.

The graph below shows the effect of starvation on the food stores of the body of human being starved for 8 weeks



(a) Explain the effect of increasing time of starvation on quantities of each of the stored food stuffs,

(i). Carbohydrate. ***(06 marks)***

The quantity is small; little carbohydrates stored as glycogen decreases gradually/ glycogen stores in the liver and muscles is converted to glucose; supplying energy for the first days of starvation.

(ii).Fat. ***(08 marks)***

Initially, the quantity was high not easily utilized. From 0 to ahalf a week; the quantity is almost constant/ decrease gradually/ carbohydrates are still being utilized. For the first weeks, the quantity of fats decreased rapidly; fats are broken down rapidly in the liver to release fatty acids; which are then used instead of glucose in cellular respiration; between 5 weeks and 8 weeks, the quantity decreases gradually; fat stores are almost depleted; other food stores other than fat e.g proteins; are being utilized; decreasing; break down of fat stores to release energy.

(iii) Protein. ***(10 marks)***

For the first week of starvation, the quantity decreases rapidly; muscle protein is converted to glucose; oxidized to provide energy; between week 1 and week 6, the quantity decreases gradually; as other alternative food stores e.g. fats; are being utilized; between week 6 and week 8, the quantity decreases rapidly; fat stores have run out; proteins utilization for provision of energy resumes/renewed.

(b) From the graph provided above what conclusion can you draw on how the body utilize stored food reserves during starvation? ***(03 marks)***

- Fats are mostly utilized in the first/initial weeks of starvation;

• Proteins are utilized mostly later/late during starvation;
• Fats are most depleted stored food staffs;
• Carbohydrates are least utilized;

(c) Suggest from the graph the advantages to the body of an individual of;

(i) storing fats over carbohydrates. ***(03 marks)***

• Larger energy stores; not completely utilized before starvation
• Provides energy for a longer period of times since they are slowly oxidized

(ii) storing fats over proteins. ***(02 marks)***

Readily releases energy; since they are readily converted to respiratory substrate; which readily avail energy

(d).Using the graph, Explain structural changes likely to occur in the body of starving person. ***(05 marks)***

The person becomes emaciated; body tissues wastes away; as protein stores are being utilized; for provision of energy as seen in the first week and the last two weeks of starvation.

(e).Suggest how a person with low fat intake in diet may become obese. ***(03 marks)***

• Intake of extra carbohydrates and proteins in diet; which can be converted to body fat;
• Having little physical exercise; making energy input as a result of eating carbohydrates greater than energy used

(f).State;

(i).three effects of prolonged under nutrition in children ***(03 marks)***

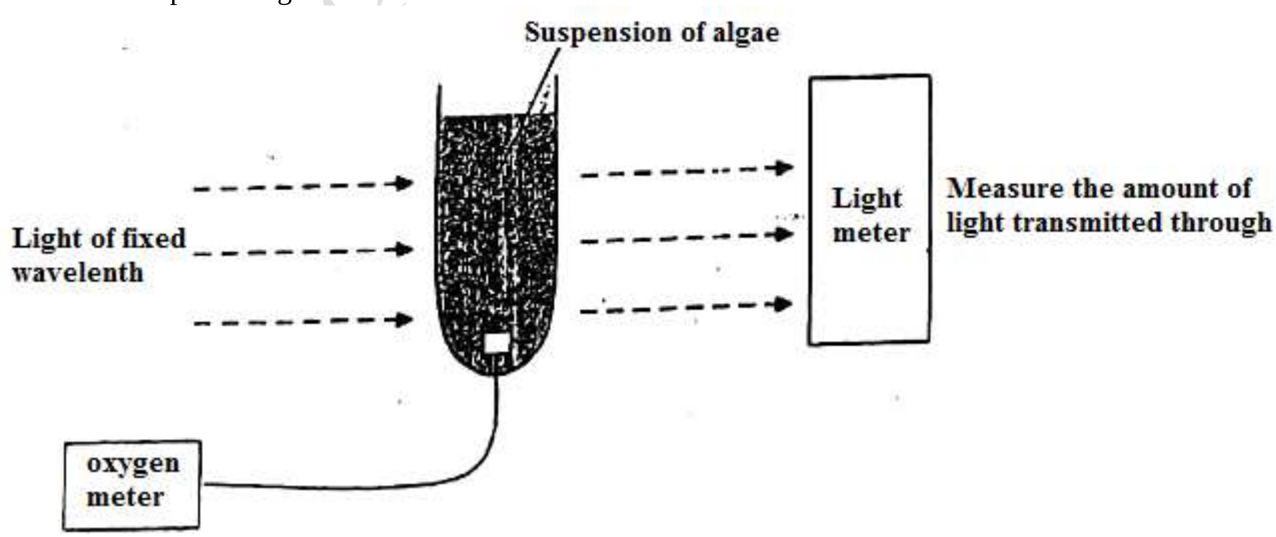
• Hypoglycemia (low blood sugars)
• Hypothermia (loss of excessive body heat)
• Dehydration
• Electrolyte imbalances
• Micronutrient deficiencies eg vitamin deficiencies
• Susceptibility to infections
• Wastage/ loss of body mass

(ii)two ways protein deficiencies may arise in individuals ***(02 marks)***

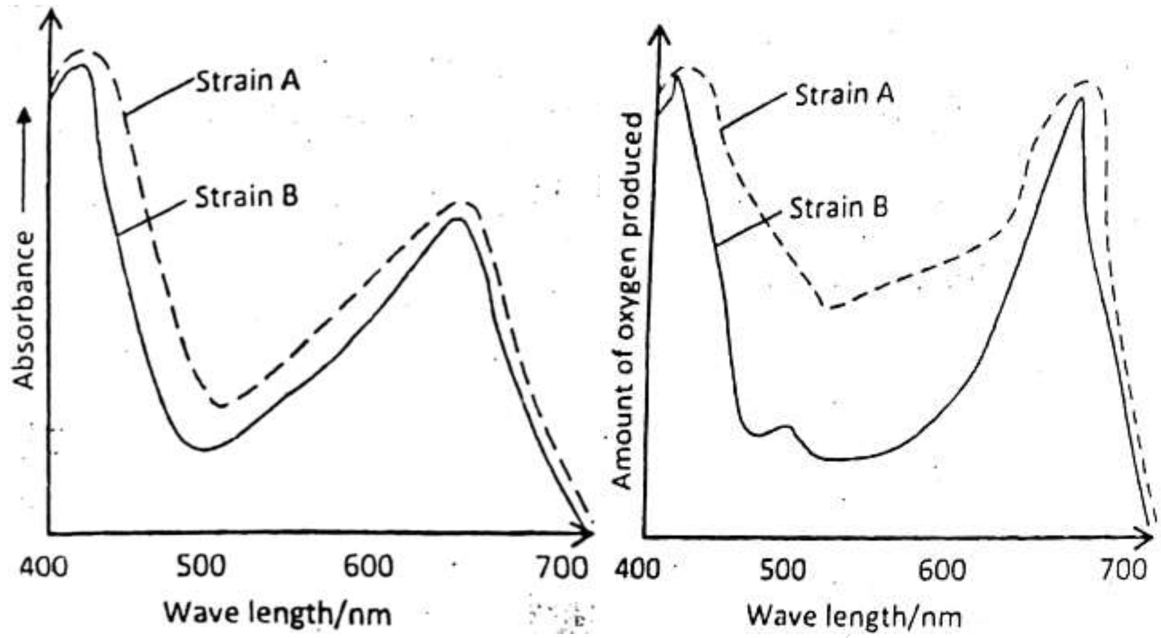
• Low proteins in the diet
• Protein losing enteropathies such as celiac disease
• Loss of protein urine eg in nephrotic syndrome
• Impaired synthesis in the liver eg in liver cirrhosis

Question 20.

Investigations were carried out using two strains of the same species of unicellular alga, one of which was a mutant that could not survive long periods of intense/ illumination. Light of known wavelength was passed through a tube containing the alga and measurements were taken both of oxygen produced and of the light transmitted. The experimental setup was staged as shown



The results obtained were used to plot the absorption and action spectra for each strain of alga as shown below



(a). State how the absorption and action spectra of the two strains are comparable

Absorption spectrum

Similarities
- Both strains show two peaks of absorbance
- Both strains have the first absorbance peak higher than the second
- For both strains; absorbance decreases between wavelengths from 430nm to 500nm and between 650nm & 720nm
- For both strains, absorbance increases from wavelengths 400nm to 430nm & wavelengths from 500nm to 650nm

Differences
- At all wavelengths absorbance for strain A is higher than that of strain B
- Peaks for strain A are higher than those of strain B

Action spectrum

Similarities
- For both strains A and B; amount of oxygen peaks twice
- For both strains A & B; amount of O_2 produced decreases from wavelength 430 to 490nm and from 660 to 700nm.
- For both strains A& B; amount of O_2 produced increases from wavelength 400 to 420nm & from 510nm to 660nm
- For both strains A and B; the first peak is higher than the second peak
- For both strains A and B; peaks are reached at about wavelength 420nm and 660nm

Differences

Action spectrum of Strain A	Action spectrum of Strain B
Peaks attained are higher	Peaks attained are lower
Amount of oxygen produced increases rapidly between 560nm and 630nm	Amount of oxygen produced decreases gradually between 430nm and 490nm
Amount of oxygen produced is higher throughout	Amount of oxygen produced is lower throughout

(b). Using the information provided, with a reason, state which of the two strains of algae is a mutant

Strain B; has a lower absorbance throughout due to bleaching of some pigment molecules by intense illumination.

(c). Explain the changes in the amount of oxygen produced by strains A and B of algae

From 400nm to 430nm and from 520nm and 650nm, amount of oxygen produced increased; the pigment in both strains; absorbance of light increased; providing more light energy for photolysis of more water molecules during the light dependent stage of photosynthesis giving off more oxygen.

From 430 to 500nm and from 650nm to 720nm, amount of oxygen produced decreases rapidly; absorbance of the pigments in the two strains decreases: less light energy is suppled; few water molecules undergo photolysis; producing a small amounts of oxygen

Amount of oxygen produced by strain A is generally higher than that of strain B. Stain B is a mutant form; once exposed to constant high light intensity, the pigment in strain B is bleached; reducing Its absorbance; less energy is trapped and provided for photolysis of water molecules; few water molecules are broken down releasing less oxygen

(d). Suggest the precautions that can be undertaken to obtain accurate results from the experiment above. Give reasons for your answer.

- Colour filter placed between light source and suspension of algae obtain a fixed wave length of light.
- Light source is placed at a constant distance from the suspension of alga to keep light intensity constant
- Experiment must be carried out at night in a closed room to prevent interference from external light
- Volume of alga suspension for strains A & B must be the same to keep surface area for absorption of light constant
- Equal concentration of sodium hydroxide solution to provide carbondioxide for photosynthesis

(e)(i). Other than the measurement of amount of oxygen produced, which other methods can be used to obtain the results of the action spectrum above

- Measurement of amount of carbon dioxide utilized
- Measurement of accumulated starch /glucose

(ii) Explain why the method used to obtain results of the action spectrum is not considered to be accurate

Not all oxygen produced of alga during photosynthesis was given off; some was retained in the alga and used for other processes eg respiration.

(f). How are the algae used in the experiment adapted for photosynthesis?

- Has a green pigment for absorption of sunlight
- Large vacuoles to enable alga to float exposing themselves to light absorbing more sunlight energy
- Pyrenoids or storage or products of photosynthesis

Question 21.

Chlorophylls and carotenoids are plant pigments that absorb light for photosynthesis. Different species of plants contain different amounts of these pigments. The pigments that each plant species has are adaptations to where and how they live their ecological niche.

Figure I shows the absorption of light of different wavelengths by chlorophyll a, chlorophyll b and carotenoids Another study was carried to show the amount of energy in light of different wavelengths reaching the ground in the forest. The energy was measured in direct sunlight and sunlight that had passed through the leaves of the trees. **Figure 2** shows the results of the study

Figure 1

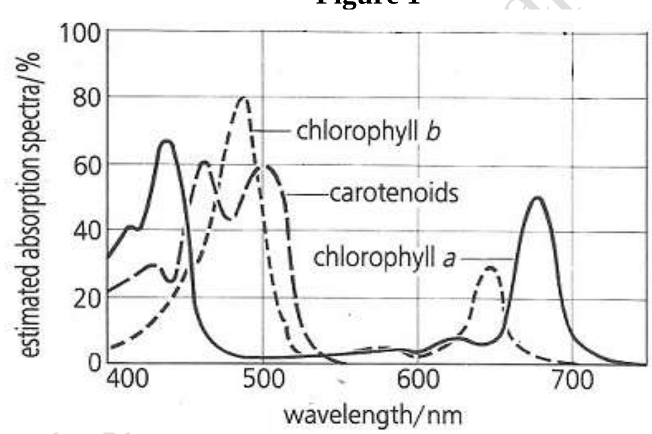
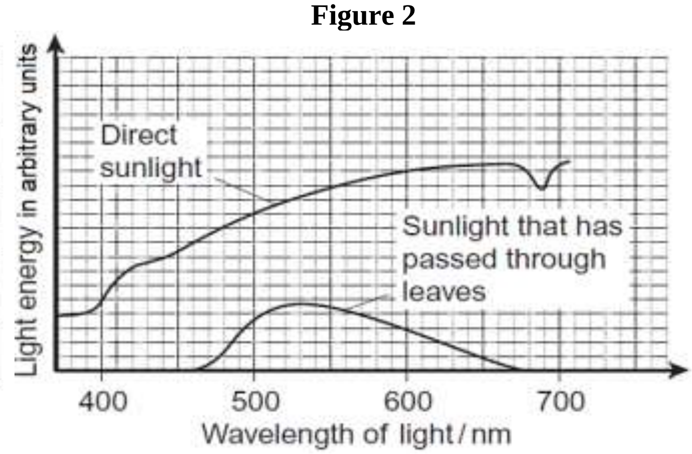


Figure 2



Sun leaves and shade leaves are two different kinds of leaves on beech trees. Sun leaves grow on branches exposed to direct sunlight, shade leaves grow on branches exposed to light that has passed through leaves. An ecologist collected sun leaves and shade leaves from beech trees and determined the mean mass of each photosynthetic pigment in both-types of leaf. The results are as shown in figure 3 below.

Figure 3

Photosynthetic pigment	Mean mass of each pigment per m^3 of leaf area/ micrograms	
	Sun leaves	Shade leaves
Chlorophyll a	299.3	288.9

Chlorophyll b	90.7	111.1
Carotenoids	0.10	0.07

(a). Plot a suitable graph to represent the data in figure 3 above

(b). Describe the absorption of light of different wavelength by chlorophyll ***(08 marks)***

Below 400nm, absorption of light is high and increasing gradually; From 400nm to 430nm, light absorption increases rapidly reaching highest peak. From 430nm to 450nm, light absorption decreases rapidly and then gradually decreases from 450nm to 520nm. From 520nm to 600nm, no absorption of light occurs. From 600nm to 640nm, absorption of light increases gradually. From 640nm to 670nm, light absorption increases rapidly to the second peak; then decreases rapidly from 670nm to 700nm & finally decreases gradually to the minimum beyond 700nm

(c).Comment on light absorption of different wavelengths by chlorophylls and carotenoids ***(06 marks)***

- Between 550nm and 600nm there is no absorption of light by all pigments because the wavelengths are reflected
- Each pigment shows at least two peaks of absorption
- All pigments show maximum absorption between 400nm and 500nm.
- Highest peaks of absorption of chlorophyll a and b are higher than the peaks of carotenoids
- Chlorophyll b shows the highest absorption
- Absorption occurs over a wide range of wavelengths for chlorophyll a and b but no absorption by carotenoids occurs beyond 550nm.

(d).Explain;

(i).The penetration of light through the forest ***(04 marks)***

All wavelength of direct light hit the ground since there is no obstruction. Only light wavelength from 460nm to 670nm hit the ground because it is not absorbed by the chlorophylls in the leaves. Other wavelengths of light pass through leaves and do not hit the ground as they are absorbed by the chlorophylls.

(ii).Why few species of plant can survive under shady habitats ***(02 marks)***

Less energy passes through leaves; smaller range of wavelengths passes through the leaves; little light for chlorophyll to absorb so insufficient photosynthesis therefore photosynthesis is unlikely to exceed respiration.

(c). Explain

(i). The advantage of producing more chlorophyll b in shade leaves to beech trees ***(03 marks)***

Enables them to absorb light from a wavelength chlorophyll a cannot absorb efficiently for example between 440 nm and 550nm and between 600nm and 650nm allowing their continued photosynthesis hence their survival.

(ii) why in leaves at the top of trees in a forest, CO_2 is often the limiting factor for photosynthesis ***(02 marks)***

- There is alot of light as there is no shading thus light dependent reaction not limiting high utilization of CO_2
- It is always warm allowing fast activity of enzymes in the light independent reactions.

(f). Each type of pigment is produced by a specific enzyme-controlled pathway. Suggest how the same plant can produce more pigment in some leaf cells than others ***(02 marks)***

Greater amounts of enzyme for production of chlorophyll b; greater gene expression/ transcription of the gene/ more mRNA/ genes switched on; thus greater translation.

(g) Suggest the morphological adaptations of plants for shady environments ***(08 marks)***

- Stomatal density is low to avoid over cooling
- Palisade to spongy mesophyll ratio is low to allow maximum light penetration
- Leaf orientation horizontal to maximize light trapping
- Dark green colour of the blade due to increased chlorophyll to enhance light absorption in the dark
- Thin leaves to maximize light penetration
- Stomatal size large to allow loss of excess water
- Elongated internodes for accessing light

(i).Explain the other significance of carotenoids to the beech tree besides trapping light ***(02 marks)***

Carotenoids prevent damage to chlorophyll from very bright light since more carotenoids are found in sun leaves than shade leaves of beech tree; yet sun leaves are exposed to too much brighter light than shade leaves.

Question 1.

(a).How are leaves adapted to perform their functions? ***(14 marks)***

(b).Describe the importance of leaves to plants ***(06 marks)***

(a).

• Shiny waxy cuticle reduces water loss
• Buds on leaf margins for vegetative reproduction e.g. Bryophyllom
• Leaf tendrils enable plants to climb for support
• Thick leaf lamina for food and water storage
• Scale leaves offer protection especially to axillary buds
• Some leaves are reduced into thorns for protection/ defence
• Thin leaves reduce the rate of water loss by transpiration.
• Large air spaces in spongy mesophyll create enough diffusion gradients for efficient gaseous exchange.
• Numerous stomata enable gaseous exchange and transpiration to occur.
• Leaf sheath in some monocotyledonous plants e.g banana offers support.
• Hairy lamina reduces diffusion distance of gases to photosynthetic cells.
• Tentacle leaves with spiny margins, attractive colour, scent and sweet secretions attract insects ant trap them to obtain nourishment in insectivorous plants.
• Rich network of veins containing vascular tissues for efficient transport of production and raw materials of photosynthesis.

(b).

• The leaves enable plants to carry out photosynthesis as the chloroplasts in leaf cells in leaf cells traps light energy which can be converted into chemical energy in the manufactured food.
• Leaves carry out transpiration and in the process cool the plants and enable transport of materials in the plant.
• The leaves enable the plants to carry out gaseous exchange and ventilation via the stomata.
• Leaves can store some metabolic wastes which are eliminated as the leaves are shed to enable excretion
• Leaf modifications enable food and water storage;
• Leaf modifications (buds) are elements for vegetative propagation, defence, support obtaining nourishment by insectivorous plants etc

Question 2.

(a).Describe the significance of pigments and light in photosynthesis ***(12 marks)***
(b).How does altitude affect the distribution of C_3 and C_4 plants? ***(08 marks)***

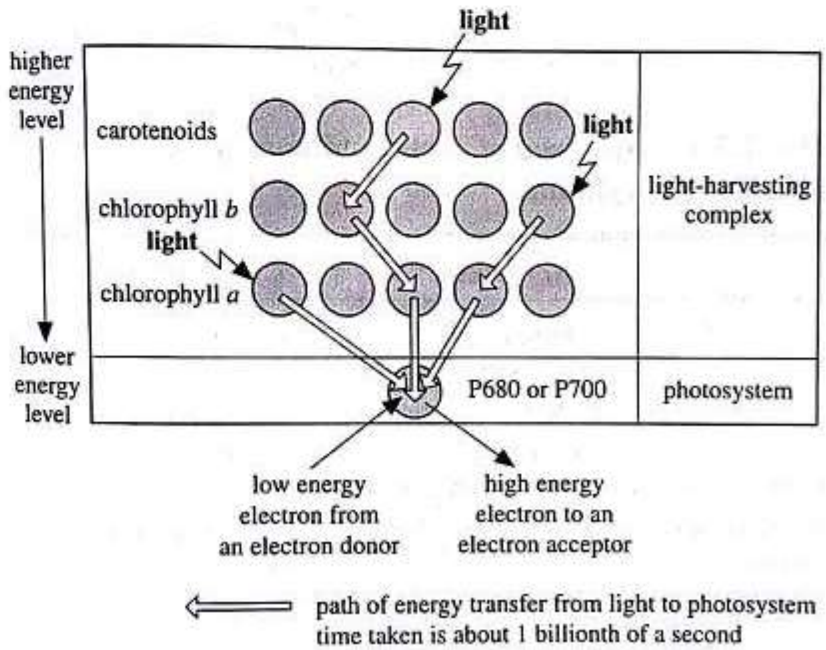
(a).

Role of pigments

Photosynthetic pigments do absorb light energy & convert it to chemical energy. These include primary pigments i.e chlorophyll a and b and accessory pigments i.e carotenoids (carotenes and xanthophylls) and phaeopytins Primary pigments, besides absorbing from their respective ranges (red and blue- violet ranges) receive additional solar energy from carotenoids (that absorb from the blue-violet range; All the energy is finally transferred to chlorophyll a; broadening the range of light utilizable by the plant. Accessory pigments also protect chlorophylls from excessive light and from oxidation by oxygen produced during photosynthesis; excites electrons at the reaction centres; Bacteriochlorophyll in photosynthetic bacteria; absorbs light energy from the UV and infrared range.

Role of light

Light provides solar energy during the light dependent stage which excites electrons; boost them up to higher energy levels and their transition through a series of electron carriers downhill in terms of energy; yields energy that is used to combine ADP with Pi to form ATP; Light, besides facilitating generation of ATP through cyclic and non-cyclic photophosphorylation; also facilitates photolysis of water; generates hydrogen ions which stabilize photosystem II and also reduce NADP to NADPH; a compound incorporated into the Calvin cycle in the light independent stage; reducing glycerate-3-phosphate to triose phosphate;



(b).

High altitude favours more growth of C_3 plants than C_4 plants; due to the low/cool temperatures; which permit C_3 plants to fully open their stomata; obtain adequate carbondioxide without risk of excessive water loss through transpiration; High carbondioxide concentration ably outcompetes oxygen at the active site of Ribulose bisphosphate carboxylase (RUBISCO); increasing photosynthetic efficiency as well as decreasing chances of photorespiration; Moderate-low altitude favours more existence of C_4 plants than C_3 plants because of their highly effective CO_2 fixing enzyme Phosphoenol pyruvate carboxylase (PEP carboxylase); whose high optimum temperature makes it tolerant to high environment temperatures; present at mid-altitudes; C_4 plants are also resistant to photorespiration; which increases their photosynthetic efficiency.

Question 3.

(a).Describe the central role of acetyl CoA in carbohydrate and fat metabolism. ***(03 marks)***
(b).Explain photophosphorylation in terms of chemiosmosis. ***(07 marks)***
(c).Explain why the light-independent reactions of photosynthesis
(i).Can only continue for a short time in darkness ***(05 marks)***
(ii)Rely on light-dependent reactions ***(05 marks)***

(a).

Acetyl CoA enters Krebs cycle; glucose/ carbohydrates converted to pyruvate in glycolysis; pyruvate enters mitochondria; pyruvate gets converted to acetyl CoA by oxidative decarboxylation in which hydrogen and CO_2 are removed Fats enter mitochondria; the fatty acid component gets oxidized to acetyl CoA.

(b).

Chemiosmosis is synthesis of ATP coupled to electron transport and proton movement and photophosphorylation is the production of ATP with energy from light. Light energy causes photolysis /splitting of water; electrons get energized (from chlorophyll)/ photoactivation. Photolysis provides (replacement) electrons for those lost from excited chlorophyll and protons/ H^+ (for thylakoid gradient). Electron trans- port (carriers on membrane of thylakoid) causes pumping of protons/ H^+ across thylakoid membrane/ into thylakoid space; protons accumulate in thylakoid space/ proton gradient set up; protons/ H^+ move down concentration gradient into stroma; flow through ATPase/synthetase leading to ATP formation.

(c)(i).

Light independent reaction involves formation of ATP/NADPH + H^+. The supply of ATP/ NADPH+H^+/ intermediates is used up / runs out in the dark. ATP and NADPH + H^+ being inadequate makes GP not to get reduced or converted to triose phosphate. RuBP therefore doesnot get regenerated, carbon dioxide fixation hence stops. GP accumulates, stomata close in the dark and carbondioxide is therefore not absorbed.

(c)(ii).

Light-independent reaction fixes CO_2 to make glycerate-3-phosphate/ to triose phosphate/ phosphoglyceraldehyde /glyceraldehyde 3-phosphate using NADPH and ATP needed to regenerate RuBP. ATP is made in light dependent reactions and causes photoactivation / excitation of electrons. The flow of electrons causes pumping of protons into thylakoid membrane; electrons are passed to NADP; NADPH produced in the light dependent reactions.

Question 4.

(a).Outline the general adaptations of leaves for photosynthesis *(15 marks)*

(b).Describe the structure of the chlorophyll molecule *(05 marks)*

(a).

Adaptations for obtaining sunlight

- Phototropism causes shoots to grow towards light in order to obtain energy.
- Etiolation causes rapid elongation of shaded shoots to enable access to light.
- The mosaic leaf arrangement minimizes leaf overlap and reduces leaves shading each other.
- Leaf large surface area enables capturing maximum sunlight.
- Thinness of leaves enables maximum light penetration.
- The transparence of leaf cuticle and epidermis allow light penetration into the mesophyll.
- The palisade mesophyll cells are densely packed with chloroplasts to trap much light.
- Cyclosis (movement of chloroplasts within the mesophyll cells) allows repositioning in the direction of light.
- The chloroplasts hold chlorophyll in an ordered way on the sides of the grana to present maximum chlorophyll to the light and also bring it close to other pigments / substances necessary for functioning.
- Multiple cell layers in the palisade mesophyll of sun plants increases photosynthetic efficiency.

Adaptations for gas entry and exit

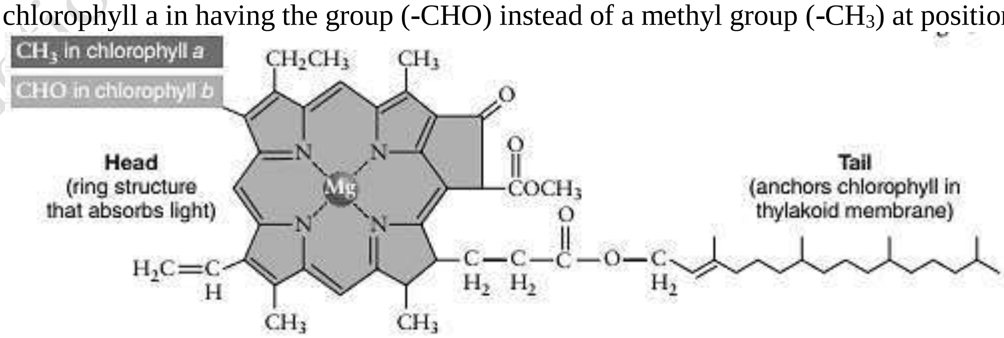
- Numerous stomata are present in the epidermis of leaves to enable entry and exit of gases.
- The guard cells bordering stomata pores can be opened & closed to regulate uptake of carbon dioxide & the loss of water.
- Spongy mesophyll possesses many air spaces to enable faster and uninterrupted diffusion of gases between the atmosphere and the palisade mesophyll.

Adaptations for liquid entry

- A large central midrib containing a large vascular bundle is possessed for the entry and transport of water and mineral salts, and the phloem for carrying away sugar solution
- A network of small veins is found throughout the leaf to ensure every cell is close to xylem vessel or phloem sieve tube for constant supply of water for photosynthesis and a means of removing the sugars they produce.

(b).

Chlorophyll molecule has a tadpole-like structure with a hydrophilic head called porphyrin and a hydrophobic tail made up of long chain alcohol called phytol. The flattened head is made up of four nitrogen containing pyrrole rings which are linked by methionine bridges (-CH=). The skeleton of each pyrrole ring is made up of 5 atoms i.e four carbon atoms and one nitrogen atom. The nitrogen lies towards the centre. A magnesium atom is held in the cent-re of porphyrin head by nitrogen atoms of pyrrole rings using 2 covalent and 2 coordinate bonds. Chlorophyll b differs from chlorophyll a in having the group (-CHO) instead of a methyl group ($-CH_3$) at position R (carbon 3).



Question 5.

(a).How are plants living under the canopy of forest trees are able to survive? *(10 marks)*

(b).Explain how light may affect the activity of organisms *(10 marks)*

(a).

- These plants possess leaves with much chlorophyll to trap the little light available for maximum photosynthesis;
- Some undergo etiolation due to sufficient Gibberellins growing taller to receive light for photosynthesis.
- Some have adopted a parasitic mode of nutrition eg the epiphytic feeders.
- Some have breathing roots that grow up from water logged soils to allow efficient gaseous exchange.
- Some plants like ferns have tissues that are tolerant to water logged environments.
- Most plants are seasonal, growing only when conditions are favourable.
- Some of the plants have developed heterotrophic feeding such as insectivorous feeding.
- Some plants have adopted C_4 photosynthesis making them more photosynthetically efficient.
- Their leaves are broad to increase the surface for maximum photosynthesis;
- The leaf litter when decomposed provides nourishment to the plants living the canopy of forest trees.
- These plants are normally reduced in number to reduce competition for light;
- They possess elongated stems to expose the leaves to maximum light available;
- Development tendrils from stems and leaves to support themselves onto trees reach the top of canopy and trap light for photosynthesis.
- Some plants have symbiotic relationship with the forest trees and other saprophytic organisms like fungi in order to obtain enough nourishment.
- Some plants possess slender twinning stems to climb other plant stems to expose their leaves to receive light for photosynthesis;
- Some grow in strategic position of gaps within the canopy where maximum direct illumination occurs.
- The leaves have thin cuticle since there is no threat of much water loss with an environment of still air, low light intensity and high humidity which tend to lower transpiration rate.
- Their chloroplasts contains enzymes that are adapted to carry out photosynthesis at low carbondioxide concentr-ations.
- They tend to have extensive root system to utilize the shallow water and avoid competition with the trees for wa-ter in deeper soil layers.
- They possess more stomata on the upper exposed epidermal leaf surface to increase the efficiency of oxygen up-take for respiration and carbon dioxide uptake for photosynthesis.

Note

- The canopy reduces the rate of transpiration of the plants under; in this way, these plants are able to survive with minimum risk of desiccation;
- The canopy protects these plants from strong winds and possible soil erosion, increasing water available at the surface

(b).

- Light energy is used in photosynthesis/ photo phosphorylation.
- Unidirectional light causes bending of plant parts by phototropism;
- Light stimulates leaf growth; formation of chlorophyll and flowering of plants;
- Light breaks dormancy or induces germination
- Too much light inhibits growth in some plants
- Very high light intensity bleaches chlorophyll molecules causing yellowing of leaves or choruses.
- Affects stomatal opening and closure.
- Light breaks diapause in insects.
- Light stimulates flowering in plants.
- Light stimulates the synthesis of vitamin D in animals.
- Light leads to an increase in the rate of transpiration;
- Light is responsible for vision, enhancing visibility of prey and predator.
- Light causes or induces mating of some organisms e.g Fire flies;
- Light affects migration / reproduction of organisms as a photoperiod.
- Ultra violet rays can induce mutation; breaks hydrogen bonds of biological molecules
- Too much light energy increases heat content of water which is not conducive to water dwelling organisms.

Question 6.

(a).What do you understand by the following?
(i).Photophosphorylation *(03 marks)*
(ii).Chemosynthesis. *(02 marks)*
(b).How light energy is transformed into chemical energy for dark assimilation *(07 marks)*
(c)(i).Giving examples, explain how some animals are able to utilize cellulose available in their food.
(ii).What problems does a man with a ruptured pancreas face in utilizing ingested food? *(04 marks)*

(a)(i).

Photophosphorylation refers to synthesis of ATP from ADP and inorganic phosphate using light energy during photosynthesis in chloroplasts. The process occurs on thylakoid membranes of chloroplast and may involve cyclic or non-flow of electrons.

(a)(ii).

Chemosynthesis refers to synthesis of complex organic substance using energy from chemical reactions involving oxidation of inorganic substances. This mainly occurs in bacteria e.g iron bacteria nitrifying bacteria etc.

(b).

This occurs on thylakoid membrane of chloroplasts; light energy is absorbed by chlorophyll molecules,this causes electrons to be excited, released and raised to a higher energy level, where they are accepted by electron acceptor such as plastoquinone; From the electron acceptor electrons flow along a chain of electron carriers, which are at different inorganic phosphate: electrons carriers include cytochromes and ferrodoxine; in non-cyclic photophosphorylation, electrons flow from photosystem II (P680) electron acceptor. The electrons then flow downhill of electron carrier system to photosystem II (P700), then to the next electron acceptor at a higher energy level, then they flow downhill via a chain of electron carriers to NADP. They combine with hydrogen ions from water to from reduced NADP; the electrons lost from photo system II are replaced by electrons from hydroxyl ions derived from photolysis of water with subsequent release of oxygen. However, in cyclic photophosphorylation electron released from photo system I flow back to photosystem I via a chain of electrons carriers; with subsequent ATP synthesis from ADP and inorganic phosphate.

(c)(i).

- Non-ruminants e.g rabbits and horses have cellulose digestion bacteria in their appendix and caecum;
- The faecal pellets are swallowed for normal absorption in ileum.
- Ruminants e.g. sheep, cattle, goats have a four chambered stomach in which mutualistic micro-organisms in their rumen secret cellulose for cellulose digestion.
- Rumen content is regurgitated for further digestion and absorption
- Termites have mutualistic flagellated protozoans in the gut which secrete cellulase for cellulose digestion.

(c)(ii).

There is failure to secrete pancreatic juice or it is secreted in limited amounts resulting in;
- Little or no pancreatic amylase hence little or no digestion of amylose in starch to maltose
- No pancreatic lipase leads to failure to digest the ingested lipids to fatty acids and glycerol
- No carboxypeptidases and hence failure to digest peptides to amino acids
- No trypsin thus failure to digest proteins to peptides and failure to activate chymotrypsinogen to chymotrypsin
- No elastin leads to failure to digest proteins to peptides.
- Steatorrhoea (fatty stools) may occur in the intestines because of indigestion of fats in the duodenum.

Question 7.

(a) Describe the adaptation which enables each of the following organisms to obtain and ingest their food.
(i) Herbivorous mammal. *(07 marks)*
(ii)Carnivorous mammal. *(06 marks)*
(b)Explain why milk cannot sustain healthy development indefinitely in mammals. *(07 marks)*

(a)(i).

- Broad and well developed molars and premolars for grinding and crushing food material
- Diastema for manipulating freshly cropped grass
- Some have 4 chambered stomachs; ensure regurgitation for maximum grinding and crushing.
- Mutualistic association with cellulose digesting bacteria; Secrete cellulase; digests cellulose into simple sugars.
- Relatively long alimentary canals which increases surface area for digestion

• Large and powerful masseter muscles; for effective chewing.
• Coprophagy (feed on their fecal matter); maximum derivation of all the nourishment from food.
• Upper jaws lack incisors; provides a hard pad against which lower incisors press and cut grass.
• Highly muscular tongue; for manipulating food during chewing
• Molars and premolars highly ridged; for maximum grinding of hard cellulose materials
• Loosely connected upper and lower jaws; whose upward, downward and sideways movements enhance efficient grinding and crushing of food material.
• Lack incisors & canines in the upper jaw; enable lower incisors effectively cut the cropped grass against the horny pad of upper jaw.
• Teeth grow continuously throughout life overcome the wear & tear effect for efficient and continuous digestion throughout life.

(a)(ii).

• Well-developed sense of smell for easily locating preys
• Fast moving such that they can outpace and capture preys
• Very sharp claws for gripping and killing the preys
• Keen eye sight to ensure long distance location of the prey
• Foot pads to ensure stealth movement to ambush the prey
• Elongated, sharp pointed canine for tearing the flesh of the prey
• Flat molars for crushing prey
• Pointed incisors for nipping and biting flesh
• Carnassial teeth for shearing flesh
• Upper jaw wider than lower jaw; facilitates shearing of flesh
• Up and down jaw movements only; prevents lateral movements reducing chances of dislocations
• Powerful jaw muscles which provide much force for chewing
• Less developed caecum and appendix; reduce body weight to enable fast running
• Relatively short alimentary canal; reduce body weight since diet is protein dominated

(b).

Much as milk contains all the nutritional requirements like protein, carbohydrates (lactose), lipids, mineral salts, vitamins and water, some amounts may be nutritionally insufficient to meet the metabolic demands of adults; In adult mammals, production of lactase enzyme; that digests lactose into simple sugars stops in the young ages; of the mammals and this would result in insufficient ATP production; Also lactose intolerant mammals are incapable of digesting lactose; thus incapable of deriving nutrients from milk; Breast milk also lacks vitamin K; weaning permits acquisition of vitamin K; an important element in blood clotting.

Question 8.

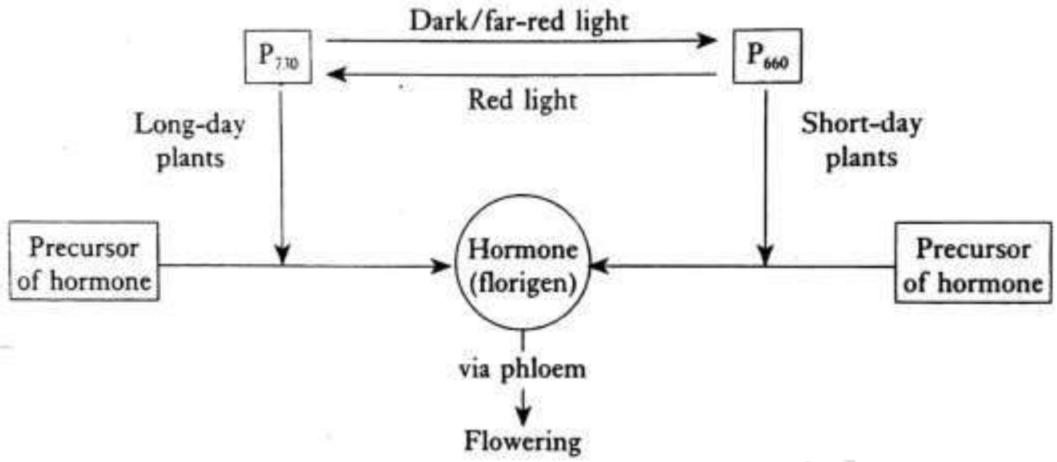
(a).How have plants been modified to obtain sufficient light? ***(09 marks)***
(b).Explain;
(i). How flowering is controlled in plants ***(08 marks)***
(ii) Other effects of light in flowering plants. ***(03 marks)***

(a).

• Broad leaves; to increase surface area for maximum light trapping.
• Mosaic leaf arrangement; prevents shading of leaves
• Concentration of most chloroplasts in the palisade layer; easily accessible by light
• Shade plants have developed climbing stems (twines, tendrils, clasps) to maximize search for light.
• Shade plants have developed elongated internodes, stem and leaves; to increase search for light.
• Tropical trees have developed canopies; increase leaf area index; increase light trapping
• Thinner leaves (one cell thick leaves); allows chloroplasts receive maximum light;
• Epiphytes live high in the branches of taller plants to maximize amount of light trapped
• Ability to reach compensation points early in shade plants
• Dense chlorophyll (green) pigmentation in both leaves and stems maximize light being trapped.
• Leaves with thin and less waxy cuticle; transparent to enable sufficient light infiltration
• Higher accessory pigment concentration; enables trapping of photons especially in shade.

• Shade plants have developed slender flexible stems; penetrate thick vegetation

(b)(i).



Flowering is controlled by two interconvertible forms of phytochrome; according to the amount of light received i.e phytochrome red (660nm) which absorbs red light and phytochrome far red (730) which absorbs; far red light. When a photoperiodic stimulus is received by the leaves; it induces the release of florigen; which is transported by phloem to the flower buds to initiate flowering. Long day plants flower after a short time exposure to red light (660 nm); this gets absorbed by phytochrome red (660); which rapidly converts to phytochrome far-red (730) that induces flowering. Short day plants flower in response to phytochrome red (660). Long time exposure to darkness gradually converts phytochrome far red to phytochrome red which is transported by the phloem to the dormant buds, induce flowering.

(b)(ii).

Photosynthesis; light energy excites electrons in chlorophyll during cyclic and non-cyclic photophosphorylation; also photolyse water molecule.
Germination; red light converts phytochrome red to phytochrome far-red which activates gibberellins with eventual activation of hydrolytic enzymes; hydrolysis of food reserves
Photomorphogenesis; like leaf expansion in dicot, leaf unrolling in grasses, chloroplast development (etioplasts converted to chloroplast), internode growth inhibition;
Phototropism; light dictates auxin distribution; facilitating positive phototropic response of the shoot and negative phototrophic response of the roots.
Stem and root elongation; light causes uneven auxin distribution in the root and the shoot facilitating differential growth of the shoot and root.
Stomatal opening and closure; light modulates the stomatal rhythm; high light intensity causes stomatal; low light intensity on the stomatal opening; Other effects of light include opening of the flower petals

Question 9.

(a)Outline the gut hormones and their effects towards digestion ***(08 marks)***
(b).Describe the events that occur when food reaches the duodenum ***(06 marks)***
(c).How are the herbivores adapted to their mode of feeding? ***(06 marks)***

(a).

Gastrin; stimulates secretion of hydrochloric acid from the parietal cells of gastric glands.
Secretin; terminates gastric acid secretion from the parietal cells; incites secretion of non-enzymatic components pancreatic juice e.g bicarbonate ions; causes contraction of gall bladder to release bile, increases gastrointestinal(GI) motility; increases GI emptying;
Cholecystokinin–pancreozymin (CCK-pz); stimulates release of the enzymatic components of pancreatic juice from the pancreas; causes contraction of the gall bladder to release bile; increases GIT motility and emptying.
Enterogastrone; inhibits any further acid secretion by the stomach
Enterocrinin; stimulates release of succus entericus from the crypts of Lieberkühn

(b).

Physical digestion in the duodenum immediately commences on arrival of acidic fatty chyme in the duodenum. Hormones secretin and CCK-pz stimulate cause contraction of gall bladder to release bile. Bile salts (sodium de-oxycholate) emulsify fats by lowering their surface tension while sodium bicarbonate neutralizes the acidic chy-me. Pancreatic juice; rich in enzymes and pancreatic salts is released from the pancreas. Sodium bicarbonate neutralizes the acid; also creates an alkaline medium for the action of the pancreatic enzymes. Carbohydrases break down polysaccharides to simpler sugars e.g pancreatic amylase breaks down starch (amylose) to maltose, trypsinogen; activated to trypsin by enterokinase; breaks down protein to smaller polypeptides; chymotrypsinogen which is converted to chyinotrypsin by trypsin digests proteins to amino acids. Carboxypeptidases break down peptides to amino acids, elastases break down elastin proteins to peptides, nucleases digest nucleic acids to nuc-leotides; pancreatic lipases breakdown lipids to fatty acids and glycerols. Chyme is finally forwarded to the ileum by peristalsis.

(c).

- Broad and well developed molars and pre-molars for grinding and crushing plant materials.
- Herbivorous mammals have large and powerful masseter muscles; for effective chewing.
- Herbivorous insects have strong mandibles with serrated edges for cutting grass.
- Alimentary canal is relatively long to ensure an increased surface area for effective digestion.
- Diastema for manipulating fleshly cropped grass from the one being chewed for maximum grinding and crushing.
- Some herbivores have four chambered stomachs for regurgitation of food
- Some like non-ruminants practice coprophagy i.e feed on fecal matter for maximum derivation of nourishment.
- Loosely connected upper and lower jaws; for up and down movements and sideways movement for efficient cr-ushing and grinding plant materials.
- Some mutually co-exist with cellulose digesting bacteria; which secrete cellulose for hydrolysis of cellulose into simpler sugars.
- Lack incisors and canines in the upper jaw; enables the lower incisors effectively cut the cropped grass against the horny pad of the upper jaw.
- Teeth of the herbivore grow continuously throughout life and are constantly replaced due to wear and tear; ensu-res efficient digestion in the organism throughout life.
- Herbivorous mollusces possess a grasping organ called the labrum (outer lip); which rubs backwards and forwa-rd against the hardened roof of the mouth; helping to tear the food material.

Question 10.

(a) Compare and contrast normal respiration with photorespiration ***(08 marks)***
(b).Explain the geographical distribution of C3, C4 and CAM plants ***(08 marks)***
(c).Briefly explain the factors that favour photorespiration in plants ***(04 marks)***

(a)

Similarities

- Both require oxygen as raw materials.
- Both produce carbondioxide as products
- Both proceed in the mitochondria
- Both are oxidative processes.

Differences

Normal respiration	photorespiration
Light independent	Light dependent
Useful energy inform of ATP is produced	Wasteful loss of ATP and NADPH
Only the mitochondria is involved	Involves three organelles; mitochondrion, Chloroplasts and peroxisomes.
Occurs in all living cells	Occurs in photosynthetic cell of some plants(C_3 plants only).

(b).

C_3 plants; distributed in temperate regions also in areas of higher altitudes due to low/cool temperature plants fully open stomata; obtain enough carbondioxide without risk of excessive water loss by transpiration. High carbondioxide concentration out competes oxygen at the active site of Ribulose bisphosphate carboxylase (RUBISCO), minimizing risks of photorespiration.

C_4 plants; distributed in tropical & subtropical regions; plants also present in areas of moderate-low altitude; because their CO_2 fixing enzyme Phosphoenol pyruvate carboxylase (PEP carboxylase), that, due to its higher optimum temperature, ably tolerates the high environmental temperature. High light intensity in the tropics is also effectively utilized, since plants are not at risk of photorespiration

CAM plants; distributed in desert/ hot regions and also in areas of very low altitude. These plants can tolerate the very high temperatures due to their ability to reverse their stomatal rhythm, ably photosynhesize at night and minimize excessive water loss that may otherwise occur if plants open stomata during the day. Plants also use PEP carboxylase to fix CO_2 a highly efficient enzyme in hot conditions and low CO2 concentration.

(c).

High oxygen concentration; oxygen outcompetes carbondioxide for the active site of RUBISCO favour oxygenation of RUBP; resulting in photorespiration

High temperature; high temperature increases both oxygenase and the carboxylase activity of RUBISCO but the oxygenase activity increases more rapidly than the carboxylase activity thus oxygenation of RUBP is favoured.

High light intensity; cause stomatal closure; accelerates photosynthesis; much CO_2 is used up and lots of oxygen is produced. This accumulates in tissues causing photorespiration.

Question 11.

(a) Outline the different digestive juices and the roles they play ***(05 marks)***

(b) Discuss the nervous and hormonal control of digestion in ***(15 marks)***

(a).

Saliva; softens and lubricates food, binds food particles together, contains amylase; digests starch to maltose;

Gastric juice; Acid kills bacteria in food; pepsin hydrolyses proteins to polypeptides; renin (coagulates milk protein).

Bile juice; bile salts neutralize acidic chyme; emulsify fats

Pancreatic juice; trypsin hydrolyses proteins to amino acids, amylase hydrolyses starch to maltose, lipases digest lipids to fatty acids and glycerols.

(b)

In the mouth conditioned reflexes e.g thought, smell and sight coupled with unconditioned reflexes when present in the mouth, leads to secretion of saliva by salivary glands. Saliva contains salivary amylase which hydrolyses starch in the mouth partly to maltose; saliva also softens and reduces friction easing swallowing. Secretion occurs in the three phases i.e cephalic, gastric and intestinal phases. Smell, sight or mere thought of food initiates the cephalic phase through the conditioned and unconditioned reflexes. HC1 and pepsinogen secretion begins; reaches peak within 30 minutes. Gastric phase starts when food has just entered the stomach; nervous stimulation of the stomach walls causes G cells within the gastric antrum, secrete gastrin, which stimulates release of gastric juice, whose major components are HCI, pepsin, rennin and gastric lipase. In the duodenum intestinal phase begins; presence of acidic fatty chyme; stimulates the release of secretin and CCK-pz from the duodenal mucosal cells, which counteract gastric acid secretion; increases GIT motility; facilitates rapid stomach emptying. Secretin and CCK-pz, also stimulate release of pancreatic juice; also cause contraction of gall bladder smooth muscles; producing bile into the duodenum at the sphincter of Oddi. Bile salts neutralize the acidic chyme as well as emulsifying fats. Pancreatic juices contain enzymes; pancreatic carbohydrases e.g amylases, pancreatic lipases, enterokinases, chymotrypsin, trypsin, carboxypeptidases and nucleases. In the ileum, presence of chyme stimulates release of Enterocrinin; stimulate release of succus entericus; containing enzymes; maltases, sucrases, lactases lipases, which complete digestion of carbohydrates, proteins and fat substrates. Both GIT secretions and motility are controlled by the enteric nervous system. Meissner's plexus controls GI secretions while the myenteric/ Auerbach's plexus controls GI motility. Inhibitory controls include fats which stimulate secretion of Enterogastrone; from the stomach walls; inhibiting HCl secretion which also stops secretion of salivary amylases. Evacuation reflexes and gastrocolic reflexes are spinal.

Question 12.

(a) Explain what is meant by photophosphorylation *(01 marks)*
(b) State the differences between leaves of a sun plant and those of a shade plant *(09 marks)*
(c).Describe
(i). how ATP can be generated in the chloroplast by the chemi-osmotic theory *(06 marks)*
(ii).the evidence to show that photosynthesis is a "two stage process" *(04 marks)*

(a).

Photophosphorylation refers to the formation of adenosine triphosphate (ATP) by addition of an inorganic phosphate to adenosine diphosphate (ADP) in presence of light

(b).

Leaves of a sun plant	Leaves of a shade plant
Smaller leaves	Larger leaves; creates large surface area
Leaves are lighter green; sometimes with red or	Leaves are deep green; maximally trap light; within
Thick cuticle (thick leaves)	Thin cuticle (thin leaves)
Much but smaller stomata	Fewer but larger stomata
Two or three layers of cells in the pallisade	One cell layer in the pallisade tissue
Most chloroplasts found in pallisade layer	Chloroplasts evenly distributed between the
Leaves slowly wilt	Leaves wilt rapidly
Short internodes	Long internodes
Higher compensation point	Lower compensation point

(c)(i).

Protons generated from photolysis of water are actively pumped from the stroma; across thylakoid membrane into the thyllakoid space; using energy from electron flow from the ETC. Protons accumulate in the thyllakoid space; concentration within exceeds that in the stroma; an electrochemical proton gradient is created across the thyllakoid membrane. Thyllakoid membrane is impermeable to protons; protons just diffuse back into the thyllakoid spaces via special chemi-osmotic channels present on the membrane. Discharge of the proton gradient releases energy that is used to link inorganic phosphate (Pi) to ADP to form ATP; reaction catalyzed by membrane bound ATPase (ATP synthase) found on the chemi-osmotic channels. Protons are in turn taken up by NAD which gets reduced to NADPH.

(c)(ii).

The **"enhancement effect."** which states that the rate of photosynthesis when red and far-red light are provided together is greater than the sum of the rates when each wavelength is provided individually‖. When the rate of photosynthesis is measured using two light beams of different wavelengths (one red and the other far-red), the rate was greater than the sum of the rates using individual beams of red and far-red light. This enhancement effect implied that the photosynthetic mechanism involved two photosystems acting in series (that is one after the other) one of which absorbs preferentially in the red which is predominant in the light stage and the other in the far-red which is predominant in the dark stage.

Question 13.

(a).Explain how light affects the geographical distribution of plants *(10 marks)*
(b).Outline differences between a C3 and C4 plants *(10 marks)*

(a).

Light intensity

CAM plants and C_4 plants are more distributed in areas where there is high light intensity e.g desert, tropical regions; because of their resistance to photorespiration and possession of an efficient enzyme PEP carboxylase that can tolerate higher temperatures usually associated with high light intensity. C_3 plants are more distributed in areas of low light intensity e.g in temperate regions to minimize chances of photorespiration. Besides their enzyme RUBISCO; has a lower optimum temperature; and can only tolerate lower temperatures associated with low light intensities.

Light duration

Short day plants (SDPs) are more distributed in areas of shorter day light (photoperiod< 12 hours); e.g in temperate regions because the plants efficiently flower under these conditions. Long day plants (LDPs) are more distributed in areas of longer day light duration e.g in tropical and desert areas because the plants efficiently flower under these conditions. Day neutral plants can be distributed in any of the above1ight durations; since their flowering is independent of the photoperiod.

Light quality.

Under sea hydrophytes are distributed at the sea bottom because of their ability to photosynthesize using light wavelengths not utilizable by the water surface hydrophytes and thus filter through:

(b).

Structural differences

C_4 plants	C_3 plants
Both bundle sheath cells and mesophyll cells are involved;	Only mesophyll cells are involved in photosynthesis.
Both bundle sheath cells and mesophyll cells contain chloroplasts.	Only mesophyll cells contain chloroplasts
Leaves have Kraanz‘s anatomy	Leaves lack Kraanz‘s anatomy
Plants generally have a large number of chloroplasts.	Leaves generally have fewer number of chloroplasts.

Physiological differences

C_4 plants	C_3 plants
CO_2 fixation occurs twice	CO_2 fixation occurs once
CO_2 acceptors are a 3 carbon compound and a 5 carbon compound RUBP.	CO_2 acceptor is a 5 carbon compound RUBP
CO_2 fixing enzyme are PEP carboxylase (highly efficient) and RUBISCO	CO_2 fixing enzyme is RUBISCO.
First compound formed is a 4 carbon compound oxaloacetate (OAA)	First compound formed is a 3 carbon compound is Phosphoglyceric acid(PGA)
Photosynthetic enzymes work efficiently at high temperatures.	Photosynthetic enzymes work efficiently at moderate and 1ow temperatures.
Need 30 ATP molecules for synthesis of one hexose sugar	Need 18ATP molecules for the synthesis of one hexose sugar.
No photorespiration	Photorespiration occurs
Involves the Calvin cycle and the Hatch-Slack pathway in the light independent stage	Involves only the Calvin cycle in the dark stage.
Compensation point occurs at lower carbondioxide concentrations	Compensation point occurs at higher Carbondioxide concentration.
Less efficient photosynthetically	More efficient photosynthetically.

Question 14.

(a).Describe the events that occur in the Z-scheme of photophosphorylation ***(08 marks)***

(b).Compare cyclic and non-cyclic photophosphorylation ***(06 marks)***

(c).Describe how the following are synthesized from glycerate-3-phosphate

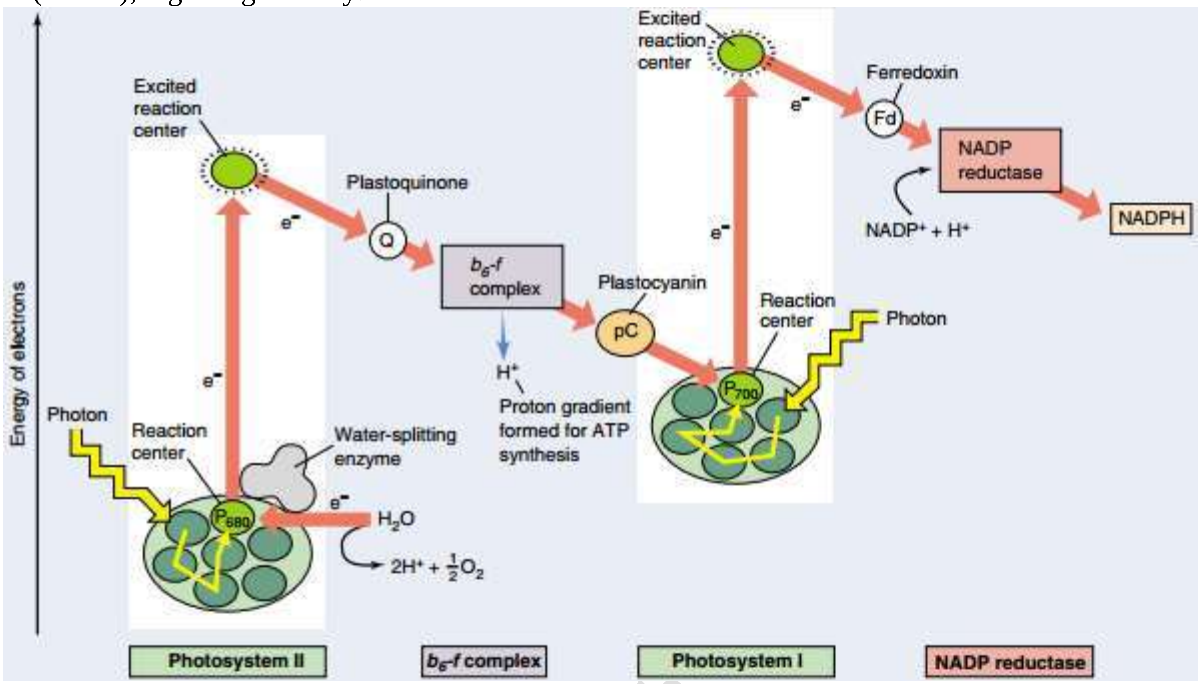
(i). Carbohydrates

(ii) Lipids

(iii)Proteins ***(06 marks)***

(a).

Sunlight energy strikes both photosystem I and II. Light absorbed by photosynthetic pigments in PS II is passed onto the reaction centre; energy excites electrons and they get lost thus the chlorophyll molecule gets oxidized and unstable (P680+). Electrons are accepted by plastoquinone (PQ); hands them over to the E.T.C; flow from one electron carrier to another downhill in terms of energy. Energy released is used to form ATP from ADP and Pi. Electrons are finally handed over to plastocyanin (PC) which forwards them to photosystem I. Light shining on PS I, causes the primary pigments to lose electrons; chlorophyll molecule gets oxidized and unstable (P700+), electrons get accepted by ferrodoxine (Fd) which forwards them to the E.T.C then pass through a series of electron carriers downhill in terms of energy; energy released is used to synthesize ATP from ADP and inorganic phosphate(Pi). The electrons are finally accepted by NADP which together with hydrogen ions from photolysis of water; gets reduced to $NADPH_2$ reaction catalyzed by NADP reductase. Electrons from photolysis of water are accepted by PS II (P680+); regaining stability.



(b).

Similarities

- In both photosystem I is involved.
- Both occur in the thyllakoid membrane.
- In both, ATP is synthesized.
- Both involve electron flow through a series of electron carriers of the electron transport chain.
- Both require light energy to occur.
- Both involve pigment systems which accept and lose electrons membranes

Differences

Cyclic photophosphorylation	Non-cyclic photophosphorylation
Electron pathway is cyclic	Electron pathway is non-cyclic
First electron donor is chlorophyll in PS I	First electron donor is water
The last electron acceptor is chlorophyll molecule in photosystem I	The last electron acceptor is NADP
Only useful product is ATP	Useful products include; NADPH, ATP and O_2
Photolysis of water not required	Photolysis of water relevant to supply $H^+$and electron to reduce NADP.
Involves only photosystem I	Involves both photosystem I and II

(c)(i).

Glycerate-3-phosphate is reduced by NADPH using energy from ATP hydrolysis; to triose phosphate (TP). T.P molecules combine forming a phosphorylated 6-carbon sugar which by dimerization forms disaccharides and by polymerization form polysaccharides.

(c)(ii).

Glycerate-3-phosphate enters the glycolytic pathway; converting it to the acetyl group; which is added to coenzyme A forming acetyl coenzyme A (acetyl-CoA); fatty acids are formed from the acetyl groups in both cytoplasm and chloroplasts. Glycerols are formed from TP molecules. Three fatty acids combine with a single glycerol molecule to form a triglyceride by condesation

(c)(iii).

Glycerate-3-phosphate; gets converted to one of the acids of Krebs cycle via acetyl CoA. Nitrates absorbed from the soil by the roots are reduced by nitrate reductase to nitrites which are reduced also by nitrite reductase to ammonia. Ammonia combines with one of the acids of the kreb's cycle forming amino acids. Other amino acids are synthesized by transamination. Numerous amino acids polymerize by condesation to form polypeptide chains.

Question 15.

(a).Outline the roles of water in photosynthesis ***(05 marks)***

(b).Describe how photorespiration affects C_3 plants ***(05 marks)***

(c).Outline the advantages and disadvantages of C_4 photosynthesis ***(06 marks)***

(d).In spite of the higher productivity of C_4, which is almost four times greater than in C_3, majority of plants perform C_3 photosynthesis. Explain this statement fully. ***(04 marks)***

(a).

- Catalytic photolysis water produces electrons and protons.
- Water is a source of electrons to replace those lost by chlorophyll / photosystem II
- Water is a source of H^+ needed to produce NADPH from NADP.
- Water is a source of H^+ which when flowing from thylakoid space into stroma via ATPase, ATP forms.
- Water is a substrate / reactant / raw material / for photosynthesis
- Water is transparent so photosynthesis can take place underwater / light can penetrate to chloroplasts.

(b).

When C_3 plants are exposed to low carbondioxide concentration (or high oxygen concentration) e.g when stomata close to reduce water loss, RuBP carboxylase catalyses the reaction between RuBP and oxygen to form a 2 carbon compound; phosphoglycolate, which is oxidized to release carbondioxide. When the carbondioxide concentration is high, RUBISCO enzyme catalyses the reaction between RuBP and carbondioxide to form a 3-carbon compound 3- phosphoglyceric acid, which undergoes several reactions to form sugar useful to the plant. It is estimated that photorespiration therefore significantly reduces the potential yield of photosynthesis.

(c).

Advantages of C_4 photosynthesis

- C_4 plants ably photosynthesize at very low CO_2 concentration (e.g. in dense tropical vegetation) because PEP carboxylase enzyme has a very high affinity for carbondioxide.
- Concentric arrangement of mesophyll cell produces a smaller area in relation to volume for better utilization of available water and reduce the intensity of solar radiations.
- The CO_2 fixing enzymes in C_4 plants are more active at hot temperature and high illumination, therefore photosynthesis occurs rapidly at low altitude, hot and brightly lit tropical conditions than in C_3 plants.

Disadvantages of C4 photosynthesis

The CO_2 fixing enzymes in C_4 plants are less active at cool, moist and low illumination conditions therefore photosynthesis occurs slowly at high altitude with cool temperature and in low light intensity of temperate conditions.

(d).

CO_2 concentration is a major factor determining the pathway of carbon dioxide fixation. While C_4 plants are more productive at low CO_2 concentration, C_3 plants form dominant plant life because they are effective at high CO_2 whose concentration is high in most environments and steadily increases due to increasing combustion of fossil fuels. C_4 photosynthesis is more complex i.e. it involves many reactions both in bundle sheath cells and in mesophyll cell, and requires a specialized Kraanz's anatomy, most plants have simpler structures. Therefore, unless water loss is a significant issue, C_3 plants dominate since C_3 photosynthesis is more effective.

Question 16.

(a).Giving an example in each case, explain what is meant by the following

(i). Saprophytes ***(02 marks)***

(ii).Chemoautotrophs ***(02 marks)***

(b).Compare saprophytes and parasites ***(07 marks)***

(c).Outline the importance of saprophytism to human life ***(05 marks)***

(d).Outline the factors for the success of saprophytes in most terrestrial habitats ***(04 marks)***

(a)(i).

Saprophytes are organisms which obtain energy from dead/decaying organic matter e.g bacterial fungi/protists.

(a)(ii).

Chemoautotrophs are organisms which synthesize organic matter; using energy obtained from oxidation of inorganic materials e.g nitrifying bacteria, iron bacteria etc.

(b).

Similarities

• Both are heterotrophic
• Both absorb soluble food materials
• Both have digestive enzymes.
• Both produce large numbers of offsprings.
• Both have sexual and asexual phases in their reproductions
• Have resistant reproductive stages.
• Have simple digestive systems

Differences

Saprophytes	Parasites
Energy is derived from the decaying matter	Derive energy from other living organisms
Involves single adult stage and spores the life cycle	Involve many stages within their lifecycle.
Use a variety of food sources	Are very specific to their hosts.
Have simple methods of nutrition.	Are nutritionally highly adapted/ complex method of feeding
Almost totally bacteria and fungi	Some plants, animal groups and protists.
There are aerobic and anaerobic forms	Most are aerobic

(c).

• Recycling of materials eg carbon, nitrogen, phosphorous etc.
• Decomposition of wastes such as sewage.
• Source of food eg mushrooms.
• Brewing and baking eg saccharomyces (yeast).
• Making antibiotics eg penicillin.
• Production of yorghurt and cheese.
• In industrial processes e.g leather tanning, production of vitamins.

(d).

• Small size to easily disperse;
• They feed on dead decomposing matter; which is readily found everywhere;
• Produce more spores; which remain dormant/ resistant during adverse conditions;
• Can employ both aerobic and anaerobic respiration; to suit the available conditions;
• Have simple life cycle; for the organism to mature faster.

Question 17.

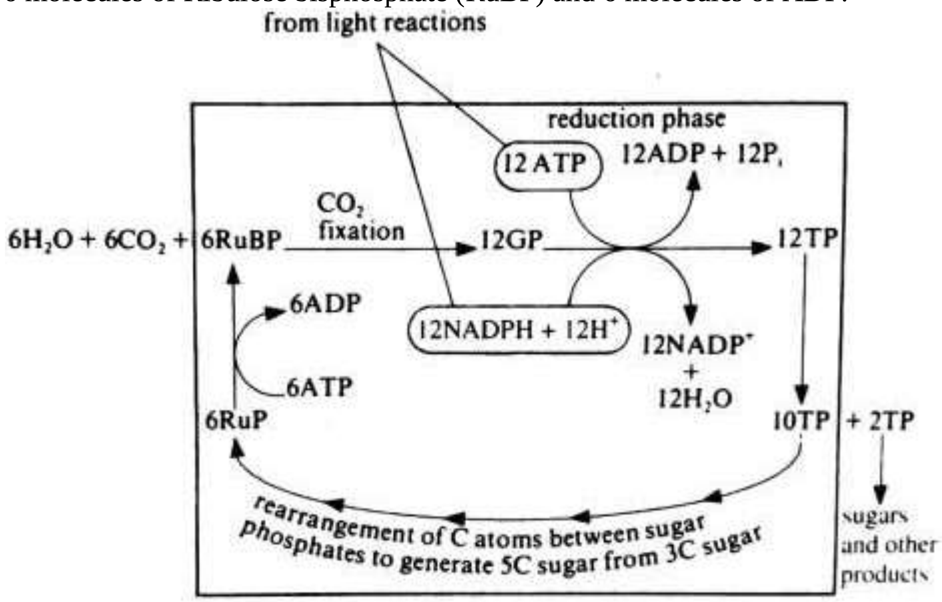
(a).Describe the events that take place in the light independent stage of photosynthesis in
(i).C_3 plants *(08 marks)*
(ii).C_4 plants *(07 marks)*
(b).Describe how Kraanz's anatomy is related to the C_4 photosynthetic compartmentalization *(05 marks)*

(a)(i).

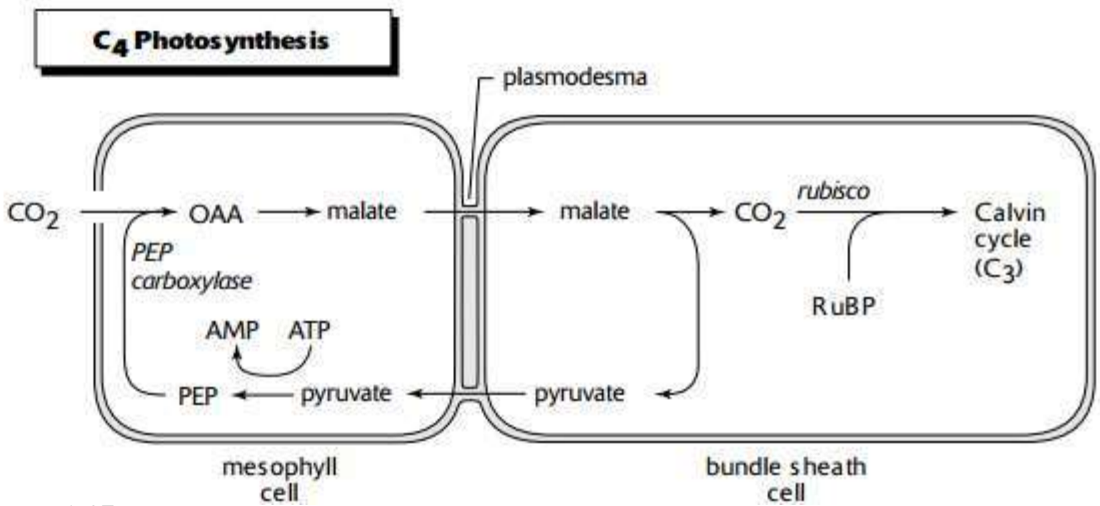
Carboxylation; Catalysed by RuBP carboxylase, 6 molecules of RuBP react with 6 molecules of CO_2 and 6 molecules of water forming 12 molecules of 3-phosphoglyceric acid (PGA), which is the first carbohydrate made by C_3 plants.

Phosphorylation and reduction; 12 molecules of PGA react with 12 molecules of ATP forming 12 molecules of 1,3-diphosphoglyceric acid and 12 molecules of ADP.12 molecules of NADPH (formed in light stage) reduce 12 molecules of1,3-diphosphoglyceric acid to form 12 molecules each of 3-phosphoglyceraldehyde (PGAL) / triose phosphate (TP), NADP and phosphoric acid. Out of these 12 molecules of PGAL, only 2 molecules undergo isomerization and several reactions to form hexose sugar, sucrose or starch and 10 molecules are recycled to produce 6 molecules of ribulose monophosphate.

Regeneration of RUBP: The remaining 10 molecules of PGAL regenerate 6 molecules of ribulose-6-phosphate when 6 molecules of a 5-carbon sugar ribulose monophosphate react with 6 molecules of ATP (formed during light stage) to form 6 molecules of Ribulose bisphosphate (RuBP) and 6 molecules of ADP.

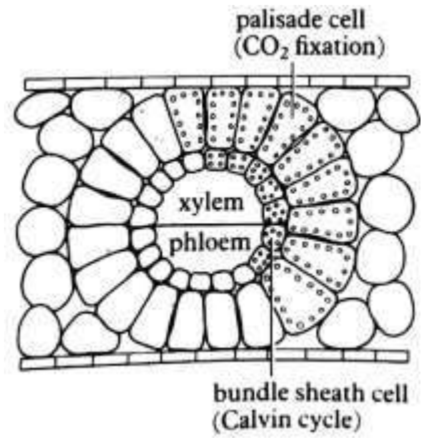


(a)(ii).



In the presence of Phosphoenol pyruvic acid carboxylase enzyme, Phosphoenol pyruvic acid is carboxylated inside the chloroplasts of mesophyll cells to form oxaloacetic acid. Oxaloacetic acid is reduced by NADPH to malic acid in the presence of malate dehydrogenase enzyme. From chloroplasts of mesophyll cells, malic acid is translocated (shunted) to chloroplasts of bundle sheath cells where it is decarboxylated by NADP to form pyruvic acid and carbon dioxide. The pyruvic acid produced returns to mesophyll cells for phosphorylation by ATP to regenerate PEP; the CO_2 acceptor. The second carboxylation occurs in the chloroplasts of bundle sheath cells through Calvin cycle. RuBP of Calvin cycle is the secondary CO_2 acceptor in C_4plants. Ribulose bisphosphate accepts CO_2 produced yield 3-phosphoglyceric acid. Some of the 3-phosphoglyceric acid is utilized in the formation of glucose-6-phosphate and sucrose while rest regenerates ribulose bisphosphate in the system.

(b).



The ring of mesophyll cells; this tight ring of specialised mesophyll cells excludes air from the cells inside the ring. The cytoplasm fixes carbondioxide. The chloroplasts capture light and carryout the light dependent reactions but not the Calvin cycle reactions

Bundle sheath cells; these carryout the Calvin cycle reactions but not light dependent reactions. No air gets into these cells and they get carbondioxide from the mesophyll cells.

Question 18.

(a) Describe the role of the pancreas in digestion of food & metabolism of the absorbed products ***(05 marks)***

(b) Explain the advantages of CAM pathway over the C_3 pathway ***(08 marks)***

(c) Outline differences between mesophyll cells and bundle sheath cells ***(03 marks)***

(a).

Digestion

Pancreas secretes pancreatic juice which contains pancreatic enzymes and mineral salts. Mineral salts neutralize the acidic chyme from the stomach; also partly emulsify fats. Enzymes include trypsin; secreted in its inactive form gets activated and converts proteins into polypeptides and amino acids; Polypeptidase converts polypeptides to peptides; chymotrypsin secreted in its inactive form; converts casein to polypeptides; pancreatic amylase converts starch to maltose; pancreatic lipase converts lipids into fatty acids and glycerols; nucleases convert nucleic acids into nucleotides.

Metabolism

Insulin; lowers blood glucose level by converting it to glycogen fat or accelerating its metabolism to carbondioxide and water

Glucagon; raises blood sugar levels by facilitating breakdown of glycogen into glucose;

(b).

• CAM plants unlike C_3 plants have maximum rate of carbondioxide fixation (double fixation of carbondioxide & stored inform of malate); ably photosynthesize even at low carbondioxide partial pressure. C_3 plants only photosynthesize at high carbondioxide concentration
• Light saturation in CAM plants takes place at much higher light intensities than the C_3 plants.
• CAM plants are more tolerant to dry conditions; due to less chances of desiccation due to ability to reverse the stomatal rhythm
• Optimum temperature for CAM plant growth is higher than it is for C_3 plants
• CAM plants unlike C_3 plants possess an efficient enzyme PEP carboxylase which can tolerate low carbondioxide tensions and high oxygen partial pressures.

(c).

Mesophyll cells	Bundle sheath cells
Contain chloroplasts with numerous large well developed grannae	Contain chloroplasts with fewer or no grana.
Starch granules absent; thus contains less starch	Starch granules present in abundance
RUBISCO absent thus no carbondioxide fixation by the C_3 pathway	High concentration of RUBISCO; thus carbondioxide fixation by the C_3 pathway occurs

High activity of photosystem II/ light independent reactions; plenty of ATP, NADPH and oxygen	Low activity of photosystem II/ light independent reactions; hence fewer ATP, NADPH and oxygen.

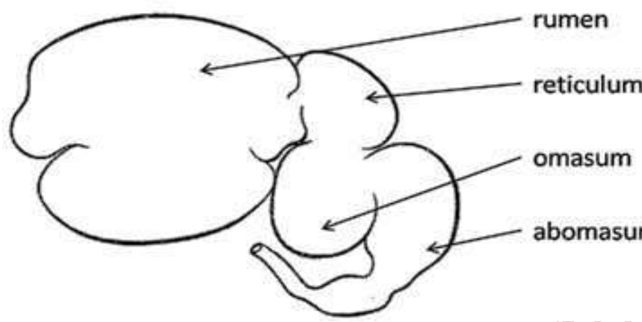
Question 19.

(a).Explain how the structure of a ruminant stomach is related to function ***(06 marks)***

(b).Compare the digestive processes in non-ruminants and that of ruminants ***(06 marks)***

(b).Describe what happens to Irish potato chips and chicken eaten by a man at dinner ***(08 marks)***

(a).



Rumen (Paunch): bacteria and protozoa in the rumen secrete cellulase enzyme which breaks down cellulose into glucose which undergoes fermentation to form organic acids, carbondioxide and ethane. The fermentation process produces heat that keeps ruminants warm.

Reticulum (Honeycomb bag): Here any foreign objects that may have been accidentally swallowed with food settle out in the honeycomb structure of the reticulum's walls. Reticulum is sometimes called hardware stomach.

Omasum (Psalterium/ manyplies): Absorbs water from food and also absorbs more nutrients called volatile fatty acids that supply ruminants with energy.

Abomasum (Reed/ true stomach): Here, the food particles are digested by hydrochloric acid in the same way it occurs in human stomachs. The remaining particles are then passed on to the small intestine where most of the nutrients are absorbed by the body and made available to the ruminant.

Similarities

- In both, physical digestion involves mechanical action of the teeth and the gut wall
- In both chemical digestion involves enzymes.
- In both, absorption of digested food involves diffusion and active transport.

Differences

Digestive process of non-ruminants	Digestive process of ruminants
No chewing cud/ rumination	Chewing cud/ rumination occurs
No fermentation of food mixed with saliva by cellulose digesting microorganisms.	Fermentation of food mixed with saliva occurs in the rumen
Enzyme action begins from the mouth and ends in the small intestines.	Enzyme action begins in the rumen and ends in the small intestines.
Organic acids, CO_2 and methane are not produced.	Organic acids, carbondioxide and methane are produced as end product of fermentation

(b).

In the mouth, irish potato chips and chicken are crushed and mixed with saliva during mastication. The food is lubricated with mucin in the saliva to facilitate swallowing. Salivary amylase/ ptyalin converts cooled starch in the chips to maltose. Food is swallowed and the moves to the stomach by peristalsis. The stomach mechanically churns food into acidic chyme thus mixing it with gastric juice which contains both gastric enzymes and HCl. Action of ptyalin on starch is stopped by the acidic medium. The enzyme pepsin converts the proteins in the chicken to peptides. In the duodenum, acidic chyme prompts release of bile which emulsifies the fats as well as partially neutralizing the acid in the chyme. Pancreatic juice which contains pancreatic enzymes and salts is added to the chyme. Pancreatic salts neutralize the acidic chyme. Pancreatic amylase converts starch to maltose, trypsin converts proteins to peptides, pancreatic lipase converts fats and oils into fatty acids and glycerols and nucleases convert nucleic acids into nucleotides. In the small intestines maltase converts maltose to glucose, peptidase converts peptides to amino acids, lipases convert fats to fatty acids and glycerols and nucleotidases break down nucleotides to pentose sugars, phosphoric acids and nitrogen organic bases. Continuous contractions of the small intestines mix the food with various intestinal juices forming chyle. Glucose and amino acids are absorbed by both diffusion and active transport across the epithelial lining of the villi into the blood capillaries. Fatty acids and glycerols are absorbed into the columnar epithelial cells via the lining the villi and re-synthesized into neutral fat; which is shed into lymph vessels of villi; then eventually into the blood stream. The pentose sugars, phosphoric acid and organic bases are absorbed by diffusion.

Question 20.

(a).Explain what is meant by;

(i). Crassulacean acid metabolism photosynthesis ***(05 marks)***

(ii).Principle of limiting factors ***(02 marks)***

(iii)Photosynthetic pigments ***(03 marks)***

(b).Explain the phases of CAM photosynthesis throughout the diurnal course ***(04 marks)***

(c).Compare the events that occur in the light dependent and independent stages of photosynthesis in a plant

(a)(i).

A type of photosynthesis in which carbondioxide is taken in at night via open stomata, fixed by phosphorenolpyruvate carboxylase (PEPC) into OAA, stored as organic acid (mainly malate) which is later decarboxylated during daytime, refixed and CO2 is assimilated in the Calvin-cycle when stomata are closed. For terrestrial CAM plants, there is increased water use efficiency in which nocturnal stomatal opening greatly reduces stomatal loss of water as it would in day light.

(a)(ii).

The principle of limiting factors state that when a chemical process is affected by more than one factor, its rate is limited by that factor which is nearest to its minimum value; its that factor which directly affects the process if its quantity is changed.

(a)(iii).

A pigment is a molecule that absorbs light. The wavelengths absorbed by a particular pigment depend on the available energy levels to which light-excited electrons can be boosted in the pigment.

(b).

Phase I: nocturnal CO_2 fixation (atmospheric + respiratory sources) mediated by PEPC & accumulation of malic acid within the vacuole.

Phase II: atmospheric CO_2 fixation at dawn which marks the transition between C_4 and C_3 activity.

Phase III: decarboxylation of malic acid and fixation of the regenerated CO_2 by RUBISCO.

Phase IV: a period of atmospheric CO_2 fixation from the end of Phase III to dusk which latterly incorporates the shift from RUBISCO to PEPC activity.

(c).

Light dependent reactions	Light independent reactions
Occurs in the thylakoids	Occurs in the stroma
Requires light to facilitate electron flow in the cyclic& non-cyclic photophosphorylation together with photolysis of water	Donot require light; CO_2 is fixed when accepted by RUBP; glycerate phosphate formed; RUBP regenerated in the Calvin cycle
Light energy is converted to chemical energy inform of ATP and NADPH; photolysis of water yields hydrogen ions and oxygen.	CO2 is reduced to carbon compounds like carbohydrates using chemical energy in ATP and protons in NADPH.
Products are ATP, Oxygen and NADPH	Products include sugars, ADP, NADP and Pi

Question 21.

(a) Describe the process of swallowing food in humans. ***(10 marks)***

(b) Explain the role of gastric juice during food digestion in adult humans ***(10 marks)***

(a).

Tongue contracts to push the bolus towards the throat, forcing the soft palate upwards to close the nasopharynx. Larynx and hyoid bone move anteriorly and upwards. Epiglottis bends downwards to close larynx to prevent food from entering the trachea. Breathing briefly stops due to closure of glottis. Pharynx shortens and the upper oesophageal sphincter (Cricopharyngeal sphincter) relaxes, to allow the bolus enter into oesophagus. In oesophagus the food bolus moves by peristalsis, a sequence of wave-like contractions that squeeze food down the oesophagus. Lower oesophageal sphincter (cardiac sphincter) relaxes to allow food into stomach.

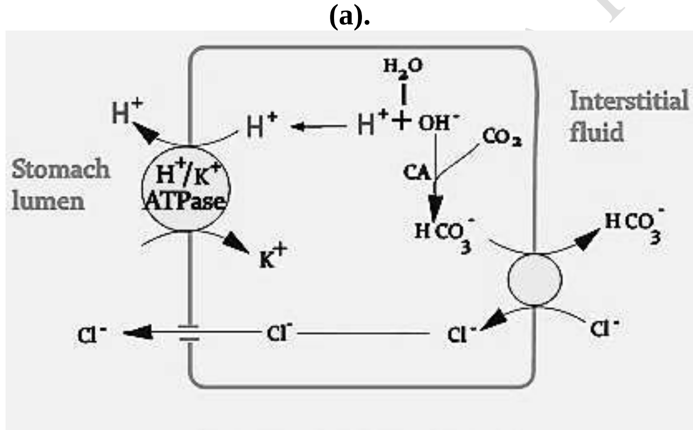
(b).

Mucous surface cells and neck cells secretes mucus that forms a barrier at the stomach lining to prevent tissue digestion. Also secretes bicarbonate; buffers gastric acid to prevent damage to epithelium. Chief/ peptic/ zymogenic cells which secrete pepsinogen activated to pepsin digests protein to polypeptides Gastric lipase digests lipids to fatty acids and glycerol. Prochymosin (Prorennin); rennin coagulates soluble milk protein caseinogen into insoluble casein in babies, whose slowed flow enables digestion by pepsin. Gastric lipase weakly hydrolyses fats to fatty acids and glycerol. Parietal/oxyntic cells secrete hydrochloric acid that activates pepsinogen to pepsin, pro-rennin to rennin, kills most bacteria in the stomach, provides an optimum acidic pH for pepsin to hydrolyse proteins into polypeptides and also stops the working of salivary amylase enzyme. Intrinsic factor forms a complex which enables absorption of vitamin B12 that is necessary in red blood cell formation. Little intrinsic factor causes pernicious anemia.

Question 22.

(a).Describe the mechanism of hydrochloric acid secretion from the parietal cell ***(13 marks)***
(b).Explain how the structure of villi in the small intestine is related to absorption of digested food.

(a).



Acid secretion by parietal cells

Hydrochloric acid is produced by parietal cells through a complex series of reactions. Catalysed by the enzyme carbonic anhydrase, carbondioxide (which diffused from capillaries) reacts with water to form carbonic acid, which dissociates into bicarbonate ion and hydrogen ion. Bicarbonate ion is transported into the blood stream by an ion exchange molecule in plasma membrane which exchanges bicarbonate ions exiting parietal cells for chloride ions entering. Hydrogen ions are actively pumped into the duct of gastric gland and the negatively charged chloride ions diffuse with the positively charged hydrogen ions. Potassium ions are counter pumped into the parietal cell in exchange for hydrogen ions. The net result is production of hydrochloric acid in the parietal cells and its secretion into the duct of gastric gland

(b).

• Large surface area by microvilli/ protrusion of exposed parts for fast uptake of soluble substances.
• Epithelium only one layer thick to reduce diffusion distance.
• Protein channels allow facilitated diffusion and active transport.
• Numerous mitochondria provide much ATP for active uptake of some nutrients like glucose and salts.
• Blood capillaries close to epithelium to reduce diffusion distance during absorption of glucose/ amino acids
• Lacteal / lymphatic vessel is permeable/has large surface area at centre to absorb fatty acids and glycerol.
• Tight junctions between adjacent villi enable controlling absorption of substances

Question 23.

(a).Describe the effects of the various hormones towards control of digestion in the duodenum ***(13 marks)***

(b).How is the ileum adapted to its function of absorption of food *(07 marks)*

(a).

Secretin hormone; its release is triggered by acid chyme in duodenum. Stimulates the liver to secrete bile into gall bladder and pancreatic secretion of non-enzymatic substances (hydrogen carbonate ions) from acinar cells. HCO_3^- neutralize the acid from the stomach to provide an alkaline pH optimum for pancreatic enzymes. Also inhibits secretion of HCl by oxyntic cells as chyme leaves the stomach. Enterogastrone hormone; whose release is triggered by acid and fat in the duodenum. It reduces stomach motility, inhibits oxyntic cells from secreting hydrochloric acid in order to provide an optimum pH for pancreatic enzymes and signals the stomach to empty slowly when fat is present, allowing much time for digestion of fat already emptied.

Cholecystokinin hormone (CCK); stimulated by the presence of partially digested fat and protein in the duodenum. CCK stimulates contraction of gall bladder to release bile into duodenum. Bile salts (sodium glycocholate) emulsify fats i.e fats physically break into droplets due to reduced surface tension, which increases their surface area. It also stimulates the pancreas to secrete pancreatic enzymes: pancreatic amylase which catalyses the hydrolysis of starch into maltose, enterokinase, a non-digestive enzyme which activates trypsinogen to trypsin; catalyses hydrolysis of polypeptides to peptides and activates chymotrypsinogen to chymotrypsin. Chymotrypsinogen; which is activated to chymotrypsin by trypsin and catalyses hydrolysis of casein /polypeptides into peptides.

Villikinin (motilin); triggered by alkaline pH in the duodenum; increases peristalsis in the small intestine and ileum villi movements, in preparation for incoming food.

(b).

- Ileum is long and highly folded for increased surface area in absorption of soluble food substances.
- Ileum has numerous villi which increase the surface area for absorption of soluble food.
- Ileum have microvilli which further increase the surface area for efficient food absorption.
- Epithelium is thin to reduce diffusion distance for soluble food substances to allow fast rate of diffusion.
- Epithelium is permeable to allow movement of soluble food substances across with minimum resistance.
- Ileum villi have permeable lacteal, a branch of the lymphatic system for carrying away fats
- Epithelial cells have numerous mitochondria to generate ATP energy for active transport of some ions.
- Ileum inner surface is lined with a lot of mucus to prevent autolysis (self-digestion) by proteolytic enzymes.
- Ileum villi have dense network of blood capillaries to rapidly carry away digested food from the absorption area which maintains a steep diffusion gradient.

Question 24.

(a).What roles do the pancreas and the liver play in

(i). Food digestion *(09 marks)*

(ii).Metabolism of absorbed products *(09 marks)*

(b).How can the diet of raw liver prevent the disease pernicious anaemia? *(02 marks)*

(a)(i).

Digestion

Pancreas

On stimulation by cholecystokinin hormone, the pancreas secretes enzymes; Amylase catalyses hydrolysis of starch into maltose. Enterokinase activates trypsinogen to trypsin which catalyses hydrolysis of polypeptides to peptides and also activates chymotrypsinogen to chymotrypsin. Chymotrypsin catalyses hydrolysis of casein / polypeptides into peptides, lipase hydrolyses fats to fatty acids and glycerol, nuclease hydrolyses nucleic acids to nucleotides and polypeptidases which hydrolyses polypeptides to amino acids. On stimulation by secretin hormone, the pancreas secretes hydrogen carbonate ions from acinar cells, which neutralise the acid chyme from the stomach to provide an alkaline pH optimum for pancreatic enzymes.

Liver

On stimulation by secretin hormone, the liver secretes bile into the gall bladder. On stimulation by CCK hormone, gall bladder contracts to release bile salts which emulsify fats i.e fats physically break into droplets due to reduced surface tension, which increases their surface area.

(a)(ii).

Metabolism of absorbed products

Pancreas

If in excess (above 90mg/100cm^3), the pancreas is stimulated to secrete insulin hormone which causes conversion of glucose to glycogen for storage, fat or metabolizing it to energy and CO_2. If little (below 90mg/100cm^3), the pancreas is stimulated to secrete glucagon hormone which causes conversion of glucagon to glucose hence increa-siing the blood glucose level.

Liver

• Blood glucose regulation; If in excess (above 90mg/100cm^3), glucose is converted into glycogen for storage and if little (below 90mg/100cm^3), glycogen is converted into glucose for use.

• The liver regulates amino acids in the body: excess amino acids are not stored in the body, but undergo deamination process i.e the amino group ($-NH_2$) from the amino acid is removed to form ammonia, which later forms urea that is carried in blood to kidneys for excretion.

• The liver regulates lipids (fats) in the body: synthesizes and degrades phospholipids and cholesterol.

• The liver forms plasma proteins from amino acids by transamination.

• The liver stores fat soluble vitamins A, D, E, K and water soluble vitamins B_{12} and C

• The liver stores minerals like Iron, potassium, copper, zinc and trace elements.

• The liver detoxifies poisonous substances i.e. toxic substances are turned harmless by the liver cells e.g. alcohol, cholesterol and hydrogen peroxide.

(b).

Raw liver is rich in vitamin B_{12} which is essential for formation of red blood cells (erythrocytes) whose absence causes pernicious anaemia characterized by paleness, slowness and death.

Question 25.

(a).Describe the digestive process that occurs in the ileum ***(08 marks)***

(b).Explain the different mechanisms of absorbing digested food in the ileum ***(12 marks)***

(a).

Distention of the small intestine by food/ tactile stimulus/ irritating stimulus stimulates the secretion of intestinal juice (Succus entericus) which consists of a mixture of substances from crypts of Lieberkühn and Brunner's glands. Some of the components of Succus entericus include the following enzymes: P**eptidases:** catalyse hydrolysis of peptides into amino acids, thereby completing the digestion of proteins; **Nucleotidases;** catalyse hydrolysis of nucleotides into phosphoric acid, nitrogenous bases and pentose sugars; Maltase catalyses hydrolysis of maltose into glucose molecules thereby completing starch digestion; **Sucrase (invertase)** catalyses hydrolysis of sucrose into glucose and fructose molecules; **Lactase** catalyses hydrolysis of lactose into glucose and galactose molecule-es; **Intestinal lipase:** catalyses hydrolysis of lipids into fatty acids and glycerol and intestinal amylase catalyses hydrolysis of starch into maltose.

(b).

Glucose and galactose; absorbed by secondary active transport with Na^+ (Co-transport with Na+). Glucose and galactose are co-transported into epithelial cells of villi with Na^+ ions, then exported into blood capillaries by facilitated diffusion. Fructose; absorbed by facilitated diffusion; moves into epithelial cells of villi by facilitated diffusion, then exported into blood capillaries by facilitated diffusion. Amino acids; secondary active transport with Na^+ (Co-transport with Na^+); amino acids are co-transported from intestinal lumen into small intestinal epithelial cells with Na^+ ions, then exported to capillaries by facilitated diffusion. Dipeptides & Tripeptides (Oligopeptides); absorbed by secondary active transport with H^+ (co-transport with H^+). Oligopeptides (dipeptides and tripeptides) are co-transported from intestinal lumen into villi epithelial cells with protons (H^+). Oligopeptides are then hydrolysed by cytoplasmic peptidases into amino acids, which are exported from the villi epithelial cells into blood capillaries by facilitated diffusion. Short chain fatty acids; absorbed by simple diffusion. Short chain fatty acids move into epithelial cells of villi by simple diffusion, then are exported into blood capillaries by simple diffusion. Monoglycerides and Long chain fatty acids; occurs by simple diffusion; diffuse into columnar epithelia of villi, recombine to form lipids, then combine with proteins to form water soluble lipoproteins called chylomicrons, which are exported by exocytosis to lacteals.

Question 26.

(a).Outline the challenges faced by parasites in their mode of life ***(06 marks)***

(b).Explain the adaptations of parasites in overcoming the above challenges ***(09 marks)***

(c).Outline some of the hygienic practices for controlling endoparasites ***(05 marks)***

(a).

Challenges/ dangers faced by ectoparasites
- Failure to cling on the host to avoid being dislodged.
- Failure to obtain nutritive molecules from the host.
- Failure to find the right host for dispersal to their final host

Challenges/ dangers faced by endoparasites
- Failure to penetrate the host
- Failure to obtain nutritive molecules from the host.
- Destruction by the digestive enzymes and immune responses of the hosts.
- Complete elimination or extinction.
- Fluctuating environment e.g. low oxygen tensions, excess heat, solute concentration, darkness
- Failure to find the right host for dispersal to their final host

(b).

Structural adaptations
- Penetrative devices for host entry e.g. fungal haustoria, cutting teeth in hook worms (Ancylostoma duodenale)
- Possession of nutrient suckers e.g. leech
- Development of digestive-resistant outer covering to avoid host's enzyme attack e.g. Ascaris and Taenia etc.
- Camouflaging morphology to increase survival chances e.g. brown ticks on brown cattle.
- Specialized mouth parts in some ectoparasites to suck hosts e.g. sharp stylets in aphids and tsetse flies.
- Possession of specialised haustorial structures in Cuscuta (Dodder plants) for obtaining nutrients from the host
- Degeneration of non-essential organs e.g. no feeding organs, no locomotory organs, no alimentary canal to reduce body size and fit in intestines /blood vessels and for reducing energy expenditure on such organs for example Fasciola hepatica (liver fluke), tape worm, hook worm

Physiological adaptations
- Production of enzymes to digest the host's tissues during penetration into the host e.g. fungi and plasmodium
- Production of anticoagulants by blood feeding parasites eg mosquitoes to avoid blood clotting during feeding.
- Rapid means of escape which increases their chances of survival e.g. fleas and mosquitoes.
- Production of much mucus for resisting digestion by host's enzymes.
- Some endoparasites produce chemicals to protect themselves against the immune response of the host.
- Highly tolerant to fluctuating environment e.g. anaerobic respiration in areas of low oxygen tensions, high temperatures, darkness and pH changes in places where they live e.g most endoparasites.

Reproductive adaptations
- Some are hermaphrodites with the ability to carry out self-fertilisation to increase the rate of reproduction e.g. Fasciola, Taenia.
- Some asexually reproduce for high rate of reproduction to avoid extinction.
- Release of sexually mature forms of the parasites as free living organisms e.g. in some parasitic animals such as the horse hair worms
- Production of large number of infective agents such as eggs, cysts and spores which increase survival chances to avoid extinction e.g. tape worms.
- Development of reproductive bodies that are highly resistant when out of the host to survive adverse conditions e.g. cysts in amoeba, fungal spores, etc.
- Use of intermediate host (vector) for their transfer to primary host e.g plasmodium in female anopheles mosquito to man.
- Some use hereditary transmission for increased spreading i.e some parasites infect the ovary of primary host which lays parasite infected eggs.
- Avoid eating infected under cooked meat

(c).
- Through proper disposal of sewage which prevents these worms from spreading
- Through cooking meat thoroughly for example prolonged heating destroys the tapeworms.
- Regular deworming to flush the worm out of the wall of the intestines in faeces.
- Through regular meat inspection before it is consumed by man.

• By prohibition of the discharge of raw sewage into inland waters and seas.

Question 27.

(a).How the following organisms are adapted to their mode of life?

(i). Schistosoma mansoni ***(05 marks)***

(ii).Ancylostoma duodenale. ***(04 marks)***

(b).Give a brief description of the major types of interspecific associations in the nature. ***(06 marks)***

(a)(i)

• Development of resistance to present medicine /drug infiltration into their bodies
• Lay large number of eggs; readily colonise the host tissue.
• Numerous cercarie /high reproductive rate; multiply and colonise the host tissue faster.
• Have ventral sucker and mouth
• They reproduce asexually in blood vessel; multiply faster and easily colonize the host.
• Always occur in male and female pairs increasing the chances and rates of reproduction.
• Miracidia intermediate stages for attacking intermediate host, the snail increases its ecological range.
• Cercarie possess glands with lytic enzymes to pierce the skin of the definite host.
• Eggs can tear through mesenteric blood vessel into gut for egestion to hatch in sunlight & optimum temperature
• Evolved resistance to current medications.
• Thick protective cuticle to avoid digestion by host's enzyme.
• Possess flame cells for efficient excretion in host's body.
• Complex life cycle with more than one host increases their survival.
• Well-developed nervous system with no sense organs to survive the host's body.

(a)(ii).

• Have strong teeth for grasping walls of intestines.
• High reproductive rate; heavily colonise the host's tissues within a short period of time.
• Attachment devices for clinging on the walls of the gut
• Thin body wall covered with a mucus lining for protection against host defences
• Protective outer coat protects them from host's enzymes.
• The delicate larval stage is short to increase survival.
• Gut is highly reduced to minimize size and fit in host's body.
• Larvae are motile and show positive thermotaxis to increase the chance of reaching the host.

(b).

Parasitism; one of the organism the parasite; lives in/on the other the host deriving metabolic benefit from it and causing harm to it.

Commensalism; one of the organism the commensal gains from the interaction while the host neither gains nor loses;

Mutualism/symbiosis; the association is mutually beneficial i.e both organisms benefit from the relationship.

Predation; One organism the predator hunts, capture, kills and feeds on another organism of different species the prey e.g. lion feeding on antelope.

Grazing; involves herbivores feeding on plant material.

Question 28.

(a).Describe the life cycle of Ascaris lumbricoides ***(10 marks)***

(b).Explain the adaptations of the above parasite to its mode of life ***(10 marks)***

(a)(i).

Adult female in lumen of ileum lays about 200,000 eggs daily, which are passed out in faeces. Fertile eggs embryonate and become infective after about three weeks (optimum conditions: moist, warm, shaded soil). On being swallowed by humans, eggs hatch into larvae, which invade intestinal wall and are carried via the portal then systemic circulation to lungs. Larvae mature further in lungs (10 to 14 days), penetrate alveolar walls, ascend the bronchi to the throat, and are swallowed into gut. Upon reaching the ileum, they develop into adult worms. Between 2 and 3 months are required from ingestion of the infective eggs to oviposition by the adult female. Adult worms can live 1 to 2 years.

Adaptations of Ascaris lumbricoides

• Feed on already digested food; saving energy that would be wasted in the digestion process.
• Higher reproductive rate; enable the organism quickly colonise the host.
• Thick body wall and covered by a mucus lining for protection against host defences.
• High reproductive rate.
• Ability to survive in low oxygen and can inspire in anaerobic conditions.
• Gut is greatly reduced to fit in host's gut.
• Possession of digestive-resistant cuticle resists destruction by the host's enzymes.
• Ability to position itself in a habitat where it gains maximum nourishment.
• Eggs have protective/resistant shell which is their main ineffective and resistant stage.
• Tolerance to oxygen deficient environment
• Ability to copulate within intestines followed by laying of very many eggs increases survival chances
• Degeneration of the gut & other senses like sight; permits organism's invasion of gut in which the light intensity is too low.

Question 29.

(a).Describe the life cycle of Phytophora infestans (potato blight) ***(10 marks)***
(b).State the adaptations of phytophora infestans to its mode of life ***(03 marks)***
(c).Explain the saprotrophic mode of nutrition in fungal moulds like mucor ***(07 marks)***

(a).

Phytophthora produce two kinds of spore i.e. diploid oospores, formed sexually from fusion of haploid antheridia and oogonia, and chlamydospores formed asexually. Both types of spore have thick cell walls for surviving harsh conditions. Under cool wet conditions, Phytophthora spores (oospores or chlamydospores) germinate to form hyphae or directly produce sporangia. Sporangia release free swimming biflagellated zoospores, which travel in moisture at the surface of leaves and in soil. On reaching plant root or leaf surface a zoospore forms a cyst. The encysted zoospore then germinates to form hyphae on the host surface, which penetrates plant leaf or root tissues to absorb nutrients. After Phytophthora infects the plant, it produces sporangia and zoospores which further infect other tissues of the same plant or nearby plants. Sexual reproduction occurs when positive and negative mating types are present. Haploid nuclei of antheridium and oogonium fuse together when the antheridium enters the oogonium to form a diploid oospore, which develops into a sporangium and the cycle will continue as is would asexually.

(b).

• Have highly developed haustoria which enable penetration of plant tissues
• Produce exo-enzymes that digest host tissues extracellularly
• Produce chemicals that interfere with normal plant growth and those killing the host.

(c).

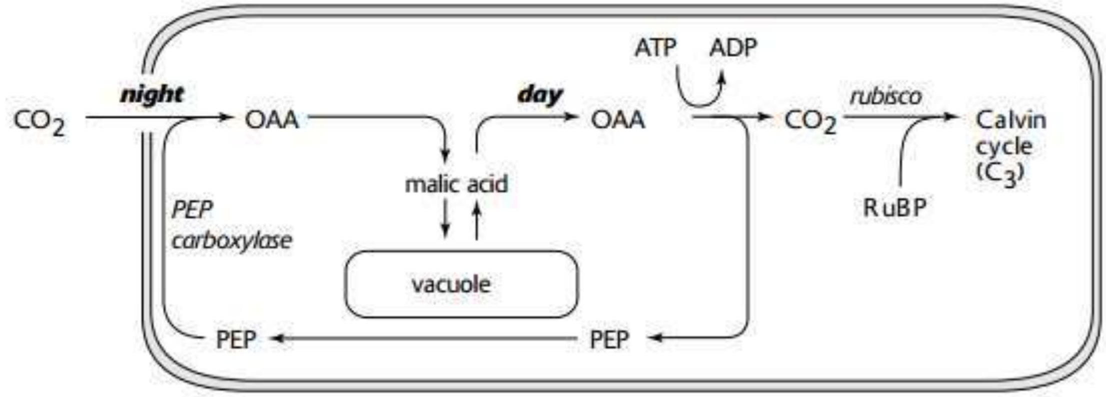
Under suitable conditions (moisture/ water, oxygen, neutral/ mildly acidic pH, temperature of about 25°C) the saprotrophs secrete different enzymes into the dead animal/plant body; proteases, lipases, carbohydrases e.g. amylase which break down insoluble complex organic substances into simple soluble substances. Proteases breakdown proteins into amino acids, lipases break down lipids into fatty acids and glycerol and carbohydrases e.g. Amylases break down starch into maltose/simple disaccharides. The end products of extracellular digestion such as fatty acids and glycerol, glucose, amino acids plus other nutrients like vitamins e.g thiamine and ions e.g. potassium, phosphorus, and magnesium are re-absorbed into the hypha through the cell wall by endocytosis/ simple diffusion /facilitated diffusion/ active transport and passed on throughout the mycelium complex to enable growth & repair

Question 30.

(a).Describe the physiology of the photosynthetic process in CAM plants ***(08 marks)***
(b).Explain how the antennae complex interacts with the reaction centre to generate chemical energy from solar energy ***(06 marks)***
(c).Describe the key evidence which shows that photosynthesis is carried out by two photochemical systems with slightly different wavelength optima. ***(06 marks)***

(a).

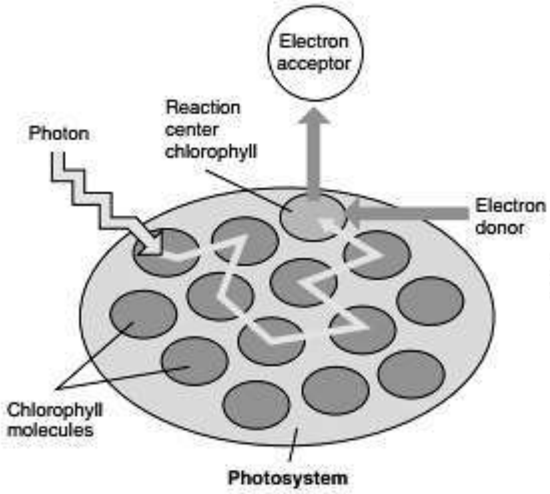
CAM Photos ynthesis

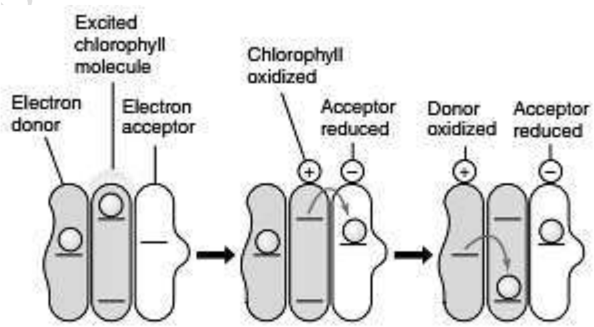


PEP carboxylase still fixes CO_2 to OAA, as in C_4 plants. Instead of malate, however, OAA is converted to malic acid. Malic acid is shuttled to the vacuole of the cell (not moved out of the cell to bundle sheath cells as in regular C_4). At night, stomata are open, PEP carboxylase is active, and malic acid accumulates in the cell's vacuole. During the day, stomata are closed (the reverse of other plants). At this time, malic acid is shuttled out of the vacuole and converted back to OAA (requiring 1 ATP to ADP) releasing CO_2. The carbondioxide is now fixed by RUBISCO and the Calvin cycle proceeds.

(b).

Antenna complex **Electron interactions in the reaction centres**





When light of the proper wavelength strikes any pigment molecule within a photosystem, the light is absorbed by that pigment molecule. The excitation energy is then transferred from one molecule to another within the cluster of pigment molecules until it encounters the reaction center chlorophyll a. When excitation energy reaches the reaction center chlorophyll, electron transfer is initiated. The reaction center chlorophyll donates a light-energized electron to the primary electron acceptor, reducing it. The oxidized chlorophyll then fills its electron hole‖ by oxidizing a donor molecule. Transition of electron downhill in terms of energy via a series of electrons carriers generates energy that is use to bond ADP with Pi to form ATP.

(c).

The "enhancement effect" which states that the rate of photosynthesis when red and far-red light are provided together is greater than the sum of the rates when each wavelength is provided individually‖. When the rate of photosynthesis is measured using two light beams of different wavelengths (one red and the other far-red), the rate was greater than the sum of the rates using individual beams of red and far-red light. This enhancement effect implied that the photosynthetic mechanism involved two photosystems acting in series (that is, one after the other), one of which absorbs preferentially in the red which is predominant in the light stage and the other in the far-red which is predominant in the dark stage.

Question 31.

(a).With examples, discuss the main features of parasites *(08 marks)*
(b).How are the various parasites in different tissues and organs able to escape from their host *(09 marks)*
(c).Plants are mainly parasitized by fungi and bacteria but are poor hosts for invertebrates. Explain why this is so *(03 marks)*

(a).

Means of attachment; help the parasite maintain its position in/on the host e.g hooks, suckers etc
Degeneration of certain unnecessary organs systems; eg the digestive systems of gut parasites is reduced or absent because the parasite is surrounded by large supply of pre-digested food.
Protective devices; to protect the parasite from the host defences eg gut parasites are covered by thick mucus and have hard cuticles; to overcome enzymatic degradation from the host.
Penetrative agents; like cellulases in fungal plant parasites such as phytophora infestans
Vectors or immediate hosts; eg anopheles is the immediate host for the plasmodium parasite and thus the vector for malaria.
Production of many eggs; because of the difficulty finding a new host eg Diphyllobothrium (fish tape worm) produces roughly 36 million eggs per day
Dominant or resistant phases; to overcome period spent away from the host e.g eggs in Ascaris, encysted cercariae in Fasciola.

(b).

Habitat	Examples	Method of escape
Lungs	Bacillus tubercle	Through respiratory aerosols released in air
Intestines	Ascaris	In the faeces
Blood	Schistosoma	Urine (eggs in the bladder wall)
Blood	Plasmodium	Immediate blood sucking organism
Under skin	Dracunculus	Discharge larvae through skin of the host
Intestines(larvae encysted in muscles)	Trichinella	Distengration of host tissues after death

(c).

- They remain in one position and so it is more difficult for the parasite to reach the new host.
- Their cellulose cell walls are difficult for animals to digest.
- They have few internal cavities suitable for the parasites.

Question 32.

(a).Explain what is meant by;
(i). Action spectra *(02 marks)*
(ii).Absorption spectrum *(02 marks)*
(b).How do certain bacteria and algae which require light for photosynthesis survive below sea weeds in rocks and ponds *(12 marks)*
(c).Explain the importance of photosynthesis of green plants in nature *(04 marks)*

(a)(i).

Action spectrum is a graph that shows the effectiveness of different wavelengths of light in stimulating a physiological process such as photosynthesis, flowering in some plants and germination in some seeds. The action spectrum gives a range of wavelengths within which a physiological process can occur.

(a)(ii).

Absorption spectrum is a graph that shows the relative absorbance of a pigment (amounts of light absorbed by a pigment) at different wavelengths of light. An absorption spectrum is obtained by plotting a graph of absorbance against wavelength.

(b).

The bacteria possess a special type of chlorophyll called bacteriochlorophyll n addition to chlorophyll a. Bacteriochlorophyll absorbs in the ultra-violet and infrared regions of the electromagnetic spectrum where water weeds cannot absorb. The water weeds absorb only in the visible range allowing the ultraviolet and infrared to filter through them so that they can reach the bacteria underneath. The bacterio-chlorophyll therefore absorbs the ultraviolet and infrared light and use their energy to synthesize NADPH from NADP; the required hydrogen being obtained from hydrogen sulphide in the rocks. The NADPH can then be used to reduce carbondioxide to form a carbohydrate in the light independent stages of photosynthesis. Some blue-green algae and red algae contain special pigments such as phycobilisomes which absorb well in the green regions of the spectrum allowing them to effectively photosynthesize under water weeds.

(c).

• Production of organic food material by primary producers which can then be made available to all trophic levels in an ecosystem.
• Photosynthesis releases oxygen as a byproduct; which can be used by aerobic organisms in respiration.
• Removes carbondioxide from the atmosphere preventing its accumulation which might result in environmental effects like greenhouse effect and global warming.
• The organic compound stored in dead organisms contributes to formation of fossil fuels; which when burnt participate in nutrient recycling/ carbon cycle.

Question 33.

(a) Describe how energy is trapped by green plants and stored by means of the light stage of photosynthesis
(b).Outline the importance of the products of the light stage to animals *(04 marks)*

(a).

Light energy is trapped by photosynthetic pigments located in the thylakoid membranes; arranged in centres called photosystems; each consisting of chlorophylls and accessory pigments (carotenoids) these harvest light and energy; the energy harvested is funneled to a single chlorophyll molecule known as the reaction centre; photosystem I has a reaction centre with a maximum absorption of at 700nm wavelength; while photosystem II has a reaction centre with a maximum light absorption at 680nm wavelength; Received light excites electrons at reaction centres electrons lost from photo-excited chlorophyll molecules in the photosystems are received by electron acceptors; then move along several electron carriers downhill; releasing energy which enables active pumping of hydrogen ions (H^+) from the stroma to the thylakoid space; At the same time photolysis of water occurs; causing the accumulation of H^+ inside the thylakoid space; The high accumulation of H^+ creates a steep electrochemical gradient; between the thylakoid space and stroma; resulting in diffusion of H^+ via the stalked particles into the stoma; along their electrochemical gradient; releasing energy during their movement; for combination of ADP and Pi to form ATP in the presence of ATPase enzyme; storing chemical energy in the phosphate bonds formed;

(b).

ATP
• For muscle contraction during formation and breaking of cross bridges;
• For transmission of nerve impulses;
• For active transport of materials across the walls of ileum and kidney tubules;
• For movement of spindle fibres during cell division;
• For activation of molecules e.g. glucose, tRNA;
• For DNA replication;
• For secretion of cell products;

Oxygen
• For oxidation of substrates to produce energy during respiration;

Question 34.

(a).Explain what is meant by holozoic nutrition *(02 marks)*
(b).Explain the basic processes involved in holozoic nutrition *(06 marks)*
(c).How is digestion controlled in the gastric compartment of the gastro-intestinal tract *(12 marks)*

(a).

This is the type of nutrition in which complex organic food is taken in and broken down inside the body of an organism into simple soluble molecules which are then absorbed and assimilated.

(b).

Obtaining food: May involve movements to capture or find new food sources from the environment.

Ingestion: The intake of food into the body (feeding mechanisms).
Digestion: Chemical breakdown (by enzymes) and physical breakdown of large insoluble molecules of food into small soluble molecules.
Absorption: The uptake of nutrient molecules into the cells of the digestive tract and, from there, into the blood stream.
Assimilation: The utilization of the absorbed soluble food substances to form energy or materials which are incorporated into the body tissues.
Defecation (Egestion): elimination of undigested residue.

(c).

Cephalic phase/ Nervous phase: occurs before food enters the stomach; Sight/ smell/ thought of food stimulate conditioned and unconditioned reflexes; involving the cerebral cortex, hypothalamus and medulla oblongata stimulating the vagus nerve whose effects are secretion of the gastrin. Gastrin stimulates secretion of gastric juice, increases contractions of gastro-intestinal tract, relaxes the pyloric sphincter to let in bolus of food from the gullet; Loss of appetite / depression inhibit cerebral cortex; parasympathetic centre is not stimulated, no gastric secretion;
Gastric phase: Arrival of food bolus distends / stretches the stomach wall which activates stretch receptors to fire impulses to the Meissner's plexus in the stomach walls stimulating local secretory reflexes in the stomach wall to activate gastric glands secrete pepsinogen and HCl. Also stimulates reflexes in the medulla, via the vagus nerve to activate gastric glands wall to secrete pepsinogen and HCl; stimulate enteroendocrine cells / G-cells to secrete gastrin hormone; which stimulates secretion of gastric juice; Gastrin also stimulate enteroendocrine /enterochromaffin cells to secrete histamine; which activates secretion of gastric juice; Partially digested proteins especially peptides / decrease in pH activates chemoreceptors, which stimulate G-cells to secrete gastrin hormone; which stimulates secretion of gastric juice; Excessive acidity (PH of less than 2) inhibits G-cells hence gastric juice secretion reduces; Emotional upset activates sympathetic nervous system whose effects override the parasympathetic nervous system;

Question 35.

(a).Explain what is meant by a balanced diet ***(04 marks)***
(c).How is digestion controlled in each of the following parts of the digestive system
(i). Mouth ***(06 marks)***
(ii).Intestines ***(06 marks)***

(a).

Balanced diet is a meal which contains the correct proportions and quantity of protein, carbohydrate, lipids, vitamins, mineral salts, water and dietary fibre/roughage required to maintain health. Carbohydrates and lipids are for energy production, proteins are for growth and repair, vitamins and mineral salts are for protection of good health, water is a solvent while roughage stimulates peristalsis to prevent constipation. An unbalanced diet can lead to deficiency diseases.

(c)(i).

Control of digestion in the mouth

Sight/ smell / thought of food stimulate conditioned reflexes involving the cerebral cortex, hypothalamus and medulla oblongata; which stimulate salivary glands to secrete saliva. Contact of food with tongue taste receptors stimulates nerve impulses via sensory neurons to the hypothalamus and medulla oblongata; relayed along motor neurons to stimulate salivary glands to secrete saliva. Salivary amylase in saliva causes hydrolysis of starch to maltose. Loss of appetite/ depression inhibit cerebral cortex; parasympathetic centre is not stimulated no secretion of saliva;

(c)(ii).

Distension of duodenum/ presence of acid chyme/ partially digested food stimulates the secretion of intestinal (enteric) gastrin hormone; which stimulates secretion of gastric juice in the stomach; Distension of duodenum/ presence of acid chyme / fatty acids / irritants / in the duodenum stimulates the secretion of Intestinal hormones. **Secretin;** which stimulates the release of bile from liver and hydrogen bicarbonate ions in pancreatic juice; **Cholecystokinin;** which stimulates the pancreas to secrete its enzymes; Enterogastrone; which inhibits/suppresses gastric activity (any further secretion of acid by the stomach); **Vasoactive intestinal peptide** inhibits gastric acid secretion. Distension of duodenum / presence of acid chyme or fatty acids / irritants / in the duodenum initiates gastric-inhibitory impulses in the enterogastric reflex causing suppression of gastric activity; and emptying of stomach;

Question 36.

(a).Describe different ways in which structure of the leaf contributes to its successful functioning ***(14 marks)***

(b).Explain

(i). the advantage of the malate shunt serving as both a carbondioxide pump and a hydrogen pump in C_4 plants ***(05 marks)***

(ii).why it is advantageous for bundle sheath chloroplasts to lack grana? ***(01 marks)***

(a).

Overall form and position

• Large surface area to volume ratio for maximum interception of light and efficient gaseous exchange.

• Blade often held at right angles to incident light; particularly in dicotyledonous plants.

Stomata

• Numerous pores allow gaseous exchange; CO_2 needed for photosynthesis and oxygen a waste product.

• In dicots, stomata are located mainly in shady lower epidermis; minimize water loss by transpiration.

Guard cells;

• Regulate opening of stomata i.e open only in light and when photosynthesis occurs

Mesophyll cells

• Contain chloroplasts; special organelles for photosynthesis.

• Chloroplasts may be phototaxic i.e move within cells towards light.

• In dicots, spongy mesophyll has large intercellular spaces for efficient gaseous exchange.

• In dicots, pallisade mesophyll cells with more chloroplasts are located near the upper surface of the leaf for maximum interception of light. Length of the cells increases chances of light absorption.

• Chloroplasts are located near the periphery of the cell for maximum absorption of light and easier gaseous exchange with the intercellular spaces.

Vascular system;

• Xylem supplies water and mineral salts; relevant as metabolites of photosynthesis

• Phloem translocates products of photosynthesis from the sources to sinks.

• Xylem, collenchyma and sclerenchyma provides a supporting skeleton to woody plants.

(b)(i).

Carbondioxide pump; by acting as a carbondioxide pump, the malate shunt increases carbondioxide concentration in bundle sheath cells; thus increasing the efficiency with which RUBP carboxylase works.

Hydrogen pump; malate carries hydrogen from $NADPH_2$ in the mesophyll to NADP in bundle sheath cells where $NADPH_2$ is regenerated. The advantage is that $NADPH_2$ is generated by the most efficient light reaction in the mesophyll chloroplasts whose own synthesis of $NADPH_2$ is limited.

(b)(ii).

Oxygen would compete with carbondioxide for the active site of RUBP carboxylase.

Question 37.

(a).Describe in detail, the function of the capillaries and lacteal in each villus ***(05 marks)***

(b).Explain how the structure of the wall of the ileum adapted to function ***(07 marks)***

(c)(i).Amylase is secreted into the lumen of the gut, but maltase is attached to the surface of the epithelial cells. Suggest the importance of this difference ***(02 marks)***

(c)(ii)Describe how the release of amylase from each of the secretory organs is controlled ***(06 marks)***

(a).

Lacteal absorbs fatty acids & glycerol/ recombined lipid/ chylomicrons; lacteal delivers lipids to larger lymph vessels; which then carry lipids to larger lymph vessels; which then carry lipids to veins/ blood stream; capillaries absorb glucose/ monosaccharides; amino acids; dipeptide; by diffusion/ active transport; capillaries deliver absorbed products to hepatic portal vein.

(b).

• Crypts of Lieberkuhn produce new cells to replace those worn off from villi tips secrete intestinal juice;

• Numerous goblet cells; secrete mucus to lubricate food; helping passage through the gut

• Epithelium is single cell layer; reduce diffusion distance for food substances
• Microvilli have enzymes in cell surface membranes; permit contact digestion.
• Numerous tight junctions; ensure digested food passes through epithelial cells
• Dense capillary network within villi; maintains a steep concentration gradient for absorption
• Smooth muscles in the villi allow movement, bringing villi into close contact with digested food.
• Longitudinal and circular muscles that are antagonistic bring about peristalsis and mixing of food
• Folds of wall of ileum; villi, microvilli/ brush border increases surface area for absorption of digested food.

(c)(i).

Pancreatic amylase hydrolyses amylose to maltose; maltase hydrolyses maltose to glucose most chyme that enters the small intestine contains more amylose than maltose; glucose absorbed by epithelial cells;

(c)(ii).

Salivary glands; unconditioned reflex; food stimulates taste buds/ tongue receptors, sensory neurones carry impulses to the brain; motor neurons carry impulses from the brain to the salivary glands which produce saliva containing amylase; conditioned reflex may also produce saliva.
Pancreas; stomach contents arriving in small intestines stimulate release of CCK/ CCK-PZ; this stimulates synthesis of amylase; nervous reflexes stimulate secretion of pancreatic juice containing amylase.
Small intestines; amylase not released; site of action is on membrane of epithelium of villi.

Question 38.

(a).What is meant by chemosynthesis? ***(02 marks)***
(b).Compare photosynthesis in purple sulphur bacteria with that in a higher plant ***(04 marks)***
(c).Explain the
(i).mutualistic relationship between mammals & microorganisms in their digestive tract ***(03 marks)***
(ii).effects of underfeeding and overfeeding in a mammal ***(04 marks)***
(d).Explain the significance of saprophytes in nature ***(09 marks)***

(a).

Synthesis of organic compounds from inorganic materials; using energy derived from oxidation of inorganic compounds;

(b).

Similarities
• Both utilize photosynthetic pigments
• Both use energy from sunlight
• Both result in production of organic food substances

Differences

Purple sulphur bacteria	Higher plants
Source of hydrogen is hydrogen sulphide	Source of hydrogen is water
Produce sulphur as a by product	Produce oxygen as a by product
Use bacteriochlorophyll as photosynthetic pigment	Use chlorophyll as photosynthetic pigment

(c)(i).

The microorganisms secrete cellulase enzyme; that digests cellulose; into simple sugars/ glucose; which is absorbed; along the walls of the tract and then assimilated; they also synthesize B vitamins; for the host; the microrganisms gain shelter; warmth; constant food supply; and protection from the herbivore.

(c)(ii).

If energy output exceeds energy input, carbohydrate reserves (glycogen) and fat reserves (adipose tissue) are respired and the person's body mass decreases. When carbohydrate and fat reserves exhaust, tissue protein is respired and the body wastes away. If energy intake exceeds energy usage over a period of time carbohydrate is turned into fat and the person's body mass increases leading to obesity (overweight).

(d).

• Decomposition of dead organic matter; unlocks mineral elements allowing nutrient recycling.
• Breakdown products of organic matter; eg CO_2 is used in brewing, baking, cheese and yorghurt making.
• Important in decomposition of sewage;
• Pathogenic saprophytes cause diseases.

• They are cultured for research for example E coli
• Cause food spoilage; rendering it inedible for human consumption.
• Important in enzyme production;
• Used in the manufacture of antibiotics eg penicillins.
• Sources of food in symbiotic relationship e.g symbiotic bacteria in human gut; are involved in production of nutrients like vitamin B_{12} complex.

Question 39.

(a).Explain what is meant by compensation point ***(04 marks)***
(b)(i).Describe the life cycle of Taenia solium in its habitat ***(10 marks)***
(b)(ii)How is the parasite described in (b)(i) above adapted to function ***(06 marks)***

(a).

This is the point at which the rate of carbondioxide production from respiration is compensated exactly by the rate of carbondioxide uptake in photosynthesis. Below the compensation point, the rate of photosynthesis is less that the rate of respiration and so carbondioxide is evolved. Above the compensation point, the rate of photosynthesis exceeds the rate of respiration and so oxygen is evolved. At the compensation point, there is no net exchange of gases.

(b)(i).

Humans are the definitive hosts for T.saginata and T.solium. Eggs or gravid proglottids are passed out in faeces; Cattle (T.saginata) and pigs (T.solium) become infected by ingesting vegetation contaminated with eggs or gravid proglottids. In the animal's intestine, the oncospheres hatch, invade the intestinal wall, and migrate to striated muscles, where they develop into cysticerci. A cysticercus can survive for several years in the animal. Humans become infected by ingesting raw or undercooked infected meat. In the human intestine, the cysticercus develops over 2 months into an adult tapeworm, which can survive for years. Adult tapeworms attach and stay in small intestine by their scolex. The adults produce proglottids which mature, become gravid, detach from the tapeworm, and migrate to the anus or are passed in the stool (approximately 6 per day). The eggs contained in the gravid proglottids are released after the proglottids are passed with the faeces.

(b)(ii).

• Thick cuticle to resist digestion by host's enzymes
• No sense organs and reduced body structures to fit in host's body.
• Excretory products like lactic acid are eliminated via cuticle.
• Can respire anaerobically in low oxygen.
• Feeds on already digested food from the host.
• Eggs remain viable for a long time.
• Secretes mucus to prevent digestion by host's enzyme.
• Has hooks and suckers for holding tightly onto ileum wall.
• Flattened body increases surface area for absorbing its host's digested food
• Degeneration of structures reduces on space occupied.
• Lays many eggs to increase survival chances; raising their reproductive success.
• Eggs have a thick shell for resisting enzyme destruction.
• Being hermaphrodite increases reproductive rate.

Question 40.

(a).Describe the chemi-osmotic synthesis of energy within the chloroplasts. ***(12 marks)***
(b).Compare chemi-osmotic synthesis of energy in (a) above & that in the mitochondria. ***(08 marks)***

(a).

Protons generated from photolysis of water; are actively pumped from the stroma; across the thylakoid membrane into the thyllakoid space; using energy from electron flow from the ETC. Protons accumulate in the thyllakoid space; concentration within exceeds that in the stroma; an electrochemical proton gradient is created across the thyllakoid membrane. Thyllakoid membrane is impermeable to protons; protons just diffuse back into the thyllakoid spaces via special chemi-osmotic channels present on the membrane. Discharge of the proton gradient releases energy that is used to link inorganic phosphate (Pi) to ADP to form ATP; reaction catalyzed by membrane bound

ATPase (ATP synthase); found on the chemi-osmotic channels. Protons are in turn taken up by NADP; gets reduced to NADPH.

(b).

Similarities

- Both involve electron transport chains which excite electrons and produce energy.
- In both, energy of the ETC pump protons across membrane against a concentration gradient
- In both discharge of the proton gradient produces ATP.
- Both involve the enzyme ATPase or ATP synthase to synthesize ATP from ADP and Pi

Differences

Chemi-osmosis in mitochondria	Chemi-osmosis in the chloroplast
Begins in the mitochondrial matrix	Begins in the stroma
Protons are pumped out the matrix across the stroma into the intermembrane space; before diffusing back into the matrix	Protons are pumped into the thylakoids across the thylakoid membranes before diffusing back out of the stroma
ATP synthase is embedded in the cristae	ATP synthase is embedded in the thylakoid membrane

Question 41.

(a).With reference to a photosynthetic pigment;

(i). Distinguish between absorption and action spectrum. *(02 marks)*

(ii).Describe the role of light in the process of photosynthesis. *(07 marks)*

(b).Describe the procedure of determining the rate of photosynthesis at varying wavelengths of white light.

(c).Explain the physiological role of carotenoids in photosynthetic plants. *(05 marks)*

(a)(i).

Absorption spectrum is a graphical representation of the relative effectiveness of a photosynthetic pigment in capturing light at various wavelengths while Action spectrum is a graphical representation of the effectiveness of a photosynthetic pigment in utilizing a given wavelength of light energy to promote a photosynthetic process.

(a)(ii).

Light excites chlorophyll molecules in photosystems I and II, raising the energy level of electrons. High energy electrons destabilize chlorophylls but the extra energy is converted into ATP during electron transport in the electron carrier system. The electron flow which generates ATP is cyclic and the production of ATP involved is by cyclic photophosphorylation Light energizes water molecules causing them to release electrons and oxygen. The electrons derived from such a reaction are used to restore the stability of oxidized chlorophyll. Hydrogen ions obtained from such a reaction are coupled with electrons derived from PS I and used to reduce $NADP^+$ to form NADPH which delivers the reducing power into the Calvin cycle. Accumulation of sugars in epidermal guard cells during photosynthesis has an effect of lowering the solute/water potential of cell sap causing influx of water into mesophyll cells which also opens stomata to allow entry of carbondioxide for photosynthesis.

(b).

- A strip of absorptive paper with concentrated spot of leaf extract is dipped in concentrated diethylether (solvent)
- The solvent rises up the paper sweeping pigments with it.
- The pigments travel at different speeds becoming separated on the paper.
- Separate solutions of pigments are made; absorption spectrum of each is determined with a spectrometer
- The wavelengths obtained are translated to read specific colors on the spectrum of white light. The wavelengths obtained in colors are now used to obtained color filters which are placed before a photosynthesizing plant placed in water.
- The evolution of gas in the water is used as a measure of the rate of photosynthesis.
- A graph of rate of photosynthesis varying with wavelength is drawn.

(c).

Carotenoids are accessory pigments because they absorb light and pass the energy on to chlorophyll. Photons especially the high-energy, short-wavelength photons in the ultraviolet part of the electromagnetic spectrum; contain enough energy to knock electrons out of atoms and create free radicals. Free radicals, in turn, trigger reactions that can disrupt and degrade molecules. Carotenoids quench‖ free radicals by accepting/ stabilizing unpaired electrons.

As a result, they protect chlorophyll molecules from harm. When carotenoids are absent, chlorophyll molecules are destroyed and photosynthesis stops.

Question 42.

(a) Compare mutualism and parasitism. *(04 marks)*
(b) Describe how
(i) Gut bacteria contribute to the well-being of herbivores *(04 marks)*
(ii)Nitrogen-fixing bacteria contribute to the well-being of herbivores *(06 marks)*
(c) Explain the roles of soil microorganisms in the recycling of nitrogen and carbon in nature *(06 marks)*

(a).

Similarities

• Both are nutritional associations between living organisms;
• In both one of the two organisms in the association may live in or on another;
• In both associations the two organisms in association show some specificity to each other;
• Both are interspecific associations;
• In both several grades of association exist from lose to tight associations but in each case the two organisms in the association may not live successfully apart;
• In both associations one of the organisms in the association is usually smaller than the other;

Differences

Parasitism	Mutualism
One partner (the parasite) benefits while the other (the host) suffers	Both partners benefit fully from the association and no harm of any kind suffered;
Benefit is almost entirely nutritional	Benefit may be nutritional and any other e.g. shelter, protection and even transport;
The parasite may require an intermediate host (vector)	No intermediate organisms required
Requires several modifications (adaptations) that are structural, physiological etc.	Modifications are not necessary
Organisms depend on high reproductive potentials are and are not usually resistant stages in their life cycles;	High reproductive potentials are always developed and are not usually

(b)(i).

Symbiotic bacteria haboured in enlarged caeca and appendix; release cellulases that digest cellulose, releasing nutrients from plant materials absorbed by the herbivore such as cow, goats; also symbionts in the rumen that is anterior to the main region of enzyme production when they die they pass through the digestive system with the food and form an important source of nutrients, especially proteins;

(b)(ii).

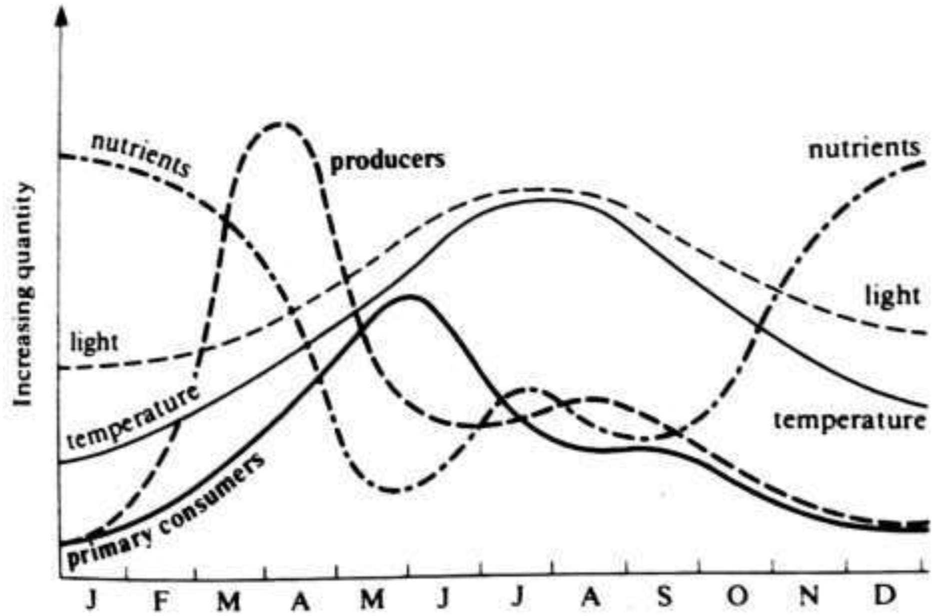
Rhizobium in a mutualistic association with roots of leguminous plants; such as peas, beans, and clover; convert atmospheric nitrogen into ammonia; this combines with carboxylic acids formed in Krebs cycle to make a range of amino acids; for synthesis of proteins and nucleic acids; constituting plant structures and also stimulate growth of plants: which are fed upon by herbivores to obtain nutrients such as vitamins carbohydrates, proteins for nourishment of their bodies.

(c).

Microorganism	Role
Saprophytic bacteria and fungi;	Decompose detritus, releasing ammonia and carbon dioxide; Return carbon dioxide to environment through respiration;
Nitrifying bacteria e.g. genera nitrosomonas, nitrobacter;	Oxidize ammonia to nitrate ions; first by conversion of ammonia to nitrite ions then nitrite ions to nitrate ions by bacteria of genus Nitrobacter
Denitrifying bacteria e.g. *Pseudomonas denitrificans:*	Reduce nitrate ions in water logged soils to nitrite, ammonia, nitrogen and oxides of nitrogen lost to the atmosphere;
Nitrogen fixing bacteria e.g. azotobacter, clostridium and rhizobium;	Reduce nitrogen gas to ammonia which they use to form amino acids

CHAPTER 6; Ecology

The graph below shows changes in the standing crop biomass of producers, primary consumers and certain environmental variables in a lake during the course of one year. Study the curves and answer the questions that follow.



(a).Describe the changes in the;

(i).environmental variables throughout the year ***(06 marks)***

Temperature increases gradually between January and July; and reaches a peak; between July and August; thereafter decreases slowly/ gradually up to December.

Light increased gradually from January to June; reaches a peak between July and August; then decreases slowly/ gradually up to December.

(ii).standing crop biomass of consumers and producers ***(05 marks)***

Standing crop biomass of consumers

From January to February, the standing crop biomass increased gradually; then increased rapidly between March and May; reaching a peak. From June to July; standing crop biomass decreased rapidly; remained constant from July to mid-September. From mid-September to mid-December, it decreased gradually then began to rise slowly.

Standing crop biomass of producers

From January to February; standing crop biomass increased gradually; then increased rapidly between February & March; attaining a peak. Then from April to May; standing crop biomass decreased rapidly; further decreased gradually between May and June. The standing crop biomass remained constant in July; increased gradually between July and August. From August to December; standing crop biomass decreased gradually. In December; it starts to rise again

(b)(i).What explanations can you give for the observed changes in the physical factors in the river?

Light energy from the sun is absorbed by water and the temperature of the water body increases. An increase in fight implies an increase in water temperature. Temperature remains constant when there is a balance between heat loss from evaporation and heat gain from the sun rays striking the water body. During the rainy season, cold rain water mixes with the river water cooling it; this could be seen from September to December. Quantity of light decreases due to the cloud cover during the rainy season. During the sunny season, the sky is clear, quantity of light is high, rapidly warming up the water; this could be in June to August. Quantity of light increases from January to June as the sky clears, water also progressively warms up. Light penetration in the water body is also affected by organisms at water surface In sunny periods there are few organisms at water surface due to high water temperature which could affect their metabolism; this, increases light penetration. At start of rain season, water cools and organisms at water surface increase causing decreased light penetration.

(b)(ii).What is the importance of increased light penetration into the water body to the ecosystem in the river?
• It increases the rate of photosynthesis; increasing productivity in the river.
• Increases the number of producers in the river ecosystem availing energy to higher trophic levels.
• Light energy warms up the water, providing a suitable temperature for breeding of the organisms
• Increased light penetration affecting the seasonal rhythms such as mating and migration of organisms
• Warming up the water can decrease the amount of dissolved oxygen in the river water.
• Increases visibility in the river serving both the predator and prey to escape from being eaten or to find food, shelter and mates.

(c).Explain the relationship between producers and

(i).nutrients ***(05 marks)***

High quantity of nutrients initially increased the quantity of producers. A decrease in the nutrient content; results in a decrease in the quantity of producers. Producers depend on nutrients for survival. Therefore a decrease in nutrient content starves producers to death; which after their decomposition; increase the quantity of nutrients in the water body.

(ii).primary consumers ***(05 marks)***

As producers increase, primary consumers increase too and a decrease in producers results in a decrease in primary consumers. This is because primary producers depend on producers for food and oxygen. Increase in producers produce more food and oxygen available for consumption by consumers which correspondingly increase as the number of producers reduce. A decrease in producers results in competition for nutrients among the consumers; so that their numbers decrease. The two therefore fluctuate in such a way that an increase in producers results in an increase in consumers and a decrease in the former resulting in a decrease in the latter.

(d).Suggest the

(i).probable sources of nutrients in the lake ***(03 marks)***

• Decomposition of dead organisms in the lake
• Drainage of nutrients into the lake by the feeding river
• Nutrient falling in with rain eg nitrates
• Dissolution of the underlying lakes
• Fertilizer washout from farms into lakes

(ii).reasons for the rapid rise in the nutrients up to the end of the year ***(03 marks)***

Death of producers adds nutrients after decomposition; Decrease in producers which would have consumed the nutrients. Death of primary producers adds nutrients after their decomposition. A low temperature reduces respiration resulting in a decrease in nutrient consumption. Low light intensity lowers the photosynthetic rate; resulting in a decrease in nutrient consumption.

(e).What factors are responsible for rapid increase in producers up to the end of march ***(03 marks)***

• Presence of much nutrients
• Increase in light intensity
• Increasing environmental temperature;
• Low level of primary consumers

(f)(i).Predict what would happen to the ecosystem if the prevailing conditions continue for yet another year

Nutrients will decrease gradually ten fluctuate around a constant; Light intensity will decrease gradually and fluctuate around a constant; Producers and consumers will increase gradually; and fluctuate around a constant.

(f)(ii).Explain your answer ***(05 marks)***

Phytoplanktons and so the consumers increase gradually; Increase in producers might shield the submerged photosynthetic phytoplanktons reducing light infiltration; and oxygen dissolution from the atmosphere into the lake. Consumers will be deprived of oxygen leading to their death and decay. Decrease in light penetration reduces temperature too; causing decay of producers hence resulting in an increase in level of toxins in the water bod which may render the ecosystem unfavourable for life.

(g).Why did the primary consumers begin to increase one month later before the increase in the number of producers?

Primary producers, besides having a lower reproductive rate than producers, depend solely on primary producers for food and therefore only start to increase when producers are sufficient in number to support their survival.

(h).Suggest three ecological effects that a decline in the population of primary producers could have on primary consumers ***(03 marks)***

- Anoxic conditions (reduced oxygen supply to primary consumers).
- Competition among primary consumers for the little available food from the producers
- Intoxication of the consumers from the toxic decomposition products of the primary producers.
- Decreased biodiversity of the primary consumers

(i).In what ways are the elements nitrogen and sulphur are obtained by plants ***(05 marks)***

- Mycorrhiza; plant roots symbiotically associate with fungi; permit intake of mineral nutrients particularrly ammonium, nitrate and phosphates into the plant.
- Mutualistic interaction with nitrogen fixing bacteria in the root nodules like Rhizobium that incorporate atmospheric nitrogen into their protoplasm; from which plants absorb.
- Nitrifying bacteria decay ammonium compounds to nitrates; nitrogen gets availed to plants inform of nitrates.
- Electrical and photochemical fixation of atmospheric nitrogen by lightening forms nitrogen oxides; which oxidize further to nitrates the form in which nitrogen gets absorbed by plants.
- Death of animals that the plants and absorbed ammonium ions released in soil get converted to nitrates absorbed by plants and transported to leaves.
- Some plants have adopted carnivorous behaviour; take in nutrients incorporated in animal proteins
- Some plants have adopted an insectivorous behaviour; take in nutrients incorporated in animal proteins.

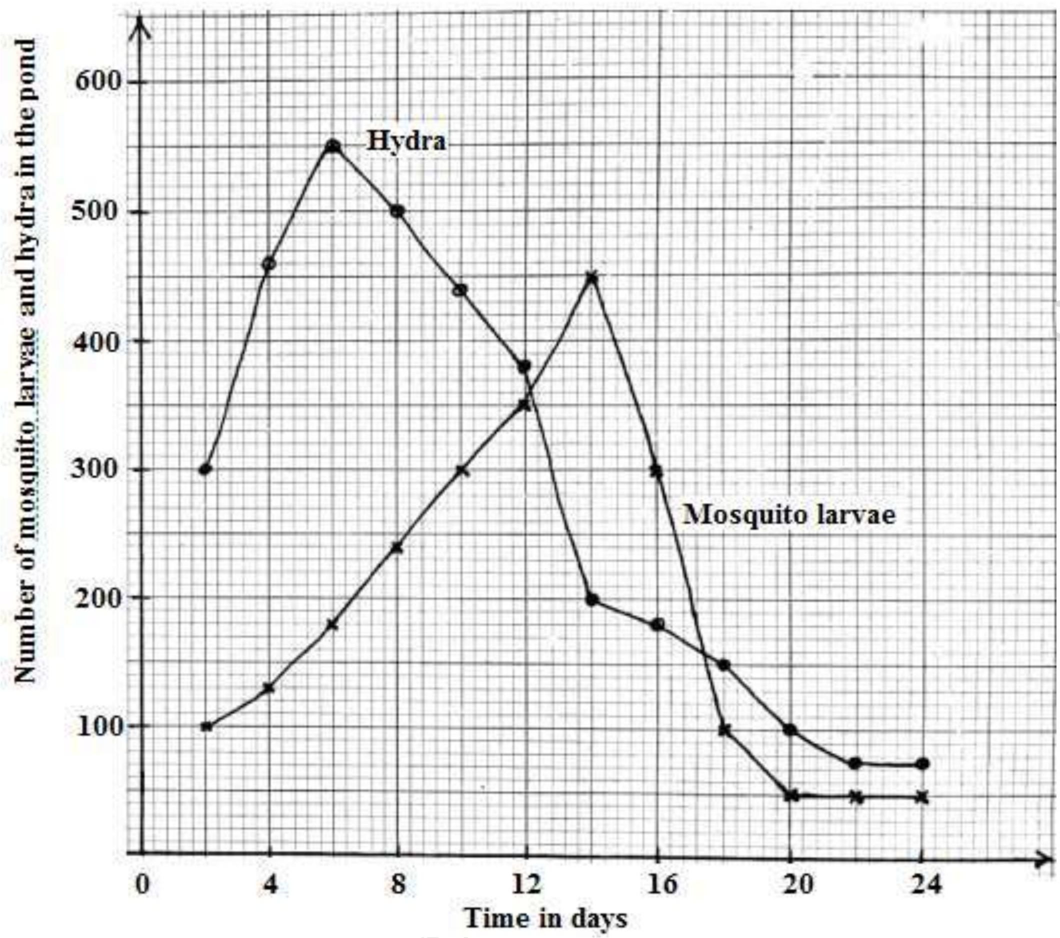
Question 2.

An investigation was carried out on the population of mosquito larvae and hydra in a pond. The results were recorded in the table below. Study the information carefully and answer the questions that follow.

Time (days)	Number of mosquito larvae	Number of hydra
2	300	100
4	460	130
6	550	180
8	500	240
10	440	300
12	380	350
14	200	450
16	180	300
18	150	100
20	100	50
22	75	50
24	75	50

(a).Using the information in the table above, plot a suitable graph ***(05 marks)***

<u>A graph showing the relationship between the population of mosquito larvae and that of hydra in a pond with time</u>



(b).From the graph, describe the trend of population growth of mosquito larvae & hydra species ***(09 marks)***

Mosquito larvae

From 2 days to 6 days, number of mosquito larvae increases very rapidly; attains a peak on day 6; From 6 days to 12 days, number of mosquito larvae decreases rapidly; From day 12 to day 14, mosquito larvae population decreases very rapidly; From day 14 to day 16, number of mosquito larvae decreases slowly/ gradually; then from day 16 to day 22, mosquito larvae population decreases rapidly; From day 22 to day 24, mosquito larvae population remains constant;

Hydra

From day 2 to day 12, population of hydra increases rapidly; then very rapidly up to day 14; where a peak is attained; From day 14 to day 18, population of hydra decreases very rapidly; then from day 18 to day 20, hydra population decreases rapidly; From day 20 to day 24, population of hydra remains constant;

(c).Explain the relationship between the populations of the two species ***(20 marks)***

Variation in hydra population almost mirrors but slightly lags behind that of mosquito larvae; because of a predator-prey interaction; in which the mosquito larvae is the prey; and hydra is the predator; Hydra population is initially lower than that of mosquito larvae; because hydra initially has fewer potential reproductive members (lower reproductive rate); From 2 to 6 days, as the mosquito larvae population rapidly in- creases, hydra population also increases rapidly; because mosquito larvae offer a steady and reliable source of food to hydra; and this prompts a higher reproductive rate of hydra; Higher birth rate and lower death rate of hydra causes its rapid population growth; From day 6 to day 14, as hydra population further increases rapidly, mosquito larvae population decreases rapidly; because the growing hydra population subjects an excessive predation pressure to the mosquito larvae; reducing their number. From day 14 to day 20, as the mosquito larvae population decreases rapidly, hydra population also reduces rapidly; because hydra dies of food shortage; and from intense intraspecific competition; From day 20 to day 22, as the population of hydra remains constant, that of mosquito larvae decreases gradually; because the death rate of hydra is already equal to its birth rate; while death rate of the mosquito larvae is still higher than their birth rate; From day 22 to day 24, as the population of mosquito larvae remains constant, that of hydra also remains constant; because the birth rate and death rate of each organism strikes a balance resulting in equilibrium of each population;

(d).Explain why number of mosquito larvae is higher than that of hydra at any one point ***(03 marks)***

- Mosquitoes have a higher reproductive rate; lay many eggs per individual;
- Mosquitoes have a shorter gestation period; many larvae thus emerge within a short period of time;
- Growth of hydra unlike that of mosquitoes is limited by seasonal changes in water pH, temperature and oxygen content;

(e). Outline the biological significance of the study above ***(02 marks)***

- Biological vector control; control of mosquito population.
- Reduction in mosquito related disease burden eg malaria.

Question 3.

A group of students carried out an ecological investigation in the distribution of two species of trees, A and B in different habitat of the woodland. They found out that one species was more common on the dry, well drained soils while the other was more common on the wet poorly drained soils. To identify which species occupied each habitat, they collected 100g of leaves from each species and hung each sample on a line to dry in identical conditions in the laboratory. Both samples were re-weighed each hour for five hours. The results were recorded in table 1 below.

Table 1.

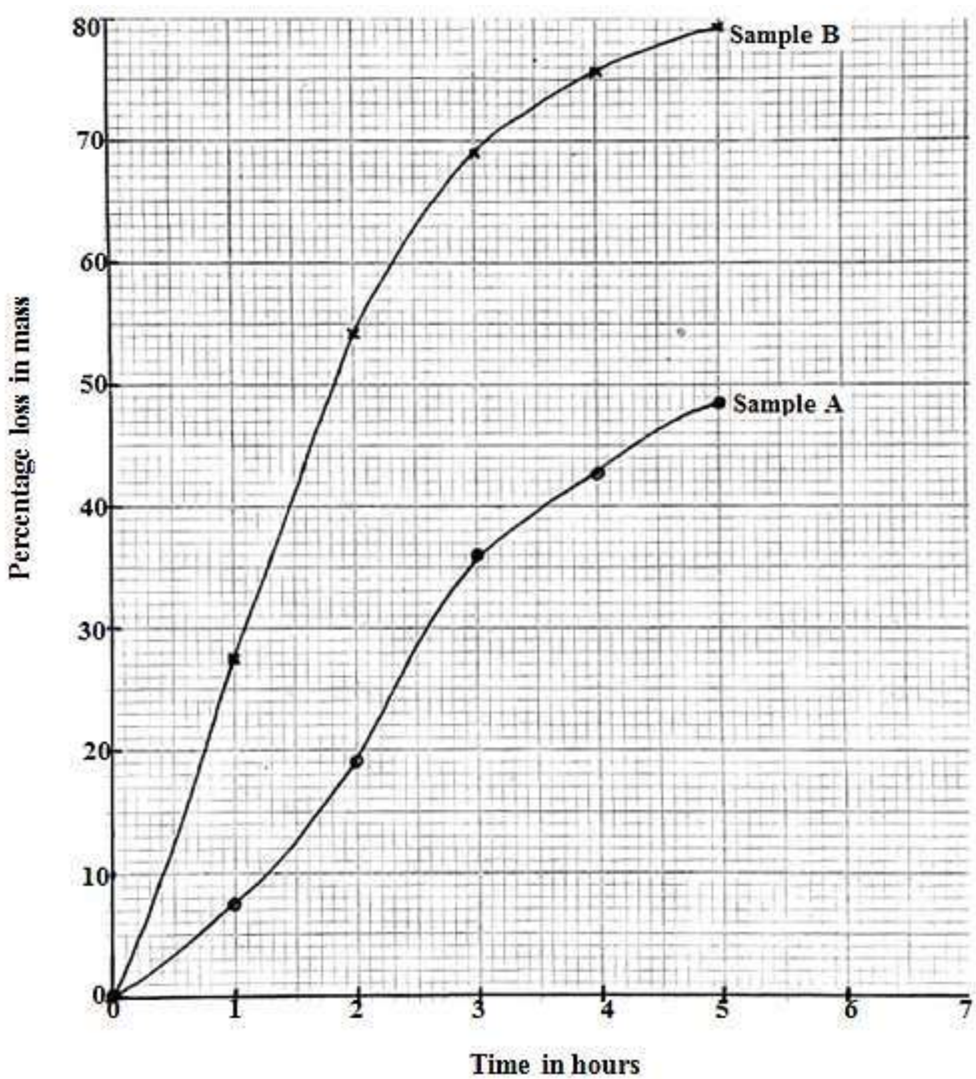
Time (hours)	Mass of sample in grams	
	A	B
1	92.5	72.5
2	81.0	45.9
3	64.0	31.0
4	57.2	24.1
5	51.6	20.8

(a).Calculate the percentage loss in the mass compared to the original mass for each sample every hour and record your data in a table. Show your working ***(05 marks)***

Time in hours	Percentage loss in mass of each sample	
	A	B
0	(0.0/100) x 100 = **0.0**	(0.0/100) x 100 = **0.0**
1	(7.5/100) x 100 = **7.5**	(27.5/100) x 100 = **27.5**
2	(19.0/100) x 100 = **19.0**	(54.1/100) x 100 = **54.1**
3	(36.0/100) x 100 = **36.0**	(69.0/100) x 100 = **69.0**
4	(42.8/100) x 100 = **42.8**	(75.9/100) x 100 = **75.9**
5	(48.4/100) x 100 = **48.4**	(79.2/100) x 100 = **79.2**

(b).Represent the information in (a) above graphically

A graph showing the relationship between the percentage loss in mass of A and B with time



(c).Explain the changes in the percentage loss in mass of species A with time ***(05 marks)***

From 0 to 2 hours of exposure, there was a slow increase in the percentage loss in mass; because of initial slow rate of evapo-transpiration from the leaves; From 2 to 3 hours, there was a gradual increase in the percentage loss of mass; may be associated with increased environmental temperature, more stomata open water loss increases following increased rate of evapo-transpiration. From 3 to 5 hours, the slow increase in percentage loss of mass was due to the progressively increasing saturation of the atmosphere with moisture; limiting further water loss. Besides, water in the leaves is almost getting depleted from the leaves.

(d)(i). From your graph, compare the percentage loss in the mass of the two species ***(05 marks)***

Similarities

- For both A and B, percentage loss of mass of the samples generally increases with time.
- From 2 to 3 hours, percentage loss of mass of both samples increases gradually.
- From 4 to 5 hours, percentage loss of mass of both samples increases slowly.

Differences

Percentage loss in mass of sample A	Percentage loss in mass of sample B
Is generally lower at all times of exposure	Generally higher at all times of exposure
Increases slowly from 0-2 hours.	It increases rapidly from 0-2 hours.

(d)(ii).Explain the differences in (d)(i) above ***(05 marks)***

Leaves from sample generally experiences less water loss through evapotranspiration than those of sample B; because water loss from the leaves of A is limited by structural and physiological features for retaining water; Leaves of sample B on the other hand are susceptible to more water loss since the plant is less structurally and physiologically adapted to minimize water loss. Initial rate of evapo-transpiration is higher in leaves of sample B than A because leaves of sample B possess larger surface area & have more exposed stomata on the leaf surfaces.

(e).With a reason for your answer, identify the habitat of each species ***(04 marks)***

Sample A; Dry well drained soils; because of the lower percentage loss in mass; suggestive of the presence of structural adaptive features for retaining water; prompts a generally lower rate of water loss;

Sample B; Wet poorly drained soils; because of a higher percentage loss in mass suggestive of presence of little or no structural adaptive features for retaining water; prompts a generally higher rate of water loss

(f)(i).What adaptive features could enable species A to survive in its habitat ***(08 marks)***

- Thick waxy shiny cuticle
- Hairy leaf lamina
- Leaves of reduced surface area (folded/ rolled)
- Fewer stomata
- Reversal stomatal rhythm
- Leaves reduced to needle like foliage like thorns, grasses
- Small size of the leaves
- Periodic shedding off of leaves during the dry season
- Grey or light reflecting foliage
- Thick fleshy/ succulent leaves
- Sunken stomata

(f)(ii).State any two factors that could have affected the change in mass of samples during the experiment

- Temperature
- Humidity
- Wind/ air currents

Question 4.

Figures 1.2 and 3 show the immigration and extinction of species on different categories of virgin islands. Figure 1 shows the rate of immigration of new species on an island nearby the shore and one that is far from the shore. Figure 2 shows the rate of extinction of species on a large island and on a small island. Figure 3 shows the rate of immigration and extinction of species on an island. Study the information and use it to answer the questions that follow.

Fig 1

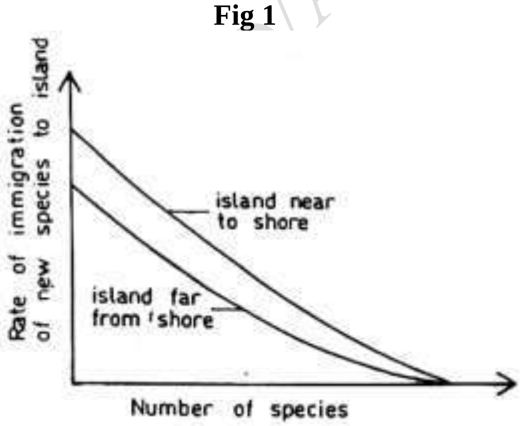


Fig 2

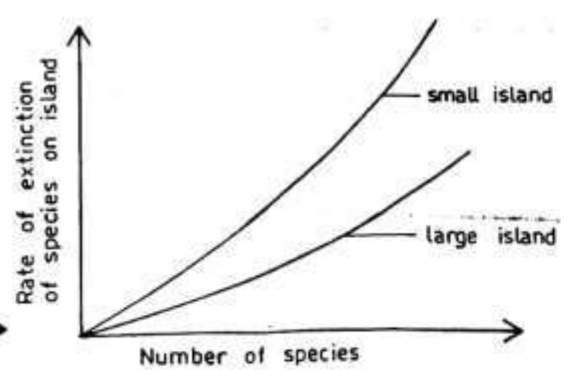
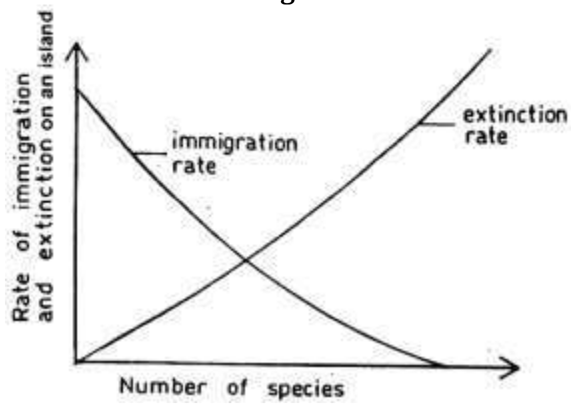


Fig 3.



(a).Explain the rate of

(i).immigration of new species on an island that is near to the shore and one that is far from the shore (figure 1). ***(10 marks)***

At first, almost every organism arriving on the island is a new species; so rate of immigration for the island is high As the number of species on the island increases, many of the organisms arriving are of the species already present so the rate of immigration decreases; as the number of species rises due to competition; An island near the shore is reached/ accessed more easily; than that far away; so immigration rate is higher on the island near the shore than the one far away; For the island far away from the shore, fewer species reach it; and the rate of immigration is much lower; even at the beginning of the colonization.

(ii).extinction of species on a small island and on a large island (figure 2) ***(09 marks)***

If there are only a few species on the island, each probably has a large population size; and little competition from the other species; is experienced so that the rate of extinction is low; As the number of species increases, the population size of some of the species will become lower and the probability of some getting extinct will be higher. If the island is small, there will be less room hence competition or any other density dependent factor will intensify highly; The rate of extinction rises as the number of species on the island rises. If the island is large, there will be more room for many viable populations of species due to minimal competition/ minimal density dependent factors; so the rate of extinction of species on the smaller island will be higher than the rate of extinction for the same number of species on a large island.

(iii).immigration and extinction of species on an island. (figure 3) ***(07 marks)***

When the number of species on the island is small, the immigration rate will exceed the extinction rate; As the number of species rises, the immigration rate falls; but the extinction rate rises due to competition for the resources; eventually the rate of immigration equalizes with the rate of extinction; where the number of species on the island is at an equilibrium point (death rate = birth rate); and when the number of species is greatest, extinction rate is also high;

(b).From figures 1, 2 and 3, what conclusions can you draw about what determines the number of species on an island? ***(05 marks)***

Every island has a balanced number of species ie carrying capacity; which depend on its size; and distance from the shore/ barriers; availability of resources; number of reproducing individuals of the component species.

(c).Describe how factors other than those depicted in the information provided may affect the immigration of new species on an island. ***(04 marks)***

Evolution (mutation/ variation); can increase the number of species without requirement of immigration which will make it harder for the new species to colonise successfully.

Habitat diversity; will determine the number of species; A small island with high habitat diversity may at- tract as many species as the big island.

Physical factors of the environment; such as light, temperature, wind, nutrients will determine the resources available for the species

(d).Suggest the factors that would cause immigration of new species to a virgin island ***(05 marks)***

• Availability of food on the island; capable of sustaining different trophic levels.

• Availability of enough space on the island; forcing some species to seek more spacious habitats;
• Conducive environmental conditions; suit immigrating species
• Availability of breeding sites; may attract species which will eventually settle
• Escape from predators; seek refuge from the island
• Disease outbreak on the main land
• Influence of the effects of man's activities such as habitat destruction on the main land

Question 5.

The population growth of two related aquatic micro-organisms were investigated together in two sets of culture media. In the first set, both species were cultured in long and cylindrical vessels while in the second set, the micro-organisms were cultured in shallow petri-dishes. Figure 1 below shows the population growth pattern of the species in the first set while figure 2 shows the population growth pattern of the species in the second set. Study the figures carefully and use them to answer the questions that follow.

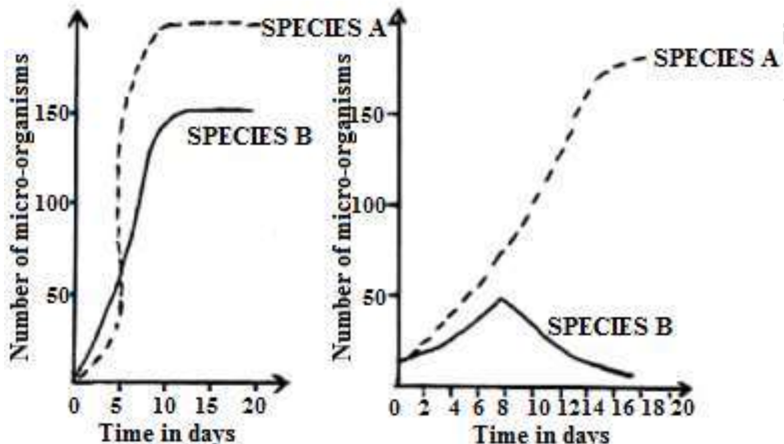


Fig 1; first set of culture   Fig 2; second set of culture medium

(a).Describe the population growth patterns of the two organisms cultured in shallow petri-dishes ***(07 mark)***

The number of A; increased rapidly/ very fast/ steeply from the 0 days to the 16th day; then increased less rapidly from the16th day up to the 19th day; and remained constant after the 19th day; The number of microorganisms of species A reached a maximum of about 150 species on the 19th day.

The number of microorganisms of species B increased rapidly/ very fast/ steeply from the day 0 up to the 9th day; where it reached its maximum/ peak of about 50 species of microorganisms; then declined rapidly from the 8th day up to the 18th day;

(b).Outline the differences in the population growth patterns of the two species in both sets (shallow petri-dishes and long cylindrical vessels ***(08 marks)***

Differences of population growth pattern of species A in

First set of container/ long cylindrical vessel	**Second set of container/ shallow petri-dishes**
Population grows faster	Population grows slowly
Maximum population reached is higher	Maximum population reached is lower
Population takes a shorter to reach carrying capacity/ stationary phase	Population takes longer to reach carrying capacity/ stationary phase

Differences of population growth pattern of species B in

First set of container/ long cylindrical vessel	**Second set of container/ shallow petri dishes**
Population of species B grows faster	Population grows slowly
Maximum population reached is higher	Maximum population reached is lower
Population remained constant/ level off after	Population declines after maximum
Population reached carrying capacity	Population declined to extinction
Population took a longer time to reach the	Population took a shorter time to reach maximum

(c).Explain the differences in the population growth pattern observed in 1(b) above ***(15 marks)***

The 1st set container was a long vessel with larger space; there was vertical separation of species A from species B; A and B had close but separate niches; there was no interspecific competition; Species A and B both reproduced rapidly; until they reached carrying capacity;
In the 2nd set of culture medium; with shallow petri-dishes; provided a very small space; species A and B shared or occupied; the same ecological niche/ overlapping niches; stiff interspecific competition occurs between the two species A and B; Species A was better adapted/ has a competitive advantage over species B; After 8 days, the population of species B declined to extinction; Species B was less adapted/ outcompeted; demonstrating the competitive exclusion principle; the reproductive potential of species B reduced due to completion.

(d). Describe a suitable method that can be used to determine the population of the microorganisms being investigated ***(07 marks)***

Microorganisms are cultured in a specific culture vessel containing optimum amounts of essential nutrients; such as carbon, nitrogen, phosphorous and sulphur; The culture vessel is plugged with a cotton wool; and maintained at a constant temperature of about 16ºC; 1cc of a sample is obtained from the culture medium/ culture solution number of microorganisms per cm^3 of culture solution is counted; the counting done using haemocytometer (counting chamber). This procedure is repeated everyday for a week; then population growth of the microorganisms is obtained by plotting number of microorganisms against time in days.

(e).Explain the external factors that limit the population growth of the microorganisms in the culture medium

- Lack of nutrient/ food; reduces cell division, growth and development of tissues/ organs
- High temperature; denature enzymes; decreases normal functioning of the organisms.
- Light; reduces photosynthesis
- Parasites or diseases; destroy the organisms;
- Toxic chemicals; destroy organisms or high concentration of CO_2 destroys tissues or denatures enzymes.

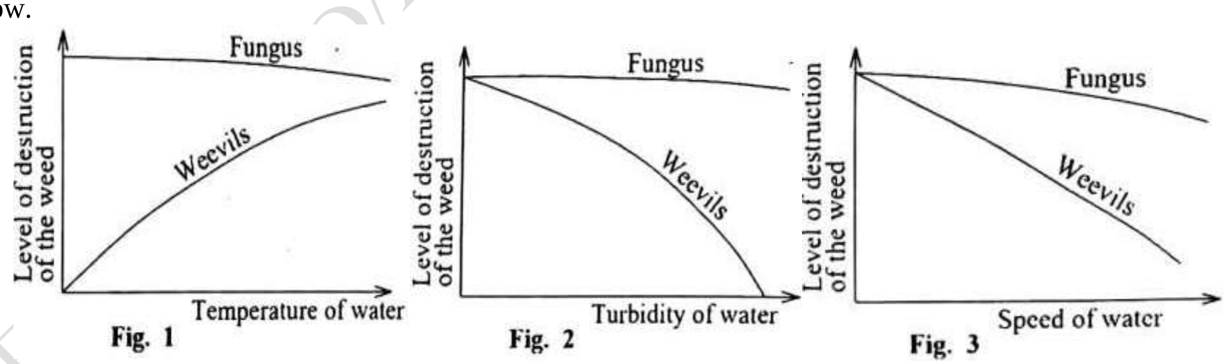
Question 6.

The water hyacinth Echhornia crassipes is a weed growing on many waters of Uganda. In the biological control of the weed on Lake Victoria, a fungal pathogen and weevils are employed. The characteristics of the fungus and the weevils in relation to their feeding behaviour are shown in Table 1.

Table 1

Fungus	Weevils
Feeds on the water hyacinth alone	May feed on other plants other than the water hyacinth
Attacks only the green parts of the plant	Attacks all parts of the plant

The level of destruction of the weed by the fungus and the weevils under varying water conditions in temperature, turbidity and speed of water are shown in figures 1, 2 and 3. Study the information and answer the questions that follow.



(a) From figure 1, 2 and 3, describe the level of destruction of the weed by each of the organisms under different conditions of water.

(i) Fungus ***(04 marks)***

Level of destruction slightly decreases; with increase in temperature; Level of destruction slightly decreases; with increase in turbidity;
Level of destruction drops slightly; with increasing speed of water;

(ii) Weevils ***(06 marks)***

Effect of weevils increases; with increase in temperature;
Effect of weevils decreases; with increasing turbidity;
Effect of weevils decreases; with increasing speed of water;

(b).From the information provided, suggest explanations for the level of destruction of the weed by each organism under different conditions of water.

(i) Fungus ***(05 marks)***

The fungus attacks the green part of the water hyacinth most of which is outside the water; so is not affected by varying temperature of the water;
Turbidity which reflects the quality of water in terms of dissolved oxygen does not affect the damage of the fungus because most of it is outside water;
The speed of water slightly reduces the effect of the fungus because moving water may cause brushing of leaves against each other; thereby brushing off some amount of fungus from leaves;

(ii) Weevils ***(06 marks)***

Weevils attack all parts of the water hyacinth thus warm temperatures increase their metabolic activity; leading to increased feeding;
Turbidity reduces activity of weevils because the higher the turbidity the less the amount of dissolved oxygen which reduces the metabolic activity of weevils;
The faster the speed of the water the less the effect of weevils; because fast moving water may dislodge some weevils; attached on/ bond into the water hyacinth plant together with their leaves;

(c).From the information provided, give advantages that the

(i) fungus has over the weevils in destroying the weed. ***(04 marks)***

Fungus is specific; so destruction of hyacinth is more intense; while weevils feed on other plants; so reducing their effect on the hyacinth;
Fungus is not affected by turbidity, speed of water and temperature;

(ii).Weevils are over the fungus in destroying the weed. ***(04 marks)***

Weevils attack all parts of the water hyacinth; making destruction of the hyacinth more complete; while the fungus attacks only the green parts; leaving some parts undamaged;

(d).What are the ecological effects of the water hyacinth on Lake Victoria? ***(08 marks)***

• Water hyacinth grows on surface of water causing shading which restricts development of photosynthetic algae; which form the basis of the aquatic food chain;
• Restricted growth of photosynthetic algae/ submerged aquatic plant deprives the water of oxygen resulting into death of fish/ aquatic organisms;
• Decay of the dead weed uses up oxygen aggregating its shortage/ increased biochemical oxygen demand
• Shallow water breeding fish compete with water hyacinth;
• Water hyacinth maybe habitat for dangerous species like snakes;
• Water hyacinth are food to aquatic organisms;
• Filters in other areas;

(e).What are the advantages of employing biological control as a means of checking population of the water hyacinth? ***(03 marks)***

• Cheap;
• Has little environmental impacts/ not very harmful to the environment/ does not cause pollution;
• An effective long term control tool.

Question 7.

Hydrilla (Hydrilla verticillata) is an aquatic plant which has become a major pest of waterways in some parts of the world. Hydrilla is usually an alien species, introduced into natural habitats from aquariums. In many fresh water habitats, Hydrilla has rapidly become the dominant plant species. In the first experiment scientists investigated the effect of the chemical fluridone, as a method of controlling Hydrilla. The study was carried out using samples of Hydrilla grown under controlled laboratory conditions. Several samples of the plant were grown at different concentrations of fluridone. The results are shown in the table below.

Concentration of fluridone in μgdm^{-3}	Days of treatment			
	0	20	40	60
	Mean biomass of Hydrilla/ g			
0.0	5.0	16.4	20.9	33.4
0.5	5.0	14.1	18.2	31.3
1.0	5.0	9.7	8.9	7.4
5.0	5.0	4.6	2.8	1.3
25.0	5.0	3.2	1.6	0.4

In the second experiment, scientists investigated the use of an integrated system to control Hydrilla. This involved using fluridone and a fungus as a biological control agent. They set up four different experiments and determined the biomass of Hydrilla at the end of each experiment.
Treatment A – Hydrilla left untreated
Treatment B – Hydrilla treated with the fungus
Treatment C – Hydrilla treated with fluridone
Treatment D – Hydrilla treated with both fluridone and the fungus.

(a).On the same axes, plot suitable graphs to represent the data in the table. ***(09 marks)***

(b)(i).What is meant by the term biomass? ***(01 marks)***

The weight of living material per unit volume or area.

(ii) Explain how the mean biomass of Hydrilla was determined in this experiment. ***(04 marks)***

The biomass of each sample is got by heating the sample at 75ºC or high temperature for 2 hours; The sample is weighed; then reheated for 15 minutes and weighed again; The cycle of reheating and weighing is continued until a constant mass can be found;

(c)(i).In many freshwater habitats, Hydrilla rapidly becomes the dominant plant species. Suggest reasons for this. ***(02 marks)***

• No/fewer consumers/pests/pathogens;
• Outcompetes /better competitor for resources/light/CO_2/abiotic factor / ideal niche;

(ii).What are the ecological and economic consequences of the spread of Hydrilla? ***(04 marks)***

• (Cost of) control/removal;
• (Cost of) restoring habitat / conservation;
• (Loss of income) from fishing;
• (Loss of income) from boating/tourism/recreation;
• Deprivation of oxygen to aerobes;
• Deprivation of light for photosynthesis;

(d) Comment on effectiveness of varying fluridone concentration in the first experiment. ***(10 marks)***

• Concentrations below 5.0 are less effective
• At 5.0, biomass/growth is reduced;
• Small difference for fluridone concentrations between 5.0 and 25.0;
• Using 5.0 is cost effective / using 25.0 is expensive;
• 25.0 /high concentrations may affect the environment/ other organisms/ chemical may remain in habitat / bioaccumulation;

(e) Explain why treatment A was carried out in the second experiment. ***(02 marks)***

Treatment A acted as a control; to compare effect with/without fungus/fluridone/control agent(s);

(f) The fungus used in treatments B and C in the second experiment was isolated from the tissue of Hydrilla growing in its country of origin. Suggest the possible advantages of using this fungus as the biological control agent. ***(03 marks)***

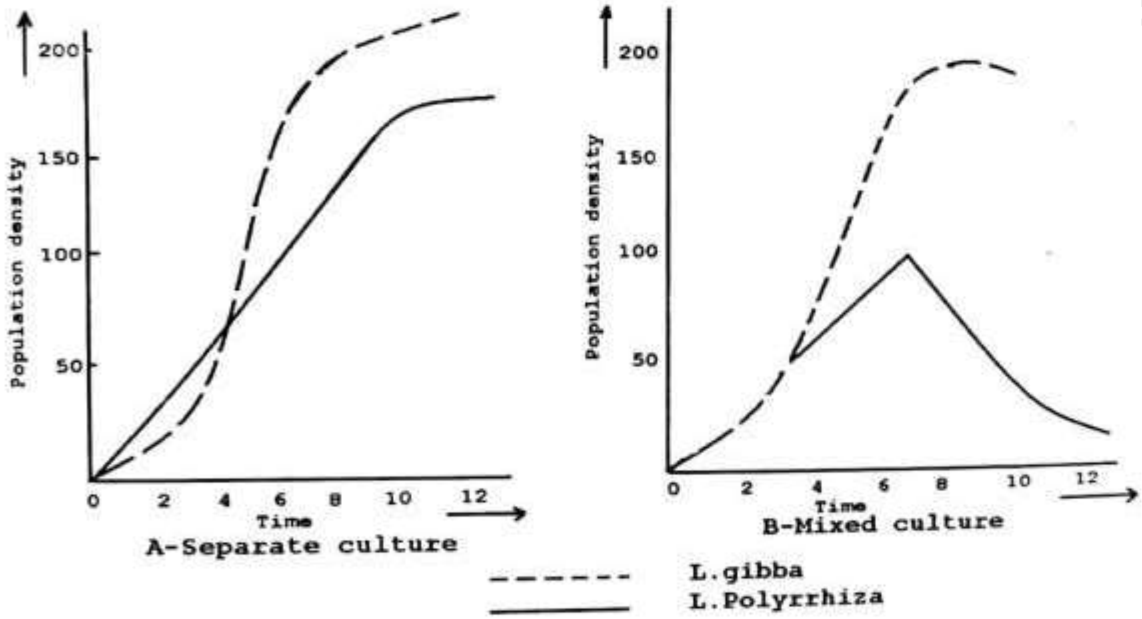
• Specific / grows/survives in Hydrilla/habitat;
• Can reproduce / only one application required;
• Does not become a pest;

(g) Using your knowledge of integrated pest control systems, comment on the likely consequences of the four treatments of pest control in the second experiment. ***(05 marks)***

• No single application is always valid for integrated pest management.
• Fluridone/chemical acts quickly / quickly reduces Hydrilla; but may result in bioaccumulation.
• Fungus/biological control keeps Hydrilla in low numbers;
• Fungus/biological control works over a long time/can reproduce
• Resistance does not develop against fungus/biological control;

Question 8.

A study was carried out on a plant population growth of two species of lemna duckweed. In one experiment the species were cultured together. And in another experiment they were cultured separately. Two growth curves were sketched for both experiments. Study the graphs and answer the question that follows.



(a).Describe the population growth curves for L.gibba and L.polyrrhiza in
(i). A

Population growth in separate culture.

L.gibba

Shows an S-shaped (sigmoid) growth curve; The population density of L. gibba increases; gradually from then start up to the 4th day to the 6th day population density increases exponentially; then increases gradually to a maximum by the 9th day and remains constant thereafter.

L. Polyrrhiza

Shows an almost linear growth curve; the population density of L. polyrrhiza increases gradually; from the start up to the 8th day; then increases slowly to a maximum on the 12th day and then remains constant; thereafter. Maximum population density of L. polyrrhiza is lower than that of L gibba.
From the start up to the 4th day L. Polyrrhiza had a lower population density than L.gibba. Population density of L gibba increases above that of L.polyrrhiza after the 4th day.
(ii).B

Population growth in mixed culture

L. gibba

Population growth shows a nearly S–shaped growth curve. From the start up to the 2nd day the population density of L. gibba increases; gradually; then increases; drastically; till the 4th day; then increase gradually up to the 8th day, reaches a maximum on the 10th day and remains constant thereafter.

L. Polyrrhiza

Population density increases gradually from the start up to the 8th day, to a maximum; on the 10th day; there after decreases gradually; In the first two days the population density of the two species is the same, there after population

density of L. gibba increases above that of L. polyrrhiza. Maximum population density of L. gibba is lower that of L. polyrrhiza. L. gibba reaches a maximum population density later after
that of L. polyrrhiza. Maximum population density in mixed culture is lower for both species and is attained earlier than in separate culture for L. polyrrhiza.

(b).Explain the shapes of the two graphs in the two cultures.

In Separate culture

L. gibba

Initially population growth shows the lag phase; slow; growth occurs due to few, reproducing individuals, adjustent and adaptation to new environment; The exponential phase; follows, population growth increases rapidly; due to increase in number of reproducing individual; adaptation to new environment; maximum reproductive rate Gradual increases to a maximum there after is due to death; of some cells; accumulation of toxins; competition for the available nutrients in the culture. Later at the constant/stationary phase number of cells that die equals the number of cells reproduced, L. gibba attains its carrying capacity, which is higher than that of: polyrrhiza because L. gibba has a higher; reproductive rate and hence higher biotic potential.

L. polyrrhiza

Shows gradual increase from the start as it easily adapts to the new environment. As its population growth increase there is increase in competition from nutrients and light. Some of the plants start to die; maximum population density is attained but soon declines; due to increased death of some plants, were number of plants that are sprout is less than those that die.

In the mixed culture

Both show an initial slow growth due to adaptation to the new environment; and few reproducing individuals; L. gibba due to its higher; reproductive rate; soon grows more rapidly; competes; more for the available resources (nutrients, light and space) than L. polyrrhiza, which shows a gradual increase to a maximum; The maximum population density for both weeds in the mixed culture is lower and is attained earlier than that in the separate culture. This is due to the increased interspecific; competition for nutrients, Sight and space in the mixed culture. L. gibba seems to have a competitive; advantage) such that L polyrrhiza is competitively nearly eliminated; Due to the interspecific competition L. gibba attains its maximum population density later in the mixed culture than in the separate culture due to limited population growth.

(c)(i).State the principle illustrated by the species in a mixed culture.

Gaussian exclusion principle or competitive exclusion principle.

(ii).Explain the principle in (c)(i) above

The principle suggests that no two; species can occupy the same ecological niche in a natural environment. This is because one species has a competitive advantage, and is favoured to reproduce more frequently than the other hence its numbers increase. The other species with a competitive disadvantages gradually eliminated; and could become extinct or resort to another niche or migrate; to a new habitat.

(iii)What is the evolutionally significance of the principle in (c)(i) above

- Extinction of one species which have a competitively disadvantage;
- Due to the interspecific competition; Individuals of a species tend to adapt; to the changing environment and only those with favourable traits; survive and pass on these traits.
- The individuals with a competitive disadvantage; a given ecological niche could migrate, or resort to other ecological niches in the same habitat; This increases ecological range of a species, colonizing new habitats and can lead to speciation by adaptive radiation.

(d).Suggest the resources the two species might be competing for.

- Food
- Space
- Light

Question 9.

Figure 1 shows the activities of two different types of ants observed on a tree trunk and at a floor wall junction over a 14-hour observation period by a biology class, study the figure and answer the questions that follow.

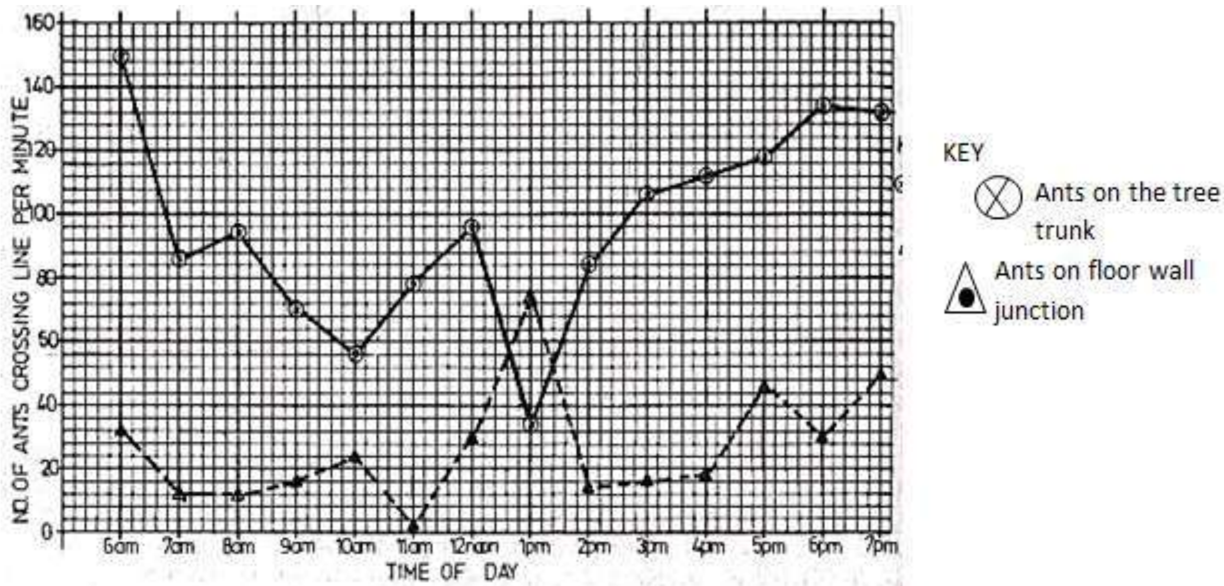


Fig. 2 (A)

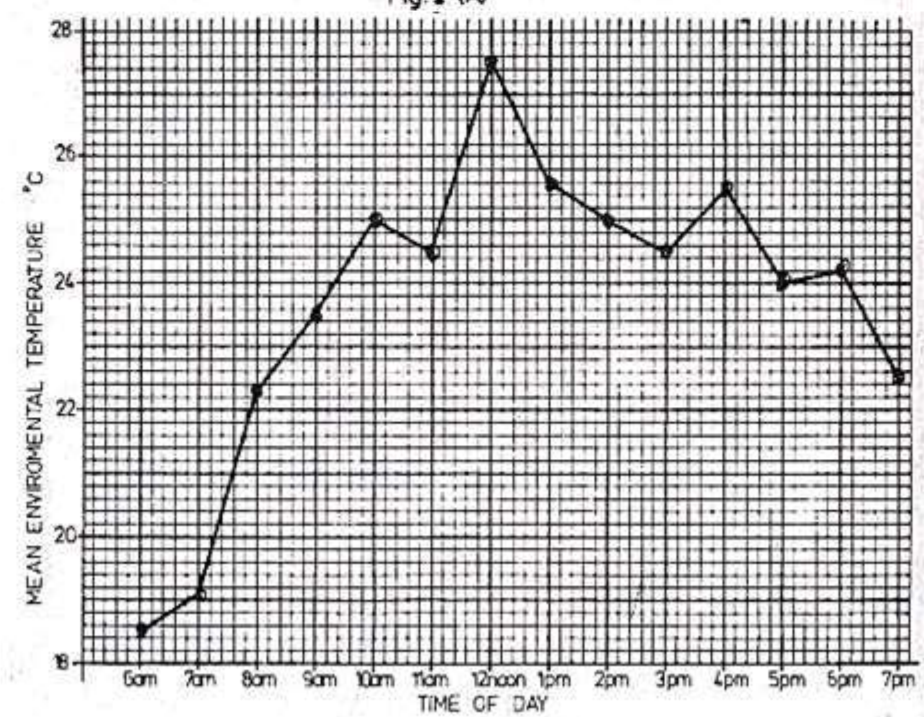


Fig. 1 (B)

(a).What are the effects of

(i). time of day

Time of the day has direct effect on the distribution of the ants on the tree trunk and on the floor-wall junction.

For ants on tree trunk

From 6 am to 7 am, activity of ants on the tree trunk decreases rapidly up to 10am. From 10am to 12 noon, activity increases rapidly: then decreases rapidly up to 1pm. From 1pm to 2pm, activity increases rapidly then increases gradually from 2pm to 5pm. From 5pm to 6pm activity increases rapidly and then nearly remains constant by 7pm. Highest activity was 150 ants at 6am and lowest activity is 34 ants at 1pm.

Ants on floor-wall junction

From 5am to 7 am activity of ants on floor wail junction decreases rapidly; then remains constant. From 7am to 8 am; Activity of the ants then increases slowly from 8 am to 10 am then decreases rapidly to a minimum of 2 ants at 11 am; From 11 am to 1 pm activity of the ants increases rapidly to a maximum of 72 ants at 1 pm; Then decreases rapidly from 1pm to 2pm; increases very slowly from 2 pm to 4 pm; increases rapidly from 4 pm to 5 pm; then in the next one hour it decreases rapidly then rises rapidly in the last hour up to 7 pm.

(ii).mean environmental temperature on the activities of the two types of ants.

For ants on the tree trunk

Maximum activity of 150 ants was recorded at a low mean environmental temperature of 18.5°C. As mean envir-onmental temperature increases rapidly up to 25°C the activity of the ants generally decreases. A slight drop in temperature from 25°C to 24.5°C drastically increases the activity of ants on the tree trunk. As temperature rises from 24.5oC to 27.5°C activity of ants on tree trunk increases rapidly. As temperature decreases rapidly from 27.5°C to 25.6°C activity of ants decreases to a minimum of 34 ants at 25.5°C. As temperature decreases gradua-lly thereafter activity ants increases rapidly. With subsequent hourly fluctuations in mean environmental temper-ature activity of the ants increases gradually, then remains constant as temperature finally decreases to 22.5°C; A slight decrease in temperature from 25°C to 24.5°C; decreases rapidly the activity of the ants; to a minimum of 2 ants at 24.5°C. As temperature increases rapidly from 24.5°C to 27.5°C, the activity of the ants increases rapidly, and continued to increase to a maximum activity of 72 ants as temperature decreases to 25.6°C. Then activity of ants decreases rapidly as temperature drops further to 25°C; A slight drop in temperature from 25° C to 24.6°C slightly increases the activity of the ants. Subsequently as temperature increases activity of the ants decreases and as temperature decrease activity of the ants increases until the end of the study period.

Ants of the floor wall junction

At 18.5ºC the activity of the ants is low; Slight increase in mean environment temperature from 18.5ºC to 19°C decreases the activity of the ants. As temperature increases rapidly from 21°C to 2.5°C, activity of the ants increases rapidly.

(b).Explain the general effect of mean environmental temperature on the activities of the two ants

Generally increase in mean environmental temperature reduces activity of the two ants while decrease in mean en-vironmental temperature increases activity of the two ants.

Temperature directly affects the metabolic activity of the ants. As temperature increases to optimum the metabolic activity of the ants increases. Below the optimum temperature enzymes are inactivated hence reduced metabolic rates leads to reduced activity of the ants. Above the optimum the enzymes are denatured, hence to avoid this, the activity of the ants reduces.

(b)(i).Name two other purely physical factors that could also cause some rhythmic behavior in these ants.

• Light intensity

• Air currents

(ii).In what ways do these two physical factors affect the ants?

Light Intensity; shows a rhythmic variation during the day and at optimum light intensity the ants have maximum activity; above or below the optimum light intensity activity of the ants is low.

Air currents; wind can blow away the insects; the air currents show a periodic rhythm during the day. When the air currents are high, due to much wind, the ants tend to go into hiding to avoid being blown and hence this reduces their activity. With low air currents the ants move about freely and easily increasing their activity.

(c).What other possible reasons could be advanced, to explain the movement of ants.

• Escape from predators

• Escape from rain drops

• Search for food and mates

• Search for shelter and new habitats

• Response to pheromones

• Kinesis as non- directional movement response in which the rate of movement relates to intensity of stimulus but not direction of stimulus

Question 10.

Table 1 below shows average mineral contents of sea water, river water and dry matter of marine brown algae. St-udy the table and answer the questions that follow.

Elements	Concentration in ppm		
	Sea water	**River water**	**Marine brown algae dry matter**
Sodium	10,500	6.30	33,000
Calcium	1,350	4.10	5,200
Potassium	380	2.30	52,000
Strontium	8.00	0.08	1,400
Iron	0.01	0.67	700
Manganese	0.002	0.012	53.00
Silicon	3.00	6.50	1,500
Carbon	28.00	11.00	345,000

(a).Comment briefly on relative concentrations of mineral elements in sea & river water ***(07 marks)***

• Generally sea water had a higher concentration of mineral elements than river water;
• River water contained more iron, manganese and silicon than sea water
• Sea water contained much higher concentration of sodium, calcium, potassium, strontium, chlorine & boron; than river water
• Highest mineral content of sea water was chlorine while for river water was carbon
• Lowest mineral content of sea water was manganese while for river water was phosphorus
• Sea water contained very low concentrations of nitrogen, phosphorus, iron and manganese
• Most abundant mineral elements in sea water were in the order; chlorine>sodium>calcium>sulphur.
• Most abundant mineral elements in river water were in the order; carbon>chlorine>silicon>sodium in both river water and sea water chlorine and sodium were among the most abundant mineral elements; while phosphorus and manganese were among the least abundant mineral elements.

(b).Explain the differences in concentrations of elements in the two water bodies. ***(09 marks)***

River water flows at a faster rate hence minerals cannot accumulate significantly. Sea water is relatively stagnant so minerals can significantly accumulate. The sea is fed by rivers and streams which significantly increase the mineral elements in the sea as compared to the river; The more abundant mineral elements are micro elements; while the least abundant are macro elements; Compounds of the more abundant elements could be less soluble hence not easily leached into the rivers and seas; Some elements are more volatile than others so the more volatile elements and those which form volatile compounds are less abundant than the less volatile elements and compounds. As water evaporates from the sea water which is relatively stagnant concentration of mineral elements significantly increases;

(c)(i).Comment briefly on the differences in mineral concentrations between sea water and marine brown algae. ***(03 marks)***

• Generally marine brown algae had a higher mineral content than sea water except chlorine which was higher in sea water;
• Marine brown algae had the highest mineral content as carbon; yet carbon is relatively of low concentration in sea water;
• Phosphorus, nitrogen, carbon and manganese are much more concentrated in marine brown algae than the sea water;
• There is relatively low concentration factor (accumulation) of fluorine, sodium and calcium in brown algae as compared to sea water;

(c)(ii). Explain what could be responsible for the above differences in (c)(i) above ***(03 marks)***

Accumulation of some minerals in the cells of the brown algae; some are very essential in forming body cell structures and biochemicals; while some are not readily utilized or accumulated into body tissues.

(d).Suggest why some minerals are more concentrated than others in marine brown algae ***(06 marks)***

• Some are more essential in forming body structures hence tend to accumulate in tissues of brown algae
• Due to selective re-absorption, some are more absorbed than others for utilization by the brown algae;
• To maintain its internal osmotic pressure in equilibrium with the sea water; the brown algae tends to accumulate some mineral elements more than others;

• Some mineral elements are more reactive than others therefore these are easily assimilated and will thus tend to concentrate more than others.
• The micro elements being nonessential are of lower concentration than the macro elements in the tissues of marine brown algae.
• Iron and phosphorus have the highest concentration factor (accumulation) since they form vital biochemical molecules such as Cytochrome;

(e).What is the source of mineral elements found in sea water? ***(05 marks)***

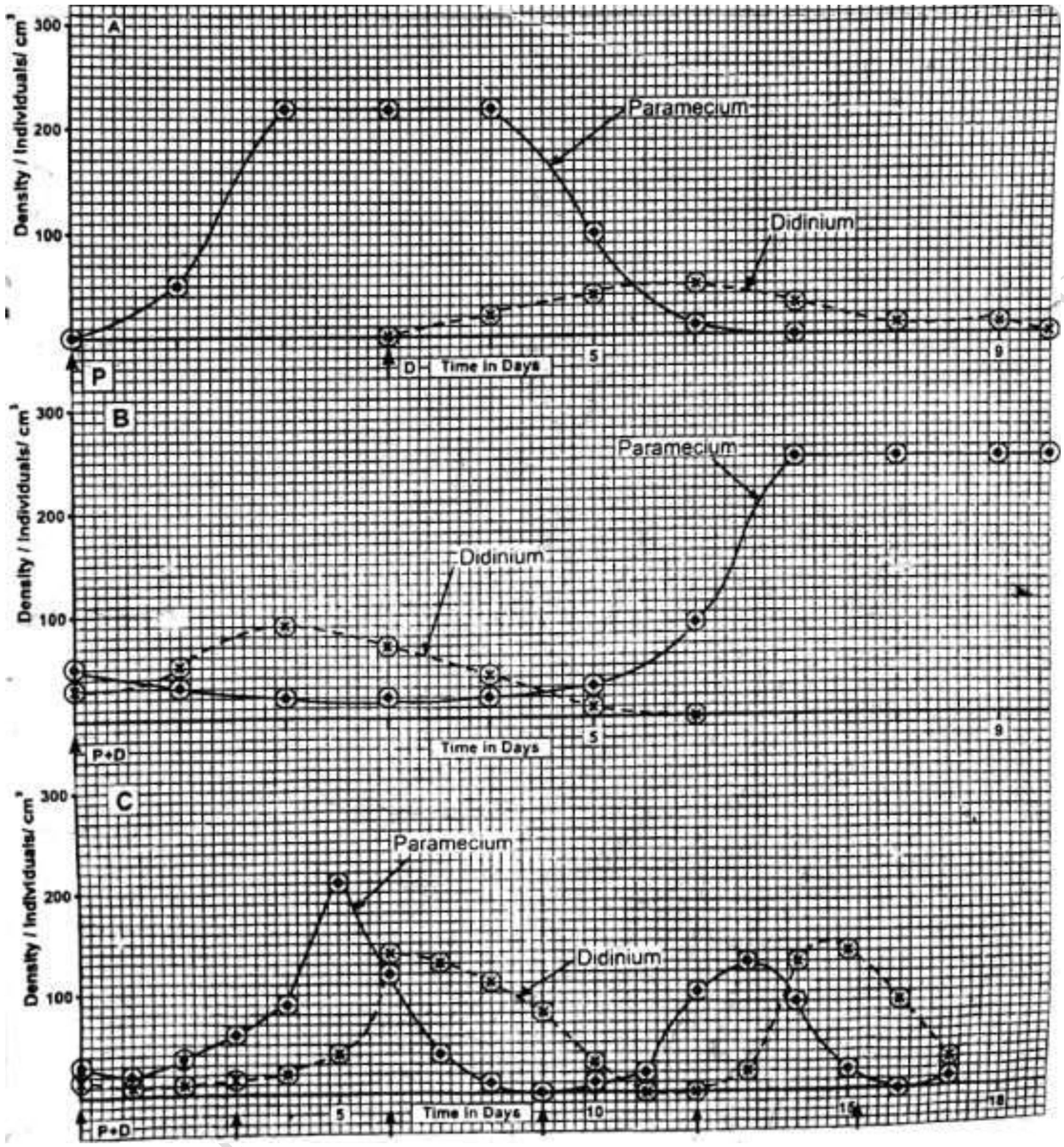
• Surface run off by rain from adjacent land mass
• Leaching of minerals from underlying rocks in the sea;
• Rivers and streams draining into the sea
• Decomposition from dead plants and animals
• Air currents carry dust particles and debris containing minerals into the sea

(f).Suggest the possible ways by which terrestrial ecosystems obtain minerals. ***(07 marks)***

• Drinking and absorbing water from the water bodies
• Break down and recycling of organic matter
• Break down of rocks forms soil from which plants and obtain minerals.
• Use of fertilisers in farms
• Nitrogen fixation by bacteria
• Rain dissolves many minerals in the atmosphere and gets into the soil then absorbed by plants
• By eating aquatic animals;

Question 11.

Graphs A, B and C show results of three experiments that were carried out to study the relationship between a predator Didinium and prey Paramecium under three sets of conditions. In the first experiment, paramecium were introduced into a culture at point P and Didinium at point D as shown in the graph A of figure 1
In the second experiment paramecium and Didinium were introduced together at point P+D at different population densities. This is shown in graph B of figure 1.In the third experiment paramecium and Didinium were introduced together at point P+D different population densities and after every three days as shown by the arrows in graph C of figure 1. Study the graphs and answer the questions that follow.



(a).Describe the trend of population growth of paramecium and Didinium in graphs A, B and C

Graph A

Population density of paramecium increased gradually in the 1st day; then increased steeply thereafter up to the 2nd day, remained constant from the second day up to 4th day; then decreased steeply from the 4th day up to 6th day; there after decreased slowly to zero on the 7th day. The maximum population density was 220 individual cm^{-3}. There was no Didinium from the start up to the 3rd day. From the 3rd day the population density of Didinium increased gradually then reached maximum of 250 individuals cm^{-3} then remained constant up to the 3rd day from the time it was introduced. Then it decreased gradually up to the 5th day; remained constant up to the 6th day. There after it declined to zero on the 7th day.

Graph B

The population density of paramecium then decreased gradually up to the 3rd day.Then increased gradually up to the 5th day; then increased steeply up to the 7th day; remained constant, at the maximum thereafter. Maximum population density was 250 individuals cm^{-3}. The population density of Didinium remained constant in the first half of the first day.it then increased gradually up to maximum of 90 individuals/cm^3 by the second day. Then it decreased gradually up to the 5th day. There after it decreased more gradually to zero on the 6th day.

Graph C

The population density of paramecium decreased slightly in the first day, then increased gradually up to the 4th day, then increased steeply, to a peak of 210 individuals/cm3 on the 5th day. Then decreased steeply up to day 7th day then decreased to zero on the 9th day. Then increased gradually up to the 11th day increased rapidly up to 13th day, then decreased rapidly to zero on the 16th day, there after it increased slightly. The population density of Didinium decreased slightly in the first day then remained constant up to 3rd day increased gradually up to the 5th day; then increased steeply up to the first peak on the 6th day; then decreased gradually to zero on the 11th day; remained constant at zero up to the zero the 12th day, increased gradually up to the 13th day, then increased to the second peak, which was a maximum of 150 individuals cm^{-3} on 14½ day then decreased drastically up to the 17th day.

(b). Explain the interaction of the two species of organism in graph: A and B

Graph A

Paramecium in the absence of its prey increased to its maximum; due to unlimited cell division and population growth in the culture. Once introduced Didinium fed on paramecium; but since the population density of paramecium was high there was no effect on its density in the first day of interaction. However the increase number of Didinium greatly fed on the paramecium and the population of paramecium decreased drastically and within the next two day Didinium was at a maximum and soon the paramecium were all eaten; thus the paramecium became exitnct, the Didinium had no food, the population of Didinium then decreased as they starved and many died & soon also became extinct.

Graph B

The Didinium feeds on the paramecium from the start, such that population density of paramecium decreased, Didinium reproduced and soon increased in number in the presence of paramecium (prey). When Didinium had reached a maximum paramecium were greatly eaten and reduced to a number that cannot support the Didinium soon Didinium was deprived of food and gradually some started to starve and die. By the 6th day Didinium extinct, meanwhile the paramecium was less eaten by its predator Didinium. The paramecium which survived, reproduced and greatly increased in number to a maximum, registered as the Didinium was extinct and the paramecium reached the carrying capacity /saturation point in the culture.

(c).Compare the trend of the population growth of the two species in the graph B and C

Similarities

In both

Didinium gradually increased to a peak and declined thereafter

The population density of paramecium was higher than that of Didinium at the start.

The maximum population density of paramecium density was higher than that of Didinium

The population density of paramecium decreased gradually in the 1st day.

The population density of Didinium decreased to zero at a certain point

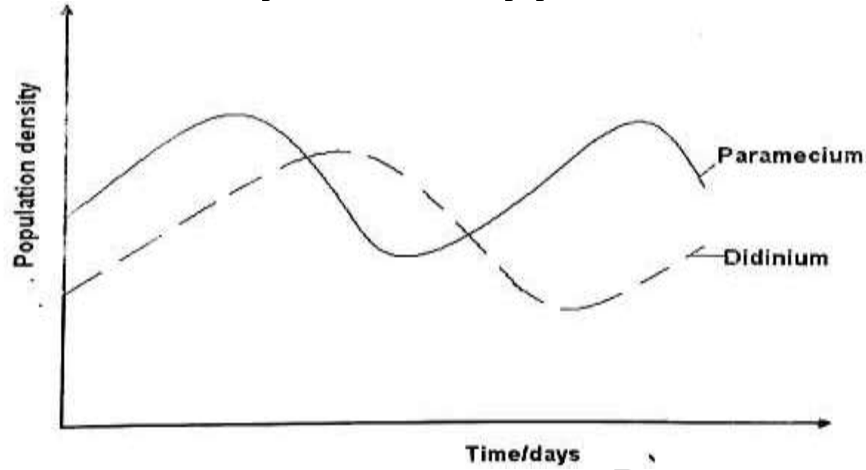
As the population of Didinium decreased to zero the population density of paramecium increased drastically

Differences

Graph B	Graph C
More Didinium and paramecium were introduced at the start	Few Didinium and paramecium were introduced at the start
Didinium and paramecium were introduced once at the start.	Didinium and paramecium were introduced at the start and then every after three days.
Population density of Didinium remained constant in the 1st half of the first day.	Population density of Didinium decreased slightly throughout the first day.
Population density of Didinium was higher than that of paramecium between the 1st and 4th day.	Population density of Didinium was lower than that of paramecium from the start up to 5th day.
Population of Didinium increased between the first and the third day.	Population of Didinium remained constant from the first to the third day.
Population of Didinium reached at peak then	Population of Didinium reached a peak once and
Population of paramecium density of 250	Population of paramecium reached a lower
Population density of paramecium decreased to	Population density of paramecium did not

When the population density of paramecium	When the population density of paramecium
Didinium was extinct by the 6th day	Didinium was extinct by the 11th day but later
There was no cyclic fluctuation.	There was cyclic fluctuation

(d). Supposing paramecium and Didinium were introduced at the same time under natural environmental conditions, sketch curves to show the expected trend of the population with time

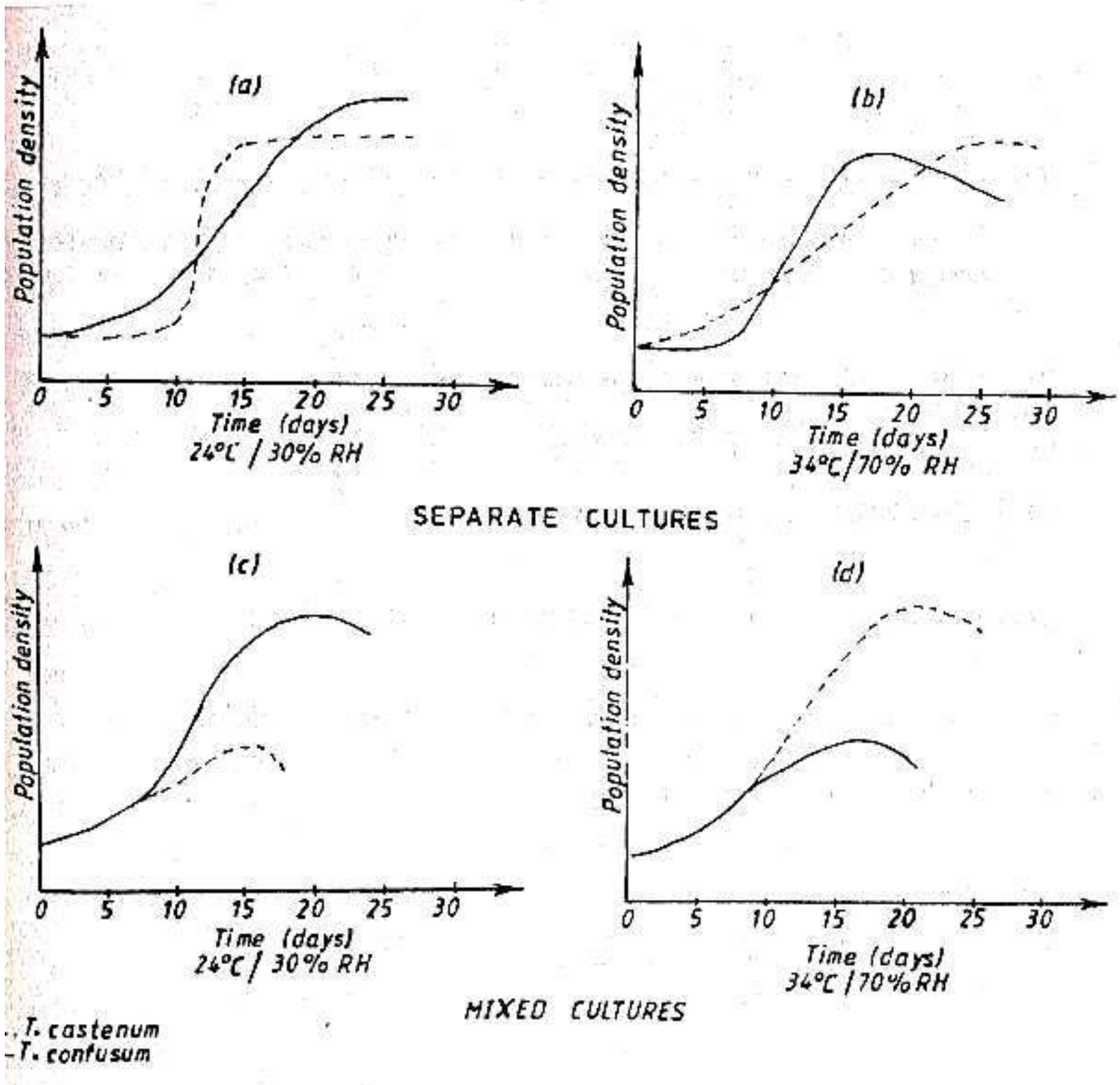


(e).Explain the trend of the population curves of paramecium and Didinium you have drawn in (d) above.

Both the prey and the predator increase with time as they reproduced. Prey population increases faster than that of the predator because of the higher reproductive rate of the prey. The predator (Didinium) eats the prey (paramecium and reduces their numbers. As the prey (paramecium) population increases the predator (Didinium) is presented with an abundance of food, hence predator population increases too. However the increase in predators' population implies the prey is greatly eaten and hence the prey decreases. As the prey decrease in number the predators start to complete with each other for the remaining prey. Many predators starve to death and hence the predator's population decreases with in the decreasing prey population. The reduction in the number of predators results in fewer prey being eaten. Hence the cyclic fluctuations occur such that the numbers of prey and predators are self-sustaining in a natural environment.

Question 12.

Two laboratory experiments to study the population growth of two species of flour beetles (Tribolium castenum and T. confusum) that were carried out under two sets of conditions of temperature and humidity. In the first experiment, the two species were cultured separately at 24°C and 30% relative humidity and 34°C and 70% relative humidity. In the second experiment the beetles were cultured together under similar temperature and relative humidity conditions as in the first. The results obtained in experiment 1 are shown in figure 1 (a) and (b), and those obtained in experiment 2 are shown in figure (c) and (d). Study the figure and answer the questions that follow.



(a). What is the effect of raising temperature and relative humidity on the population growth of the bettles in experiment 1.

T. Castenum

- Raising temperature and humidity increased the population growth.
- The population growth showed a gradual increase up to a maximum.
- At higher temperature and humidity, maximum population density was attained later, on the 25th day, than at lower temperature and humidity which was attained on about the 14th day.
- Maximum population density was higher at raised temperature and relative humidity
- After attaining the maximum at raised temperature and humidity, the population density showed slight decrease, yet at low temperature and humidity it remained constant.

T. confusum

- Raising temperature and humidity initially in the five days stopped or inhibited the growth of T. confusum. There after caused an exponential/rapid increase to a maximum.
- The maximum population density was attained earlier; on about the 16th day; at raised temperature and humidity as compared to that of lower temperature and humidity which occurred on about the 23rd day.

• Maximum population density was lower at raised temperature and relative humidity
• After attaining the maximum population density at raised temperature and humidity the population density of T. confusun gradually decreased; yet at lower temperate humidity it remained constant.

(b).Explain the interaction of the two species of beetles in experiment 2.

At low temperature and humidity, T. confusum had a competitive advantage; out-competed T. castenum. T. confusum thus had a higher maximum population density that was attained on a later day (20th day) compared to the 15th day for T. Castenum At raised temperature and humidity T. castenum had a competitive advantage out competed T. confusum. Maximum population density for T. castenum was higher and was attained later on about the 21st day compared to T. confusum which was attained on the 16th day. In both after attaining the maximum population density there is a decline in population growth at both low and raised temperature and humidity. This could be due to accumulation of toxins, reduction in food resources and death rate exceeding reproduction rate.

(c).Explain why the population of the beetles in experiment 1 level off.

Populations of the beetles level off as they reach the carrying capacity or saturation Point; the maximum that the culture can support. At this point further increase is stopped due to limitation by density dependent factors such as competition for food, mates and space and accumulation of waste and over-crowding. The reproductive rate is in balance with the death rate.

(d).Suppose experiment 2 was to continue running for a few more days. Suggest with reasons what would happen to the populations of the beetles.

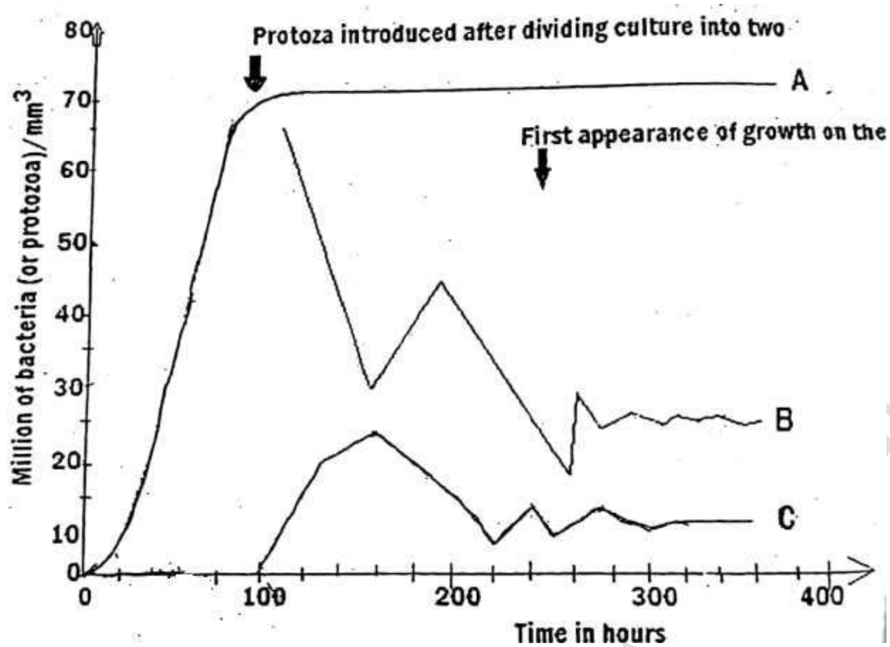
At low temperature and humidity, population of T. castenum would drastically decrease and possibly become extinct. T. confusum having a competitive advantage would remain in the culture, may start to increase as T. castenum becomes extinct. Population density of T. confusum would gradually increases; soon reaching a new carrying capacity; where its population density would remain relatively constant. At raised temperature and humidity population of T. confusum would gradually decrease and possibly become extinct. Population of T. castenum would then start to increase with limited interspecific competition, as T. confusum becomes extinct. T. castenum would reproduce greatly and its population would soon reach a relatively constant, new carrying capacity.

(e). How do the results of these two experiments relate to a natural ecosystem?

• In limited natural resources individuals of a given species tend to reproduce attaining their biotic potential.
• Changes in environmental conditions result in changes in population density of different species as they adapt to the new environments.
•Some individuals have favourable traits and are more adapted to survive in prevailing environmental conditions than others.
• Competition between members of different species reduces their carrying capacity and may cause extinction of the less adapted individuals.
• Each species has a favourable set of environmental conditions for its maximum rate of reproduction as its ecological niche in a natural ecosystem.

Question 13.

A bacterial culture was established in a liquid medium at an initial concentration of 1 million bacteria per mm^3 of solution. The growth of the culture was monitored by sampling every 10 hours and counting the number of bacteria in the sample. After 100 hours the culture was split into two equal volumes labeled A and B in the figure. A protozoa was introduced into the culture B and the subsequent changes in the protozoa numbers were plotted in culture C. The results are shown graphically below. Study the information fully and answer the following questions:



(a). State the time range during which the bacterial culture is growing at its maximum rate in the absence of the protozoa. ***(02 marks)***

40 hours to 80 hours.

(b). State how long it takes the bacteria colony to double its numbers in the absence of the protozoa

(i). After the colony has been growing for 40 years ***(01 marks)***

16 hours

(ii)When the numbers present is 35 million per mm^{-3} ***(01 marks)***

24 hours

(c).Explain the difference between your answers to (b) (i) and (ii) above. ***(02 marks)***

It takes a longer time for a population to double when the bacterial population already present is high than when the bacteria have been growing for a short time. At high population, environmental resistance factors or environmental stress factors eg diseases, accumulation of toxins etc have set in. But when bacteria have just been introduced, their stress factors are at their minimum.

(d).Explain the change in the bacterial population after 80 hours. ***(09 marks)***

Bacteria in A

Gradual increase between 80 to 120 hours; because of the environmental stress factors like accumulation of toxic wastes, inadequate space, inadequate oxygen if aerobic or limited nutrients etc. The population remains constant from 120 up to the end of the experiment because the culture medium has attained its carrying capacity during which birth rate balances with death rate.

Bacteria in B

Rapid decrease in population between 112 and 160 hours; due to introduction of the protozoa which feeds on the bacteria causing a crash. Gradual increase in the population from 160 to 200 hours; was due to decreased protozoa (predator) population. Gradual decrease between 200 and 260 hours was because the predator population has increased again. Oscillations increase up to 300 hours beyond which the population remains almost constant up to the end due to wall growth and the bacteria can escape predation.

(e)(i) Describe the relationship between the population of the bacteria in B and the protozoa in C up to 260 hours. ***(04 marks)***

Initially when the bacteria population is high, the protozoa population is also low, when they have just been introduced. An increase in the protozoa population cause a decrease in the bacteria population; when the bacteria population decreases, it causes a decrease in the protozoa population which in turn causes an increase in the bacteria population. These cyclic changes continue up to 260 hours.

(ii).Explain the relationship in (e) (i) above. ***(08 marks)***

This is a predator-prey relationship in which the protozoa is the predator and feeds on the bacteria (prey). When the bacteria population is high, the protozoa are provided with food exerting a predation pressure on the bacteria, causing a clash in their population. This makes many protozoa to starve to death and their population reduces causing a decrease in the predation pressure. This allows the growth of bacteria again which had survived the previous predation.

(f).The protozoa stays in the liquid part of the culture medium but the bacteria in B soon were observed to form colonies on the walls of the vessels.

(i) Explain how growth on the walls may be an advantage to the bacteria in this experiment. Use evidence from the graph. ***(05 marks)***

Wall growth gives two separate but over lapping habitats so the bacteria can escape predation attaining the carrying capacity of its microhabitats hence remaining constant after wall growth

(ii) Comment on the possibility of the wall growth in A. Explain. ***(03 marks)***

No wall growth due to the absence of predation thus no need for separate microhabitats

(iii) Assuming that there was no wall growth that occurs in B, what would happen to the bacteria and protozoa population ***(01 marks)***

Predator prey oscillations will continue

(g).How do the results of the experiment relate to the natural ecosystem? ***(04 marks)***

• In nature, there is both prey and predator population
• In nature, the prey lives in a separate habitat to escape predation
• In absence of predation, the prey population grows up to the carrying capacity
• Co-existence of the preys and predators checks on the population of each other

Question 14.

Figure below shows the changes in the number of species, biomass and the net productivity in an area. Study the figure and answer the following questions.

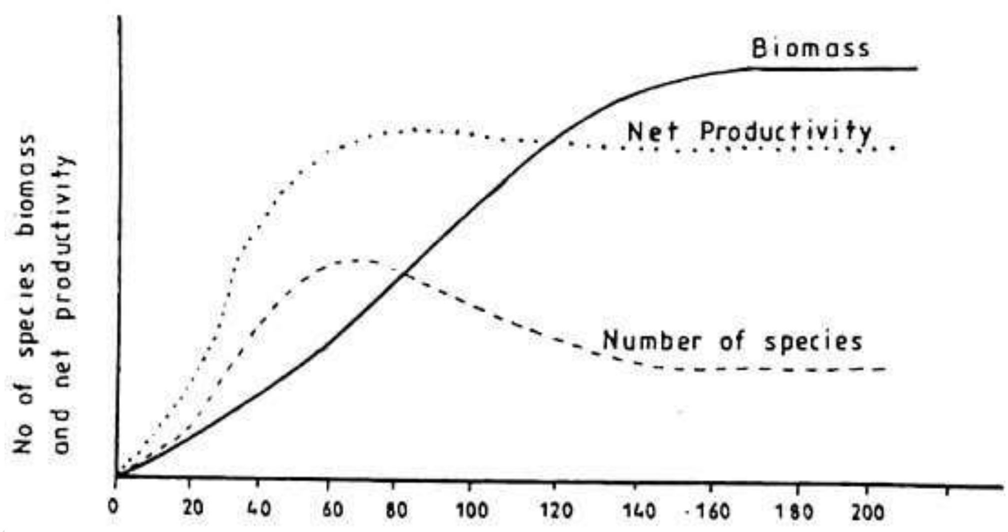


Fig. 1

(a).Describe the changes in the number of species, biomass & net productivity in the area ***(06 marks)***

Number of species

Number of species increased gradually for the first 70 years; attains maximum number at 70 years; then reduce slowly from 70 years to 140 years; remains constant thereafter.

Biomass

Biomass increased gradually for the first 140 years; then increased slowly between 140 years and 170 years; attained maximum biomass by 170 years; then remained constant thereafter.

Net productivity

Initially net productivity increased rapidly in the first 20 years; then increased gradually to a maximum by 80 years; then slightly decreased in the next 40 years; remained constant by 140 years and thereafter;

(b).How are the numbers of plant species, biomass and net productivity related? ***(13 marks)***

Number of plant species determines the net productivity and the bio mass; initially when the plant species are few they are normally small plants whose productivity is low and also there bio mass is low; As the plant species increase; larger plants are established; these have higher productivity and higher biomass; However the number of species reaches a maximum; the biotic potential of the habitat: then due to interspecific competition some species become extinct; this results in a reduction in number of species to a constant level; the carrying capacity of the habitat; Biomass tends to continue increasing even when number of species was reducing between 60 and 160 years; this is because of establishment of larger plants; there biomass compensates for the bio mass lost from the smaller plant species which are extinct; Net productivity reached a maximum 20 years after number of species had reached a maximum; this is because as the large plants are established; there; productivity gradually compensates for that from the extinct species are constant as this is a stable self-sustaining; self-perpetuating system; a climax community; comprising of large trees; With one or two dormant plant species and an associated animal community;

(c)(i).Name the process illustrated above . ***(01 marks)***

Primary succession

(ii).What is the stage of the process at 160 years? ***(01 marks)***

Climax community

(d). Account for the changes in the numbers of species between 0 and 50 years. ***(08 marks)***

In the first 20 years number of species increased slowly as the amount of soil available was low; As some plants and other organisms die; they decompose and amount of soil increases; As deeper soil forms more and larger plant speaes are established; such that between 20-50 years there was a drastic increase in number of species; as the many plant species were established to occupy all possible ecological niches; The plant community has an associated animal community as it grows; With numerous ecological niches; there is minimum inter specific competition; many species are established;

(e).Suggest the starting ecosystem for this forest ***(01 marks)***

The pioneer stage and would comprise of lichens on a rock.

(f) Which other ecosystem could undergo similar changes? ***(02 marks)***

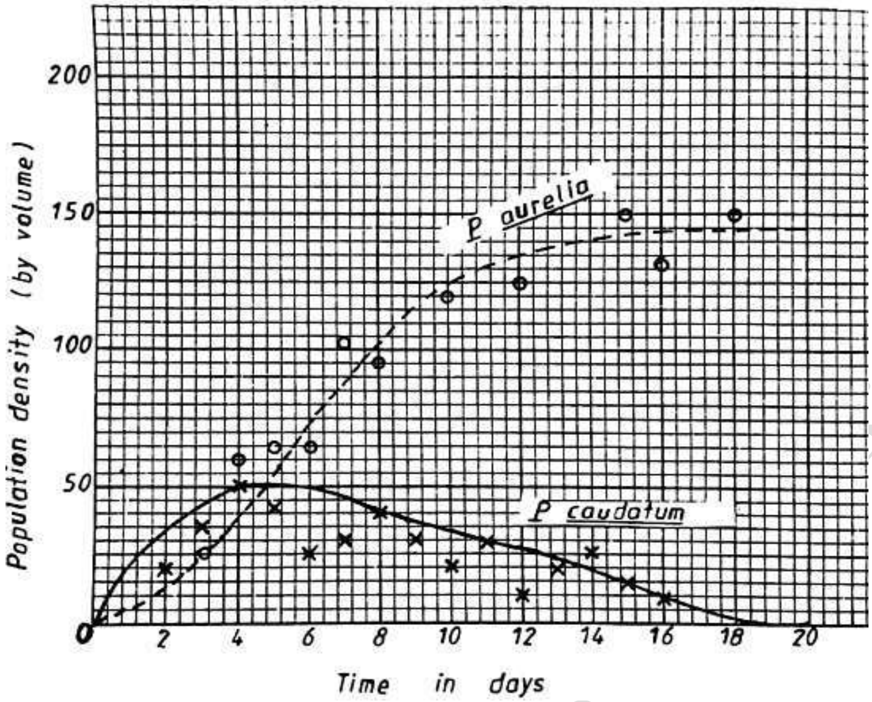
• Aquatic ecosystem; like open water ecosystem (river, sea, lake, ocean), Fish farm;
• Grassland; wetland; mountain;

(g).Mention the factors that can interrupt the process of change illustrated ***(03 marks)***

• Human activity
• Fire
• Natural disaster like earth quakes
• Over grazing

Question 15.

The figure below shows results of an experiment conducted to investigate the interaction between two species of Paramecium: P. aurelia and P. caudatum with environmental resources



(a)(i).Describe the population changes of the two species of Paramecium during the period of investigation.

P. aurelia

Initially population density increased slowly in the first two days; then increased steeply/ rapidly up to the 8th day then increased gradually thereafter to a maximum of 145 by the16th day; remained constant thereafter;

P. caudatum

Initially the population density increased rapidly in the first one day; then increased gradually to a maximum of 50 by the fourth day; remained constant up to 6th day then decreased gradually thereafter to zero just after the 18th day;

(ii) Suggest factors underlying the changes in the population of the two species of paramecium as observed.

Initially P. caudatum had a higher reproductive rate than P. Aurelia. However, after reaching the maximum, P. Caudatum was competitively eliminated by P. Aurelia; which had a competitive advantage; reproduce more frequently and survived more. As P. candatum was gradually eliminated; P. Aurelia continued to increase due to reduced inter specific competition. Further increase in population of P. Aurelia when P. Candatum was extinct was prevented by intraspecific competition; abundance of food and accumulation of toxins.

(b).In another experiment P. Caudatum was replaced by P. bursaria. P.bursaria occupied mainly the bottom part of the culture medium while P.aurelia occupied the rest of the culture medium other than the bottom.

(i).Why was it possible for P.aurelia and P. bursaria to co-exist in the culture medium? ***(06 marks)***

Since P. bursaria occupied mainly the bottom part of the culture medium; this presented a different micro habitat; with different ecological niche; As such interspecific competition was reduced between P.aurelia and p.bursaria; given that they occupied relatively different ecological niches;

(ii).How do members of the species, P. bursaria affect each other at the bottom of the culture medium?

At the bottom of the culture, intra specific competition occurs between members of the species P.bursaria. This limits their exponential increase; also, accumulation of toxins, overcrowding limits the exponential/ rapid increase;

(c) What possible conclusions would you make from the two experiments outlined above with respect to interactions between the three species of paramecium? ***(06 marks)***

- No two species can occupy the same ecological niche
- Each habitat has a different carrying capacity
- Different species have different biotic potentials
- Microhabitats provide different ecological niches enabling survival of two species within same habitat;
- Members of a species with a selective disadvantage are competitively gradually eliminated leading to extinction

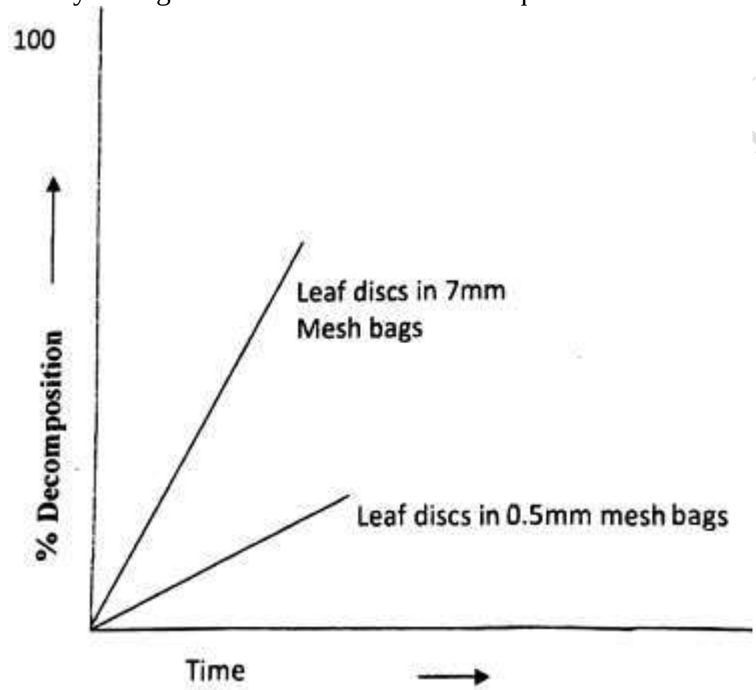
• Density dependent factors like intraspecific competition; accumulation of toxins, overcrowding availability of food limit population growth.

(d).State one way in which results from these experiments would be of value to game scientists in national parks. ***(03 marks)***

• Prevent extinction of some species
• Create micro habitats in parks for breeding of endangered species
• Control population growth to maintain ecological balance.

Question 16.

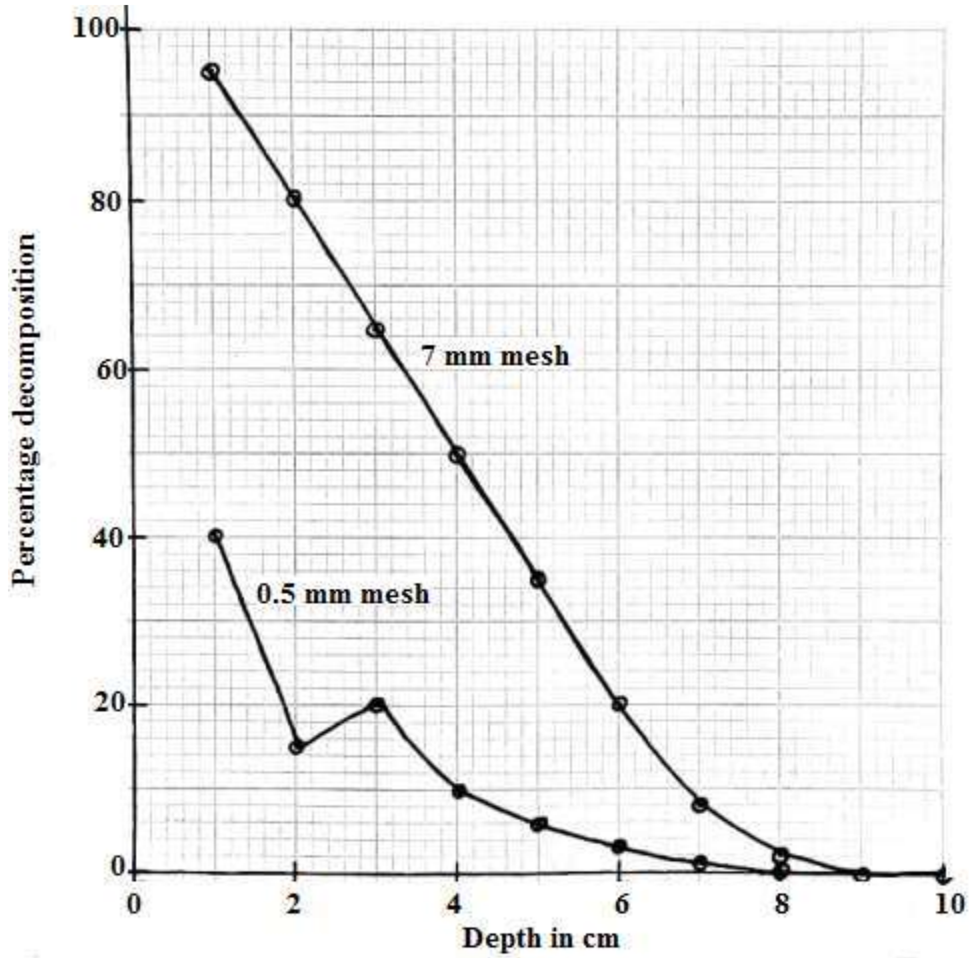
The graphs in figure l below show the rate of decomposition of discs of oak leaves in mesh bags of different mesh sizes with time and table1 shows the rate of decomposition of the same plant material with depth below the soil surface in a forest habitat. Study the figure and table and answer the questions that follow.



Depth (cm)		1	2	3	4	5	6	7	8	9	10
Percentage decomposition	**7 mm mesh**	95	80	65	50	35	20	8	2	0	0
	0.5 mm mesh	40	15	20	10	6	3	1	0	0	0

(a).Using the same axes plot graphs of percentage decomposition against soil depth. ***(08 marks)***

<u>A graph showing the variation of the percentage decomposition of discs of oak leaves in mesh bags of different mesh sizes 7mm and 0.5mm with the depth.</u>



(b) Explain the relationship between;

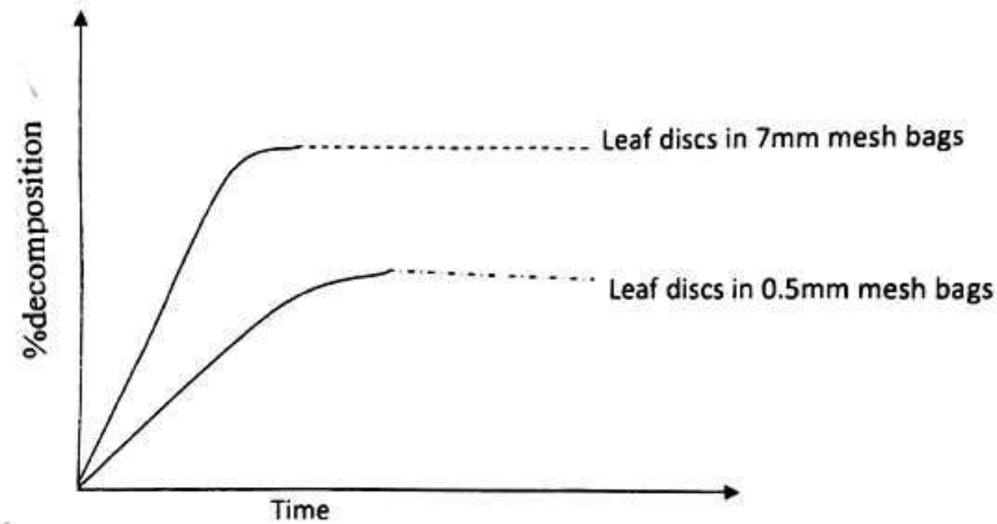
(i) The mesh size and the decomposition of the leaf discs ***(08 marks)***

The rate of decomposition is faster and higher in larger (7mm) mesh bags than in smaller (0.5mm) mesh bags. The larger mesh size allows more and larger organisms to enter the bags and decompose the leaf discs. The large decomposers breakdown leaf discs to smaller size; increasing surface area for decomposition by smaller decomposers such as bacteria and fungi. The smaller mesh size restricts entry of large decomposers such as earth worms allowing only the smaller decomposers. In the smaller mesh size decomposition is slow due to the reduced surface area of the leaf discs attacked by the small/microscopic decomposers.

(ii) Soil depth and the rate of decomposition of leaf discs. ***(10 marks)***

The rate of decomposition decreases with increase in soil depth in both larger and smaller mesh bags. Decomposition is higher in larger mesh bags than in smaller mesh bags at different soil depth. No decomposition occurs at soil depth of 8cm and beyond for the 0.5mm (Smaller mesh bags); while for larger (7mm) mesh bags no decomposition occurs at soil depth of 0.9 cm and beyond. As soil depth increases number of decomposing organisms decreases. However lager mesh bags allow in more organisms causing increased decomposition even to deeper soil layers; The large mesh bags increase aeration providing better conditions for decomposition than the smaller mesh bags. The large mesh bags could allow in more large decomposers like earth worms which could improve aeration within the bags by their burrowing activity; unlike the smaller mesh bags where it is not possible.

(c)(i) Copy out figure 1 and extrapolate both graphs in the figure to show the trend of decomposition of the leaf discs with time. ***(02 marks)***



(c)(ii).Explain the trend of decomposition of the leaf discs drawn in (c)(i) above ***(03 marks)***

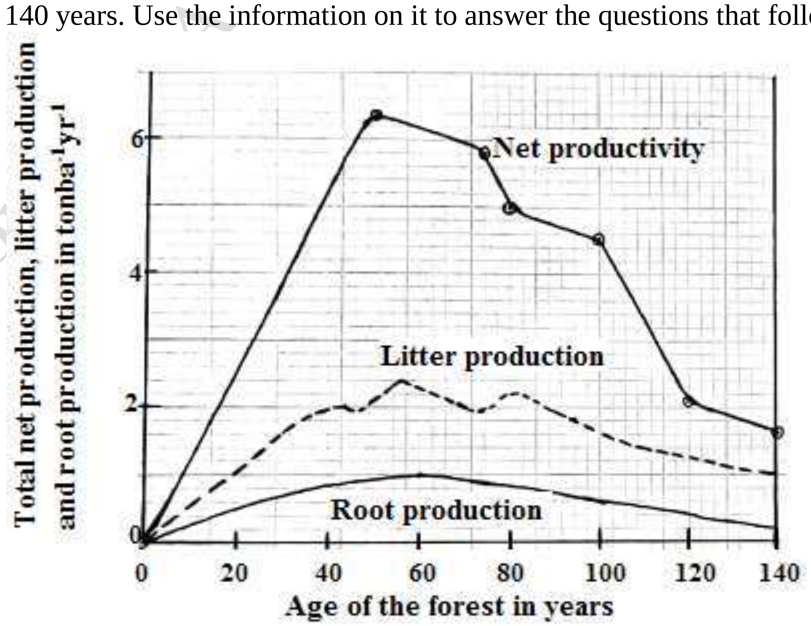
Maximum percentage decompostion for large mesh bags is higher and comes to completion earlier than that of small mesh bags. This is because of higher rate of decomposition in the larger mesh bags.

(d).What is the ecological significance of leaf decomposition in a natural habitat ***(09 marks)***

- Increases the amount of humus in the soil
- Increases stock of nutrients in the soil
- Improves water retention and drainage in the soil
- Removes organic matter and enables recycling of nutrients
- There is mutual benefit between the decomposersand the plants getting nourishment
- lmproves soil structure by affecting particle size
- Enables root growth to deeper soil layers to obtain more nourishment.
- Enable earthwonns drag organic matter (humus) to deeper soil layers; increasing soil productivity.
- As earthworms decompose organic matter, they improve soil aeration, pH and increase water content in the soil.

Question 17.

Figure 1 shows the variation in the total net productivity, litter production and root production in a freshly planted forest over a period of 140 years. Use the information on it to answer the questions that follow



(a).Compare net productivity with litter production ***(04 marks)***

Similarities

• At zero years, both net productivity and litter production are at zero.
• Both increased between zero years and 30 years.
• Both decreased between 90 years and 140 years.

Differences

Net productivity	Litter production
Between 0 years and 30 years; increased rapidly	Between 0 years and 30 years; increased gradually.
Peaks once	Peaks twice/ forms two peaks
Between 80 and 90 years; decreased gradually	Between 80 and 90 years; increased rapidly
Between 90 years and 140 years; decreases rapidly	Between 90 and 140 years; decreased gradually

(b).Explain the changes in the following variables;

(i).Total net productivity ***(06 marks)***

Between 0 years and 50 years, total net productivity increased rapidly; number of leaves and photosynthetic tissues increased; increasing the photosynthetic surface; therefore the rate of photosynthesis is greater than the rate of respiration. Between 50 years and 140 years; total net production decreased; most of the trees had reached their maximum size and accumulated a large volume of support tissues; requiring more energy; rate of respiration is greater than rate of photosynthesis.

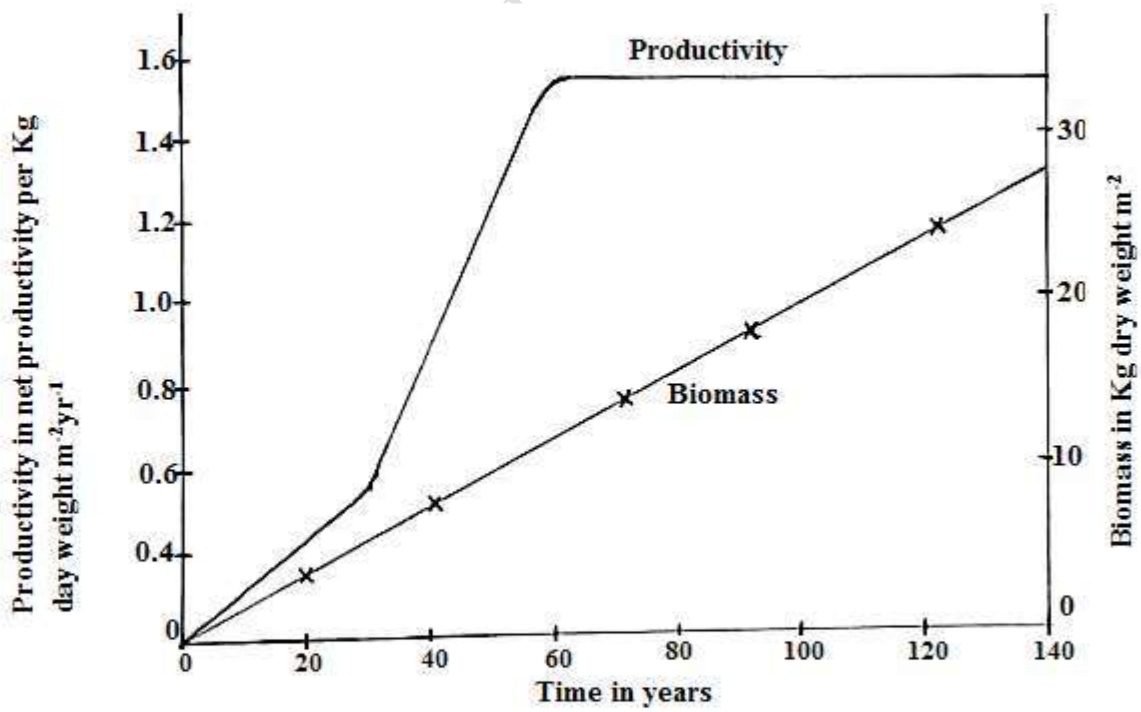
(ii).Root production ***(05 marks)***

Between 0 years and 80 years; root productivity increased gradually; as more trees develop; roots grow faster; to increase the surface area for absorption of water; between 80 years and 140 years; root production decreased gradually. Most of the trees had reached their maximum size; no more root production/ development; roots increase in size to provide extra support.

(iii).Suggest why litter production increased rapidly during the early years after planting ***(04 marks)***

Tree density increases; plant organs such as leaves; branches; stems; fruits and flowers grow faster; which fall off as litter upon senescence.

(b). ***Figure 2*** shows the changes in net primary productivity and biomass above the ground in a forest following an ecological fire



(i). Describe the change in each of the variables shown in figure 2 above ***(05 marks)***

Net primary productivity

Between 0 years and 30 years; productivity increases gradually/ slowly; between 30 years and 60 years; productivity increases rapidly to the maximum at 60 years. Between 60 years and 140 years, productivity remained constant.

Biomass

Between 0 years and 140 years, biomass increased gradually/ slowly

(ii).Account for the changes described in (b)(i) above ***(07 marks)***

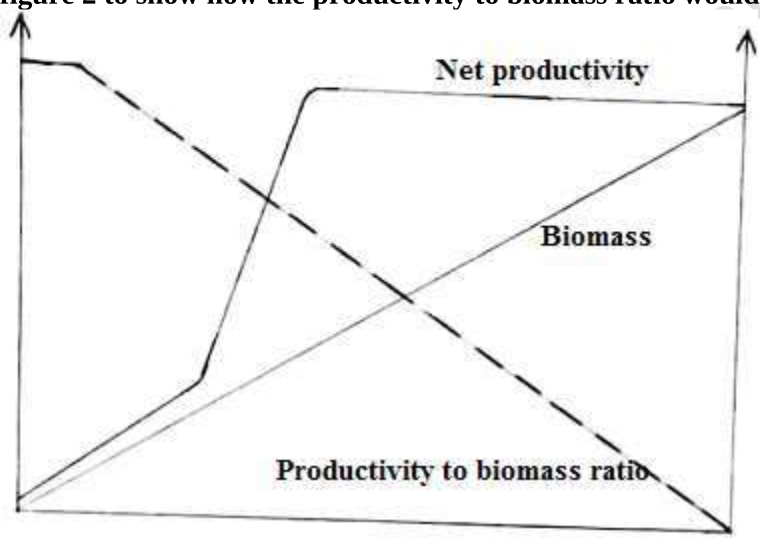
Net productivity

At first, there are few survivors of the fire; hence the net productivity is very low; As more plants germinate from the fire resistant seeds/ perennating organs grow more leaves; increasing the photosynthetic tissue gradually; at first and then rapidly; making net productivity greater; as succession proceeds, gradual replacement of the species occurs; towards woody types until the climax community is established whose productivity levels remain constant for further replacement of species by others/ the species composition remains constant.

Biomass

As succession proceeds, there is gradual replacement of the shrubs with trees which have large biomass and the young tress germinating after the fire also grow to large sizes so that the biomass goes on increasing.

(iii)Sketch the curve in figure 2 to show how the productivity to biomass ratio would change with time

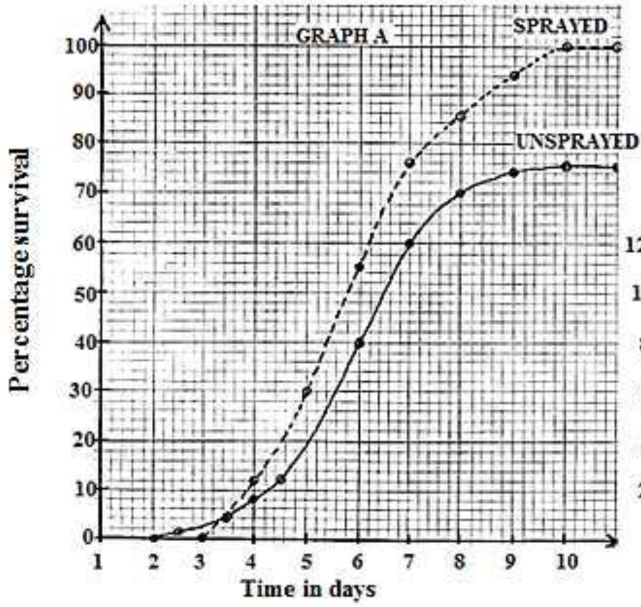


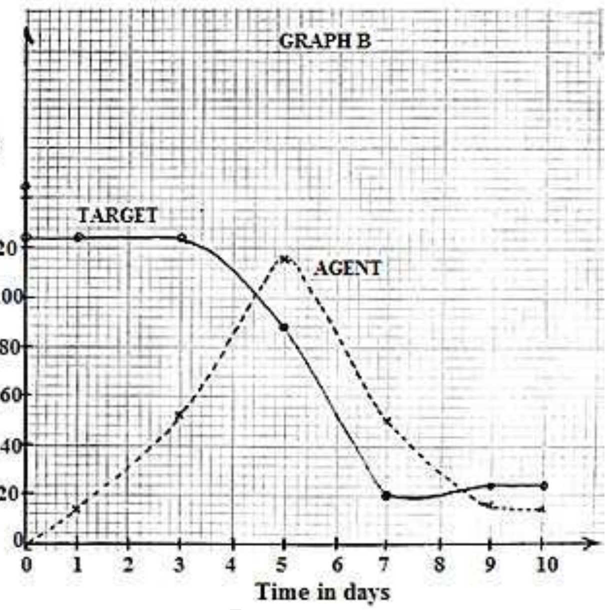
(iv).Suggest an explanation for the curve drawn in (iii) above ***(05 marks)***

Initially the productivity to biomass ratio is constant; productivity is most stored in terms of supporting tissues but most is lost in respiration. It increases gradually; because species that dominate later are slow growing but they eventually achieve large sizes; hence they monopolize both space and use of light. They therefore outcompete herbaceous plant species. Their large structures is composed of more photosynthetic tissues; and dead tissues which causes biomass to exceed productivity; as a result the productivity to biomass ratio is reduced.

Question 18.

In an experiment to study the effectiveness of DDT towards the cabbage pest, Pieris rapae which feeds on cabbage leaves, two adjacent farmyards where prepared Pieris was introduced in each farm and left for some time. After spraying one farmyard with DDT for three consecutive times the number of eggs that survived and hatched into larvae at the sprayed and non-sprayed 1mm yards was determined, as shown by Graph A. In another set of experiment, Pieris rapae was exposed to birds as its control agents and the changes in the population of both with time was determined, as indicated by Graph B. Study the graphs and answer the questions that follow.





(a)(i) Account for the increase in the population of control agent. ***(05 marks)***
(ii).Explain the decrease in the population of control agent. ***(05 marks)***
(b)(i).Account for the decrease in the population of Pieris rapae. ***(03 marks)***
(ii).Account for the population of Pieris and that of the control from the 8 ½ to the 9th week. ***(02 marks)***
(c).Compare the number of eggs of Liens before and after spraying. ***(04 marks)***
(d).Account for the differences in the number of eggs of Liens before and after spraying ***(08 marks)***
(e).Explain any one property of DDT other than the one shown above, which render it unsuitable for environmental use ***(05 marks)***
(f).Outline any three advantages of the method used in Graph B to that used in Graph A ***(03 marks)***

Question 19.

A factory emitting smog containing sulphurdioxide and carbon dioxide was cited in a rural district. The tables below give distances and directions of:
(i) Number of moth species and
(ii) Concentration of sulphur dioxide in smog in different directions from the factory chimney.

Table 1.

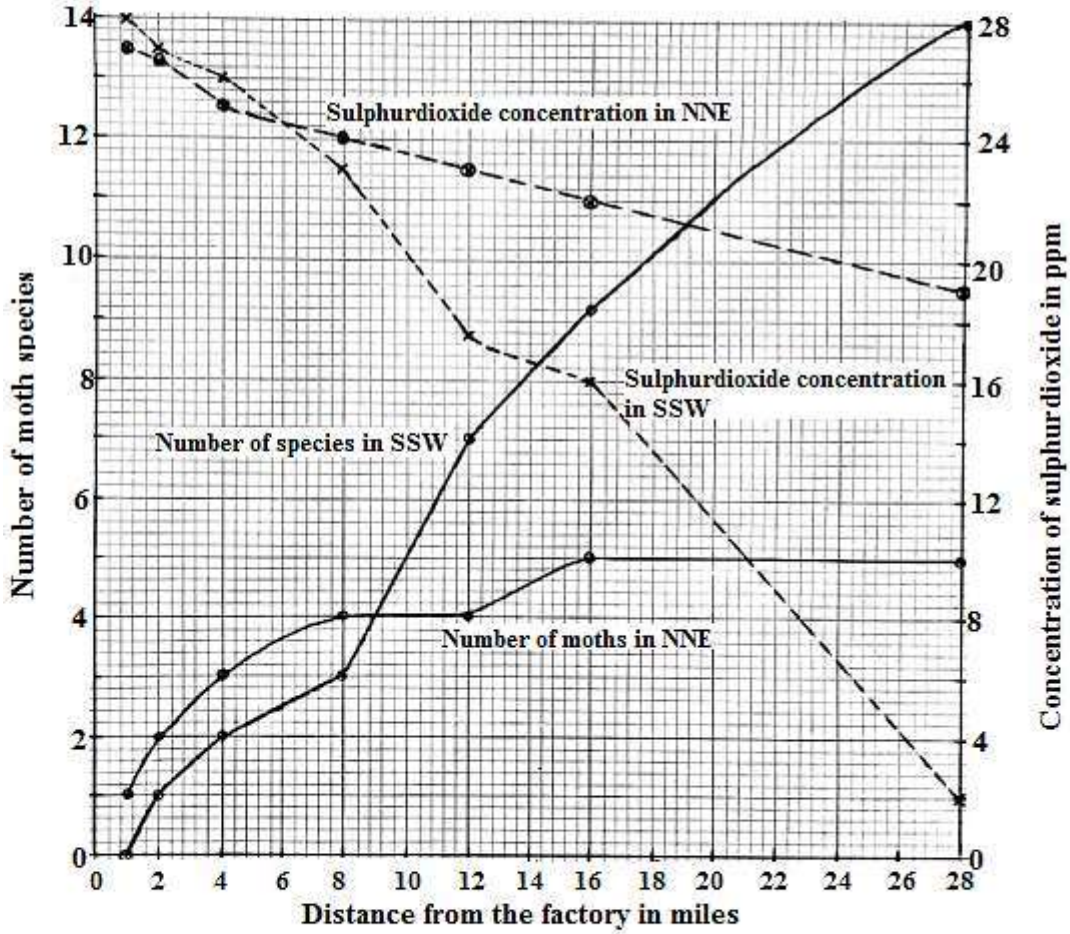
Distance from the factory in South, South West (SSW)/ miles	1	2	4	8	12	16	28
Number of moth species	0	1	2	3	7	9	14
Sulphur dioxide concentration (parts per million)	28	27	26	23	19.5	16	2

Table 2.

Distance from the factory in North, North East (NNE)/ miles	1	2	4	8	12	16	28
Number of moth species	1	2	3	4	4	5	5
Sulphur dioxide concentration (parts per million)	27	26.5	25	24	23	22	19

(a) Plot the information to show the relationship between the moth species and the sulphurdioxide concentration using the same x-axis and two y-axes. ***(09 marks)***

A graph showing variation of the number of moth species and sulphurdioxide concentration with distance from a smog emitting factory in the North-north east(NNE) and South-south west directions (SSW)



(b) Explain the difference in results between those obtained for the SSW direction and those obtained for the NNE direction. ***(16 marks)***

One miles range in the NNE direction has atleast a moth species; none was noticed in a SSW direction due to decreased sulphurdioxide concentration hence reduced poisoning of the moths and some lichen varieties withstand such a sulphurdioxide concentration; hence camouflaging backgrounds for this moth species are provided.

For the 8th to 12th mile from factory, moth species in the NNE direction increased gradually but the increment was rapid in the SSW direction because NNE direction had relatively more sulphurdioxide concentration than in the SSW direction hence more moths poisoning and lichens varieties to withstand relatively high sulphurdioxide concentration; few and hence no sufficient camouflaging backgrounds for some species.

For 16th to 28th miles from the factory, number of moth species in the SSW direction increased rapidly while that in the NNE direction remained constant because in the NNE direction, concentration of sulphurdioxide was relatively constant and higher hence constantly poisoning certain moth species and camouflaging lichens for particular moths which would have migrated to the area. The rapid increase in the SSW direction is due to the rapid decrease in sulphurdioxide concentration resulting in less lichens poisoning to offer more lichens varieties for more moths camouflaging. The trend also reduced the poisoning effects of sulphurdioxide hence favouring existence of more moth species.

In the range of 1 mile from the factory, NNE direction had relatively reduced sulphurdioxide concentration due to the smog outlets being more in the SSW direction than in the NNE direction. The steep decrease in sulphurdioxide concentration in the SSW direction and the gradual decrease in the sulphurdioxide concentration in the NNE direction could be due to more wind blowing the sulphurdioxide away from the SSW direction and less of these winds in the NNE direction. The relatively more rainy SSW direction also results in a relatively higher rate of sulphurdioxide dissolution in the rain and its subsequent removal from the air

(c) Explain why number of moth species increases with increasing distance from factory ***(04 marks)***

Generally as the distance from the factory increases, the concentration of sulphurdioxide decreases. This reduces the toxic effects of sulphurdioxide to some moth species resulting in their migration to the area. Such levels can also start off mutations of moths to form new species.

As the concentration of sulphurdioxide decreases with increasing distance from the factory, less poisoning of lichens varieties was experienced resulting in more camouflaging backgrounds for the moth species, reduced predation and increase in their population.

(d) The results obtained give evidence of present-day evolution. Explain this evidence fully and its significance in evolution. ***(05 marks)***

Before the industrial revolution, most backgrounds were white and the non-melanic moths form the predominant population. Upon onset of the industrial revolution that was associated with the use of the coal as the major industrial fuel; produced a lot of soot which changed the camouflaging background to black. This trend made the white moths not easily spotted by their predatory birds since the background had turned black and could easily blend with the new background. The allele frequency of the black moths increased while that of the white moths reduced hence evolution of the new moth generation of mainly the more adapted melanic forms.

(e).What are the environmental effects of sulphurdioxide and carbondioxide pollutions? ***(04 marks)***

- Sulphurdioxide directly poisons living organisms in the environment reducing biodiversity
- It changes camouflaging backgrounds by killing lichens making organisms at risk of predation.
- Sulphurdioxide produces acid rain; which kills organisms, make soil acidic, damage mycorrhiza etc
- Carbondioxide causes planetary greenhouse effects coupled with enhanced global warming

Question 20.

Table 1 below shows results of an experiment carried out to estimate the number of dragonflies in a known area of forest.

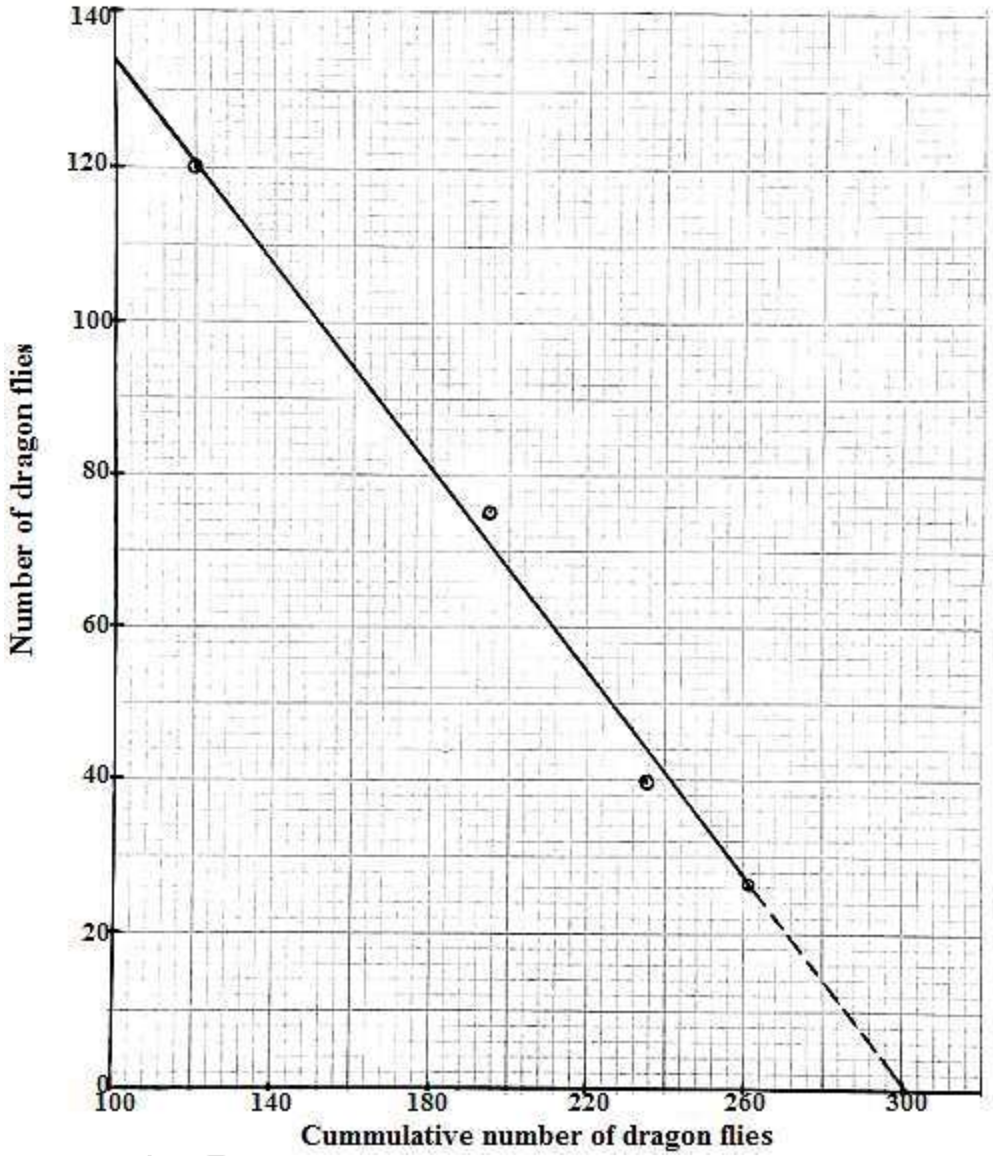
Sample	**Number of dragonflies in the sample**	**Cumulative sample size**
1	120	
2	75	
3	40	
4	26	

(a)(i)Copy & complete table 1, by calculating cumulative number of dragonflies ***(02 marks)***

Sample	Number of dragonflies in the sample	Cumulative sample size
1	120	120
2	75	195
3	40	235
4	26	260

(ii).Plot a graph to show the relationship between number of dragonflies captured per sample and the previous cumulative number of dragon flies. ***(04 marks)***

<u>Graph showing the variation of the number of dragon flies captured per sample with the previous cumulative number of dragon flies</u>



(b)(i).From the graph estimate the number of dragon flies in the sampled area. ***(01 marks)***
300 dragon flies
(ii).Briefly explain how you arrived at the answer. ***(03 marks)***
The graph was extrapolated to touch the horizontal axis. The intercept value indicates the total population. The number of organisms/ dragonflies in the cumulative sample corresponding to the zero number of dragon flies on the vertical axis is the estimated population of the dragonflies. This implies that all the dragonflies were captured and no flies were in the environment.
(c). Suggest the method used to estimate the number of dragon flies in the sampled area ***(01 marks)***
Removal method
(d)(i).With a reason, state one other method you can use to estimate the population size of dragonflies.
Capture-recapture method (Lincoln index method)
Organisms were small, fast moving and often concealed in the habitat.
(ii). Describe how this method can be used to estimate the population size of dragonflies ***(14 marks)***

Procedure

- By using a sweep net in a chosen area, the dragonflies are captured, counted and recorded.
- They are then marked with a permanent ink which doesnot kill/ affect them.

- They are then released back to the same environment/ area. This is the first catch N_1
- Enough number of days is allowed to elapse to allow random mixing of the flies
- The flies are captured again from the same area using the sweep net, counted and recorded as a representative of the second catch N_2.
- The number of marked flies in the second catch is counted and recorded as a representative of the total recaptured marked flies. These are marked as N_3

Assumptions made;

- That organisms mix randomly within the population.
- That the time allowed for random mixing is enough.
- That changes in population size due to immigration, emigration, death and birth are negligible.
- That the movement of organisms is restricted geographically.
- That there is even dispersing of organisms within the study area.
- That the mark does not hinder the movement of organisms or make them conspicuous to predators

Treatment of results

The estimate of the population is expressed or calculated as

Population of dragon flies= $\frac{\text{Total number of flies in the first catch x total number of flies in second catch}}{\text{Total number of flies recaptured (Already marked flies)}}$

$$\mathbf{N=(N_1 \times N_2)/N_3}$$

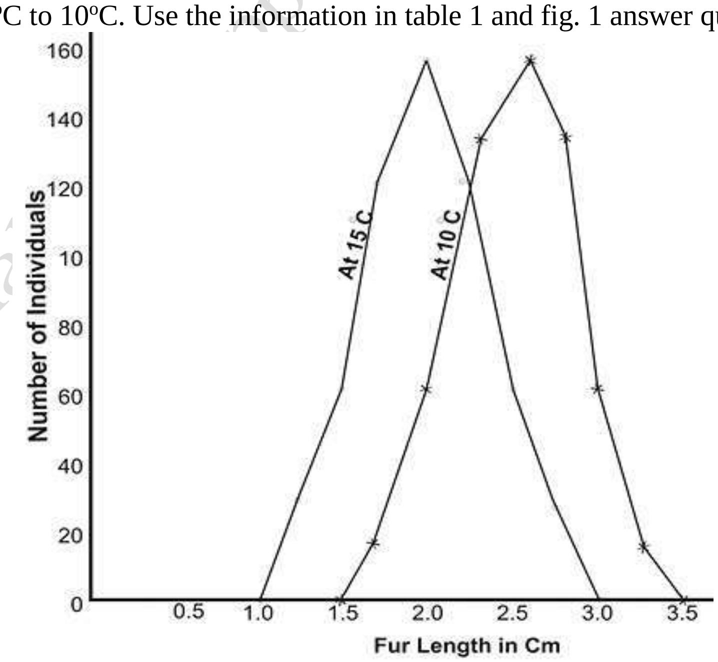
Derivation of the expression

It is assumed that all individuals have the same probability of being captured in the second sample regardless of whether they were previously captured in the first sample. This therefore implies that in the second sample, the proportion of the total population that is marked (N_3/N_2) should be equal to the proportion of the total population that is marked on the first catch (N_1/N) where N is the total population.

$$(N_3/N_2)= (N_1/N)$$

$$\mathbf{N=(N_1 \times N_2)/N_3}$$

Fig. 1 shows the relationship between fur length and number of individuals with a given length of fur in a population of a terrestrial mammalian species for two different generations and during which the prevailing climatic temperature changed form 15°C to 10°C. Use the information in table 1 and fig. 1 answer questions that follow.



(e).State precisely, what the graphs in fig. 1 represent. ***(01 marks)***

The graphs represent directional natural selection

(f).What is the optimum length of fur at each temperature? ***(02 marks)***

Optimum fur length at 10ºc is approximately 2.7cm
Optimum fur length at 15ºc is approximately 1.9cm

(g)(i).What is the effect of temperature on fur length among individuals. ***(03 marks)***

When the temperature drops from 15ºC to 10ºC, the mean fur length shifts from 1.9cm to 2.7cm implying that there are more individuals with longer fur at 10ºC than at 15ºC.

(g)(ii).Suggest an explanation for the effect of temperature on fur length. ***(07 marks)***

A drop in temperature from 15ºC to 10ºC imposes a selection pressure in that individuals with longer fur above 1.9 cm became better insulated and lose less heat; thus more likely to survive and reproduce to pass on their genes to the next generation. Over subsequent generations, their numbers increase and become the majority of the population. Those with shorter fur are selected against; sine they are less insulated and thus lose more heat. These fail to survive up to their reproductive age; and over time become the minority of the population. Therefore such a selection pressure results in a population dominated by individuals with longer fur at the expense of those with shorted fur.

Question 21.

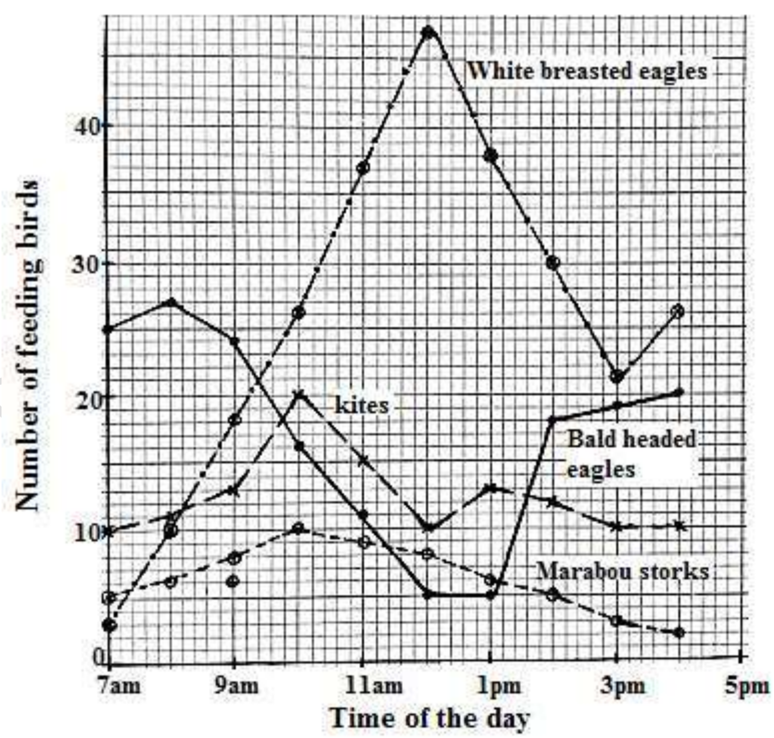
In nature, organism of the same kind rarely occupy the same niche at the same interval. However, a study carried out around Najjembe Market, Mabira forest, showed four flesh eating birds occupying the same niche. These birds were found either pecking feathers, resting, soaring or feeding. The feeding patterns of all these bird species were recorded over a time interval on a daily basis and averages computed for over a period of one month.

Birds species	7am	8am	9am	10am	11am	noon	1 pm	2 pm	3pm	4pm
Marabou storks	5	6	8	10	9	8	6	5	3	2
Kites	10	11	13	20	15	10	13	12	10	10
Bald headed eagles	25	27	24	16	11	5	5	18	19	20
White breasted eagles	03	10	18	26	37	47	38	30	21	26

The sizes of these birds from the largest to the smallest are as arranged in the table above.

(a).Plot graphs of the diurnal feeding patterns of these birds, one the same axes.

Graph showing the variation of the average number of organisms feeding in Najjembe market with time of the day.



(b)(i).Describe the nature of the graphs.

Marabou storks; few birds feed early in the morning at 7am; From 7am to 10am; there is a gradual increase in the number of feeding birds; and from 10am to 4pm; there is a gradual decrease in the number of feeding birds.

Kites; there is a moderate number feeding at 7am; gradual increase in the number of birds feeding from 7am to 9am. Rapid increase in the number of feeding birds from 9am to 10am followed by rapid decrease in the number of feeding kites from 10am to 12 noon. From 12 noon to 1pm; there is a gradual increase in the number of feeding birds and from 1pm to 4pm; there is a gradual decrease in the number of feeding kites

Bald headed eagles; at 7am, there is large number of birds feeding; gradually increased up to 8am. From 8am to 12 noon, there is a generally rapid decrease in the number of feeding birds. From 12 noon to 1pm, there is a gradual decrease in the number of feeding birds and from 1pm to 2pm, there was a very rapid increase in the number of feeding birds beyond which there was a gradual increase in the number of feeding birds from 2pm to 4pm.

White breasted eagles; at 7am, there are very few eagles feeding. From 7am to 12 noon, there is rapid increase in the number of feeding eagles followed by a rapid decrease in the number of feeding eagles from 12 noon to 3pm. 3pm to 4pm; there is a rapid brief increase in the number of feeding breasted eagles.

(ii). Suggest explanations for the patterns described in b) (i) above.

Marabou storks; there were very few marabou storks at 7am because they are relatively large birds with small surface area to volume; hence adequately insulated from heat loss. There is thus no need for feeding at such a morning to obtain substrates whose respiration produces warmth/ energy. From 7am to 10am, there is a gradual increase in the number of birds hence feeding due to opening of the market with consequent food provision. From 10am to 12 noon, there is gradual decrease in the number of feeding marabou storks due to increased interspecific competition for food; storage of enough food in the crop, heat exhaustion and many of these birds migrate after feeding.

Kites; few feed at 7am because they are relatively big and hence small surface area to volume ratio; hardly lose heat to the surrounding; donot need for regeneration of heat. Rapid increase in the number of feeding kites from 9am to 10am; due to increased food availability since the market is in operation. General gradual decrease in the number of feeding kites was due to heat exhaustion, interspecific competition; most are satisfied; all of which stimulate their migration or resting.

Bald headed eagles; very many of them found feeding at 7am because they are very small with large surface area to volume ratio; hence lose a lot of heat in the cold morning and thus need feeding to generate heat in their bodies. The gradual increase up to 8am in the number of feeding birds was due to the need to generate heat in their bodies to replace that lost in the cold morning. From 8am to 11am, rapid decrease in the number of feeding bald headed eagles was due to over competition from the bigger species of birds so they migrate away or rest. From 12 noon to 1pm, rapid increase in the number of feeding bald headed eagles was due to reduction in competition following reduction in the number of bigger competitor birds. Gradual increase in the number of feeding birds from 2pm to 4pm was due to heat exhaustion and most of them have got satisfied.

White breasted eagles; initially very few feed early in the morning by 7am due to their very small size thus a large surface area to volume ratio; prompts rapid heat loss which makes them less active or compelled to stay clumped together and warm themselves. The rapid increase in the number of feeding white breasted eagles from 7am to 12 noon is due to the need to feed rapidly so as to generate adequate heat to replace the lost one. From 12 noon to 3pm, there was rapid decrease in the number of feeding white breasted eagles due to heat exhaustion since they easily take up heat from the surroundings; having a high surface area to volume ratio. From 3pm to 4pm, there was a rapid increase in the number of feeding birds due to reduction in the heat of the day hence majority could adequately go back and feed. The competition from the bigger species at such times is also less.

(iii).Identify the curve which behaves abnormally and account for the strange behavior of the bird it represents.

The curve for white breasted eagle has the lowest number of feeding birds in the early morning and a very high number of feeding birds during noon. This is because this eagle is the smallest in size among the birds under study. This implies that during the early mornings, they cannot go out to feed since their large surface area to volume ratio is associated with alot of heat loss. This makes them feed during noon. These birds also show the most rapid decrease in the number of feeding birds after midday because they easily take up heat of the day as well and exhibit heat exhaustion. They are also poor competitors and this makes them to rapidly decrease in number one other bigger species of birds appear.

(c)(i).From your graphs suggest how organisms of the same kind can occupy the same niche.

Through resource partitioning i.e exploiting the resources at different times eg feeding at different times of the day on different resources.

(ii).What would happen to the organisms if they do not adapt to these mechanisms in (c) i) above.
There would be stiff interspecific competition resulting in reduction in the population of the poor competitors following their death, migration or predation. All will be in line with the competitive exclusion principle.

(d)(i).What is the importance of vultures in nature?
• Recycling of nutrients
• Clean environment by preventing accumulation of decaying organisms.
• Create room for exploitation by other living organisms

(ii).What would happen to the habitat if all the vultures were poisoned?
• Increased accumulation of decaying organisms matter
• Reduced nutrient recycling
• Bad smell in the environment
• Reduced room for living organisms

(e)(i).Outline the method which was used to obtain these data.
Direct counting using binoculars/ slow moving or motion cameras/ video recording

(ii).Suggest two advantages of the method given in (e) i) above. Give reasons for your answer.
• Counting is done from a distance hence birds not disturbed
• Reduces attack from any aggressive organisms
• Method is quick and cheap
• Reduced mathematical manipulation.
• Reduces chances of counting organism more than one

Question 22.

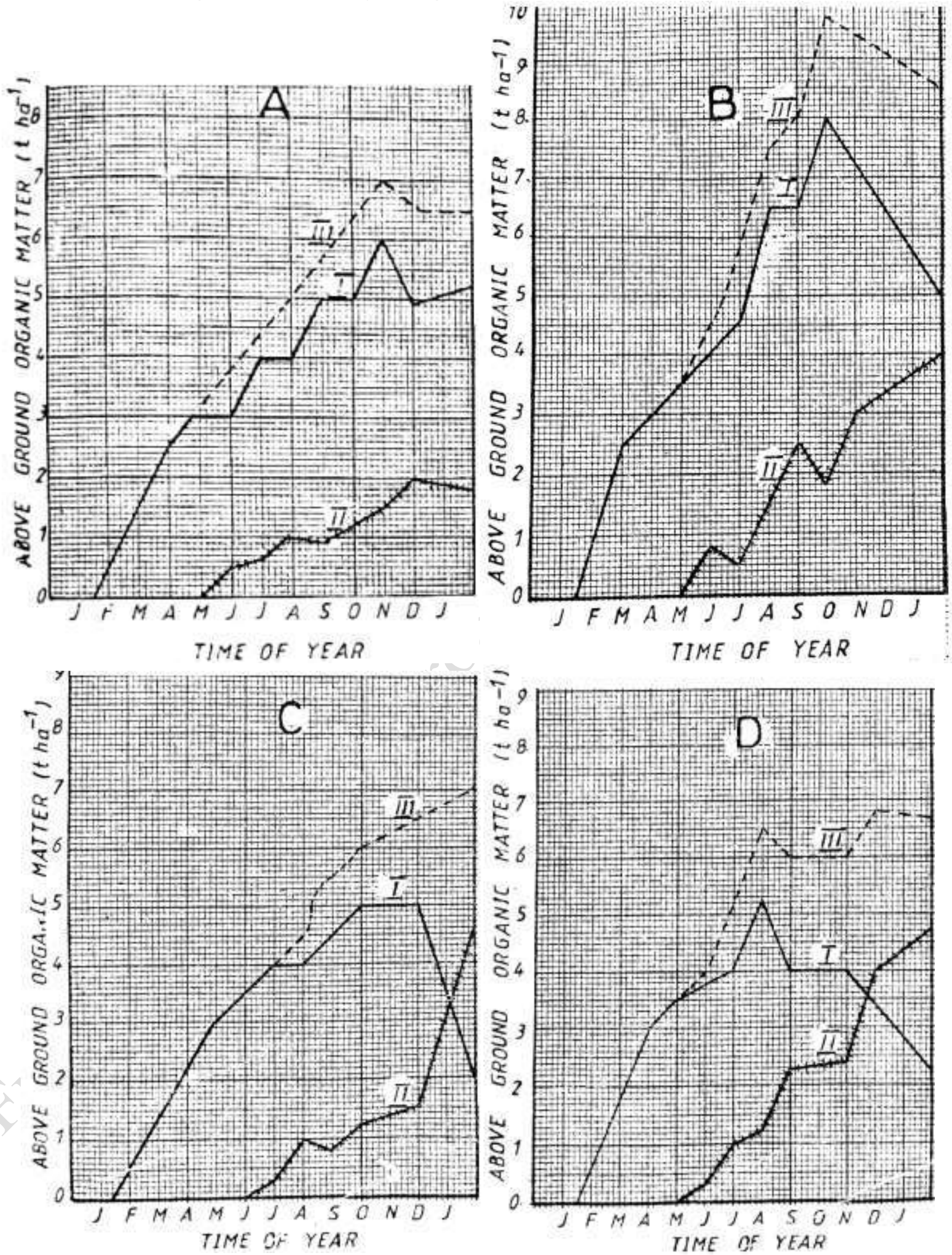
An ecological study was conducted in a small fresh water body located in the centre of a heavily forested area. Annual measurements of some aspects of its biotic and abiotic components were carried out for a duration covering one decade. The table blow gives the results of average estimates made on:
(a).The population changes of the residing Haplochromis fish species expressed in thousands,
(b).The biomass of accumulated decomposing plant materials, expressed in thousands of arbitrary units,
(c).The depth of light penetration of the water body in arbitrary units.
Study the data on the table and then answer the following questions.

Time (Years)	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Number of estimated Haplochromis spp (x10^3)	36	76	60	82	104	120	114	60	20	26	28
Biomass x10^3 (arbitrary unit)	100	86	70	64	72	86	102	94	60	50	50
Depth of light penetration in arbitrary units	38	27	48	43	15	10	12	25	55	25	30

(d).Using same axes and suitable scales, draw line graphs to reflect the information in the table above.
(e).Describe the changes in;
(i). number of Haplochromis
(ii).biomass of accumulated decayed plant materials
(iii).depth of light penetration covering the period of investigation
(f).Explain the relationship between the Haplochromis population and
(i). biomass of accumulated decayed plant materials
(ii).depth of light penetration
(g).Other than the depth of light penetration and biomass of accumulated decayed plant materials, suggest four other factors that may determine the population size of the Haplochromis in the water body.
(h).Briefly explain how each of the factors you named in (d) above influences the population size of the Haplochromis.
(i). Describe how you would, in two days, estimate the population size of Haplochromis in a small lake.
(j). What would be the effect of dumping untreated sewage and excess fertilizers in the water body.

Question 23.

Fig.1 below shows the results of an ecological study of four previously cleared areas A, B, C, and D undergoing secondary colonization by plants over a period of one year. For each area of study, three graphs of the above ground organic matter (in tons per hectare) were plotted against time. Graph I represents living matter (biomass), II dead matter and III total organic matter. Study the figure carefully and answer the following questions:



(a) For each of the four study areas, describe the changes in
(i).Living matter (biomass)

In A; Living matter increased rapidly from January to April; less rapidly to May; then showed monthly constancy followed by rapid increase from May to October; reached a maximum in November; then de- creased rapidly in December and finally increased slowly at the end in January.
In B; Living matter increased rapidly from January to March; then increased gradually from March to July; incre-ased rapidly in August; remained constant from August to September; increased rapidly to a maximum in Octob-er; there after decreased rapidly up to the end.
In C; Living matter increased steeply from January to May; then less steeply to July; remained constant from July to August; again increased steeply to October; then remained constant and at maximum u to December; there aft-er decreased steeply up to the end;
In D; Living water increased steeply from January to April; then increased slowly to July; increased steeply to a maximum in August; decreased steeply in the next month; remained constant up to November; then decreased steeply thereafter.
(ii).Dead matter,
A; Started to form in May; increased gradually up to August; followed by a slight decrease in September; then in-creased more gradually up to a maximum in December; there after decreased slightly;
B; Started to form in may; increased rapidly to June; then decreased rapidly to July; then increased rapidly from July to September; then decreased rapidly to October; increased rapidly to November; then
increa-sed drastically up to the end in January;
C; Started to form in June; increased slowly to August; decreased slightly to September; then increased slowly to December; then increased rapidly up to the end in January.
D; Started to form in May; increased gradually to July; then increased slightly to August and increased rapidly to September; nearly remained constant to November; increased rapidly up to December; and finally increased grad-ually at the end.
(iii).Total organic matter.
A; increased rapidly from January to a maximum in November; decreased slightly up to December and remained constant thereafter;
B; Increased rapidly from January up to March; less rapidly up to May; then increased more rapidly to a maxim-um in September; then decreased rapidly up to the end.
C; Increased rapidly from January up to August; then increased more rapidly in August; then increased more gra-dually up to the end.
D; Increased steeply from January up to June; then increased more steeply up to August; followed by a drastic decrease up to September; remained constant up to November; then increased steeply to a maxim- um December; then decreased slightly up to the end.
(b)(i).Point out the differences between the rates of increase and peaks of biomass in the four study areas
Plot B had the highest biomass peak; 8 t ha^{-1}; while plot C had the least biomass peak; 5 t ha^{-1}
Peak for biomass of plot C remained constant for two months; while for other plots biomass decreased steeply after the peak
Plot A had four months when bio mass was constant; Plot C had two months when biomass was constant
Plot B1, D had only one month when bio mass was constant;
Plot A showed an increase in bio mass after declining from the pick; the rest showed continued decline after the peak;
Peak biomass for plot A was lower than for plot D.
(ii).With reference to areas A and C, suggest with reasons the types of vegetation likely to be pre-dominant in the two areas.
Plot A: Open grassland savannah
There are many organisms in this kind of vegetation hence the high living matter; however due to the grass cover at the surface there is little dead matter; The intermittent living matter could be attributed to the numerous arthro-pods which show intermittent growth.
Plot C: Shrubs and few trees

Living matter is relatively lower at the plant cover is minimal; dead organic matter tends to increase as some small plants die as they are eliminated by competition from the larger shrubs and trees. Total organic matter tends to increase as larger plants gradually replace the smaller plants.

(c).Briefly explain how environmental factors could have influenced the rate of increase of biomass

Rainfall pattern; following a rainy season; many plants grow; increase in plant communities implies an increase in consumer communities at higher trophic level; many plants die in dry season; leading to death of some consumers and hence decrease in bio mass

Light intensity: This affects rate of photosynthesis; and hence bio mass of producer; which in turn determines bio mass of consumers at higher trophic level;

Soil factors: The soil factors affect productivity of the producers; and hence bio mass of the producers increases with favourable soil factor such nutrients; PH; temperature, moisture, soil organisms; The biomass of the producers then determines the biomass of the consumer at higher trophic levels.

Other physical factors include

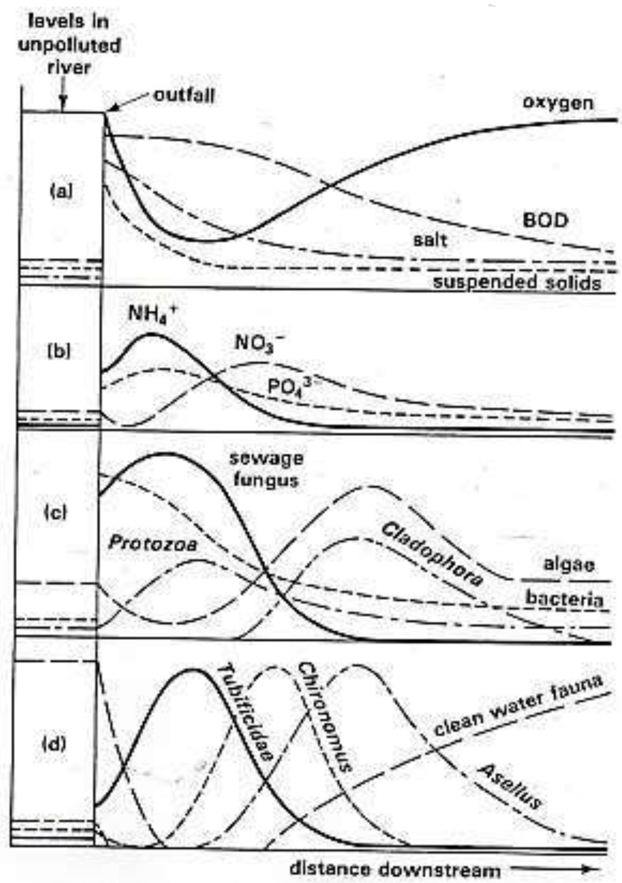
Temperature, humidity, air currents and topography

Question 24.

The graphs below were obtained in a study on the effect of sewage discharge into a river. Graph A and B show physical and chemical changes

Graph C shows changes in micro organisms

Graph D shows changes in aquatic invertebrates



(a).What is meant by the term biochemical oxygen demand (BOD) and how is it measured?

BOD is mass of oxygen consumed by microorganisms in a sample of water in a given time. It is usually measured as the mass (in mg) of oxygen used by 1dm3 of water stored in darkness at 20ºC for 5 days.

(b).Explain the changes in BOD shown in the diagram

Dissolved oxygen level is high in unpolluted water; decreases rapidly at sewage discharge to the minimum; and then increases gradually downstream, returning to a normal level further downstream. BOD is very low in unpolluted water, increases rapidly at sewage discharge then decreases gradually downstream. This is because of decomposition of organic components of sewage by aerobic bacteria coupled with reduced photosynthesis because of low illumination caused by suspended solids in sewage rapidly reduce oxygen (cause oxygen sag) and create a high BOD at outfall. The gradual increase of dissolved oxygen downstream is because of increased photosynthesis and dissolution from atmosphere. The death of aerobic bacteria due to reduction in organic substances decreases BOD downstream.

(b).Describe the changes in the

(i). physical and chemical components

Dissolved oxygen; drastically decreased within a short distance downstream after the sewage outfall to minimum then gradually increased further downstream to a maximum; above the level in unpolluted water upstream;

Suspended solids; downstream decreased gradually after the sewage outfall; to a level downstream, that is similar to that in unpolluted water upstream; remained constant further downstream.

Salt levels; decreased gradually downstream to a level that is higher than that upstream in the unpolluted waters; remained constant further downstream.

BOD; initially decreased very slightly downstream; then further downstream it is decreased more gradually to a level that is higher than in the unpolluted water upstream;

Ammonium ion (NH_4^+); concentration increased drastically to the maximum at a short distance downstream from the point of sewage outfall; they decreased gradually further downstream and remained constant; at a level slightly higher than that in unpolluted water upstream;

Nitrate ion (NO_3^-); initially decreased to a minimum with a short distance after a sewage outfall; then it increased gradually to a maximum; further downstream it decreased gradually and then remained constant; at a level higher than in unpolluted water upstream;

Phosphate ion concentration; increased gradually to a maximum; at short distance downstream from the point of sewage outfall; there after it decreased much gradually then remained constant downstream; at a level slightly higher than that in unpolluted water upstream. In unpolluted water upstream, there was no sewage fungus

(ii).micro-organisms

Sewage fungus; increased gradually to a maximum & short distance downstream after the point of sewage discharges; thus after it decreased gradually to a minimum & remained; constant further downstream;

Cladophora; was not in unpolluted waters upstream and only appeared further downstream; there numbers gradually increased to a maximum; then decreased gradually further downstream;

Unicellular heterotrophs; were few in unpolluted waters; after sewage outfall they increased gradually to a maximum; then decreased gradually and remained constant further downstream;

Algae; population was higher than other micro-organisms in unpolluted waters upstream; after the sewage outfall algae decreased gradually to a maximum further downstream thereafter algae decreased gradually and finally remained constant; at a level slightly higher than that in unpolluted waters upstream;

Bacteria; were more than unicellular heterotrophs in unpolluted waters but less than algae; after the sewage outfall bacteria drastically increased to a maximum at the point of discharge they then decreased gradually and more gradually downstream; thereafter bacteria remained constant at a level slightly higher than that in unpolluted waters upstream;

(iii).Aquatic invertebrates

Tubificidae was the least in the unpolluted waters; increased gradually after sewage outfall; to a maximum a short distance downstream; before any other invertebrate hits its maximum; thereafter it decreased gradually and remained constant downstream; at a level comparable to that in unpolluted waters upstream;

Clean water fauna was the highest in the unpolluted water; after the sewage out fall they decreased drastically and were totally absent a short distance downstream from the point of sewage outfall; further down there appeared and increased gradually to a number comparable to those in unpolluted waters upstream;

Chironomus were few in unpolluted waters upstream; after the sewage outfall they decreased slightly to a minimum a short distance after the point of discharge; they increased drastically to a maximum midstream; after which they decreased initially drastically then gradually and finally remained constant; further downstream.

Asellus was higher than Chironomus and tubeficidae fauna but less than clean water fauna in the unpolluted waters upstream; after sewage out fall they decreased drastically and soon disappeared for a distance downstream but shortly before the clean water fauna.

Question 25.

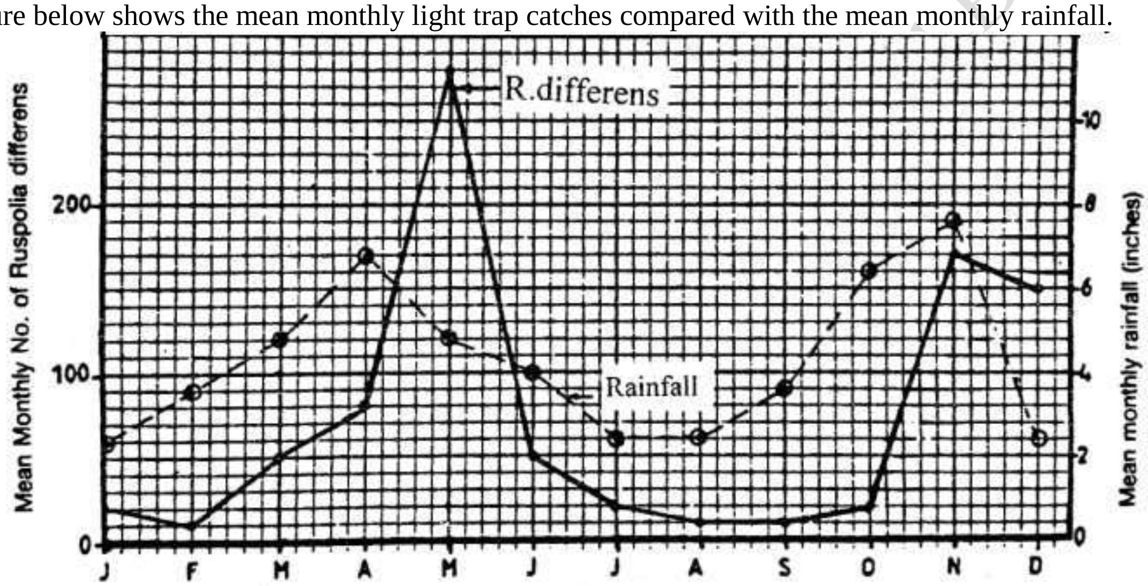
Part 1.

Ruspolia differens is a swarming East African grasshopper referred to as Nsenene (in Luganda). There ca- n be two alternative colours of Nsenene, namely green or brown depending on the environment. Table be- low shows the percentage of the green grasshoppers compared with the greenness of the grass where they live.

Month	J	F	M	A	M	J	J	A	S	O	N	D
Percentage greenness of grass	40	10	50	90	90	80	50	30	10	70	70	60
% of green grasshoppers	50	30	50	90	85	30	75	45	40	80	70	65

(a).Using the data provided, draw a graph to show the relationship between the colour of the grass-hoppers and the colour of grass.

(b). Figure below shows the mean monthly light trap catches compared with the mean monthly rainfall.



(i).In which months would you expect to find an abundance of green grass? Explain why?

Abundance of green grass is in April to May; then October to November

Explanation: In these months the percentage greenness of grass is high; also there is an abundance of rainfall, which promotes plant growth

(ii).Suggest in which months you would expect swarms to occur in R. differens

Swarms of R. differens are likely to occur in May and November; in these months they afford camouflage from the high percentage greenness of grass and obtain food from the abundant grass

(c) Explain how rainfall may affect the swarming behaviour of the grasshoppers

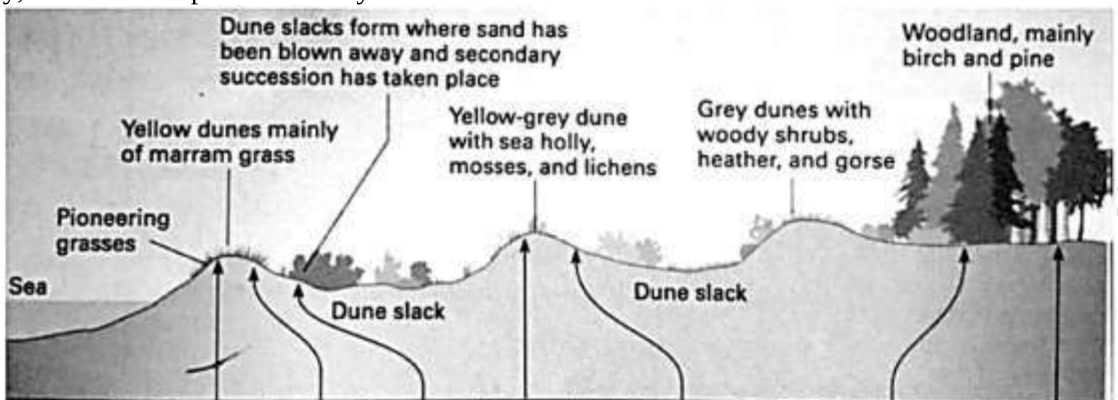
Following a rainy season, many plants sprout; increasing the percentage greenness of grass and camouflage; incr- easing in number. Reduction in rainfall leads to drying up of plants; % greenness of grass decreases; the grass ho- ppers have little or no camouflage are less eaten and also have little grass to feed on; many die and their numbers decrease with time. The grass hoppers have evolved to synchronize their breeding cycle with rainfall pattern; eggs hatch and develop into adults in the rainy season; which live for a short time; mate and lay eggs; which survive through the dry season;

(d)Briefly describe the life history of a grasshopper bringing out clearly the morphological differences bet- ween the adults and juvenile form.

Grasshopper show incomplete metamorphosis; eggs hatch into nymphs when suitable conditions are available; The nymphs undergo series of moults; allowing for growth and development into adults. The nymphs resemble adults but lack wings; which develop later on after several moults before the adults emerges; the nymphs also lack mature reproductive organs

Part 2.

The figure below shows the changes in soil properties and plant communities on a land scape and sand dune at st-udland bay, dorset over a period of 365 years



Age/years	0–65	65–95	95–125	125–185	185–245	245–365	> 365
Soil pH	6.6–7.0	4.8–5.5	3.9–4.6	3.9–4.5	3.9–4.5	3.6–4.5	~ 4.5
Humus/%	0.2	0.6	2.5	3.2	8.2	13.5	> 40
Colour of soil	Yellow			Yellow-grey		Grey	Brown

(a)(i).With a reason, identify the type of primary succession that took place at stud land bay. ***(01 marks)***

Hydrosere; changes / succession begins with an aquatic ecosystem/ sea

(a)(ii)State two abiotic factors that would prevent the observed changes on the water body from taking place.

Constant high water table

Water flowing at a faster speed through the sea.

(iii).Identify which of the factors changing on the bay are physical and chemical ***(02 marks)***

Physical factors- colour of soil

Chemical factors; Soil pH, humus

(b)Explain the observed changes in the soil properties over the 365 years period

(i).Soil pH

(ii).Humus

(iii).Colour of soil

(c).Basing on evidence from the table, state the period of time when primary productivity of the ecosystem is highest

365; highest humus content; more nutrients availed; supporting more plant growth

(d).Describe the events that lead to the observed changes in landscape between zero(0) years and 65 years

Organic matter builds up from the dead remains of plants and animals and sediments brought in by water running off the land; plants growing around the shore consolidate and dry out the debris at the sea margin; leading to soil formation; floating plants colonize more open waters and reed swamps plants extend further into formerly open water; progressively sea is filled by organic debris and plant life. Sea is eventually reduced to marshy area; with a stream flowing through it, with trees of dry land replacing the alders later builds up into aerated and drained soil;

(e).State the factors that affect the number and diversity of species reaching an area

(f).How does the pioneer community differ from climax community?

Question 26.

The table below shows changes in population of a prey (snowshoe hare) and its predator (lynx) over a period of years of study

Year	1845	1855	1865	1875	1885	1895	1905	1915
Preys in thousands	50	180	150	70	250	30	95	130
Predators in thousands	10	20	50	15	60	90	18	50

(a)(i). Using the same axes, draw graphs to show the changes in the population of the prey &the predator over the years.

(ii). Describe and explain the changes in the populations over the years

Generally the population of prey was higher than that of the predator population except in 1895; This is because abundance of prey determines the population size of the predator; when the prey is scarce the predators starve to death or migrate to new habitats; Also the prey has a higher reproductive rate than the predator. An increase in the predator population limited further increase in prey population since with increased predators the prey was greatly eaten; A reduction in the predator resulted in prey being less eaten; the prey increased in number. A drastic reduction in predators between 1865 to 1875; resulted in a drastic increase in prey in the next ten years; maximum prey was in 1885; This provided abundant food to the predators such that they rapidly increased in number to a maximum in the next five years and hence their numbers rose above that of the prey; in 1895. This was followed by a drastic decrease in prey population as they were greatly eaten by the many predators. Drastic decrease in prey resulted in drastic reduction in predators as they starved to death or migrated to new habitats.

(iii).Describe the type of graph of the prey population which could be obtained if there were no predators in the habitat.

In absence of predators the prey population would show an S-shape of population growth. With the initial lag phase, the prey population would increase slowly; followed by an exponential phase; with a drastic increase; then would increase steadily /linearly and finally reach a maximum; at the maximum the population would show fluctuations about the carrying capacity with periodic increase and decrease;

(b).Outline the procedure you would follow to determine the population size of buffalos in any of Uganda's national parks.

Suitable method is aerial photography

Materials: overhead air craft, good camera, park maps

Procedure

By means of aircraft the park is patrolled to locate the animals; photographs are taken from the aircraft from strategic places; numbers in the developed photographs are counted; several counts can be made from photographs taken at the different regions of the park. Results are tabulated and population size can be estimated from the following formula

$$\text{Population size} = \frac{\text{Total average number of photographs} \times \text{Total area of the park}}{\text{Total average area photographed}}$$

Other methods that can be used include

Strip census: This involves counting the numbers of buffalos along a straight path or strip over a period of time. Average numbers are summed from which the population estimate can be established.

Line transect; Counting stations are established along a straight line marked by pegs. The numbers of buffalos in each counting station is recorded at fixed time intervals over a period of time.

The population size is estimated from

$$\text{Population size} = \frac{\text{Total average number in counting station} \times \text{total area of the park}}{\text{Total average area of counting station}}$$

A belt transect involves establishing courting stations between two line transect.

Question 27.

An analysis of oxygen dissolved, pH in upper layer and productivity was carried out in one of Uganda's most productive lakes. The results of this analysis are shown in the tables below. Study the tables and answer the questions that follow.

Table 1; OXYGEN DISSOLVED AND PH

	Dark (night)			Day (light)			Dark (night)		
Time in hours	24.00	3.00	6.00	9.00	12.00	15.00	18.00	21.00	24.00
% saturation of O_2	65	55	35	65	85	115	105	85	75
Ph	6.6	6.5	6.4	6.6	6.8	6.8	7.0	6.8	6.7

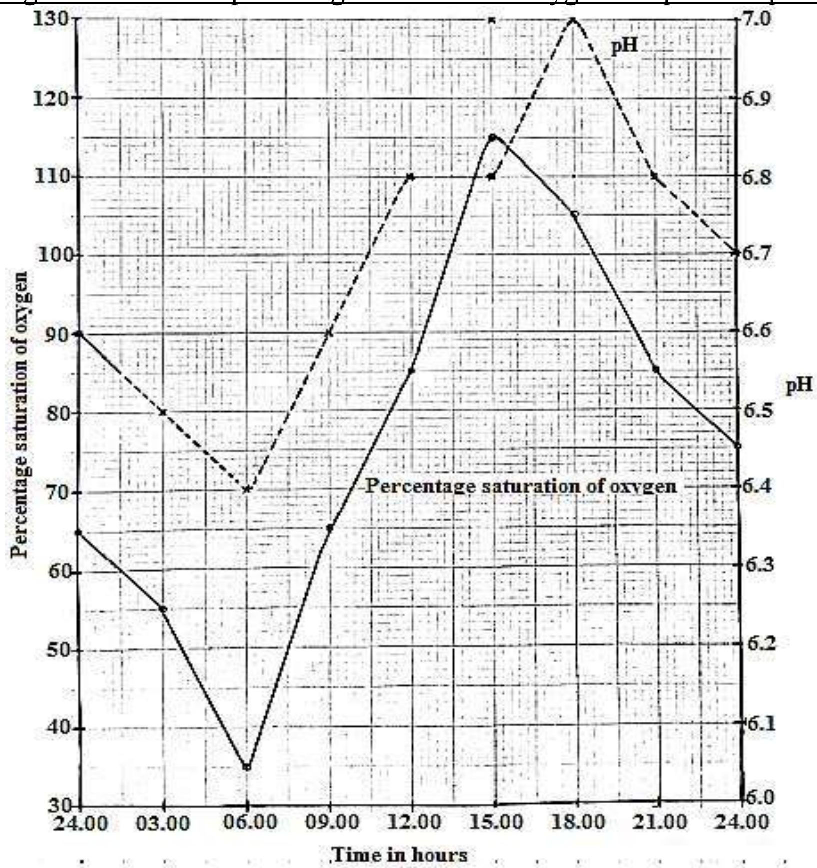
Table 2; PRODUCTIVITY

	In still air			Windy air		
Zone and depth(m)	Day	Dark	Net productivity	Day	Dark	Net productivity
Limnetic 100	3.03	1.03	2.00	2.70	0.3	2.40

Littoral 300	7.05	1.05	6.00	7.80	2.0	6.80
Profundal 500	4.70	0.40	4.30	5.30	0.6	4.70
Benthic 700	1.30	0.10	1.20	0.40	0.2	0.20

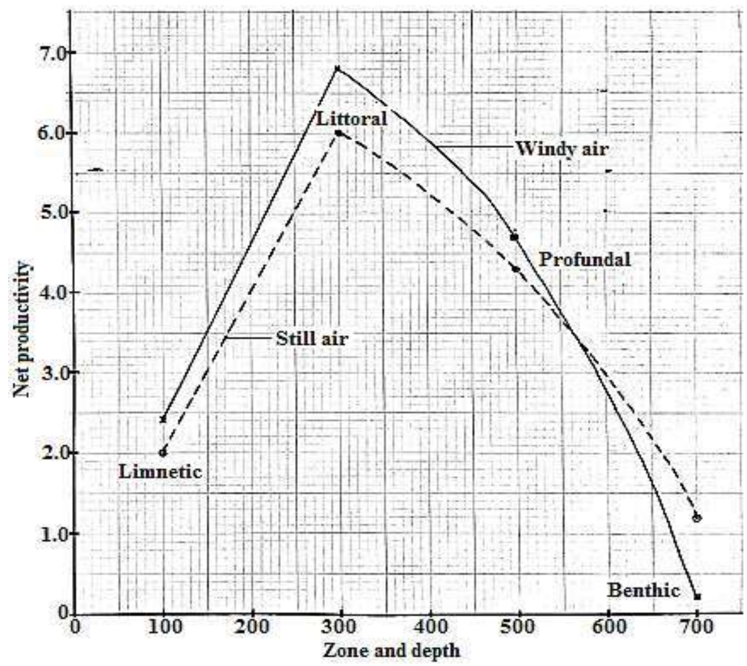
(a)(i)On the same axes, plot a graph of percentage saturation or oxygen and pH for a period of 24 hours.

A graph showing the variation of percentage saturation of oxygen and pH for a period of 24 hours.



(ii) Plot a graph of net productivity in the different zones/layers of the lake under still and windy conditions.

A graph showing the variation of net productivity of different zones in the lake under still & windy conditions



(b)(i).Describe and explain the pattern of oxygen content dissolved and pH in the upper layer of the lake for a period of 24 hours. ***(10 marks)***

In darkness from 24.00-6.00, the percentage saturation of oxygen rapidly declines; because there is no photosynthesis to release it but respiration is maximally consuming oxygen; during the same period, the pH falls rapidly because respiration releases carbondioxide which dissolves forming carbonic acid; During the day (between 6.00-15.00), there is a sharp rise in both pH and percentage saturation of oxygen; because photosynthesis is taking place releasing oxygen; and consuming carbondioxide; Between 12.00-l 500 hours, the percentage saturation of oxygen remains constant; because the compensation point is attained; Between 18.00-24.00, both percentage saturation of oxygen and pH sharply decline; because darkness has set in again; no photosynthesis; but respiration is maximally releasing carbondioxide;

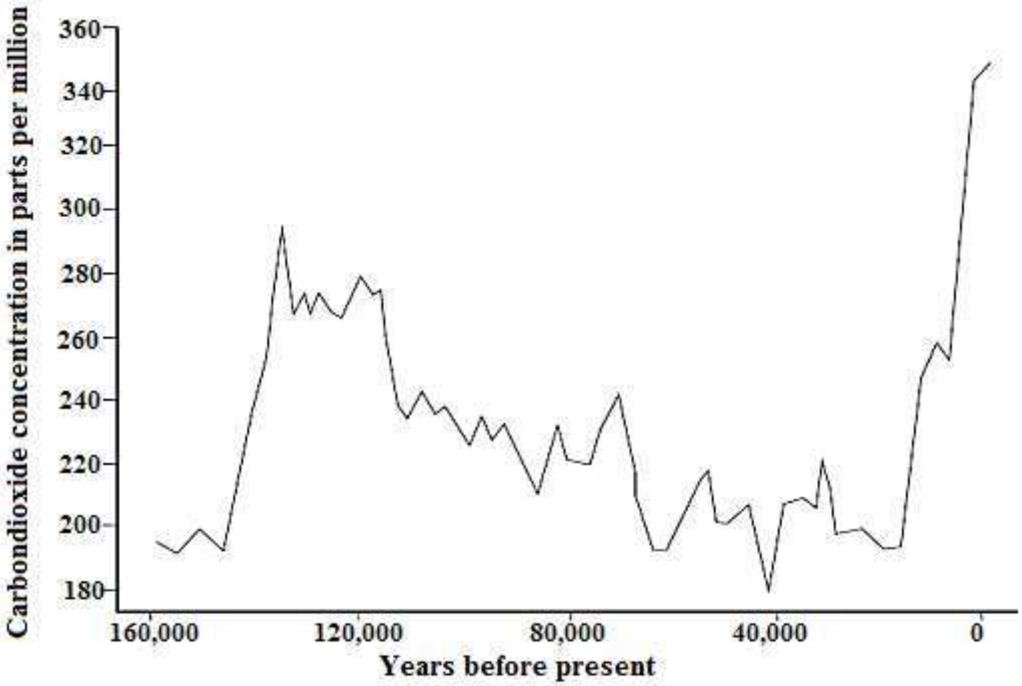
(ii)Describe and explain the pattern of variation of productivity in still and windy conditions in the different layers of the lake. ***(09 marks)***

Productivity is low in the limnetic zone; because this is the uppermost layer of water body and is a region of high disturbance due to the wave action so it is not inhabited by phytoplanktons; productivity increases to a peak in Littoral zone; which is a zone of effective light penetration and no wave action; so inhabited by many phytoplanktons responsible for highest productivity; Productivity sharply declines through the profundal to the benthic zone because of a decrease in light penetration; in the benthic zone; no light reaches and any productivity is due to chemosynthesis; Net productivity is higher under windy conditions. There is under still air conditions; in all layers of the lakes except benthic; because windy air ensure better dissolution of gases/oxygen/carbondioxide; Photosynthesis; and mixing of water for better distribution of heat; and nutrients.

(c).State and explain two other physical factors which may influence productivity of lake. ***(06 marks)***

Temperature; water has a cooling effect and usually lowers the temperature limiting enzyme controlled reactions of the dark stage.

(d). The graph shows changes in atmospheric carbon dioxide levels over the last 160,000 years.



(i) Describe and explain the causes of increasing atmospheric carbon dioxide concentration.

Increased burning of fossil fuels/ coal/ oil oxidizes carbon forming carbondioxide; increased deforestation thus less carbondioxide used in photosynthesis; oceanic pollution reduces phytoplankton levels which fix the gas in photosynthesis decreased oceanic storage of the gas; temperature increases since solubility of CO_2 in water decreases as temperature rise.

(ii).Explain why global warming may accelerate loss of biodiversity.

Organisms may be unable to adapt with sufficient speed to changes in temperature/ rainfall/ water availability; die out and interrupt the food chain/knock on effect sea level rise will cause flooding/ habitat destruction.

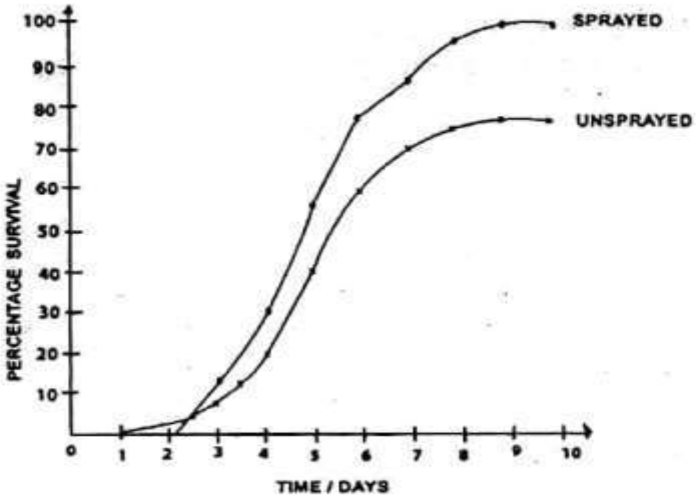
(iii).Outline the indicators of global warming in the world today

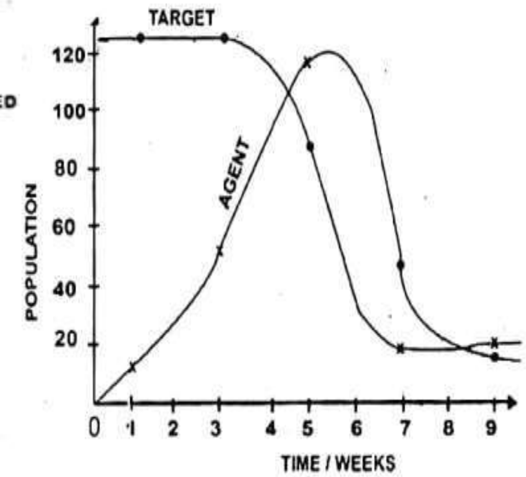
- Plants of a species flowering and fruiting at different times of the year.
- Change in seasons/ weather or climate changes in a given area
- Increased occurrence of epidemics;
- Hurricanes on the increase;
- Longer dry seasons; melting of polar ice;
- Rise in sea levels; increasing cases of sea waves and currents;
- Skin cancer due to ultraviolet light from the sun;
- Migrations of the fauna e.g birds

Question 28.

In an experiment to study the effectiveness of DDT towards the cabbage pest Pieris rapae which feeds on cabbage leaves, two adjacent farm yards were prepared and Pleris was introduced in each farm and left for sometime. After spraying one farm yard with DDT for three consecutive times, the number of eggs that survived and hatched into larvae at the sprayed and non-sprayed farm yards was determined as shown by Graph A

In another set of experiment, Pieris rapae was exposed to birds as its control agents and the changes in the population of both with time was determined as indicated by Graph B. Study the graphs and answer the questions that follow.





(a)(i).Account for the increase in the population of the control agent ***(05 marks)***

The population of the control agent was initially low; then increased gradually for the first 3 weeks; because the control agents were adapting to their new environment; and there were fewer reproductively potential members at that time; From 3 weeks to 5.5 weeks; the population of the control agents increased rapidly; attaining maximum/ peak population at 5.5 weeks; because the control agents have got adapted to their new environment; The steady food supply offered by the target species; prompted maturation of many control agents to reproductive age; thus reproduced rapidly; This higher reproductive rate and the minimal density dependent determinants of population size(eg competition, food scarcity, accumulation of toxins) prompts a higher birth rate and a lower death rate of the control agent; causing a rapid population growth;

(a)(ii).Explain the decrease in the population of the control agent ***(05 marks)***

Population of the control agent decreased rapidly from 5.5 weeks to 7 weeks; then decreased slowly from the 7th week to the 9th week; because the intense predation pressure imposed on the target organisms; rapidly crashed their population; causing food shortage to the control agents. Onset of density dependent factors eg accumulation of toxic wastes; diseases; limited space; stiff competition for the limited resources (food, mates, space etc) compromised survival and reproductive potential of the control agents. Many control organisms thus died due to these environmental resistances; making their death rate exceed birth rate;

(b)(i). Account for the decrease in the population of Pieris rapae ***(05 marks)***

There was a gradual decrease in the target population from the 3rd week to the 4th week; then rapid decrease in the target population from the 4th week to the 6th week; Population then gradually decreased from the 6th week to the 7th week; The overall decrease in population size of the target organisms was due to the rise in the population of the control organism; that imposed an intense predation pressure; onto the population of the target organisms. The onset of density dependent factors like accumulation of toxic wastes; diseases; interspecific competition for food, space etc might have compromised reproductive potential of the target population; Many target organism thus die due to these environmental resistances; making their death rate exceed birth rate; translated into a decrease in target population;

(b)(ii).Account for the population of Pieris & that of control agent from 8.5 to 9th week ***(04 marks)***

Equal population size for both the control and target organisms at 8.5 weeks; because two populations had established equilibrium; Population of the control organisms however decreased slightly below that of the target organisms; between 8.5 weeks and 9 weeks possibly due to existence of a natural predator to the control agent that continued to exert a predation pressure to the few remaining control organisms such that their numbers kept depreciating;

(c).Compare the number of eggs of Pieris between the sprayed &non-sprayed farm yards ***(05 marks)***

Similarities

- Generally percentage survival of eggs increases with time in both sprayed and unsprayed farms.
- Equal percentage survival of eggs at 2.4 days; in both sprayed and unsprayed farms.
- Both sprayed and unsprayed farms; attain maximum percentage survival of eggs in the same time range.

• For both sprayed and unsprayed farms; percentage survival of eggs rapidly increase between 4 to 6 days;
• For both sprayed & unsprayed farms; percentage survival remain constant between the 9th and 10th day;

Differences

Percentage survival of eggs in the sprayed farm	Percentage survival of eggs in unsprayed farm
Zero between 1 and 2.4 days/ lower	Slowly increasing/ higher
Higher beyond 2.4 days	Lower beyond 2.4 days
Increases rapidly from 2.4 days to 4 days	Increases gradually from 2.4 days to 4 days;
Attains higher maximum	Attains lower maximum

(d).Account for the differences in the number of eggs of Pieris at the sprayed and non-sprayed farm yards

The sprayed farm initially had a lower percentage survival of eggs (no egg surviving for the first 2 days) because of use of DDT; a non-specific pesticide that initially kills both the pest and their natural predators; Percentage survival of eggs in the unsprayed farm was higher initially(existed right from the first day) because pest population was being checked by the pest‘s natural predators; Later the percentage survival of eggs in the sprayed farm increased more rapidly and became higher than that for unsprayed farm because of emergence of pest resurgence. A few surviving pests subjected to DDT; mutate and become resistant strains to the pesticide. Over time, such resistant pest populations grow so rapidly without being checked upon by their natural biological predators unlike the pest population in the unsprayed farm that is constantly being checked upon by the natural predators. As a result, the resistant pest population booms; past the habitat's carrying capacity; despite continous aggressive pesticide application.

(e).Explain any one property of DDT other than the one shown above which renders it unsuitable for environmental use ***(05 marks)***

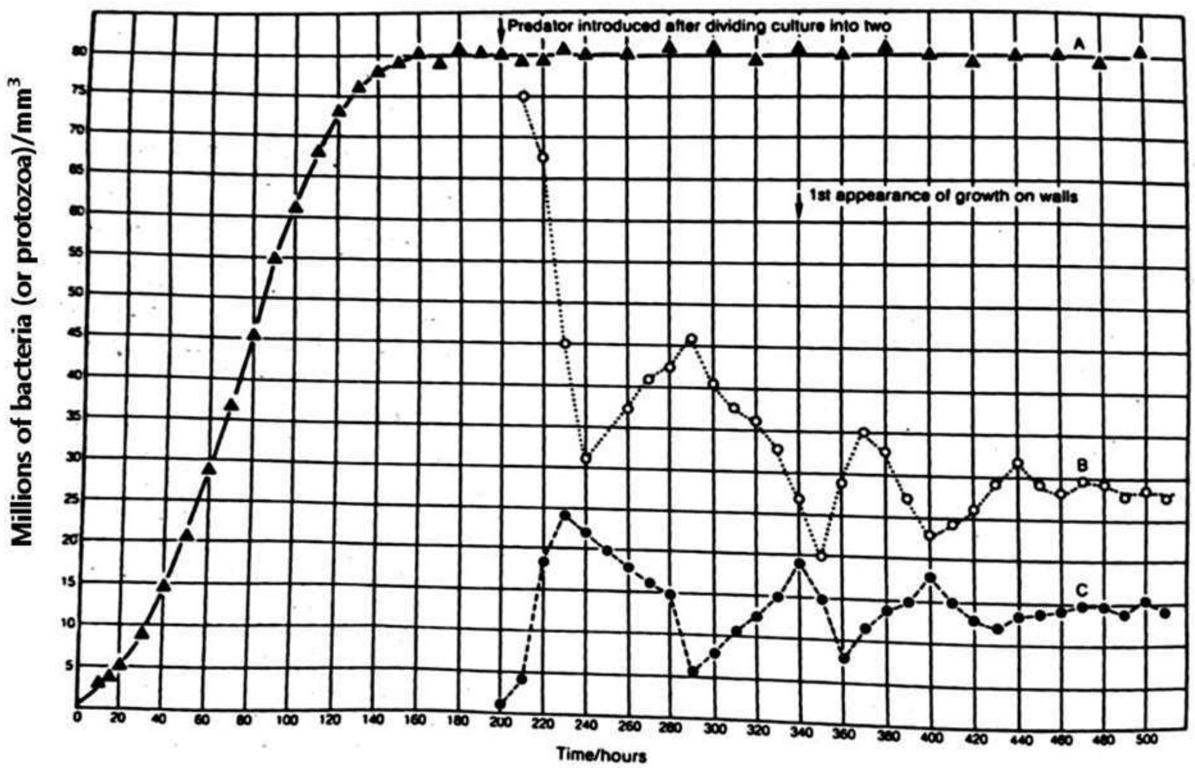
Persistence/ non-biodegradability in the ecosystem; DDT is not readily biodegradable and thus persist in the environment for long periods of time. It thus concentrates in fat tissue of plants and animals. As one organism eats another, the toxin becomes more and more concentrated resulting in biomagnification/ bioaccumulation. Biomagnification is disastrous to top carnivores as toxicity of the accumulated DDT may result in infertility, induce hormonal changes that affect calcium metabolism making birds lay thin shelled eggs that consequently break. Such hindrances to reproductive success may threaten extinction of top carnivores.

(f).Outline any three advantages of the method used in Graph B to that used in Graph A. ***(03 marks)***

• Cheaper as compared to chemical means;
• Has little environmental impacts/ not very harmful to the environment/ does not cause pollution;
• An effective long term control tool; unlike chemical means that is associated with pest resurgence.
• Bioaccumulation; toxicity to members of higher trophic levels is non-existent in biological pest control.
• Doesnot affect biodiversity unlike the non-specific pesticides that kill pests & their predators;
• Accidental misuse of toxic chemicals that can result in death of humans and domestic animals doesnot occur with biological pest control.

Question 29.

A bacterial culture was established in liquid medium at an initial concentration of 1 million bacteria per mm^3 of solution. The growth of the culture was monitored by sampling every 10 hours and counting the number of bacteria in the sample. The results are shown graphically below. After 200 hours the culture was split into two equal volumes labelled A and B in the figure. A protozoa was introduced into the culture B and the subsequent changes in the protozoa numbers were plotted in culture C. Study the information fully and answer the following questions



(a). State the time range during which the bacterial culture is growing at its maximum rate in the absence of the protozoa. ***(02 marks)***

Between 20 hours and 80 hours

(b) State how long it takes the bacteria colony to double its number in the absence of the protozoa

(i).After the colony has been growing for 40 hours ***(01 marks)***

72 hours–40 hours = 32 hours; accept between 30–34 hours

(ii).When number present is 35 million per mm^3 ***(01 marks)***

Time from 48 hours up to 92 hours = 44 hours; accept 42-48 hours

(c). Explain the difference between your answer to b (i) and (ii) ***(02 marks)***

It takes a shorter time for the bacteria number to double when it has been growing for 40 hours because no environmental resistance; but when the population is 35 million it takes longer time because environmental resistance factor sets in.

(d).Explain the change in the bacterial population after 80 hours ***(09 marks)***

Gradual increase/slow increase in population of A from 80 up to 112 hours is because environmental resistance sets in accumulation of own toxic wastes; severe competition for limited space, oxygen if aerobic nutrients; from 112 hours up to 380 hours, the population of A remained constant because birth rate balances with death rate or carrying capacity/too much toxins. From 108 up to 160 hours, population of bacteria B decreased rapidly because of introduction of protozoa which feeds on bacteria B; from 160 up to 200 hours, population of bacteria B increased rapidly because of decrease in the population of protozoa/some protozoa were feeding on bacteria B. From 200 up to 260 hours. The population of bacteria decreased rapidly because those protozoa feed on the bacteria ounce again; from 260 up to 360 hours, the population of bacteria rises and falls very slowly fluctuating at almost constant levels because of the wall growth so can escape predators (Protozoa).

(e)(i) Describe the relationship between the population of the bacteria in B and the protozoa in C up to 260 hours ***(04 marks)***

From 100 up to 160 hours; as the population of protozoa increases rapidly its population of bacteria decrease rapidly; from 160 up to 200 hours as the population of protozoa declines rapidly the population of bacteria increases rapidly to a peak; population of protozoa declines rapidly while the population of bacteria increases rapidly to the peak. From 200 up to 220 hours, population of protozoa decreases with decrease of population of the bacteria both population of protozoa and bacteria decrease.

(ii). Explain the relationship in e(i) above ***(08 marks)***

From 100 up to 160 hours protozoa is a predator and feeds on its prey the bacteria; population of bacteria is high providing enough food for the protozoa but the population of bacteria declines rapidly. From 160 up to 240 hours, the population of bacteria is too low at its minimum causing many protozoa to starve to death. Few protozoa feed on bacteria due to decline; their population while bacteria get the chance to reproduce too many bacteria give chance for the protozoa to increase again.

(f).The protozoa stays in the liquid part of the culture medium but the bacteria in B soon were observed to form colonies on the walls of the vessel

(i).Explain how growth on the walls may be an advantage to the bacteria in this experiment. Use evidence from the graph. ***(05 marks)***

Wall growth gives two separate habitats so the bacteria can escape predation and the population of both bacteria and protozoa will remain constant; reach carrying capacity since from about 320/340 up to 360 hours the population of both protozoa and bacteria B remained almost constant.

(ii).Comment on the possibility of wall growth in A ***(03 marks)***

Wall growth is not possible in A since there are no predators, the liquid part at the bottom is due to absence of factors limiting distribution of the liquid part.

(iii).If no wall growth occurs in B, explain what would happen to the bacteria and protozoa population

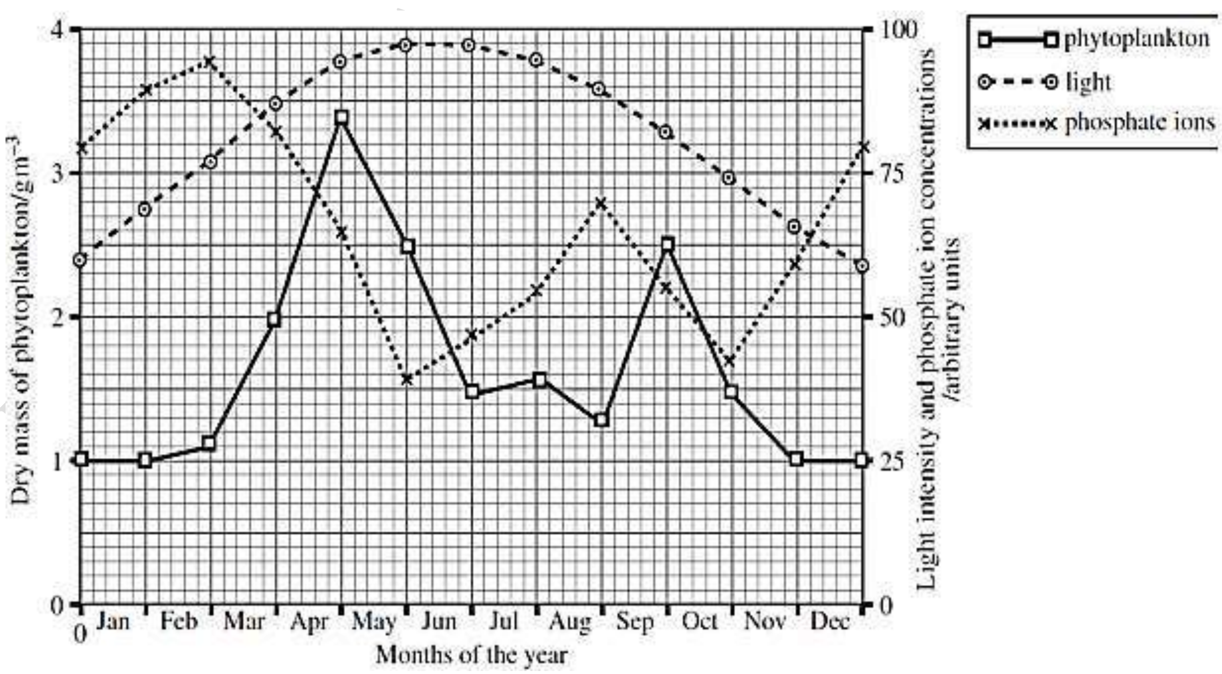
Their population would continue to fluctuate; in predator-prey relationship

(g).How do the results of the experiment relate to natural ecosystem? **(02 marks)**

- Organisms separate niches/habitats to reduce a competition
- Organisms migrate/immigrate to avoid predation
- Population remain constant at carrying capacity
- It takes time for organisms to adapt to new habitats
- Predator-prey relationship occurs in a population

Question 30.

The graph below shows abundance of phytoplankton (microscopic plants) throughout one year in the surface waters of a lake. The changing amounts of light and phosphate ions in the water are also shown in the graph. Phosphate ions are necessary for the growth of the phytoplankton.



(a).Comment on the relationship between dry mass of phytoplankton with;

(i) light intensity over the year ***(03 marks)***

At low light intensity, dry mass of phytoplankton is low; increase in light intensity increases the dry mass of phytoplankton and decrease in light intensity decreases the dry mass of phytoplankton.

(ii).phosphate ion concentration over the year ***(10 marks)***

When the dry mass of phytoplankton is low at the start in January, the phosphate ion concentration was high. Increase in the dry mass of the phytoplankton resulted in decrease in phosphate ion concentration up to late May. The decrease in phosphate ion concentration resulted into decrease in dry mass of phytoplankton up to July and this resulted into increase in phosphate ion concentration up to September. The increase in phosphate ion concentrati-ion resulted into increase in dry mass of phytoplankton up to October. The increase in dry mass of phytoplankton later resulted into decrease in phosphate ion concentration which in turn resulted in decrease in dry mass of phytoplankton The decrease in the dry mass of the phytoplanktons caused increase in phosphate ion concentration up to December.

(b).Describe and suggest an explanation for the changes in the phytoplankton population during the months of May and September. ***(07 marks)***

In May, phytoplankton population is decreasing rapidly hem 349gm^{-3} to 2.5gm^{-3} due to in decreasing phosphate ion concentration and much light in march and April that favoured much productivity and due to this resources become limited hence competition results into death hence the rapid decrease. In September dry mass increased rapidly from 1.3gm^{-3} to2.5gm^{-3} due to increasing/ high phosphate ion concentration and favourable light intensity.

(c) The zooplankton populations peak twice during the year. During which months are these peaks most likely to occur? Explain your choice. ***(02 marks)***

June and Nov because zooplankton populations peak after phytoplankton population since they feed on phytoplanktons.

(d).Discuss how different biotic factors affect distribution of organisms in an ecosystem. ***(18 marks)***

Parasitism; parasites feed on the host. Parasites are either on the bodies of their hosts or within their close microenvironments e.g leeches and black flies are micro-predators that feed on man and are distributed in man‘s environment, ticks on cattle etc

Competition; here two organisms compete for the same resources; can be intraspecific or interspecific. Competitively inferior organisms are distributed in habitats devoid of competevely superior organisms.

Mutualism; each organism benefits from the relationship. The two mutually existing organisms co-exist in the same microenvironments.

Predation; one organism called the predator feed on the other called the prey. Predators are thus distributed in areas with a high number of preys while preys opt for areas devoid of predators.

Commensalism; here one organism benefits and the other neither benefits nor gets harmed. Benefiting organisms are distributed in areas occupied by the non-benefiting commensal.

Dispersal agents; Certain plants may rely on insects or other small animals for dispersal and pollination. Their distribution therefore depends on such organisms.

Mimicry behaviours; some animals closely resemble other species unpalatable to their predators. As such the distribution of these animals depend on presence of species they resemble.

Camouflaging behaviour; some organisms have developed structures that make them blend with their immediate environment lie tree barks, leaves or thorns. As such the distribution of such organisms depends on the presence of plant species they resemble.

Disease vectors/ pathogens; decline the distribution of susceptible organisms.

Question 31.

When DDT was first manufactured it was used as a method of controlling housefly populations. The populations of two species of houseflies and the spider were monitored over a period of thirteen months. Shortly after the second month of data collection the DDT was applied and it was not toxic to the spider. The results of the study are recorded are recorded in table 1 overleaf. Study the table carefully and answer the following questions.

Time (months)	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Housefly W(x1000)	35	35	35	20	2	7	17	32	50	65	79	88	82	81
Housefly Y (x 1000)	79	82	79	80	62	40	17	0	-	-	-	-	-	-

Spider R (x1000)	72	76	81	78	66	56	49	46	46	48	55	70	85	86

(a) Plot suitable graphs on the same axes to represent the results in the study.

(b)(i) How does the population of the spider relate with the populations of the houseflies in this investigation?

In the first 4 months, the population of the spider was fluctuating about the norm similar to that of population of housefly Y as the population of housefly Y decreased rapidly from the fourth month to the 8th month, that of the spider also decreased rapidly from the 4th month to the 7th month then gradually to the 8th month before attaining a constant from the 8th month to the 9th month. The population of housefly W remained constant for the first 3 months. Its population then thereafter decreased rapidly from the 3rd month to the 5th month. As the population of housefly Y decreased from the 5th month to the 8th month rapidly to extinction that of W increased rapidly from the 5th month to the 12th month to a maximum The spider population also increased gradually from the 9th to the 10th month and thereafter rapidly from the10th to the 13th month. From the 13th month to the14th month the population of spider continued to increase gradually as that of housefly W decreased rapidly at first from the 12th to the 13th month before decreasing gradually from the 13th to the 14th month.

(ii).Explain the relationship in the populations in (b)(i) above.

Initially the populations of the spider and housefly Y were at equilibrium. This was a predator-prey relationship where the spider was feeding more on housefly Y at the carrying capacity. High population of Y over W implies that the former had a competitive advantage over housefly W, whose population remained much lower. Decrease in population of housefly Y from the 4th year reduced the available food for the spider such that some of them starved to death due to competition among themselves. Significant decrease in housefly Y enabled population of housefly W to increase due to reduced competition between the two species of the houseflies. The low constant population of the spider was due to individuals transiting from feeding on housefly Y to W. With increase in the population of housefly W, the spiders subsequently fed on them and started increasing until they stabilized at higher populations.

(c)(i).How do you explain the effect of the use of DDT on the observed trends of the three populations of the animals?

The toxic DDT had an immediate effect of killing W but this effect came about a month later on housefly Y whereas it was able to kill species Y to extinction. Species W was able to develop resistance to DDT. The few files that survived reproduced and inherited the resistant variety and out competed the less resistant variety Y. Consistent use of DDT in the subsequent months became less effective in killing the flies W. DDT therefore, provided an environmental factor that resulted in natural selection.

(ii).Basing on the information given, what would happen if DDT was toxic to the spider?

The population of spider would have decreased rapidly. There would have been population explosion for housefly W if the spider failed to develop resistance to DDT. If the spider had developed resistance to DDT then their population and that of species W would have stabilized much later than it was observed.

(d)(i).Outline the properties of DDT as an effective pesticide in controlling population of pests.

DDT is highly toxic/ has a low LD 50;
DDT is persistent;
DDT is a broad spectrum pesticide/non-specific

(ii) Explain the following: Biomagnification, Bioaccumulation; and Bioremediation

Biomagnification/Bioamplification/biological magnification; is the rise in concentration of a substance such as a toxic organochemical in the tissues of tolerant organisms at successively higher levels in a food chain

Bioaccumulation: is the increase in concentration of a substance such as pesticides, or other organochemical in tissues of an organism; due to an organism absorbing a substance at a rate faster than that at which the substance is lost by catabolism and excretion; not being metabolized more so if it is lipid soluble thus embeds in adipose tissue

Bioremediation: is the use of either naturally occurring or deliberately introduced microorganisms to consume and breakdown environmental pollutants inorder to clean a polluted site.

Question 32.

Figures 1 & 2 show the results of experiments carried out on two species of flour beetle, *Tribolium* and *Oryzaephilus*, which were grown together in slightly different environments. In figure I *Tribolium* and *Oryzaephilus* were grown in plain flour culture while in figure 2 they were grown in a culture which had glass tubings. For each experiment four adult beetles of each species were introduced in the culture and the population size of each species was determined at regular intervals. Study the information and answer the questions that follow.

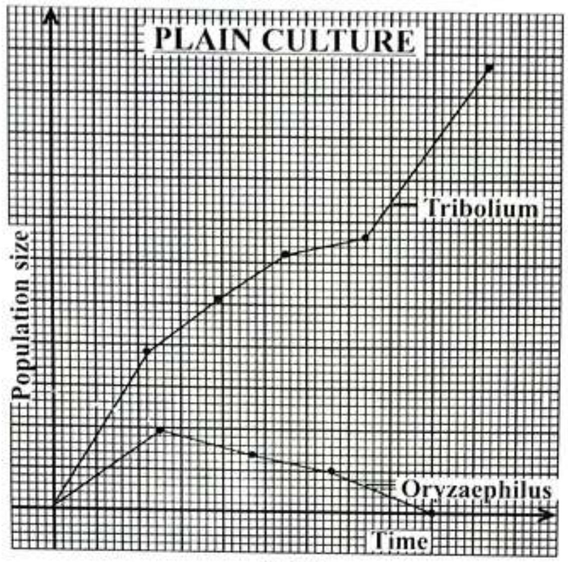


Fig. 1

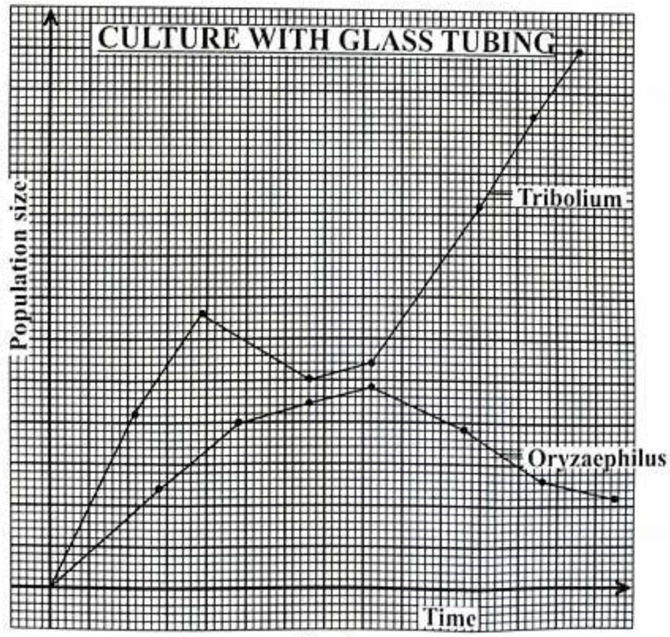


Fig. 2

(i). Compare the population growth during the time of the experiment for *Tribolium and Oryzaephilus* bettle in:

(i) figure l.

Similarities

• Population size of both tribolium and oryzaephilus reaches maximum
• Population size of both tribolium and oryzaephilus increases at the start of experiment

Differences

Population size of Tribolium	Population size of Oryzaepilus
Reaches maximum later	Reaches maximum earlier;
Does not reach a peak	Attains a peak;
Higher throughout the experiment	Lower throughout the experiment;
Increases rapidly at the start of the experiment	Increases gradually at the start of the experiment;
Increases gradually in the middle of the experiment	Decreases gradually in the middle of experiment;
Increase gradually and then rapidly at the end of the experiment	Decreases gradually to extinction at the end of the experiment;

(ii) figure 2.

Similarities

• Population size of both tribolium and oryzaephilus attains a peak;
• Population size of both tribolium and oryzaephilus increase at the start of the experiment;
• Population size of both tribolium and oryzaephilus decrease after the peak;
• Population size of both tribolium and oryzaephilus increases gradually in the middle;
• Population size of both tribolium and oryzaephilus increase at the start of the experiment;

Differences

Population size of tribolium	Population size of oryzaephilus
Attains a higher peak	Attains a lower peak;
Attains a peak earlier	Attains a peak later;
Increases rapidly at the start of the experiment	Increases gradually at the start of the experiment;
Decreases rapidly after the peak	Decreases gradually after the peak;

Higher throughout the experiment	Lower throughout the experiment;
Increases rapidly at the end of the experiment	Decreases gradually at the end of the experiment;

(b). Explain the population growth of the two species;

(i). Figure 1

Population size of tribolium increases rapidly as that of oryzaephilus decreases to extinction due to higher reproductive potential/growth rate of tribolium; hence putting oryzaephilus at a disadvantage in terms of competition for food/flour. At the end of the experiment the population size of tribolium increases rapidly in the absence of oryzaephilus; due to reduced competition for food/flour/habitat;

(ii).Figure 2

Glass tubings provide a microhabitat for oryzaephilus and hence giving it some advantage to compete with tribolium; In the middle of the experiment, population size of oryzaephilus increases gradually as that of tribolium is decreasing rapidly due to increased inter-specific competition. At the end of the experiment population size of tribolium increases rapidly as that of oryzaephilus deceases since tribolium is a better competitor. However population size of oryzaephilus does not decrease to extinction due to some oryzaephilus avoiding direct competition from tribolium by utilising the microhabitats provided by the glass tubings;

(c). Suggest what is being demonstrated by the interaction of the two species in;

(i) figure 1.

Gause's competitive exclusion principle; where two different species competing for the same resource; cannot co-exist; so the weaker species is outcompeted to extinction;

(ii) figure 2.

Resource partitioning; where two different species share the same resource then allow co-existence so both species survive;

(d). From the interaction of the species in figure 1 and 2, explain the effect of interspecific competition.

- Harmful to both species as they don't adequately utilize resources as they would do in absence of other species;
- Important in spacing out individuals; in areas where they can adequately obtain resources;
- Allows niche differentiation/specialization preventing niche overlap;

(e) Suggest what would happen if:

(i) the experiment in figure 2 was continued for some time.

Population size of tribolium would continue increasing; as that of oryzaephilus decreases; Population of both tribolium and oryzaephilus later decreases to extinction; due to food resources becoming scarce; and due to accumulation of wastes;

(ii) *Oryzaephilus* bettle was grown alone. ***(02 marks)***

Population of oryzaephilus would increase rapidly than when mixed with tribolium; to a carrying capacity where it stabilizes and later decreases due to scarcity of food;

Question 33.

In an investigation, pea plants were dug up from the field and washed thoroughly. The nodules were removed surface sterilized and transferred aseptically to a sterile liquid liquid culture medium. After two weeks incubation, small samples of the liquid culture medium were removed and added to trays each containing a batch samples of pea plants growing in an inert medium. Each batch was watered regularly with a nutrient solution containing a particular concentration of sodium nitrate for four weeks. At the end of the four weeks, the mean number of root nodules and biomass were obtained from the investigations as shown below.

Nitrate concentration of nutrient solution(arbitrary units)	Mean number of nodules per plant	Biomass of pea plants/ gm^{-2}
0	82	140
1	70	200
2	68	230
3	40	350
3.5	20	400
4	10	460
5	0	440

5.5	0	400
6	0	350

(a).Represent the results of the table above graphically

(b).Explain the effect of increasing nitrate concentration of nutrient solution on

(i). the mean number of nodules per plant

Between 0 and 3 arbitrary units, mean number of nodules per plant decreases gradually; nitrate concentration is still low with little inhibitory effect on root nodule per development. Between 3 arbitrary units and 5 arbitrary units, the mean number or nodules per plant decreases rapidly; nitrate concentration is high greatly inhibiting root nodule development; between 5 arbitrary units and 6 arbitrary units there is no root nodule development; nitrate concentration is very high completely stopping development of root nodules on plant.

(ii).biomass of pea plants

From 0 to 2 arbitrary units; biomass increases gradually; nitrate concentration is still low; rate of uptake of ions is still low; few proteins and hence less tissues are synthesized; From 2 to 4 arbitrary units, biomass increases rapidly; concentration of nitrates increased uptake of ions by the plant roots; more proteins and hence tissues are synthesized. Beyond 4 arbitrary units, biomass decreases gradually and then rapidly; very high concentration of nitrates increases the solute concentration of the surrounding solution above that of the plant cell sap. Plant tissues thus lose water to the surrounding by osmosis; causing wilting of the plant; reducing the photosynthetic surface thus reduction in rate of photosynthesis. Accumulation of organic molecules by photosynthesis is less than the utilization of such organic molecules during respiration/ more organic molecules arc respired compared to that fixed by photosynthesis.

(c). How was the accuracy of results to be obtained ensured throughout the experiment?

• Surface sterilization of nodules excluding other microbes
• Addition of sample medium to batches introducing bacteria (rhizobia) to stimulate nodule development
• Four weeks allowed for development of the nodules.
• Batch of plants used and averages obtained to reduce errors.
• Roots washed to expose the nodules clearly
• Sterile liquid used to prevent contamination.

(d)(i). On the graph draw a graph to represent the plot for biomass you would expect if the experiment was repeated and in this case the sample culture medium was not added to the trays containing pea plants

(ii) Suggest reasons for the appearance. of the graph drawn in d(i) above

Biomass is higher than when the sample was added; absence of bacteria in the batches cuts down the energy and nutrient utilization from the pea plants by the bacteria; thus being reserved for building biomass.

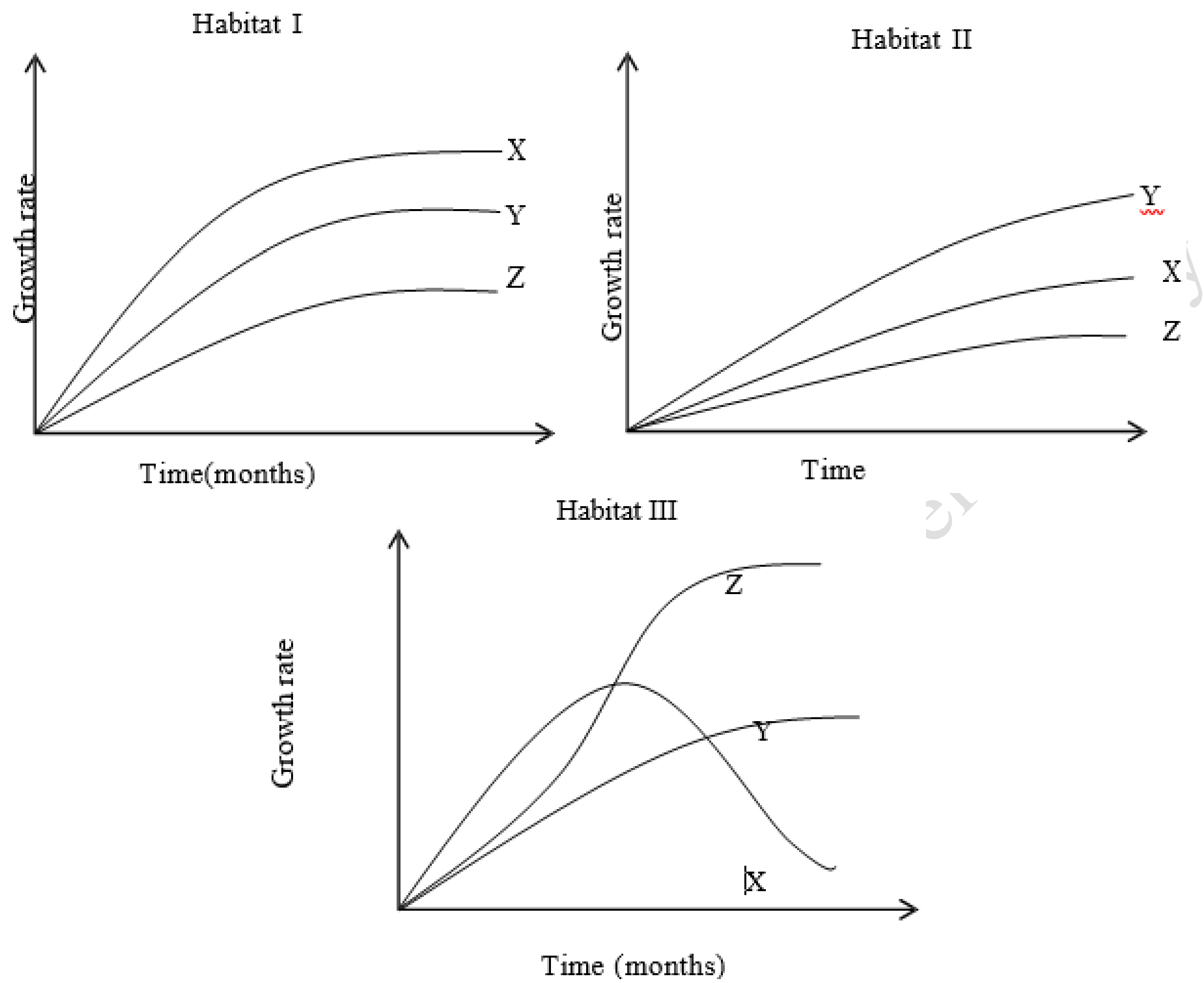
(iii). How can the information from the investigation be beneficial in crop production?

• Farmers would avoid excessive application of nitrogenous fertilizers to fields as it reduces crop production
• Apply small amounts of nitrogenous fertilizers by farmers in fields containing legumes to allow fixation of atmospheric nitrogen by the bacteria in the root nodules; cutting off the costs of buying fertilizers.
• In case of nitrogen deficient atmosphere, moderate amounts of nitrogen salt fertilisers supplied to plants to maintain high crop production.

Question 34.

3 different varieties of maize X, Y and Z were grown in three separate habitats with different soil conditions. The characteristic features of the soils in each habitat are summarized below. Use it to answer the questions that follow.

Habitat I: 95% nitrogen, 85% organic matter, more micro-organisms.
Habitat II: 20% nitrogen, 24% organic matter, few micro-organisms.
Habitat III: 95% nitrogen, 85% organic matter, more weeds, more micro-organisms.
Results of the study for each habitat are shown in figures below



(a).Compare the growth rate for the three varieties in;

(i).Habitat I *(06 marks)*

Similarities

• In all the three, growth rate increases with time;
• Growth rate of the three attains a maximum;
• Growth rate of the three becomes constant on attaining the maximum

Differences

• Growth rate in variety X is higher than in varieties Y and Z:
• Growth rate in X attained a higher maximum than in Y and Z;
• Growth rate in Z. is lower than in X and Y

(ii).Habitat II *(06 marks)*

Similarities:

• In all the three varieties, growth rate increased with increase in time
• Growth rate increased gradually in all the three varieties;
• Growth rate never attained a maximum in all the three varieties

Differences:

• Growth rate in Y is higher than in X and Z;
• Growth rate of Z is lower than that of X and Y
• Growth rate of Z is almost constant towards the end of the study time while that of X and Y increases gradually towards the end of the study time.

(b).Giving reasons, describe the habitat preferences for each variety of maize. *(16 marks)*

Variety X: Preferred habitat is I to II and III because its growth rate was higher than other varieties growth rate in only habitat I. Since habitat I soils contained much nitrogen, organic matter and microorganisms resulting into more decomposition of the organic matter by the microbes forming nitrates which are hence required by varieties X in large amounts hence their much absorption to form the proteins resulting in increase in growth rate

Variety Y; Preferred habitat II to habitats I and III since its growth rate was higher than other varieties' growth only in habitat II. This is attributed to the lower concentration of nitrogen, organic matter and microorganisms in the soils resulting into less decomposition of the organic matter by the few microbes forming less nitrates which are hence required by variety Y but in small amounts hence their less absorption to form the few required proteins. This results in increase in growth rate without favoring the growth of competitor varieties X and Z.

Variety Z: Preferred habitat is III to habitats I and II since its growth rate was higher than other varieties' growth rate in only habitat III. This is attributed to the higher concentration of nitrogen, organic matter, microorganisms and weeds in the habitats' soil resulting into more decomposition of the organic matter by the many microbes forming much nitrates which are hence required by variety Y in large amounts hence their much absorption to form the few required proteins. This results in increase in the growth rate without favouring the growth of competitor varieties X and Y which cannot out compete the weeds for nourishment.

(c).Explain;

(i) the differences in growth rate of variety X in habitat I and II. ***(06 marks)***

Variety X has a higher growth rate in habitat I than II. In habitat I, there are more microorganisms, more nitrates and more decomposing organic matter forming much more nitrogen compounds absorbed in needed large amounts by variety X to form plant proteins which are required for plant growth.

In habitat II, there are few micro-organisms decomposing; little organic matter to form little nitrogen compounds hence little nitrates resulting in absorption of just little nitrates forming less proteins and compromising growth.

(ii) how the significance of the growth rate of the varieties in habitat III to a farmer? ***(03 marks)***

Variety Z does better in habitat III than X and Y. A lazy at weeding farmer or a farmer with weeding challenges ought to plant Variety Z inorder to get better harvests since it can compete favorably with many weeds for the soil resources.

(d)(i). What are the possible sources of nitrogen to plants. ***(10 marks)***

Atmospheric nitrogen (Molecular Nitrogen): Although about 78% of the earth's atmosphere is composed of nitrogen, the majority of the plants cannot utilize from of nitrogen. Only some bacteria, some blue-green algae, leguminous plants (having root nodules) etc can fix atmospheric nitrogen or can be fixed by lightning and thunder storms.

Nitrates, nitrites, ammonia in the soil; (Inorganic Nitrogen): Among these, the nitrate is the chief form of nitrogen taken up by the plants from the soli. Decay of these plant and animal materials avails the nitrogen to plants.

Amino Acids (Organic Nitrogen) in the soil; Many soil micro-organisms make use of this form of nitrogen. Sometimes It may also be taken by higher plants.

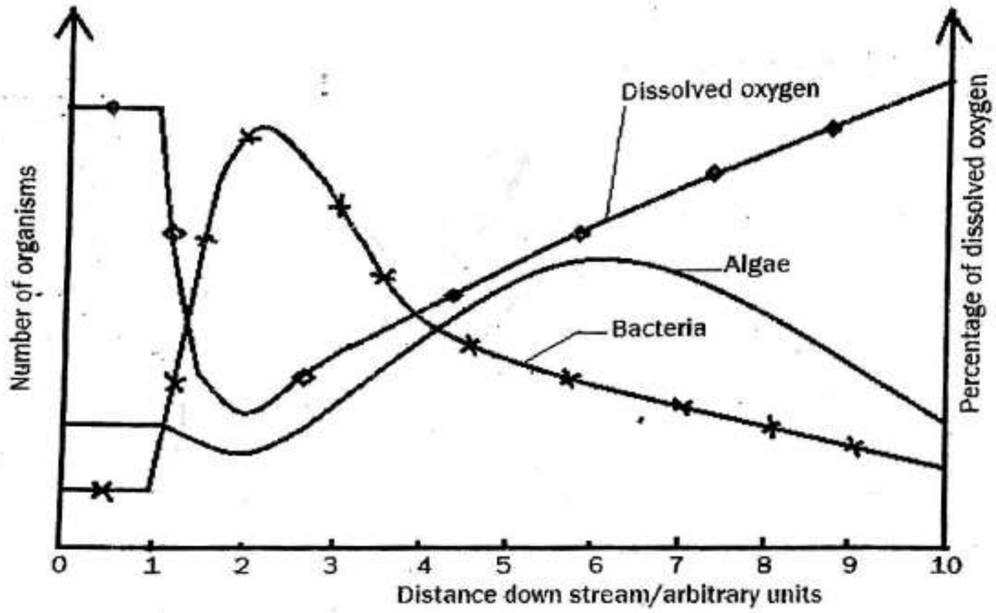
Organic nitrogenous compounds in bodies of the insects: Insectivorous plants fulfill their nitrogen requirement by catching the small insects and digesting them.

(ii).Briefly explain the importance of organic matter in the soil. ***(08 marks)***

- Nutrient Supply; Organic matter is a reservoir of nutrients that can be released to the soil.
- Water holding Capacity: Organic matter behaves like a sponge with the and hold most of the soil water
- Soil structure Aggregation: Organic matter causes soil to clump & form soil aggregates; improve soil structure,
- Erosion Prevention: due to increased water infiltration & stable soil aggregate formation by the organic matter.

Question 35.

The effects of discharging untreated sewage on the physical and biotic factors in the lake ecosystem from the point of sewage discharge downstream has been studied. The outcome of the results of the study is presented in figure 1 below.



(a)(i). Compare the changes in the number of the two organisms downstream. ***(07 marks)***

Similarities

- In both the number of algae and bacteria remained constant from 0 up to 1 distance downstream;
- In both the number of algae and bacteria Increased rapidly to reach the peak;
- In both, the number of algae and bacteria reached peak;
- In both, the number of algae and bacteria declined rapidly after the peak;
- The number of algae and bacteria is the same at about 1 and 4 distance down stream

Differences

Number of algae	Number of bacteria
Is higher from 0 upto 1 and from 4 upto 10 distance downstream,	Is lower from 0 upto 1 and from 4 upto 10 distance down stream
Is lower from 1 upto 4 distance downstream,	Is higher from 1 upto 4 distance downstream
Declined gradually to a minimum from 1 upto 2 distance downstream	Increased rapidly to a peak from 1 upto 2 distance downstream;
Increased rapidly from 2 upto 6 distance downstream	Declined rapidly from 2 upto 4, then gradually up to 10 distance downstream.
Reached peak at 6, longer distance down stream	Reached peak at 2, shorter distance downstream

(ii).Explain the relationship in the number of organisms over the range of distance downstream. ***(15 marks)***

From 0 upto 1 distance downstream; both the numbers of algae and bacteria are low and remained constant; this is because at this point sewage is not yet discharged into the water and little organic matter present. From 1 upto 2 distance downstream, the number of Bacteria increased rapidly to the peak while the number of algae declined gradually to a minimum; this is because sewage is discharged into the water and the levels of organic matter increased rapidly; saprophytic filamentous bacteria known as sewage fungus feed on the organic matter in the sewage and reproduce rapidly; but the organic matter in the sewage reduce the amount of light penetrations reducing photosynthesis by algae; From 2 upto 6 distance downstream; the number of algae increased rapidly as the number of bacteria declined more rapidly; then gradually; this is because rapid breakdown of organic matter has reduced the levels of organic food for bacteria/ some bacteria starved to death/ their reproductive rate declined; but the bacterial break down of sewage released many minerals like nitrates; which algae absorbed for rapid growth and development; light also penetrates to reach the algae for rapid photosynthesis. From 6 upto 10 distance downstream; both the number of algae and bacteria declined gradually; because the minerals are used up and algal population returns to normal and all organic matter in the sewage has been broken downstream. At 1 and 4 distances downstream, the rate of breakdown of sewage and nutrient release is at equilibrium.

(b).Explain the changes in concentration of dissolved oxygen,

(i) Before discharge of sewage into the lake. ***(04 marks)***

From 0 upto 1 distance downstream, the concentration of oxygen is very high and remained constant; atmospheric air mixes with water at upper surface to dissolve oxygen; light penetration enable the green algae to photosynthesis releasing oxygen into the water; no dissolved oxygen utilized by the aerobic bacteria for decomposition of organic matter in the sewage;

(ii).From the point of sewage discharge downstream. ***(05 marks)***

From 1 upto 2 distance downstream percentage of dissolved oxygen declined rapidly and then gradually to the minimum levels; dissolved oxygen is rapidly used by the aerobic saprophytic bacteria (putrefying bacteria); to decompose the organic matter in the sewage (urea and uric acid) into ammonia; then the aerobic nitrifying bacteria similarly uses oxygen to convert ammonia into nitrates; increase in the temperatures of the water due to respiration reduced rate of dissolution of oxygen; untreated sewage that enters the river creates a very high BOD which declines gradually downstream as organic matter in the sewage is decomposed utilising the dissolved oxygen to very minimum levels.

(c).From the figure 1 above, determine the distance downstream where Biochemical oxygen demand (BOD) reaches peak. Give reasons for your answer. ***(03 marks)***

2 distance downstream in arbitrary units; this is where percentage of dissolved oxygen is at its minimum;

(d). State factors that may offset BOD in a river. ***(04 marks)***

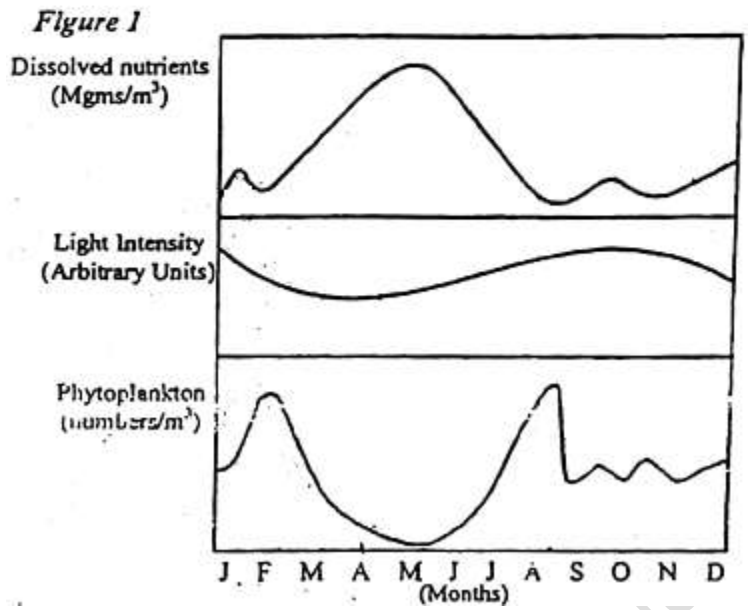
• More dissolution of oxygen;
• Turbulence/ water waves;
• Fast moving waters;
• Shallowness of the river;
• Treated sewage when discharged into water.

(e). Explain other chemical and biotic changes likely to occur due to the effects of discharging untreated sewage in the lake ecosystem. ***(04 marks)***

• A high BOD that depletes the dissolved oxygen in the lake.
• Increased toxicity of water which arises due to release of ammonia from the process of decomposition;
• Increased competition for oxygen by aerobic aquatic organisms as percentage of oxygen decreases downstream.
• Extinction of some species of organisms due competition and suffocation to death from the lack of oxygen;
• Decrease in pH levels of water;
• Decline in the population of fish due to fish kill and other aquatic organisms;

Question 36.

Graphs in figure 1 show the fluctuations in number of phytoplankton, light intensity and dissolved nutrients over a period of a year in a pond found in temperate biome. It is connected by an outlet to a stream.



Study the graphs and answer the questions that follow;

(a)(i) Sketch other graphs on the same axes to show the relationship between zooplanktons and temperature in the same ecosystem. *(03 marks)*

(ii). Explain why the pattern of temperature change during the year is as you have shown in a(i) above. *(06 marks)*

(b). Account for the relationship between the dissolved nutrients in the pond and

i) Population of phytoplanktons *(13 marks)*

ii) Light intensity. *(10 marks)*

(c).Suggest 3 ecological effects that a decline in phytoplankton population could have on zooplanktons *(03 marks)*

(d).In what ways are elements nitrogen and sulphur obtained by plants. *(05 marks)*

Question 1.

(a) Explain what is meant by the following

(i) Food chain.

(ii) Ecosystem

(iii)Indicator species ***(06 marks)***

(b).Compare advantages & disadvantages of using food webs rather than food chains in ecological studies.

(c).Describe briefly the flow of energy through an ecosystem, clearly illustrating how energy is lost in passing through the ecosystem ***(05 marks)***

(a)(i).

Food chain refers to a linear series of stages through which energy passes from primary producers through a sequence of consumers in which each eats the one below it and is eaten by one above it. Food chain is either grazing (based on living plant material) or detritus (based on dead fragments of plant material).

(a)(ii).

An ecosystem is a community of all living organisms interacting with each other and also with the abiotic component of their environment; functioning together as single complex ecological unit. The biotic and the abiotic components are linked by nutrient cycles and energy flow. Ecosystem can be categorized into aquatic and terrestrial ecosystems.

(a)(iii).

Indicator species is an organism whose presence, absence or mere change in chemical composition serves as sign that reveals a distinctive aspect or quality of the environment e.g absence of lichens reveals SO_2 pollution, overgrowth of mosses reveals acidic soils, turbifex worms reveal oxygen deficient soils.

OR.

Indicator species is a species whose distribution is largely determined by some particular factor. The presence, absence or mere change in chemical composition gives some measure of the level of that factor.

(b).

Advantage of both food chains and food webs.

• Both give qualitative information about the feeding relationships in a given ecosystem

Disadvantage of both food chains and food webs.

• Both do not show quantitative information i.e information about number of organisms, amount of mass or energy stored at each trophic level.

Advantages of food web over food chain

•Unlike food chains, food webs are more realistic as most organisms have many predators and are also prey to many other organisms

• Unlike food chains, food webs are more representative and describe true feeding relationship

• Food webs reveal more trophic levels than food chains

• Food webs stabilize the ecosystem and show more energy transfer; compared to food chains

• By using food webs, top most predators & preys as well as most unpalatable species in a given environment get to be identified.

Disadvantage of food web compared to food chain

• Unlike food chains, food webs are hard to construct; do increase the complexity of representing theoretical feeding relationship.

(c).

Primary source of energy is the sun; most (95-99%) of the energy is lost through radiations or reflections; little (1-5%) of the energy is absorbed by green plants (primary producers). These manufacture organic matter by photosynthesis; rate of storage of this energy is Gross productivity. Some of this energy is used by plants in respiration other lost in form of fruit and leaf fall; rest is stored as Net productivity. Organic matter in plants is consumed by the primary consumers mainly herbivores. Primary consumers are then eaten by secondary consumers; which are also fed on by tertiary and other top consumers. At each trophic level, a certain proportion of energy is through egesta, excreta and respiration. Decomposers utilize energy lost through egestion, excretion, and dead organic matter. Nutrients finally get recycled into the environment. Generally; energy flow decreases as ones moves from lower to higher trophic level.

Question 2.

(a).Giving examples, describe the uses of nitrogen to plant and animal bodies. ***(05 marks)***
(b).How is concentration of nitrogen maintained at a constant level in nature? ***(15 marks)***

(a).

• Used for protein synthesis

• Amino acids & proteins are used to make structures and components of vital biochemical such as enzymes and hormones.

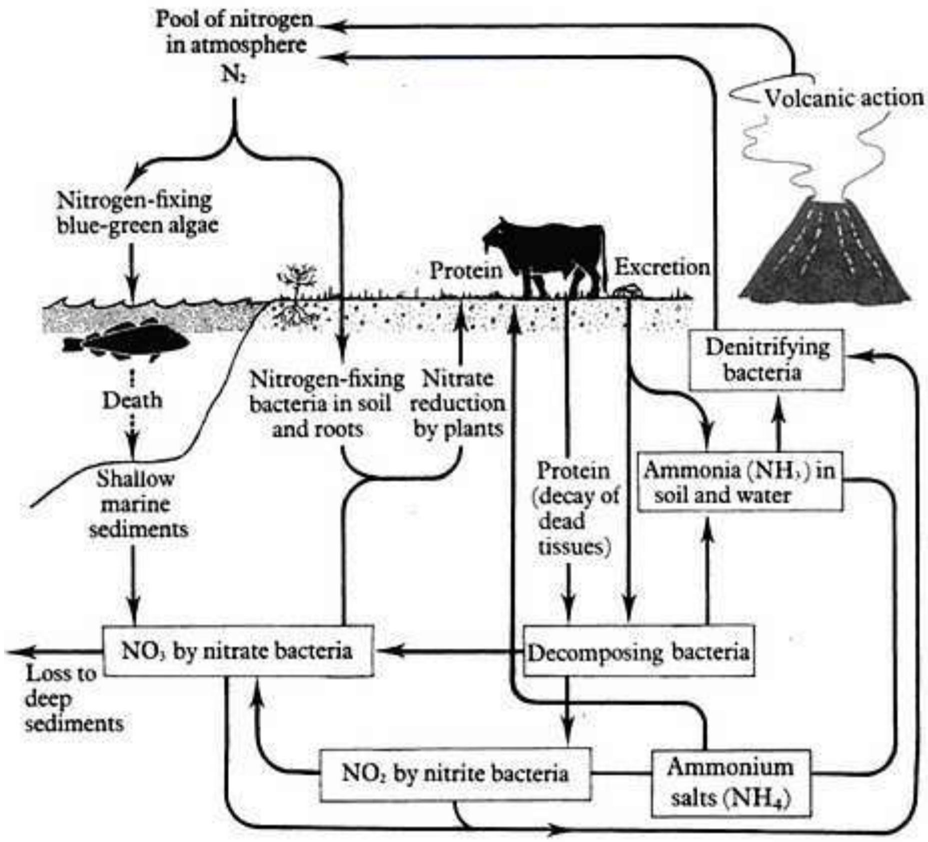
• Synthesis of nucleic acids.

• Involved in cation-anion balance as nitrates

• Used in determining osmotic pressure of cell sap as nitrate

(b).

The atmosphere contains a large amount of free nitrogen about 79% compositions by volume. Nitrogen circulates between organism and the atmosphere to maintain a balance. Denitrifying bacteria in the soil reduce nitrates and ultimately form free nitrogen which is turned to the atmosphere. Gaseous nitrogen is absorbed from the atmosphere and utilized on a large scale in manufacturing industries, forming fertilizers that can be utilized by plants. Nitrogen fixing bacteria; blue-green algae and the effect of lighting enable atmospheric nitrogen to reach the soil as nitrates, or nitrites. Nitrogen enters organisms mainly via plants as nitrates, the plants using organic products of photosynthesis build up plant proteins; these are then taken up when animals eat the plants. Nitrogen in plants and animals is recycled back to the atmosphere by either excretion of nitrogen metabolic wastes, defecation of animals or death. Nitrifying bacteria then convert the complex organic compounds containing nitrogen into nitrites by decay, forming ammonium ions, these are then oxidized to nitrites by nitrosomonas, then the nitrites are oxidized to nitrates by nitrobacter and nitrate bacteria.



Question 3.

(a).Describe ecological effects of drainage of nitrate fertilizers into rivers and streams. ***(10 marks)***
(b).Suggest the ecological effects of other forms of water pollution ***(05 marks)***
(c).Outline measures that can be taken to control water pollution ***(05 marks)***

(a).

- Nitrates accumulate in the water body leading to eutrophication; the enrichment of water bodies with nutrients.
- The nutrients promote growth of green proticsts and algae leading to algal blooms.
- The algae and the other autotrophs use up oxygen in their respiration and begin to die off.
- Aerobic decomposers mainly bacteria increase in number; use up even more oxygen;
- Aerobic aquatic organisms such as fish die to lack of oxygen (anoxia)
- A reduction in the large aerobic organisms leads to an increase in aerobic decomposers, using up more oxygen.
- The very low levels of oxygen result in death of aquatic aerobic organisms.
- Anaerobic decomposers increase in number; low levels of oxygen result in reduced metabolic activity hence low productivity.
- The load of decomposing organisms cuts off light penetration; photosynthesis greatly reduces visibility also reduces; this leads to death of many aquatic plants and animals.
- Oxygen depletion disrupts breeding in migratory species.
- Increase in anaerobic decomposers result in accumulation of hydrogen sulphide; makes water smelly and unsuitable for human consumption
- As organisms die, they settle at the bottom of the water body leading to sedimentation.

(b).

Oil spills due to discharge from aquatic vessels, oil refineries and washing automobiles

- The oil spills clog feathers of sea birds reducing insulation and can be lethal.
- Oil coat seeds and leaves of aquatic plants and hence hinders dispersal and limits photosynthesis.
- Oil clogs gills of fish preventing gaseous exchange; cause death of fish.

• Oil decreases oxygen dissolution; greatly affecting aquatic aerobes
• Oil decreases visibility and light penetration; impair photosynthesis.
• Ingestion of oil by aquatic organisms causes gut irritation.

Industrial wastes like heavy metals and phosphates

• Intake by aquatic organism die due to disrupted metabolism; reduce biodiversity.
• Phosphates cause eutrophication; disrupt aquatic food chains

Thermal pollution from industrial effluents or water used as coolants

• Decreases amounts of dissolved oxygen.
• Increased warmth increases metabolic rate of aquatic organisms and hence their oxygen demand.
• Warm waters disrupt migration of some fishes and hence their breeding cycle.
• Warm water may promote microbial activities in polluted waters & lead to rapid restoration of good quality water.
• Very hot water kills aquatic organisms at the point of discharge.

Pesticides and herbicides may be washed down into water bodies from farms.

• Non-biodegradable pesticides and herbicides accumulate in tissues of organisms thus their concentrations keep increasing with higher trophic levels in the trophic levels.
• Higher levels of non-biodegradable chemicals are lethal.

(c).

• Sewage treatment before discharge.
• Water from industries is cooled before discharge into water bodies.
• Control and limit use of insecticides and herbicides such that only biodegradable ones are used.
• Control and limit discharge of heavy metal in industrial effluents.
• Use of specially designed oil spill cleaners that are less toxic and biodegradable.
• Spraying on oil spills, naturally occurring bacteria such as pseudomonas which digest oil.

Question 4.

(a).Explain what is meant by eutrophication ***(04 marks)***
(b).Outline the effects of eutrophication in the ecosystem ***(08 marks)***
(c).Describe ways in which nitrogen is incorporated into food chains. ***(08 marks)***

(a).

This is the addition of nutrients (nitrates and phosphates) to water bodies which encourages blooming or proliferation of algae, fungi and other aquatic plants. The human activities that cause eutrophication are; Discharge of untreated sewage into water bodies/industrial wastes &extensive use of fertilizers which later wash into waterbodies.

(b).

Effects of eutrophication

• Algal bloom reduces light penetration into the water body, so algae and other photosynthetic plants in the deeper regions of the water body are unable to photosynthesize leading to death of aquatic plant species.
• Algae decays and increased decomposition reduces oxygen level in water leading to death of other aerobic aquatic organisms since nitrifying bacteria uses oxygen in breakdown of ammonium compounds to nitrates by saprophytes.
• Sewage exposes aquatic organisms to their predation due to poor visibility.
• The process of decomposition also depletes the water off oxygen leading to increased biochemical oxygen demand
• Such water is unsuitable for drinking and cause irritation to the skin. They also cause diseases to man like cholera and typhoid.
• Due to anaerobic activity and decomposition the water becomes alkaline due to high concentration of ammonia.
• Eutrophication is greatly accelerated by thermal pollution because heat increasing the rate of decomposition that bring about a higher oxygen demand into aquatic environment.

(c).

Nitrogenous wastes products such as urea or protein contained in dead organic matter are putrefied to ammonia by putrefying bacteria. Through chemical combination, ammonia is further converted to ammonium compounds. With the aid of nitrifying bacteria such as Nitrosomonas, a soil living bacteria; ammonium compounds get oxidized to nitrites; which also get oxidized to nitrates by Nitrobacter. Nitrates get absorbed by the plants; nitrogen gets incorporated into plant proteins; enters food chain when plants are eaten by animals; gets stored inform of animal proteins. Electrical and photochemical fixation of atmospheric nitrogen mainly by lightening forms nitrogen oxides which form nitrates and can be absorbed by plant roots. Nitrogen fixing bacteria e.g Rhizobium in root nodules of leguminous plants; incorporate atmospheric nitrogen into their protoplasm; host plants then absorb some nitrogenous molecules from the bacteria and incorporate them into plant proteins. A small percentage of nitrogen is artificially used to form ammonia by Haber process; nitrogen therein is the incorporated into plant proteins.

Question 5.

(a)Describe each of the following biotic interactions in an ecosystem

(i).Predation ***(03 marks)***

(ii)Antibiosis ***(03 marks)***

(b).Explain the adaptations of predators to capture their preys in an ecosystem ***(14 marks)***

(a)(i).

Is an association between two organisms of different species; where one organism called the predator hunts, kills and feeds on another animals the other animals fed on or eaten are called the preys;

(a)(ii).

Is an interspecific or intraspecific association; where one organism produces antibiotics or chemicals; which inhibits growth and survival of another organism in the same environment;

(b)(i).

• Predators camouflage in their environment and are not easily seen by preys;
• High locomotory speed to chase and capture the preys;
• Long pointed and curved canine teeth to pierce and kill the prey;
• Possession of strong visual acuity and ability to be able to clearly see preys hiding;
• Large size of brains to increase their intelligence to capture the preys
• Have very sensitive olfactory cells for detecting the smell of the prey from a distance and those hiding;
• Group/communal hunting to increase chances of capturing preys;
• They possess strong curved claws for capturing and holding the prey;
• Nocturnal predators eg bats have highly developed hearing sense for detecting sound made by prey.
• Some snakes have glands to secrete venom which the fangs inject into prey to immobilize it (prey).
• Web-spinning spiders use their silky cob webs to catch small sized ground walking or flying insects.
• Ant-lions lay traps by making pits in the ground where preys fall
• Some have soft pads on their so that they are not easily detected as they walk towards prey
• Some of stinging cells which paralyse their prey e.g sea anemones
• Well developed limbs which increase the speed of locomotion to chase and capture prey.
• Predators being nocturnals hunt, capture and feed on the preys at night when the preys are at rest and have poor vision at night;

Question 6.

(a).Explain what is meant by invasive species? Give two examples ***(03 marks)***

(b).How have invasive species affected the ecosystem? ***(07 marks)***

(c).Briefly explain ways how biodiversity can be conserved? ***(10 marks)***

(a).

Invasive species are organisms not native to a specific location (introduced species); have a very high reproductive potential and do spread at a degree believed to cause ecological, economic or even human harm. Examples include; water hyacinth that forms a vegetation mat on the water surface impeding light penetration, brown mammorated stink bugs(bed bugs); nuisance in homes.

Others; west Nile virus; invasive pathogen that cause disease to humans and wildlife (birds), Asian carps outcompete native fish for food and habitat, zebra mussels; outcompete native mussels and cray fish, fesal pigs outcompete native wildlife, cogon grass; outcompete native plants.

(b).

• Invasive species prey on the native species; native species population decline over time and the endangered species are predisposed to extinction.
• Invasive species outcompeting native species for food, shelter, water, and other resources; & over time invasive species force localized extinction of many native species.
• Acting as vectors transmit disease causing organisms to native species

• Preventing native species from reproducing or killing young ones impeding growth of native species population.
• Changing food webs; destroying or replacing native food sources; invasive species may provide little or no food value for wildlife. .
• Decreasing biodiversity; by accelerating death of many other native species.
• Altering ecosystem conditions; such as altering soil chemistry, pH; these new emergent conditions may be unfavourable to life original native species.

(c).

• Control of pollution; measures such as reducing smoke emission, control of pesticide and fertilizer use and prevention of oil spills; to avoid destruction of species and habitats.
• Effective control and monitoring of invasive species population and other introduced species to prevent them from out competing indigenous species.
• Ecological study of the threatened habitats and endangered species prompt better management.
• Endangered species rescue programmes like breeding in captivity; endangered under controlled conditions before being returned to the wild.
• Implementing conservation strategies e.g afforestation, re-afforestation and swamp conservation.
• Water recycling reduces demand stress on the natural resources some of which are habitats to several organisms.
• Planned use of land; to restrict human activities that might threaten nature e.g designating land as an Environmentally Sensitive Areas (ESA) or Site of Special Scientific lnterest (SSSI)
• Advocating for natural methods of pest control such as biological pest control
• Incorporation of renewable and environmentally friendly energy sources e.g solar energy.
• Designation of national parks and nature reserves; to protect vulnerable species and habitats.
• Community sensitization about the importances of the environmental conservation.
• Legislation to protect wildlife; to combat extinction of the endangered species.

Question 7.

(a).Explain what is meant by biological control method? ***(04 marks)***
(b).Explain the precautions to be taken in application of biological pest control ***(06 marks)***
(c).Outline the main steps involved in biological pest control ***(05 marks)***
(d)(i).Describe the ecological qualities of a good pesticide ***(05 marks)***
(d)(ii)State the problems associated with chemical pesticides

(a).

Biological control method is the regulation of the population of a particular organism like a pest using their natural enemies. These can be their predators, pathogens and parasites. E.g use of cats to eat rats, using beetles to feed on the water hyacinth on Lake Victoria, placing fish in ponds to eat mosquito larvae. Biological control aims at bringing the target population to a level where they are economically harmless. Biological control method can be used to; control of vector, parasite, pathogen (virus and bacteria) or weed population.

(b).

• Climatic conditions should be carefully matched to ensure that they favour the natural enemy of the pest especially when the population of the pest is at its peak.
• Interractions of the organism with native species should be carefully monitored to ensure that the natural enemy used is not preyed upon by other unsuspected organisms. It also helps to identify prey organisms that may be preferred instead of the target pest.
• The predator must be released at a time when the pest population has reached large numbers to provide sufficient food for the natural enemy otherwise these organisms may be wiped out prematurely resulting in pest resurgence.

(c).

• Identifying the pest and tracing its origins, i.e. where it came from.
• Investigating the original site of the pest and identifying its natural predators, parasites or pathogens
• Testing the potential control agent under careful quarantine to ensure its specificity.
• Mass culturing of the control agent.
• Development of the most effective distribution / release method for the control agent.

(d)(i).

• Should be biodegradable / non-persistent;
• Should be specific so that only pest species is killed.
• Should not accumulate either in specific parts of an organism or as it passes along food chains.
• Should effectively control the pest under field growing conditions
• Should be easy to apply at the correct dosage.

(d)(ii).

• Accidental misuse of toxic chemicals results in death of humans and domestic animal.
• Many are non-specific, killing non-target species, particularly natural predators of the pest species.
• Bioaccumulation; an event that may be toxic to members of higher trophic levels like the top carnivores.
• Pest resurgence may occur i.e. rapid multiplication of a small residual pest population may without being checked by their natural predators.
• Pest resistance occurs i.e. genetic variation enables a few individuals in the pest population to survive and may quickly reproduce.
• There is pest replacement i.e. since most crop are susceptible to attack by more than one pest species, and the pesticide may be more deadly to one species than another, elimination of one species may simply allow another species to assume major pest proportions.

Question 8.

(a).In what ways may predator-prey relationships benefit;
(i). the prey
(ii).the predator? ***(08 marks)***
(b).Explain the different ways how preys may combat predation ***(07 marks)***
(c).Biological organisms are sometimes introduced in control areas to manage populations of pests.
(d).Outline the precautions taken before introducing the predator in the control area ***(05 marks)***

(a)(i).

• Regulating/checking on the prey population; reduce crowding; and competition
• Promoting co-evolution of preys with more advanced adaptive features for escape.
• Promoting colonization of new localities by preys
• Decreasing intraspecific aggression.
• Availing food to the predators.

(a)(ii).

• Promoting evolution of selectively advantaged predator species.
• Promoting co-evolution of predators with better hunting adaptive features.
• Regulates predator population by constantly checking on it.

(b).

• Camouflage; organism adopts colour features of the environment and ably survives predation
• Mimicry; organism resembles surrounding or takes on properties of a specific object that seems unpalatable or noxious to the predator.
• Warning signals; may take on forms of conspicuous colours, sounds, odours or any perceivable characteristics alerting the predators on the possible harm associated with feeding on it.
• Fast escape; adopted powerful; highly flexible muscles; in the locomotory devices like wings, legs etc; that promote rapid escape of the prey from the predator.
• Excellent senses (smell, sight, hearing); enables timely and accurate detection of the predator's presence; prompting timely, well-judged and planned escapes.
• Defensive structures; e.g sharp teeth, spines, horns, claws, shell etc to guard against predation.
• Alarms; inform of warning sounds; enables one organism to successfully alert others of the presence of the predator.
• Nocturnal behaviour; some preys are active at night without being noticed by the predators.
• Social behaviour; preys move, work and stay in groups; scare away predators.
• Some organisms detach off the captured body parts; like lizards detach off tails when captured.
• Herbivores graze in open grounds; enabling clear view of the predators.

• Repulsive smells; repel the predator.
• Toxic poisons; cause metabolic derangements or even death of the predator after ingestion.
• Threat postures displayed by preys; such as expansion/increase in size to scare away predators

(c).

• Specificity to the target preys (pests). Control agent must be highly specific to only the targeted preys.
• Control agent's adaptability in its new environment. Control agents should be adapted to survive in new area.
• Measures to regulate population of control agent when, the pest controlled has increased its reproductive rate.
• Size of the pest population at the time of introducing the control agent; control agent must be introduced when the pest population is very high.
• Environmental friendliness of the control agent; control agent must be environmentally friendly.
• Intensity of the potential predators to the control agent; must be fewer and population closely monitored throughout the control process.
• Climatic suitability; control agent must be favoured by the climatic conditions of the area.

Question 9.

(a).Outline the causes of nutrient deficiencies in soils *(06 marks)*
(b) Explain how plants have overcome the problem of nitrogen and phosphorous deficiencies in the soils they grow in *(09 marks)*
(c).Explain the functions of nitrates and magnesium in plants; stating the deficiency symptoms *(05 marks)*

(a).

• Low pH/acidity/immobilization of nutrients.
• Leaching
• Soil erosion
• Over cultivation/ over cropping
• Monoculture
• Bush burning.

(b).

• Mycorrhiza; plant roots symbiotically associate with fungi; permit entry of mineral nutrients particularly ammonium, nitrate and phosphates into the plant.
• Some plants have adopted carnivorous behaviour; take in nitrogen incorporated in animal proteins
• Some plants have adopted an insectivorous behaviour; have leaves that trap insects/ small animals.
• Leaf surfaces have adopted secretory glands that secrete digestive enzymes such as proteases, catalyse digestion of proteins into amino acids
• Mutualistic interaction with nitrogen fixing bacteria in the root nodules like Rhizobium that incorporate atmospheric nitrogen into their protoplasm; from which plants absorb.
• Nitrifying bacteria decay ammonium compounds to nitrates; nitrogen gets availed to plants inform of nitrates.
• Electrical and photochemical fixation of atmospheric nitrogen by lightening forms nitrogen oxides;
which oxidize further to nitrates the form in which nitrogen gets absorbed by plants.
• Nitrates enter soil in rain water or get artificially introduced by the Haber process; get readily availed for absorption.
• Death of animals that the plants and absorbed ammonium ions released in soil get converted to nitrates absorbed by plants and transported to leaves.

(c).

Nitrates provide the nitrogen utilized by plants to construct vital molecules like amino acid nucleic acids & some vitamins. Lack of nitrates manifests with stunted growth, yellow 1eaves, low yields.
Magnesium forms the prosthetic group in the porphyrin structure of chlorophyll; thus the element is important in the synthesis of this light trapping pigment chlorophyll. Without it, leaves turn yellow or red orange, shrivel and die. Magnesium is also a cofactor of many plant enzymes.

Question 10.

(a).What is meant by:
(i). biotic potential *(03 marks)*
(ii).primary productivity *(02 marks)*

(b).Discuss the factors which influence the size of populations in an ecosystems ***(12 marks)***

(a)(i).

Biotic potential refers to the maximum rate at which members of a species can reproduce; given unlimited resources; and ideal environmental conditions.

(a)(ii).

Primary productivity refers to the rate at which biomass is produced per unit time by the primary producers

(b).

Availability of food /water; plenty of which favours reproduction and hence increase in population size; and lack of food /water leads to reproductive failure and death hence decrease in population size. Availability of light; when adequate it favours the growth of plant population and favours survival of animals directly and indirectly; its inadequacy or absence of light limits plant population.

Availability of oxygen; oxygen presence raises the survival rate of many aerobic organisms; their populations thus increase. Oxygen absence on the other hand limits population growth.

Feeding interactions among different organisms; such as predation and parasitism. Population of the organisms fed on reduces; that that feeds increases.

Environmental resistances like drought, diseases and catastraphies limit population growth as potentially reproductive members die.

Accumulation of toxic wastes; such as carbondioxide, nitrogenous wastes can limit population growth of certain organisms

Stress or psychological factors such as overcrowding leads to abnormal behaviour which may lead to reproductive failures/ deaths.

Climatic changes; favourable climatic environments favour population growth; unfavourable climate inhibits population growth

Availability of mates; high number of mates increases chances of reproduction; fewer mate limit reproduction.

Question 11.

(a).What are chemoheterotrophic bacteria? ***(01 marks)***

(b).Give three groups of the type of bacteria in (a) above ***(03 marks)***

(c).Using examples in each case, explain the ecological importance of each of the groups in above in an ecosystem. ***(08 marks)***

(c).How do nitrogen fixing bacteria differ from round worms in their relationship with hosts? ***(04 marks)***

(d) What is the economic importance of nitrogen fixing bacteria? ***(04 marks)***

(a).

Chemoheterotrophic bacteria are bacteria that obtain energy from oxidation of chemicals in their food

(b).

• Saprotrophs
• Mutualists
• Parasites

(c).

• Saprotrophs; e.g bacteria; obtain food from dead decaying matter; they are chief decomposers bringing about nutrient recycling.
• Mutualists e.g Rhizobiurn; nitrogen fixing bacteria is part of the nitrogen cycle as nitrogen fixers.
• Parasites e.g cocci and bacilli benefit from their hosts from which they obtain food and shelter; host suffers harm. Obligate parasites only survive in the host. Facultative parasites feed on the host bringing about their death and then live saprophytically on the host remains.
• Both obligate & facultative bacterial parasites are pathogens; cause disease; which check on the host population.

(c).

Nitrogen stomata fixing bacteria have a mutual benefit with the host; by providing nitrates and amino acids to the host; while deriving shelter and carbohydrates from the host.

Round worms on the other hard derive benefit from the host, which receive no again but instead is harmed. The worms can lead to death of the host.

(d).

• They recycle nitrogen in the atmosphere
• They enrich the soil with nitrates
• They fix free atmospheric nitrogen into nitrates, which can then be utilized by plants
• Their presence in the ecosystem increase productivity and hence food yield.

Question 12.

(a).Explain what is meant by pollution *(01 marks)*
(b).Outline the ecological effects of water hyacinth on the animal and plant life in the aquatic habitats
(c).Suggest ways of eradicating the water weed giving the possible advantages and disadvantages of each eradication method *(12 marks)*

(a).

Pollution is the release of materials, substances or energy into the environment in such quantities and for such a period that causes harm to the humans/ organisms or their environment.

(b).

• Impedes light infiltration into the water; reducing photosynthetic activity of the aquatic plants.
• Deprives aquatic animals like fish; oxygen resulting in anoxic deaths.
• Hinders mixing and circulation of contents of lakes and those of rivers.
• Deprives aquatic organisms their ecological niches.
• Species diversity decreases and dominant biotic change
• Adversely affects food chains and food webs in lakes and rivers.
• Reduces water quality by increasing turbidity and reducing the water oxygen content etc
• Increased siltation and sedimentation.
• Increased nutrient load; following decomposition of nutrient loaded plants;
• Stops bottom water from heating; hinders appropriate breeding of aquatic living organisms
• Provision of breeding ground to vectors increasing the disease burden; as one of the environmental resistances.

(c).

Method of eradication	Advantages	Disadvantages
Mechanical or physical removal of the weed by use of human labour or harvesters	• Weed is put to other use like fodder for animals. • Rotten one constitute humus • Hyacinth can offer raw materials for the paper industry	• Slow process requiring deployment of larger number of people or machines • It is a laborious undertaking • It is cost ineffective
Use of selective weed killers	• Massive destruction of the weed	• Increased decomposition; reducing the oxygen content of water. • Chemicals interfere with food chain/ webs • Can cause eutrophication

Biological control method; like use of arthropod control species	• Weed is a source of food to the selected control species; lower down decomposition. • Highly specific in comparison with chemical control - allows the targeting of a specific organism. • Longer lasting as the target and the control can enter a predator-prey relationship. • Although biological control has a high start-up cost to carry out research and trials it can be inexpensive if the solution works long term. • Biological control mechanisms are also more environmentally friendly	• Takes long time for the control species to multiply; • After eliminating the weed, the weed killer species may become an environmental menace. • There is a high initial capital outlay to carry out research and trials because detailed knowledge of the target organisms life cycle is required.

Question 13.

(a).Describe the physiological and structural factors of the water hyacinth which have enabled it to spread and persist on lake victoria. ***(07 marks)***

(b).Outline the ecological dangers of this weed on the water. ***(05 marks)***

(c).Suggest three control methods of water weed, and for each method, point out its weaknesses ***(08 marks)***

(a).

• Their leaves are rounded (ovate) and rossetedly arranged to trap enough light
• The stems and leaf stalk s and hollow to reduce weight so as to enhance floatation.
• It multiplies rapidly because it reproduces both sexually and asexually (vegetative).
• The seeds are very resistant to adverse conditions and can live for years in the land on lake shores without losing viability
• The weed can move by weed or water currents over fast distances, with its sail like leaves giving it the mobility.
• Movement of machinery and equipment by water or man facilitates its movement because it is a floating plant.
• Its orchid-like funnel shaped flowers are nice to enthusiasts who have facilitated its spread by man.

(b).

• It prevents access to water by animals and humans.
• It affects water quality which becomes unsuitable for drinking.
• It prevents light penetration into the water leading to death of submerged aquatic plants.
• Its mats are ideal incubator of anopheles mosquitoes & perfect ground for disease carrying water snails.
• It clogs drainage channels, which is a disadvantage to farmers on the banks of the lake.

(c).

Biological control by use of pests.
Weaknesses
• The pests may destroy even other useful plants.
• The pests may be slow at destroying the weed and therefore fail to eradicate it.
Manual eradication by hand.
Weaknesses
• It is tiresome.
• It is time consuming.
Mechanical removal by machinery.
Weaknesses
• Machinery may cut the weed into smaller pieces which propagates further.
• It is very expensive. Chemical spray. Weaknesses
• Leads to water pollution
• It is non- specific.

Question 14.

(a).Explain the appropriate conservation methods for each of the following natural resources in an ecosystem

(i). Wildlife *(04 marks)*

(ii) Endangered species *(04 marks)*

(iii)Fisheries *(04 marks)*

(b). State the factors affecting the number and diversity of species reaching or colonizing an area *(08 marks)*

(a)(i).

- Game cropping; scientific killing of game animals to keep population at its carrying capacity
- Legislation of strict laws against poaching and encroachment
- Use of botanical gardens and seed banks; keep plants that are endangered.
- Guarding against fire outbreaks; prevent death/ destruction of plant and animal species.
- Prevent over grazing, bush burning; so as to preserve the vegetation cover
- Re-afforestation and a fight against deforestation; maintain the natural habitats/ food for the organisms.
- Creation and conservation of more state national game parks/ reserves; preventing many wildlife from extinction.
- Preventing land, water and air pollution; to reduce harm to organisms that may predispose them to extinction.

(a)(ii).

- Protecting and restoring habitats; to preserve breeding sites and hiding areas.
- Establishing game parks, game reserves; to preserve the endangered species.
- Reduce the use of pesticides; prevent massive death of organisms.
- Restrict or ban trade on endangered species
- Zoos and botanical gardens; provide a safe breeding ground for the endangered species.
- Establish sperm banks and seed banks; to maintain genetic diversity of the species.
- Strict regulation of newly introduced species; to avoid out-competing the endangered species.
- Removal of animals from habitats threatened by man; settle them in more secure habitats
- Practicing improved and environmentally friendly methods of agriculture and control impacts of modern intensive agriculture.
- Ecological study of the threatened habitat and careful analysis of the natural habitats permit conservation of the maximum number off species
- Legal protection: for endangered species by making it illegal to collect or kill endangered species.
- Commercial farming: the development of farms which produce sought out after goods e.g. sheep and deer farming, may produce enough material (wool) to satisfy the market and so remove the necessity to kill these animals in the wild.
- Pollution control; measures to control pollution such as smoke emissions, oil spills, over use of pesticides, fertilizer run off, all help to prevent habitat and species destruction.
- Recycling: the more material that is recycled, the less need there is to obtain raw materials from natural sources, e.g. through mining; avoid habitat destruction.
- Education: it is important to educate the people in ways of preventing habitat destruction and encouraging the conservation of organisms.

(a)(iii).

Quotas; the amount of fish each country is allowed to catch; should be regulated

Minimum mesh size; should be large enough to allow small, fast growing and immature fish to pass through. These fish can then reach maturity, spawn and help replenish fish stocks.

Closed seasons; during which fishing is not allowed usually during the breeding seasons of particular fish species.

Exclusion zones; gazette areas in which fishing is banned completely.

Fish farming; deliberate cultivation of fish; to catch up with the high demands that are overriding the supplies.

(b).

- Geographical barriers like mountain ranges/ river/lake/rift valley.
- Ecological barriers like unfavourable habitats separating areas of favourable habitats.
- Distance over which dispersal must operate
- Size and nature of invasion areas

Question 15.

(a).Outline the characteristics of a succession process *(04 marks)*
(b).Describe the trend of primary succession in an aquatic ecosystem *(06 marks)*
(d).Explain the factors that interfere with energy flow and nutrient recycling *(06 marks)*
(c).Outline five main physical features of an eutrophied water body *(04 marks)*

(a).

• A pioneer community which is quite simple in biomass content and composition.
• A series of intermediate stages/seres
• Increasing biomass/productivity and species biodiversity
• Ends into a stable community which is in equilibrium with its environment called the climax community.

(b).

Eutrophied water promotes growth of suspended organisms like algae. Algae die and decompose adding more nutrients. Floating plants like nymphia, water weeds and water hyacinth form. These attract animals which feed on them; leading to death of the floating plants which decompose and sediment. This occurs over a long period of time making the water body shallower. Papyruses emerge in shallow water bodies. Papyruses die and decompose adding more organic matter thereby causing more sedimentation. A few plants like palm trees emerge followed by small trees which constitute the climax community.

(c).

Hunting; reduces energy available to the carnivores or higher level consumers.
Bush burning; reduces the amount of energy available to herbivores limiting energy transfer to higher trophic level consumers. It also kills decomposers impairing nutrient recycling. Nutrients get destroyed.
Pollution; this kills decomposers preventing nutrient recycling, cause death of some plants and animals preventing energy transfer to organisms feeding on them in the food chain.
Defforestation; reduce productivity of the primary producers; reducing energy available to consumers.
Swamp reclamation; destroys niches of some members of the food chain.

(d).

• Increased turbidity
• Decreased biodiversity
• Algal bloom
• Increased sedimentation
• Decreased oxygen content in water.

Question 16.

(a).Explain the different activities that result in pollution *(10 marks)*
(b).Explain the effect of water pollution on an aquatic ecosystem *(10 marks)*

(a).

<u>Air pollution</u>

• Burning domestic fuels; produce pollutants such as soot, CO and CO_2, nitrous oxides etc.
• Industrialization; release pollutants inform of industrial fumes containing sulphurdioxide and various toxic gases. Others pollutants include cement dust, asbestos, fluorine.
• Agricultural; pesticide sprays pollute the air.
• Radioactive fallout during extraction, transportation etc
• Bush burning and deforestation; allow accumulation of toxic gases like CO_2 and CO in air.

<u>Water pollution</u>

• Discharge of domestic sewage and detergents into water; adding pollutants like nitrates, phosphate compounds & non-biodegradable substances like polyethene
• Agricultural work; pollution through fertilizer and pesticide run off.
• Industrial; through discharge of toxic wastes such as heavy metals like mercury, radioactive elements, oil etc.

<u>Thermal pollution</u>

• Discharge of hot water into the water from electrical turbines during power generation.

<u>Sound pollution;</u>

• Population explosion, sound from automobiles, industries, quarries, recreation centres etc

(b).

There is an increase in the productivity of the phytoplanktons resulting into a large biomass. Algal blooming occurs and this reduces light penetration into the water body; leading to death of aquatic plants at lower levels. There is increased decomposition which reduces oxygen levels in water or the BOD of water rises significantly leading to death and suffocation of aerobic aquatic organisms. Species diversity decreases upsetting the food chain and the food web. Biotic changes occur where the blue-green algae/ cyanobacteria replace the green algae of the phytoplanktons/ emergence of aerobic organisms. Water turbidity increases due to increase in the concentration of suspended solids decreasing transparency. Rate of sedimentation increases; dense algae mats formed may block microfilters and sand beds.

Question 17.

(a).Explain what is meant by biogeochemical cycles ***(02 marks)***

(b).Describe the role of bacteria in a named biogeochemical cycle ***(08 marks)***

(c).Describe how biotic factors, other than human influence may affect the distribution of living organisms

(a).

Biogeochemical cycles are cycles that show the flow of elements through the biotic components and the geological/ abiotic component (rocks, soil, water and the atmosphere).

(b).

Nitrogen cycle

• Nitrogen fixing bacteria like Rhizobium, azotobacter perform nitrogen fixation using nitrogenase enzyme to convert nitrogen to ammonia which is then fixed into soil.
• Decomposers bacteria; perform Ammonification/ mineralization in which organic nitrogen contained in the dead organic matter is converted into ammonium compounds.
• Putrefying bacteria; perform putrefaction in which nitrogen incorporated in proteins is converted into ammonium compounds.
• Nitrifying bacteria; perform nitrification. Nitrosomonas converts ammonium compounds into nitrites which also get oxidized to nitrates by Nitrobacter.
• Denitrying bacteria like pseudomonads, Thiobacillus denitrificans perform denitrification in which nitrates reduced to atmospheric nitrogen.

Carbon cycle

• Photosynthetic bacteria e.g cyanobacteria (blue-green bacteria) perform carbon fixation; fix atmospheric carbondioxide into organic compound.

Sulphur cycle

Sulphide oxidizing bacteria e.g purple and green sulphur bacteria perform hydrogen sulphide oxidation; in which hydrogen sulphide is oxidized to sulphate in anaerobic conditions during their anoxigenic photosynthesis.

(c).

Parasitism; parasites feed on the host. Parasites are either on the bodies of their hosts or within their close microenvironments e.g leeches and black flies are micro-predators that feed on man and are distributed in man's environment, ticks on cattle etc

Competition; here two organisms compete for the same resources; can be intraspecific or interspecific. Competitively inferior organisms are distributed in habitats devoid of competively superior organisms

Mutualism; each organism benefits from the relationship. The two mutually existing organisms co-exist in the same microenvironments.

Predation; one organism called the predator feed on the other called the prey. Predators are thus distributed in areas with a high number of preys while preys opt for areas devoid of predators.

Commensalism; here one organism benefits and the other neither benefits nor gets harmed. Benefiting organisms are distributed in areas occupied by the non-benefiting commensal.

Dispersal agents; Certain plants may rely on insects or other small animals for dispersal and pollination. Their distribution therefore depends on such organisms.

Mimicry behaviours; some animals closely resemble other species that are unpalatable to their predators. As such the distribution of these animals depend on presence of species they resemble.

Camouflaging behaviour; some organisms have developed structures that make them blend with their immediate environment lie tree barks, leaves or thorns. As such the distribution of such organisms depends on the presence of plant species they resemble.

Question 18.

(a).What are endangered species? ***(02 marks)***
(b).Describe how organisms become endangered? ***(14 marks)***
(c) Suggest reasons why large mammals are more prone to extinction than small mammal ***(04 marks)***

(a).

Species whose numbers have been greatly reduced and are likely to become extinct if the factor causing their numbers to decline is not removed.

(b).

Habitat destruction: through deforestation, bush burning, swamp reclamation e.g. the Uganda cranes breeds in wetlands, when such wet lands are destroyed, their existence is threatened.
Hunting and collection: elephants are hunted for their ivory, rhinos for their horns, python for its skin; threatening their survival.
Some organisms are massively destroyed due to their being health hazards to man. E.g. vectors like mosquitoes & snails are killed because they are dangerous to man.
Competition between exotic and local breeds. In cattle, exotic breeds are preferred because of their hybrid vigor reducing the number of local breeds greatly to near extinction.
Process of natural selection; where some species are better adapted to the conditions of the environment than others, those less adapted are likely to reduce in number.
Stiff predation pressure; where the predator has a preferred prey, the preferred prey will be over consumed leading to its population to decline.
Pollution e.g oil spills, excessive use of fertilizers due to industrialization result in release of dangerous gases.

(c).

- Large animals need more food than small ones, in conditions of food scarcity they are likely to die which reduces their numbers up to extinction.
- Problems in achieving fast enough locomotion so that prey fails to escape from predators or predators fail to catch prey and die due to lack of food.
- Food specialization limits range of consumed food, population may be wiped in case of sudden shortage of food.
- Large animals are normally at the end of a food chain so get less energy, accumulate more stable pesticides

Question 19.

(a).How are the following organisms adapted to their modes of life?
(i) Tick ***(05 marks)***
(ii).Witch weed (Striges asiatica) ***(05 marks)***
(b).How do they affect the organisms with which they interact? ***(10 marks)***

(a)(i).

Adaptation of ticks
- Hard thick cuticle
- Mouth parts called hypostomes for piercing and sucking blood from host
- High reproductive rate; many eggs per day
- Dorso-ventrally flattened body to fit and hide on host's body
- Hook like mouth parts enable it to cling onto host.
- Body colour camouflage with host's skin colour
- Claws on legs for attachment on host
- Very sensitive to presence of host.

(a)(ii).

Adaptation of witch weeds (Striges asiatica)
- High reproductive rate producing many seeds
- They can carry out photosynthesis and compete favorably with autotrophs
- Seedlings quickly get attached to the host plant

• Seeds can remain viable and dormant for a long time germinating when conditions are favourable.
• Vascular connection between its seedling and the host plant to derive nourishment

(b)(i).

Effects of the ticks on their host
• Cause loss of blood from the host
• Damage to host's skin due to bites
• Cause irritation to the host;
• Transmit various diseases
• Cause wounds which become site of secondary infection

(b)(iii).

Effects of witch weed on the host
• Damage to hosts plant tissue
• Computer with host plant for light
• Reduces productivity/ photosynthesis of the host
• Host plant soon shows symptom of nutrient deficiency
• Cause water stress
• Host plant may fail to reach reproductive maturity

Question 20.

(a)(i). Outline the importance of population size of different organisms in a given area to an ecologist.
(ii).Differentiate between sample count and total count. ***(03 marks)***
(b).Give five factors to be considered before carrying out a counting exercise. ***(04 marks)***
(c).Describe a suitable method you could use to estimate the population of
(i). Fish e.g. tilapia in a lake.
(ii).Flying insects in an open wood land.
Give a reason for your choice of method in each case. ***(08 marks)***

(a).

• It enables construction of food webs, food chains, pyramids of number, biomass and energy.
• It helps an ecologist to understand the existing food relationships within the habitat.
• To know the population of pests which helps to work out control methods.
• To be able to estimate the rates of increase in population and carrying capacity of a habitat so as to maintain ecologically balanced habitat.
• To find out population changes over time so as to understand ways in which populations are affected by various environmental factors.
• It helps in the management of national parks, game reserves and forest reserves, to be able to design or alter boundaries of various conservation areas.

(a)(ii).

Total count	Sample count
All organisms are counted	Only organisms in part of an area are counted
The whole area is searched	Only parts of an area are selected and searched.
It gives absolute number of organisms in the whole area	The total number of organisms in part of the whole area is determined

(b).

• Size of the area
• Nature of topography/terrain
• Nature of vegetation
• Size of the organisms to be counted
• Behavior social structure and activity of the organisms to be counted
• Nature of the habitat; aquatic or terrestrial.
• Available resources e.g apparatus, transport, money etc.

(c)(i).

Capture mark release recapture method / Lincoln index method.

Reason

Because fish is large in size and can easily be identified, captured and counted

Lincoln index method

The fish are netted and their operculum tagged with an aluminum disc and then released back into the water without harming them. The number of fish marked and released I counted and recorded, N_0

After some time, a fish net is again laid and fish captured. Let the number be N_1. The number of fish with an aluminum disc on their operculum in this sample is counted, N_2.

The population of fish is then estimated from;

Estimated population = $(N_0 \times N_1)/N_2$

This method depends on the following assumptions;

- That organisms mix randomly within the population.
- That the time allowed for random mixing is enough.
- That changes in population size due to immigration, emigration, death and birth are negligible.
- That the movement of organisms is restricted geographically.
- That there is even dispersing of organisms within the study area.
- That the mark does not hinder the movement of organisms or make them conspicuous to predators

(c)(ii).

Removal method

Reason

They are small and mobile

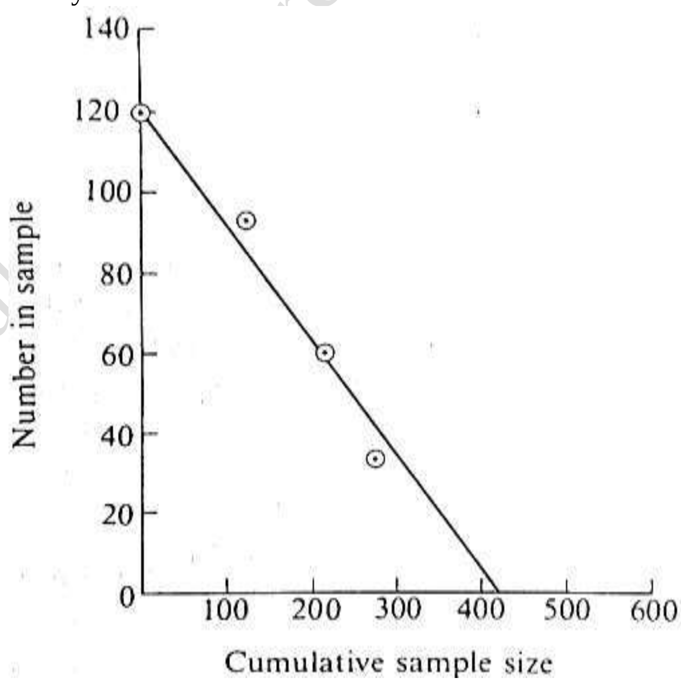
Method

Using a net, in form of a sweep net, the number of insect captured is recorded and animals kept.

This procedure is repeated a further three to four times and the gradually reducing numbers recorded.

A graph of number of insect captured per sample against the previously cumulative number of insect is plotted, as shown below.

By extrapolating the line of the graph to the point at which no further animals would be captured i.e capture per effort = 0, the total population may be estimated.



Question 21.

(a).Discuss ways in which equilibrium is maintained in the biosphere. ***(06 marks)***

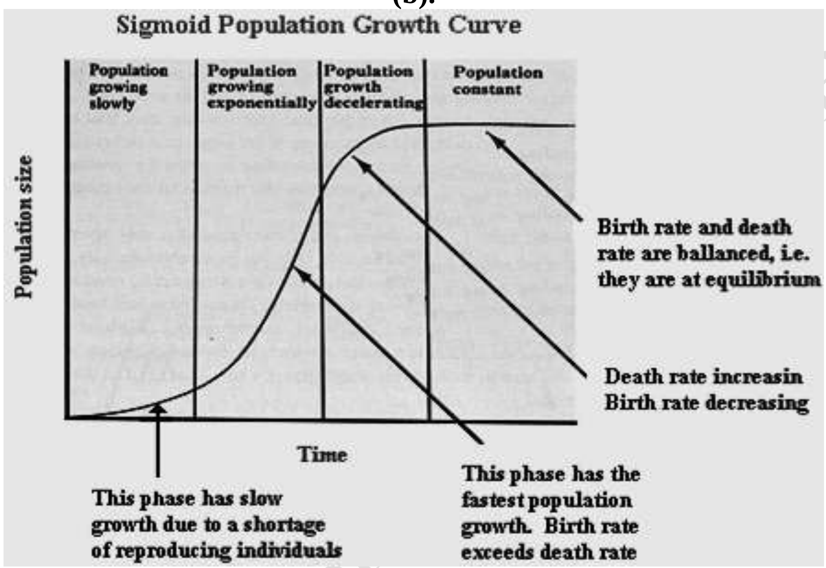
(b).Explain factors that cause a population to follow the sigmoid growth curve. ***(08 marks)***

(c).Apply the concept of carrying capacity to the struggle for survival resulting from over production of off-spring. ***(05 marks)***

(a).

• O_2 used and CO_2 produced in respiration; CO_2 used and O_2 produced in photosynthesis
• Water evaporates from lakes/ oceans/ soil and also given off in transpiration but condenses falls as rain
• Nitrogen from atmosphere is fixed; denitrification returns nitrogen to the atmosphere
• Plants/ autotrophs make organic compounds/ biomass; heterotrophs/ decomposers break down organic compounds/ biomass.
• Numbers of prey is controlled by numbers of predators and that of predators controlled by numbers of prey.
• Energy in sunlight continually supplied to biosphere and is lost from biosphere as heat

(b).



During exponential growth the population grows at an increasing rate; All or most offspring survive/ birth rate higher than death rate and all or most offspring reproduce such that each generation produces more offsprings that the last. Plateau reached eventually/ population levels off / birth rate equals death rate when carrying capacity of environment is reached e.g. when no more food / nutrients / resources/ space available, numbers of predators/ parasites have increased or diseases have become more prevalent. Transitional phase starts when limits to growth are starting to act.

(c).

The environment can only support a certain maximum population which is sometimes exceeded (due to overproduction of offspring), food/ space/ resources are insufficient /competition for resources. Some individuals fail to obtain enough; deaths/ failure to reproduce/ survival of the fittest; population falls to carrying capacity; evolution by natural selection occurs over successive generations.

Question 22.

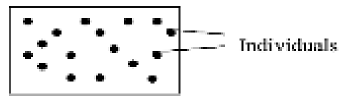
(a).Explain what is meant by population dispersion? ***(02 marks)***
(b).Describe the major forms of population distribution and their significance ***(09 marks)***
(c).Explain the reasons why many communities are dominated by clumped patterns of distribution
(d).Outline the importances of dispersion of animals ***(05 marks)***

(a).

Dispersion refers to the structure/distribution of individuals or organisms within an area. Dispersal mechanism of the population supplements natality and mortality in shaping population growth form and density.

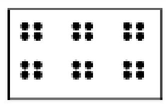
(b).

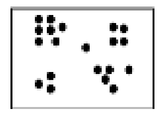
Random dispersion/distribution; This is relatively rare in nature. It occurs where the environment is very uniform in terms of resources and there is no tendency of organisms to aggregate. There is equal and even distribution of resources. There is low or no competition.



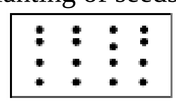
Clumped distribution/aggregate/clustered; It's the naturally occurring type of distribution where individuals tend to aggregate at a particular point on the habitat. It's due to distribution of resources that are not regularly distributed due to climate and soil factors and social behaviour like termites and bees have division of labour among members, animals that live in colonies like buffalos, baboons, monkeys, etc. clumps could be irregular or regularly distributed.

Regular pattern **Irregular or random pattern**





Uniform/regular distribution; This occurs where intraspecific competition is severe. However, man artificially can induce it through agricultural practices e.g. planting of seeds.



(c).

- Effects of parent plant i.e. seeds may not be dispersed far from the parent plant hence plant seedlings are usually found near the parent plant.
- Distribution of environmental factors. These are not uniform for all areas.
- Species interrelations i.e. a species may be depending on another directly e.g. epiphytes.
- Animals exhibit dispersion in form of territorial behaviours.
- Natural barriers like rivers and rift valley restrict animals in particular areas e.g. bush backs, chimps and elephants.

Importance of dispersion in animals

- Individuals acquire a home/nest/habitat within which they can live and breed.
- Individuals are spread out such that resources like food, breeding grounds become enough.
- Chances of obtaining a mate is increased since males attract females into their territories.
- Natural barriers like rivers & rift valleys restrict animals in particular areas e.g. bush backs, chimps & elephants.
- Reduces distances moved away from home to search for food, mate, etc. this saves energy, time and prevents exposure to predators.

Question 23.

(a).Explain what is meant by environmental degradation *(02 marks)*
(b).Outline the causes of environmental degradation *(09 marks)*
(c).State some of the ecological effects of environmental degradation *(09 marks)*

(a).

This refers to the physical, chemical and biological changes to the physic al nature and or biological behaviour of the components of the environment by various human activities in attempt to meet their live hood requirements or by natural disasters.

(b).

Degradation in land quality
- Poor cultivation methods
- Poor methods of mining; such as open cast mining destroys habitats.
- Overgrazing
- Wild fires associated with pastoralists
- Excessive and continuous of agro chemicals i.e. herbicides, pesticides etc
- Dumping of toxic wastes from industries
- Deforestation and de-vegetation
- Equipment used in war-heavy machinery, explosives etc.

Degradation in water quality
- Accumulation of soil and other debris drained from land

• Chemicals drained from land
• Dumping of sewage/garbage.
• Invasive weeds e.g. water hyacinth
• Loss of soil fertility
• Increased dust in the air; reduce visibility.
• Increased dirt in water
• Silting of water bodies
• Pollution of land, water and air
• Loss of biodiversity

(c).

• Acid rain- leading to corrosion of structures and death of organisms.
• Accumulation of chemical residues along food chains; cause bioaccumulation.
• Global warming
• Ozone depletion leading to increased ultra violet radiation reaching organisms resulting in increased mutation and diseases like cancer.
• Drought and desertification
• Diseases that are in air and water-borne.

Question 24.

(a).Explain what is meant by environmental resistance ***(02 marks)***
(b).Outline the factors
(i).Affecting biotic potential ***(05 marks)***
(ii)Hindering biotic potential ***(05 marks)***
(c).State the properties of r and k selected populations ***(06 marks)***

(a)(i).

Refers to the sum/ total of limiting factors, both biotic and abiotic which interact together to prevent the biotic potential from being obtained or all the factors that tend to reduce population numbers. External factors include; predation, food supply, heat, light, space, toxic wastes. Internal factors/ regulatory mechanisms include intraspecific competition, behavioral activities, stress/ psychological factors.

(b)(i).

• Procreation; the number of time per year the organisms reproduce.
• Maturity; the age at which reproduction begins.
• Male to female ratios in the population.
• Age structure; age at which reproduction is high e.g. in man is 45, chances of producing become minimal
• Clutch size (number of offspring produced at each reproductive event)
• Frequency of reproduction
• Reproductive lifetime
• Survivorship of offspring to reproductive maturity

(b)(ii).

• Loss of food.
• Increased predator population.
• High pollution in the environment.
• Fire outbreak; destroys organisms, breeding sites, nest, eggs, slow moving organisms.
• Man’s activities e.g. encroaching on swamps, wet lands, forests, road construction (separates ecosystems)
• Diseases, parasites and pests.

(c).

Characteristics of r-selected populations
• They are found in habitat/environments which undergo many changes.
• The individuals are small in size.
• Have a short life span i.e. they attain reproductive potential very early.
• Have a high mortality rate not density dependent.
• Reproduce at a high rate.

• Off springs grow rapidly with little parental care provided.
• Favourable conditions favour rapid explosion of population growth hence no or less competition. Thus selection pressure in such species favours high reproduction rate and short generation.
• A sudden environmental change results in a massive number of deaths. But their rapid birth rate and short life span favour the ability to adapt to a changing habitat e.g. insects, seeds, spores, bacteria, annual plants, paramecium.
• They are opportunist pioneer species of new and disturbed habitats. Migration & dispersal are key factors of their strategy.

Characteristics of k-selected population

• Reproduce slowly (low fecundity, long generation time) therefore low value of r.
• Reproduction rate is sensitive to population density, rising rapidly if density falls.
• Population size stays close to equilibrium level determined by K.
• Species are persistent in a given area.
• Disperse slowly
• Large in size e.g. woody stems and large roots if plants.
• Individuals live long
• Habitats stable and long lived (forests for monkeys).
• Good competitors
• Many become dominant.
• Less resistant to changes in environmental conditions e.g. butterflies, birds, humans and trees.

Question 25.

(a).Outline the events that take place in a functional ecosystem ***(06 marks)***
(b).Describe the various types of ecosystems ***(05 marks)***
(c).Explain the factors limiting distribution of organisms in an aquatic ecosystem ***(10 marks)***

(a).

• Recycling of matter i.e. nitrogen cycle, carbon cycle, etc.
• Energy flow/transfer from producers, consumers and decomposers.
• Food interactions/food chain and water.
• Development and evolution of species of organisms (death due to competition and resistance due to competition /survival for the fittest).
• Population control/dynamics/cybernetic of the population.
• Succession.

(b).

Terrestrial ecosystems; exist on land. Here regional climates interact with regional biota and substrate to produce large recognizable community units called biomes. A biome is identical with a major plant formation but it is a total community unit in which both animals and plants are considered. The six major biomes of include:
Tropical rain forest; tropical savanna and grass land, desert, semi-desert, mountain forests and temperate region
Aquatic ecosystems; occurs in water. Aquatic ecosystems support a great diversity of life forms. Water occupies 50% of the earth's surface. Water provides a more constant and protective environment than land (desiccation, less affected by sudden and drastic changes in physical and chemical conditions, some change due to climatic or seasonal variation). It provides support and dissolved oxygen and nutrients to aquatic organisms. Aquatic ecosystems are classified as Fresh water ecosystem, marine ecosystems or estuarine ecosystem depending on the concentration of salts they contain;

(c).

Temperature: Water has several unique thermal properties. Aquatic organisms have narrow thermal tolerance. Temperature changes therefore produce characteristic patterns of circulation which greatly influence aquatic life for example breeding.
Light penetration: Penetration of light is often limited by suspended materials (turbidity). This restricts the photosynthesis zone. Plants cannot survive below the compensation level. Primary productivity indirectly affects energy transfer at other trophic levels.

Water currents: Currents determine the distribution of vital gases, salts and small organisms. Water current is a limiting factor in fast flowing streams and on shores when it prevents colonization by weak swimming organisms.
Dissolved gases: Gases from the atmosphere dissolve in water at the surface. However, some gases are more soluble than the others e.g. oxygen is 30 times less abundant in water than in air. This limits the distribution of living organisms. The diffusion of dissolved gases through deep layers of water is very slow. Once there is little oxygen available, it is used up by decomposers, the effects may be disastrous anoxic conditions to the whole community. Dissolved nitrogen is used by nitrogen fixing bacteria and blue-green algae in the manufacture of proteins.
Dissolved salts: Fresh water ecosystems show a considerable variation in salt content. This depends on the minerals present in drainage water from the surrounding land mass and activities of living organisms.
Deposition of nutrients in water is known as eutrophication. Nitrate and phosphate are the most limiting factors in fresh water ecosystems.

Question 26.

Fire is an important ecological factor in population control
(a).Describe the factors that affect the effectiveness of fire. ***(10 marks)***
(b).Outline the ecological importances of fire ***(10 marks)***

(a).

Kind and amount of fuel: Tall grasses produce much fire more than heavily grazed areas. However, forest fires are more vigorous than grass fires and they cause much more destruction. This is due to the amount of fuel that takes time to be completely burned.
Weather conditions: During the rainy season fires do not spread very far and become wild but in a dry season fires are more wild, strong and destructive.
Topography: fires are fastest uphill and slowest downhill therefore the effect of fire on soil is greatest on fires downhill rather than uphill.
Frequency of burning: continued burning has a more permanent destructive effect. It does not only destroy vegetation cover but kills soil and fauna.
Direction of fire: back fire burning against the wind direction is more severe on the soil than forward fire burning with the wind direction.

(b).

Positive ecological importances of fires

- It breaks seed dormancy due to hard seed coat leading to fast germination.
- It increases rate of nutrient recycling in an ecosystem.
- It is a non-selective weed killer
- It controls pests and diseases.
- It improves on herbage in an area.
- It improves on light penetration leading to rapid under growth in the forest.
- It improves on the visibility of the prey to predators by burning the vegetation cover down.

Negative ecological importances of fires

- It destroys the habitat of animals which may cause extinction of some animals.
- It causes air pollution
- It destroys green plants which are producers of the community.
- It destroys animals in the ecosystem reducing animal biodiversity.
- It increases predation due to improved visibility.
- It leads to loss of some nutrients from the soil by decomposition e.g. humus and nitrates.

Question 27

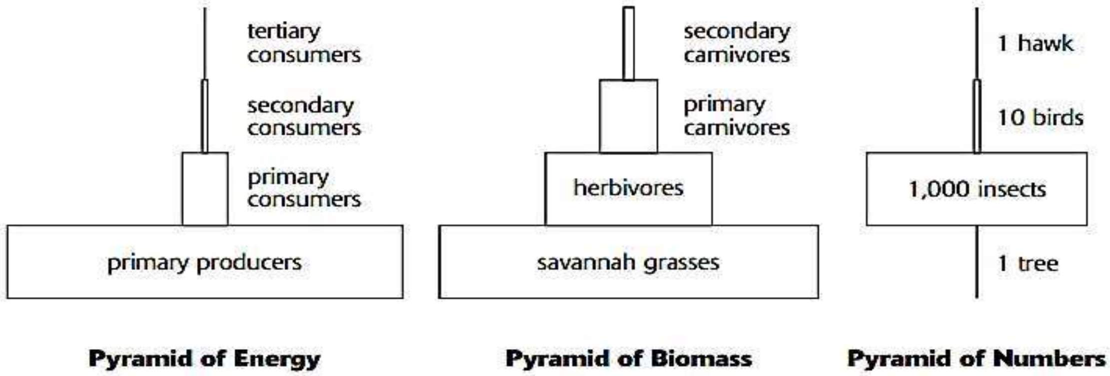
(a).Explain what is meant by the following;
(i). Trophic level ***(01 marks)***
(ii) Ecological pyramids ***(03 marks)***
(iii)Carrying capacity ***(03 marks)***
(b).Outline the factors that limit the number of trophic levels ***(03 marks)***
(c).State the environmental indicators of a population that has exceeded its carrying capacity
(d).What are some of the applications of ecological studies ***(07 marks)***

(a)(i).

Trophic level is a stage at which organisms obtain their food in the same general manner eg herbivores

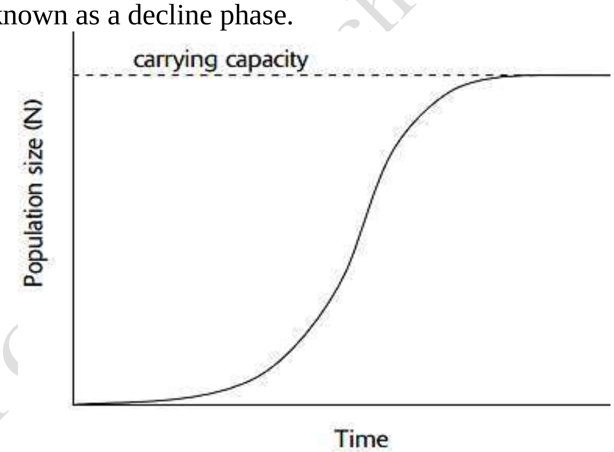
(a)(ii).

Ecological pyramids are bar diagrams showing number or biomass or energy of organisms in a food chain. Horizontal bars or tiers are used to represent the relative sizes of trophic levels, each represented in terms of energy (also called productivity), biomass, or numbers of organisms. The tiers are stacked upon one another in the order in which energy is transferred between levels.



(a)(iii).

Carrying capacity of a population refers to the maximum number of the individuals of a population which the resources in a particular environment can support maximally at a given time. Beyond carrying capacity, changes in environmental factors such as food supply decline/reduced rainfall, fluctuation in temperature or an outbreak of epidemics, temperature, etc. results in an increased death rate which over powers the birth rate hence leading to a fall in the population. This is known as a decline phase.



(b).

- Loss of energy during the transfer
- Limited territorial space for the end chain organisms
- Insufficient food of preferred type to the top consumers.

(c).

- Increased rate of vegetation destruction
- Rapid environmental degradation
- Extinction of some species
- Accumulation of wastes
- Increased rate of emigration
- Increased death rate

(d).

- Applied in the field of agriculture, fisheries and forestry
- Predict incidences of pollution and how they can be prevented.

• Understand consequences of construction of dams, diversion of rivers and reclamation of swamps, construction of infrastructure on the environments.
• Biological conservation methods
• Applied in pest control measures
• Ecological studies form the basis of conserving biodiversity
• It‘s a mean through which number of organisms in a given sample area is estimated

Question 28.

Write short notes on the following modes of resolving competition within a community
(a).Competitive exclusion principle (Gause's principle). ***(06 marks)***
(b).Resource partitioning. ***(04 marks)***
(c).Character displacement (niche shift). ***(04 marks)***
(d).Realized niche. ***(06 marks)***

(a).

The competitive exclusion principle, formulated by Gause states that; no two species can sustain coexistence if they occupy the same niche i.e when two species compete for exactly the same resources (or occupy the same niche), one is likely to be more successful. As a result, one species outcompetes the other, and eventually, the second species is eliminated. In his experiments, Gause mixed two species of Paramecium that competed for the same food. One population grew more rapidly, apparently using resources more efficiently. Eventually the second species was eliminated.

(b).

Some species coexist despite apparent competition for the same resources because they occupy slightly different niches. By pursuing slightly different resources or securing their resources in slightly different ways, individuals minimize competition and maximize success. Dividing up the resources in this manner is called resource partitioning e.g five species of warblers coexist in spruce trees by feeding on insects in different regions of the tree and by using different feeding behaviors to obtain the insects.

(c).

As a result of resource partitioning, certain characteristics may enable individuals to obtain resources in their partitions more successfully. Selection for these characteristics reduces competition with individuals in other partitions and leads to a divergence of features, or character displacement. Two species of finches that live on two different Galapagos Islands have similar beaks, both suited for using the same food supply (seeds). On a third island, they coexist, but due to evolution, the beak of each bird species is different. This minimizes competition by enabling each finch to feed on seeds of a different size.

(d).

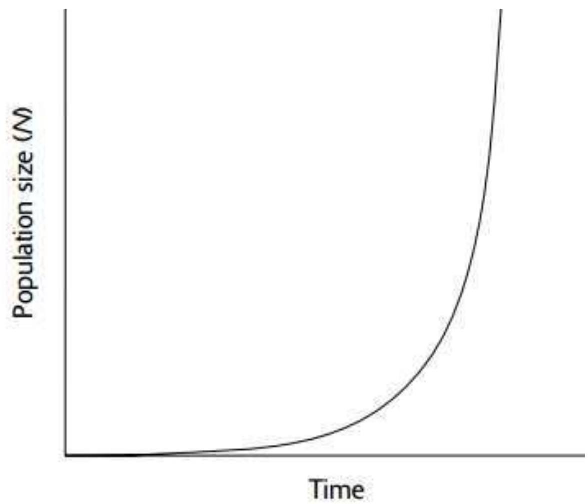
The niche that an organism occupies in the absence of competing species is its fundamental niche. When competitors are present, however, one or both species may be able to coexist by occupying their realized niches, that part of their existence where niche overlap is absent, that is, where they do not compete for the same resources. Under experimental conditions, one species of barnacle can live on rocks that are exposed to the full range of tides. The full range, from the lowest to the highest tide levels, is its fundamental niche. In the natural environment, however, a second species of barnacle outcompetes the first species, but only at the lower tide levels where desiccation is minimal. The first species, then, survives only in its realized niche, the higher tide levels.

Question 29.

(a).Describe the two general patterns of population growth in an ecological setting ***(04 marks)***
(b).With the aid of appropriate graphs, discuss the ecological concept of survivorship curves ***(08 marks)***
(c).The human population began an exponential growth about a thousand years ago. Explain the factors that have contributed to this exponential growth ***(08 marks)***

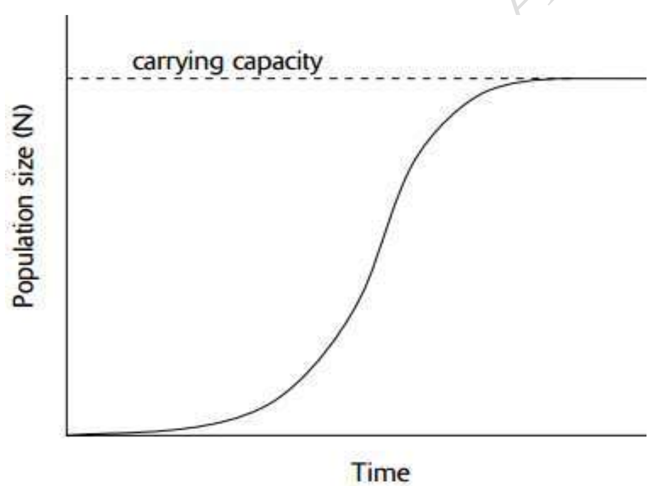
(a).

Exponential growth occurs whenever the reproductive rate is greater than zero. On a graph where population size is plotted against time, a plot of exponential growth rises quickly, forming a J-shaped curve.



Exponential Population Growth

Logistic growth occurs when limiting factors restrict the size of the population to the carrying capacity of the habitat. A plot of logistic growth forms an S-shaped or sigmoid, curve



Logistic Population Growth

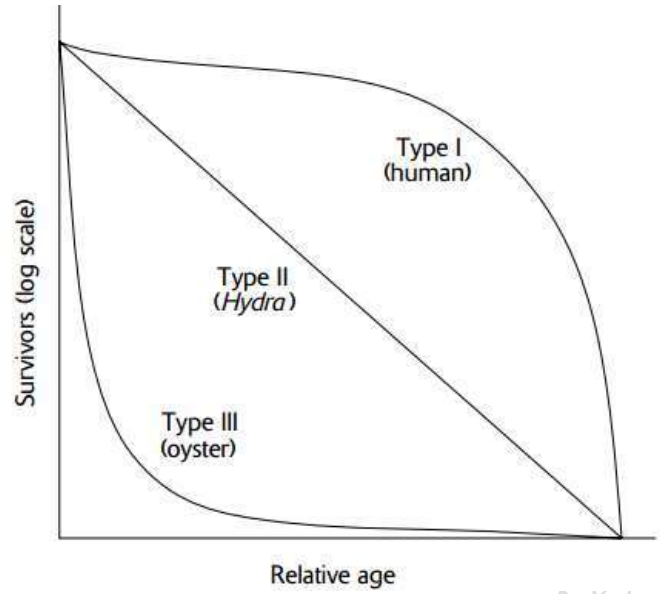
(b).

Survivorship curves describe how mortality of individuals in a species varies during their lifetimes

Type I curves describe species in which most individuals survive to middle age. After that age, mortality is high. Humans exhibit type I survivorship.

Type II curves describe organisms in which the length of survivorship is random, that is, the likelihood of death is the same at any age. Many rodents and certain invertebrates (such as Hydra) are examples.

Type III curves describe species in which most individuals die young, with only a relative few surviving to reproductive age and beyond. Type III survivorship is typical of oysters and other species that produce free swimming larvae that make up a component of marine plankton. Only those few larvae that survive being eaten become adults.



(c).

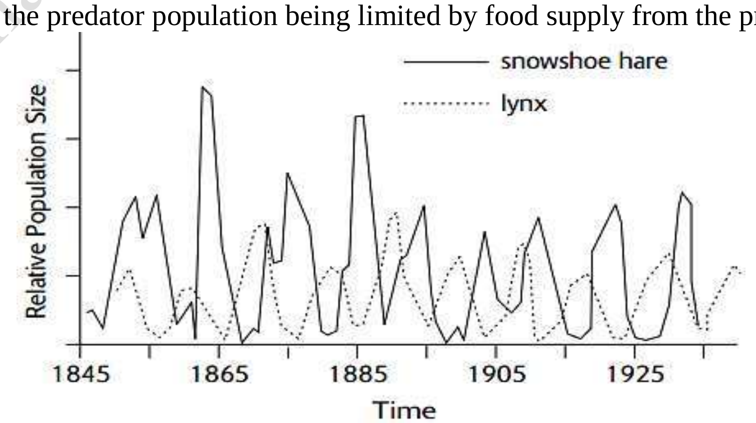
Increases in food supply; By domesticating animals and plants, humans were able to change from a hunter or gatherer lifestyle to one of agriculture. In the last hundred years, food output from agriculture was increased as a result of technological advances made during the industrial and scientific revolutions.
Reduction in disease; Advances in medicine, such as the discoveries of antibiotics, vaccines, and proper hygiene, reduced the death rate and increased the birth rate.
Reduction in human wastes; By developing water purification and sewage systems, health hazards from human wastes were reduced.
Expansion of habitat; Better housing, warmer clothing, easy access to energy (for heating, cooling and cooking, for example) allowed humans to occupy environments that were previously unsuitable.

Question 30.

(a).With an example, explain what is meant by population cycles ***(03 marks)***
(b).Describe the effects of limiting factors and carrying capacity on population growth within a particular habitat ***(08 marks)***
(c).Explain how two closely related species can occupy the same habitat seemingly competing for the same kind of resources. ***(09 marks)***

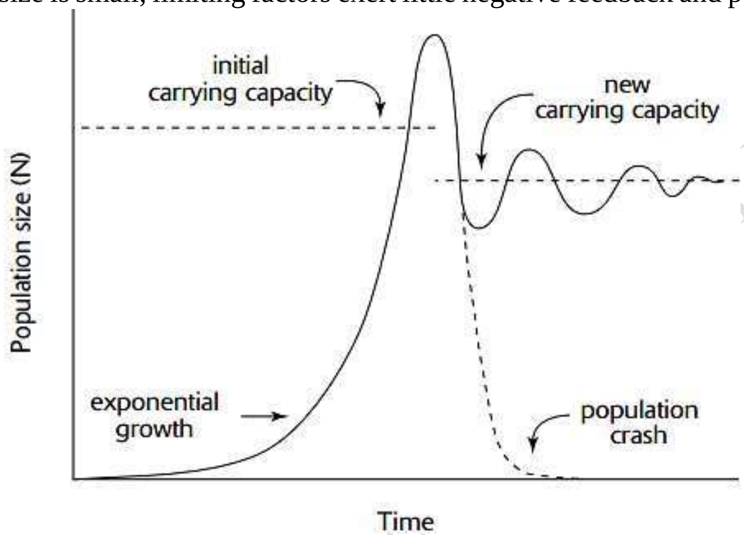
(a).

Population cycles are fluctuations in population size in response to varying effects of limiting factors eg the fluctuation cycles observed between predators (eg lynx) and preys (eg snowshoe hare) in which the prey population is limited by predation and the predator population being limited by food supply from the preys.



(b).

Since many limiting factors are density-dependent, they have a greater effect when the population size is large as compared to when the population is small. In addition, a newly introduced population may grow exponentially beyond the carrying capacity of the habitat before limiting factors inhibit growth. When limiting factors bring the population under control, the population size may decline to levels lower than the carrying capacity (or it may even crash to extinction). Once reduced below carrying capacity, however, limiting factors may ease and population growth may renew. In some cases, a new carrying capacity, lower than the original, may be established (perhaps because the habitat was damaged by the excessively large population). The population may continue to fluctuate about the carrying capacity as limiting factors exert negative feedback on population growth when population size is large. When population size is small, limiting factors exert little negative feedback and population growth renews.



(c).

Resource partitioning; Some species coexist in slightly different niches inspite of apparent competition for the same resources. By pursuing slightly different resources or securing their resources in slightly differrent ways, individuals minimize competition and maximize success. Dividing up the resources in this manner is called resource partitioning.

Character displacement (niche shift); As a result of resource partitioning, certain characteristics may enable individuals to obtain resources in their partitions more successfully. Selection for these characteristics reduces competition with individuals in other partitions and leads to a divergence of features, or character displacement.

Realized niche. The niche that an organism occupies in absence of competing species is its fundamental niche. When competitors are present, however, one or both species may be able to coexist by occupying their realized niches, that part of their existence where niche overlap is absent i.e where they do not compete for the same resources.

Question 31.

Write short notes on the following ecological concepts

(a).Ozone and Ozone depletion *(04 marks)*
(b).Greenhouse effect and global warming *(06 marks)*
(c).Acid rain *(05 marks)*
(d).Biomagnification *(05 marks)*

(a).

The ozone layer forms in the upper atmosphere when UV radiation reacts with oxygen (O_2) to form ozone (O_3). The ozone absorbs UV radiations and thus prevents it from reaching the surface of the earth where it would damage the DNA of plants and animals. Various air pollutants, such as chlorofluorocarbons(CFCs), carbonmonoxide and carbondioxide enter the upper atmosphere and break down ozone molecules. CFCs have been used as refrigerants, as propellants in aerosol sprays, and in the manufacture of plastic foams. When ozone breaks down, the ozone layer thins forms ozone holes; allowing UV radiation to penetrate and reach the surface of the earth.

(b).

Accumulation of carbondioxide and other greenhouse gases like methane, CFCs, CO etc contribute to planetary global warming. The carbondioxide layer in the atmosphere is transparent to the incoming short wavelength radiations from the sun but absorbs strongly the long wavelength radiations which the earth re-radiates into space. It therefore traps the outgoing radiations, warming the lower atmosphere which in turn radiates energy back to the earth's surface. This raises the planetary surface temperatures (greenhouse effect); and would eventually result in global warming. The drastically rising levels of carbondioxide and other greenhouse gases may lead to increasingly warmer surface environment (enhanced greenhouse effect); increase rate of evaporation; lead to more loss of water (a powerful long wave absorber); cause further increase in surface temperatures resulting in changes in the distribution pattern and intensity of the major planetary weather systems (global warming) which would profoundly affect human activities and distribution of organisms.

(c).

The burning of fossil fuels (such as coal) and other industrial processes release into the atmosphere air pollutants that contain sulfur dioxide and oxides of nitrogen. When these substances react with water vapor, they produce sulfuric acid and nitric acid. When these acids return to the surface of the earth (with rain or snow), they kill plants and animals in lakes and rivers and on land and makes soils acidic affect crop productivity. Acid rain also leaches magnesium and calcium from soil, eventually aluminum, manganese and other heavy metals come into solution, reach their toxic levels; causing damage to tree roots and mycorrhizas; thus reducing the capacity of plants to take in nutrients and water. Diseases induced by mineral deficiencies emerge so commonly especially in the dry season. The problem of acid rain has been addressed through reducing release of pollutant gases, employing the desulphurization technology and adding lime to acidic waterbodies.

(d).

Biomagnification/ bioaccumulation is build-up of a metabolically persistent chemical substances or toxins high up along the trophic ladder. Many pollutants are not readily biodegradable and thus persist in environment for long periods of time. Such toxins, like the pesticide Dichlorodiphenyl trichloroethane (DDT), concentrate in fat tissue of plants and animals. As one organism eats another, the toxin becomes more and more concentrated. Biomagnification is disastrous to top carnivores as toxicity of the accumulated chemical like DDT may result in infertility, induce hormonal changes that affect calcium metabolism making birds lay thin shelled eggs that consequently break. Such hindrances to reproductive success may threaten extinction of top carnivores.

Question 32.

Briefly discuss the major biogeochemical cycles outlining the reservoirs, mode of assimilation and release back into the environment ***(20 marks)***

Hydrologic cycle (water cycle);

Reservoirs: oceans, air (as water vapor), groundwater, glaciers. (Evaporation, wind, and precipitation move water from oceans to land.)
Assimilation: plants absorb water from soil; animals drink water or eat other organisms (which are mostly water).
Release: plants transpire; animals and plants decompose.

Carbon cycle.

Reservoirs: atmosphere (as CO_2), fossil fuels (coal, oil), peat, durable organic material
Assimilation: plants use CO_2 in photosynthesis; animals consume plants or other animals.
Release: plants and animals release CO_2 through respiration and decomposition; CO2 is released when organic material (such as wood and fossil fuels) is burned.

Nitrogen cycle.

Reservoirs; Atmospheric nitrogen; soil (ammonium or ammonia or nitrite or nitrate ions)
Assimilation; plants absorb nitrogen either as nitrates or ammonium ions; animals obtain nitrogen by eating plants or other animals. The stages in the assimilation of nitrogen are as follows
Nitrogen fixation; nitrogen to ammonium ions by nitrogen fixing prokaryotes (in soil and root nodules); nitrogen oxidized to nitrates by lightning and UV radiations
Nitrification; ammonium ions to nitrite ions and nitrites to nitrate ions by various nitrifying bacteria. Ammonium ions or nitrates to organic compounds by plant metabolism

Release; denitrifying bacteria convert nitrates back to nitrogen (devitrification); detrivorous bacteria convert organic compounds back to ammonium ions(ammonification), animals excrete ammonium ions or ammonia or urea or uric acid.

Phosphorous cycle

Reservoirs: rocks and ocean sediments. (Erosion transfers phosphorus to water and soil; sediments and rocks that accumulate on ocean floors return to the surface as a result of uplifting by geological processes.)
Assimilation: plants absorb inorganic phosphate ions from soils; animals obtain organic phosphorus when they eat plants or other animals.
Release: plants and animals release phosphorus when they decompose; animals excrete phosphorus in their waste products.
Biogeochemical cycles of other minerals, such as calcium and magnesium, are similar to the phosphorus cycle.

Question 33.

(a).Explain what is meant by co-evolution ***(05 marks)***
(b).With examples, describe the different ways in which co-evolution has been exhibited in an ecological setting and the importance of each ***(15 marks)***

(a).

Evolutionary relationship between two species that are ecologically very closely associated. In the contest between predator and prey, some prey may have unique heritable characteristics that enable them to more successfully elude predators. Similarly, some predators may have characteristics that enable them to more successfully capture prey. The natural selection of characteristics that promote the most successful predators and the most elusive prey leads to coevolution of predator and prey.

(b).

• Secondary compounds are toxic chemicals produced in plants that discourage would-be herbivores.
• Tannins, found in oaks, and nicotine, found in tobacco, are secondary compounds that are toxic to herbivores.
• Camouflage (or cryptic coloration) enables an animal to blend with its surroundings. Both prey and predator benefit from camouflage.
The fur of the snowshoe hare is white in winter (a camouflage in snow) and brown in summer (a camouflage against the exposed soil).
• The larvae of certain moths are colored so that they look like bird droppings.
• The markings on tigers and many other cats provide camouflage in a forested background. In contrast, the yellow-brown coloring of lions provides camouflage in their savanna habitat.
• Some plants escape predation because they have the shape and color of the surrounding rocks.
• Aposematic coloration (or warning coloration) is a conspicuous pattern or coloration of animals that warns predators that they sting, bite, taste bad, or are otherwise to be avoided.
• Predators learn to associate the yellow and black body of bees with danger.
Mimicry occurs when two or more species resemble one another in appearance. There are two kinds of mimicry:
• Müllerian mimicry occurs when several animals, all with some special defense mechanism, share the same coloration. Müllerian mimicry is an effective strategy because a single pattern, shared among several animals, is more easily learned by a predator than would be a different pattern for every animal. Thus, bees, yellow jackets, and wasps all have yellow and black body markings.
• Batesian mimicry occurs when an animal without any special defense mechanism mimics the coloration of an animal that does possess a defense. For example, some defenseless flies have yellow and black markings but are avoided by predators because they resemble the warning coloration of bees. Pollination of many kinds of flowers occurs as a result of the coevolution of finely-tuned traits between the flowers and their pollinators.
• Pollen from flowers of the Yucca plant is collected by yucca moths. Pollination is accomplished when the moths roll the pollen into a ball, carry it to another Yucca plant, and deposit it on the stigma of a flower. The moth also deposits its eggs into some of the flower's ovules, but only about a third of the flower's seeds are eaten by the moth larvae after hatching from the eggs. There are no other pollinators for Yucca and no other hosts for yucca moth egg-laying.

• Red, tubular flowers with no odor have coevolved with hummingbirds who are attracted to red and have long beaks and little sense of smell. The flowers provide a copious amount of nectar in exchange for the transfer of their pollen to other flowers.

Question 34.

(a).Describe the structure of an ecosystem ***(06 marks)***
(b).Explain the mechanism of emergence of pest resurgence in an ecological setting ***(04 marks)***
(c).Explain how human activities interfere with nutrient recycling and energy flow in an ecosystem

(a).

Biotic component (density dependent factors); These are the components which interact between the different living organisms e.g. competition, predation, symbiosis. The biotic part includes producers, primary consumers (first level carnivores), tertiary consumers (higher carnivores), decomposers, detritivores etc.
Abiotic factors (density independent factors); These are factors affecting the population regardless of the number of individuals within e.g. temperature changes, natural catastrophes like foods, storms, volcanicity, fire, earth quake, drought, etc.
Edaphic factors; The soil directly influences plant growth and indirectly the animal population e.g. soil texture, soil pH, air, humus, salts, water, etc.
Climatic factors (density dependent); E.g. light, water/rain fall, wind/air, relative humidity, temperature.

(b).

Use of non-specific pesticides initially kills both the pest and its natural biological predators such that their populations reduce so low. However a few surviving pests may mutate and become resistant strains to the pesticide. Over time, such resistant pest populations grow so rapidly without being checked upon by their natural biological predators. As a result, the resistant pest population booms; past the habitat's carrying capacity; despite continous aggressive pesticide application.

(c).

Deforestation; associated with reduction in gross productivity from the primary producers; hence affecting the energy flow. Accumulation of carbondioxide secondary to deforestation increases carbon deposition in the ecosystem; altering carbon cycles.
Bush burning; destroys vegetation thus lowering primary productivity. Other organisms at the different trophic levels are also killed; hence affecting energy flow. The increase in carbondioxide levels increases carbon deposition into the environment altering with the carbon cycle.
Burning fossil fuels for domestic use and industries; deposits excesses of carbon in form of carbondioxide into the environment altering the carbon cycle.
Use of artificial inorganic fertilizers; such as phosphorous and nitrogen containing fertilisers; add extra nitrogen and phosphorous into their respective cycles. Surface runoff into water bodies result in eutrophication that results in algal bloom; increasing primary productivity. Death of other organisms however occurs at different trophic levels due to anoxic (no oxygen) conditions in the water thus limiting energy flow.
Use of chemical pesticides; Excess pesticides leads to bioaccumulation that poisons organisms at different trophic levels more so the top carnivores; limiting energy flow.
Poor agricultural methods: like monoculture inform of over-cultivation of legumes, beans, soyabeans etc deposit excesses of nitrogen in biologically available forms altering the nitrogen cycles.
Industralization; production of sulphur and carbon containing pollutants like oxides of sulphur impact the sulphur the carbon cycle by adding excesses of sulphur and carbon respectively. The toxic effects of acid rain and precipitate resulting from the accumulation of sulphurdioxide; affects organisms at different trophic levels; limiting energy flow.
Poor methods of mining; such as open cast mining destroy habitats. Heavy metals like lead and mercury drain into water bodies causing severe destruction of aquatic fauna and flora, poison water for human consumption; alt-ering the structure of plant and animal communities. This limits nutrient recycling and energy flow.
Livestock ranching/ animal rearing; releases large amounts of nitrogen into the environment inform of ammonia through the animal excreta. This elevation in the environmental nitrogen content alters the nitrogen cycle.
Extensive use of automobiles; discharge fumes containing plenty of sulphur and carbon compounds. The respective nutrient cycles are altered due to this extra deposition.

Sewage waste and septic tank leaching; also contribute to the large increase of the nitrogen being released.
Irrigation; may encourage leaching of nutrients to deeper layers; inaccessible for recycling; Also increases the water content of the soil altering the hydrologic cycle.

Question 35.

(a). Light is an important abiotic component of the ecosystem. State the role of light in influencing the various processes in living organisms ***(10 marks)***
(b).Outline the ecological significance of
(i) Water ***(05 marks)***
(ii).Wind ***(05 marks)***

(a).

- It is a source of energy for photolysis (breakdown of water during photosynthesis).
- Absence of light causes etiolation (elongation of shoot inter nodes).
- Induces flowering in long-day plants e.g. barley, but inhibits flowering in short day plants.
- Phototropism, by redistributing auxins on the darker sides of shoots and roots, allows growth.
- Permits germination in positively photoblastic seeds i.e seeds that only germinate in presence of light
- Influences stomatal opening and closure in plants.
- Predation (hunting and killing of prey by predators require certain levels of illumination and visibility).
- Courtship; with some animals preferring light so as to carry out courtship.
- Light breaks dormancy of seeds.
- Stimulates synthesis of vitamin D in mammals;
- It enables the mechanisms of photoreceptions in eyes.
- Light is important in chlorophyll formation.
- Photoperiod affects migratory and reproductive behaviour in various animals e.g. sunlight polarized by water acts as a compass for migration of salmon fish.

(b)(i).

- Habitat for many aquatic organisms e.g amphibians, fish etc
- Raw material for photosynthesis; main energy source for primary producers and their dependents.
- Act as cooling agent for terrestrial organisms e.g plants during transpiration, sweating in
- Agent for fruit, seed, spore, larva and gamete dispersal; allowing colonization of new territories
- Important factor in decay and decomposition facilitating recycling of nutrients in an ecosystem.
- Necessary condition for germination
- Its transparency allows light reach aquatic organisms for photosynthesis & aquatic predators to locate their prey.

(b)(ii).

- Medium for migration of flying mammals, winged insects; thus reducing the level of competition.
- Agent of pollination; key in plant reproductive cycles
- Dispersal of seeds and spores; important in establishing new colonies.
- Takes part in rain formation; facilitating the hydrologic biogeochemical cycle
- Current and wave formation in water bodies enable distribution of warmth and nutrient key in breeding.
- Increase transpiration; thus promoting water and mineral salt uptake from the soil by plant roots
- Causes physical damage to vegetation and soils e.g soil erosion; lowering competition
- Increases dissolution of oxygen in aquatic bodies; thereby increasing aerobic activities of organisms.

Question 36.

Global warming and acid rain are some of the disastrous effects of massive air pollution.
(a).Explain each of them and how it comes about ***(04 marks)***
(b).Outline the
(i). effects of each of them ***(08 marks)***
(ii).practical remedies available to address each one of them ***(08 marks)***

(a).

Global warming

This is the observed average global temperature rise of 0.8^{o}C as a result of the enhanced natural greenhouse effect The origins of greenhouse gases are; Combustion of fossil fuels by automobiles & industries release greenhouse gases, deforestation and clearing of grasslands reduces the uptake of carbondioxide in photosynthesis, ruminant fermentation produces methane, use of aerosol propellants which contain CFCs, cultivation of rice in swamps and paddy fields causes anaerobic fermentation, which produces methane and use of inorganic fertilizers cause the release of nitrous oxide.

Acid rain

Acid rain is one whose pH is less than the neutral pH of 7. It is formed by combustion of fossil fuels that release sulphur dioxide and nitrogen oxides into the atmosphere catalyzed by ammonia and unburnt hydrocarbons. These oxides react with water in the clouds to form solutions of sulphuric acid and nitric acid, which make up acid rain.
Effects of global warming.

(b)(i).

Effects of global warming

- Rise in sea level due to melting of polar ice and thermal expansion of seas.
- Altered temperature gradients cause cyclones and heavy rains as water evaporates quicker.
- Species migration which are likely to cause pests/diseases to extend their ranges.
- Reduced cropped fields due to drier weather.
- Increased crop yields because of more rainfall and longer growing seasons in some regions.
- Flooding in low-lying islands and coastal cities.
- Extinction of some animal and plant species.
- Increased death of human population.
- Greatly increased wild fires in areas where the climate becomes drier

Effects of acid rain

- Acidity prevents organisms from thriving; especially invertebrates
- Aluminum ions are displaced from soil by SO_4^{2-} ions into water are toxic when absorbed by plants.
- Contributes to humans respiratory diseases such as bronchitis and asthma.
- Can leach toxic heavy metals such as lead and copper from water pipes into drinking water.
- Damages buildings and other infrastructures.
- Decreases atmospheric visibility, mostly because of sulphate particles.
- Promotes the growth of acid-loving mosses that can kill trees.
- Loss of fish population and other acid intolerant organisms when the pH goes so low.
- Aluminum ions are displaced from soil by SO_4^{2-} ions into water where it interferes with gill functioning of fish
- The leaching action of acid rain removes calcium and magnesium ions from soil causing poor formation of middle lamella and chlorophyll in leaves.

(b)(ii).

Practical remedies to acid rain

- Installation of SO_2 extraction units (wet scrubbers) in chimneys of industries.
- Reduce release of pollutant gases by reduce burning fossil fuels especially coal use to reduce re.
- Increase use of renewable resources.
- Tax emissions of sulphur dioxide, polluter pays principle‖ should be adopted everywhere.
- Use of desulphurization technology
- Addition of lime to acidic waterbodies
- Cleaning up of exhaust emissions by encouraging several pollutants to react with one another to give less harmful products in catalytic converters.

Practical remedies to global warming/ greenhouse effect

- Preserving forest cover by combatting deforestation and advocating for afforestation/ re-afforestation.
- Use of environmentally friendly renewable energy sources like hydro, solar and wind generated power.
- Use of fuel efficient automobiles that use smokeless fuels; to reduce emission of greenhouse gases.
- Minimizing CO_2 production by limiting the use of fossil fuels like coal, fire wood as domestic fuels.
- Encouraging waste recycling/ re-use other than burning; reduces emission of greenhouse gases.
- More efficient agriculture equipment, fuel use and water use.
- Discourage smoking to reduce release of carbondioxide into air.
- Encouraging use of energy efficient appliances.

• Law enforcement against events that increase release of greenhouse gases.
• Sensitization/education programs;
• Reduction in overstocking;
• Ban on the use of appliances that use CFCs eg CFC containing aerosol propellants, refrigerators, air conditioner coolants etc

Question 37.

(a).Outline the characteristics of the early and late stages of primary succession ***(12 marks)***
(b).Describe the trend of succession in a terrestrial ecosystem ***(08 marks)***

(a).

Early succession

• Species grow very close to the ground and have low biomass.
• Species have short life span.
• Species are simple and small sized.
• Species diversity (number of species present in a habitat) is very low.
• Community is open i.e allows space for other colonizers.
• Species may show symbiotic relationships to aid their establishment.
• The community is mostly is mostly composed of producers and a few decomposers.
• Net productivity is high.
• Feeding relationships are simple, mostly herbivores feeding on plant with few decomposers.
• Species are poor competitors hence get replaced by higher, more demanding plants like grasses shrubs and trees.

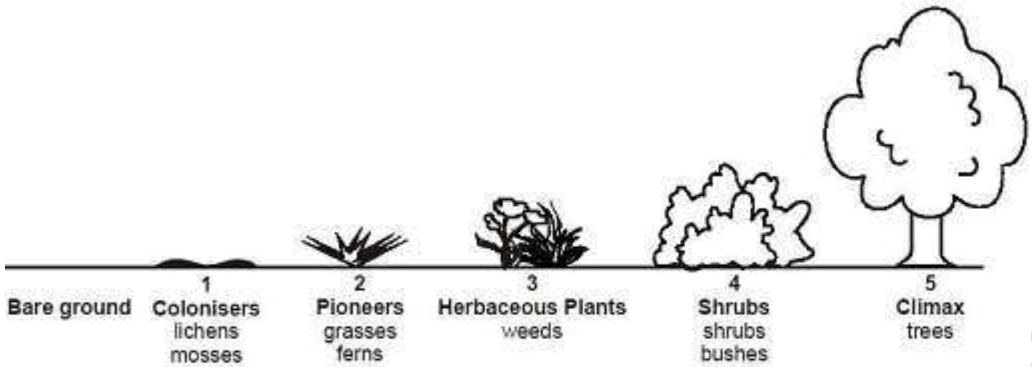
Late succession

• Plants are of large size and complex.
• Species diversity is high
• Community is a mixture of producers, consumers and decomposers.
• Biomass is high
• Net productivity is low
• Community takes a longtime to establish.
• Climax community is often determined by one dominant species.
• There is increased soil depth and nutrients.
• Interspecific competition is very high.
• There is little space for new species
• The climax community is stable and is in equilibrium with its environment.
• Feeding relationships are complex, dominated by decomposers.

(b).

Primary succession

In primary succession; pioneer organisms such as lichens that are tolerant to dessication; inhabit previously unoccupied areas such as bare rocks. Weathering of the rocks occurs creating a thin soil film. Lichens also die later; decompose and add humus. This provides favourable conditions for the emergence of mosses. Death and decay of mosses add more nutrients to the soil. Herbs like ferns and grasses emerge and replace mosses. Animals like amphibians, reptiles, birds and some herbivores also emerge due to presence of food and shelter offered by the available vegetation. Herbs also die and add more organic matter forming a thick soil layer; large woody shrubs begin to grow, then trees begin to appear. Larger animals may come in and eventually a mature forest community grows to reach a climax community.



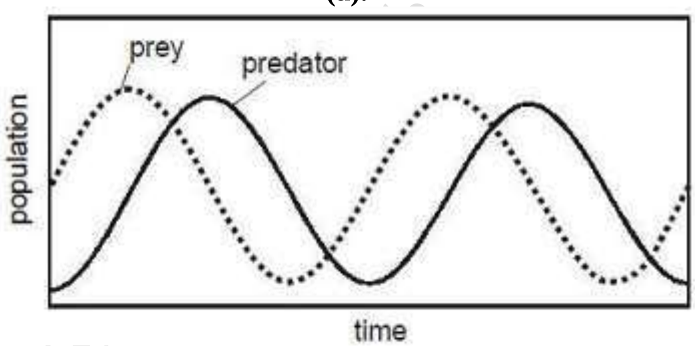
Secondary succession.

In secondary succession, annual herbs like the Bidens pilosa and Commelina are the pioneer organisms. They occupy an area which has ever been occupied before. Arthropods like insects and flat worms like earthworms; may come in; these die and decompose to add organic matter into the soil. After years, perennial herbs such as Lantana camara begin to establish in the area; then shrubs establish to replace the perrennial herbs; birds and small animals come in; trees begin to establish themselves in the area; eventually forests and larger animals; develop into a climax community.

Question 38.

(a).With aid of an appropriate graph, explain the pattern of predator-prey interactions ***(06 marks)***
(b).Describe how the preys are adapted to combating predation in an ecosystem ***(10 marks)***
(c).What is the evolutionary significance of predator-prey relationship ***(04 marks)***

(a).



Description of the changes in population numbers:

Generally there is a corresponding cyclic/ fluctuating variations in the populations of both the predator and the prey with the predator population following that of the prey. Initially, the population of the prey is higher than the population of the predator. Within a short time, both populations of prey and predator increase rapidly. The population of the prey reaches a maximum earlier the predator. As the prey population decreases rapidly, the predator population continues to increase gradually for a short than time to a maximum then also decreases rapidly. As the predator population continues to decrease, the prey population starts to increase rapidly, followed by a rapid increase in predator population. The cycle is repeated.

Explanation for the observed changes in populations:

At the beginning, there are more prey than predator to provide food to the predators. When the predator population is low, they get enough food and few preys are eaten so they both increase rapidly. The large number of preys provides food to predators, so they reproduce fast and increase in numbers. The increased predator population eats many preys and the prey population crashes. The decrease in prey numbers causes the predators to starve & even their reproduction reduces, so the predator numbers crash as well. Finally, the very low number of predators allows the prey population to recover, causing the cycle to start again.

(b).

• Ability to run, swim or fly faster; for quick escape from the predator
• Possession of highly developed sense of sight or smell alerting the presence of predators.

• Possession of protective shells eg in tortoise and snails for rolling into armour-plated ball
• In some lizards, the tail breaks off when attacked giving the animal (lizard) time to escape.
• Possession of spines (porcupines) or thorns (cacti and rose-bushes) for pricking predators.
• Other preys gain some protection by living in large groups e.g. schools of fish, herd of antelope
• Some prey scare predators by puffing up e.g. blowfish, or spreading wings e.g. peacock.
• The flesh of some slow-moving fish is poisonous e.g. porcupine fish.
• Some preys secrete poisonous or repellant substances e.g. scorpions, caterpillars and some grasshoppers
• Other preys employ alarm signals and calls e.g. ants, various fish, small birds and mammals.
• Group defense, occurring among those that live and feed in herds
• Some prey species produce poisonous or irritating secretions that discourage predators
• Possess conspicuous warning colorations that warns a predator about their unpalatability or being poisonous e.g poisonous frogs, some snakes, monarch butterflies, and some grasshoppers.
• Some exhibit disruptive colouration/patterns, works by breaking up the outlines of an animal with a strongly contrasting pattern, thus decreasing detectability e.g. group of zebras
• Some have cryptic colouration allows an organism to match its background and hence become less vulnerable to predation e.g chameleon.
• 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 (a cat fish) produces high voltage discharge of up to 350v that shocks any predator that makes contact with it.

(c).

Predation imposes a selection pressure that 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 long-time survival. They thus pass on their good traits to their off springs which can improve their evolution.
Predator-prey relationship is the basis for coevolution on both the prey and predator side.

Question 39.

Describe the three ecological pyramids highlighting their advantages and limitations and the significance of inversion if any ***(20 marks)***

Pyramid of numbers; It is a histogram representing the numbers of different organisms at each trophic level in an ecosystem at any one time. As a pyramid is ascended, the number of organisms decreases but the size of each individual increases. In some cases, the consumers may be more than the producers e.g in a parasitic food chain, inverted pyramids are obtained, because parasites progressively become smaller and many along a food chain.

Limitations of pyramid of number

• Drawing the pyramid accurately to scale may be difficult e.g where there a million plants.
• Pyramids may be inverted
• The trophic level of an organism may be difficult to ascertain.
• The young forms of species may have a different diet from adults.

Pyramid of biomass; a histogram showing the total dry mass of organisms present at each feeding level

Advantages of pyramids of biomass

• Reduces the possibility of forming inverted pyramids because its construction depends on biomass of organisms
Inverted pyramid of biomass is typical of an aquatic ecosystem, because diatoms (phytoplankton) have a lower biomass but with higher productive rate (caused by so rapid turnover rate), therefore capable of supporting a larger biomass of zooplanktons.

Disadvantages/limitations of pyramid of biomass

• Does not allow for changes in biomass at different times of the year e.g deciduous trees have larger biomass in summer than in winter when they shed off leaves.
• Does not take into account rate at which biomass accumulates e.g a mature tree has a large biomass which increases over many years.
• Impossible to measure exactly biomass of the organisms in an ecosystem, because the sample used may not true representation of the whole population.

• Results maynot be accurate, e.g where killing is not allowed, results are obtained by estimating the fresh mass.
Pyramid of energy flow; it is a histogram showing the total amount of energy present at each feeding level. Because only a proportion of energy is in a trophic level is transferred to the next, energy pyramids are never inverted nor do they have a central bulge. More informative than pyramids of numbers and bio- mass because it shows the amount of energy required to support each trophic level.

Advantages of pyramid of energy

• It compares productivity because a time factor is incorporated.
• Biomass may not be equivalent to energy value, e.g 1g of fat has many more kJ than 1g of cellulose or lignin.
• No inverted pyramids are obtained because of the automatic degradation of energy quality.
• The solar input of energy may be included as an extra rectangle at the base.

Disadvantage/ limitation of pyramid of energy

• Obtaining the necessary data required in constructing pyramids of energy flow is difficult.

Question 40.

(a)(i).Discuss the importance of bacteria in the maintenance of soil fertility ***(06 marks)***
(a)(ii).How can farmers encourage the maintenance of soil fertility by these bacteria? ***(03 marks)***
(b). Bacteria are sometimes cultured in a batch culture fermenter, describe and explain the shape of the population growth of such bacteria. ***(11 marks)***

(a).

• Bacteria carry out putrefaction (decomposition); helps recycle nutrients that are stored in organisms over their lifetime, like nitrogen back into the environment.
• Bacteria like rhizobium and Azotobacter fix nitrogen from the atmosphere to a form the plants can use since they cannot use atmospheric nitrogen directly.
• Nitrosomonas takes ammonium compounds from the soil and converts them to nitrites.
• Nitrobacter then converts the nitrites into nitrates which the plant can use.
• Plants need nitrogen from the synthesis of proteins and for nucleic acid production.
• They convert the atmospheric nitrogen into organic nitrogen.

(a)(ii).

• Ploughing and the drainage of waterlogged land create aerobic conditions which stop denitrifiers.
• Growing leguminous crops such as broad beans can encourage nitrification.
• The addition of waste products containing nitrogen (in some form) also encourages bacteria activity e.g. use of manure, urea and other organic waste products.

(b).

The growth curve begins with the lag phase. During the lag phase the population grows slowly. This is because during the lag phase the bacteria are adapting to the environment. They do this by carrying switching on the required genes, synthesizing the proteins they require, producing enzymes and substrate breakdown. Following the lag phase is the log phase during which the population of bacteria undergoes exponential growth. This is because during this phase there is an excess supply of nutrients and no environmental resistance which allows the population to grow rapidly. Bacteria undergo binary fission and the population doubles in unit time. As the bacteria consume more of the nutrients, nutrient supply becomes limiting factor to population growth along with the accumulation of waste products. When this happens the bacterial growth curve levels off and enters the stationary phase. During the stationary phase the bacteria population remains constant with cell production equalling the number of deaths. The population at this point has reached the carrying capacity of the fermenter. In this phase secondary metabolit-es like penicillin are produced. As space runs out the death rate begins to exceed the cell production rate so the bacteria enter the death phase. In the death phase the bacteria population plummets until there are no bacteria left.

Question 41.

(a).Explain what is meant by;
(i). wildlife conservation ***(01 marks)***
(ii).Extinction. ***(01 marks)***
(b).Why is conservation of wildlife important and how is it carried out? ***(18 marks)***

(a)(i).

Conservation is the planned preservation of wildlife and their habitats.

(a)(ii).

Extinction is the loss of the last surviving member of a particular species.

(b).

Reasons for conservation

• Conservation is carried out to preserve existing gene pools.
• It is important to ensure the survival of the species.
• Maintenance of the gene pool conserves potentially useful genes for future generations.
• Conservation serves as a defence mechanism against extinction of species.

Methods of conservation

• Genes can be preserved using a gene bank.
• Sperm or seed banks can also be used for this purpose.
• Conservation can also entail the planned preservation of habitats like hedgerows.
• Reintroduction programs for species like the Red-kite in a bid to increase the number of breeding pairs.
• Many zoos also have captive breeding programs both nationally and internationally.
• Formation of rare breeds societies such as for cattle and the like which have little commercial value.
• Trade restrictions in endangered species are also a form of conservation.
• Ecotourism is another conservation method.
• Public awareness campaigns concerning the importance of conservation.
• Ecological study of the threatened habitats and endangered species to prompt better management.
• Advocating for natural methods of pest control such as biological pest control
• Incorporation of renewable and environmentally friendly energy sources e.g solar energy.
• Designation of national parks and nature reserves; to protect vulnerable species and habitats.
• Community sensitization about the importances of the environmental conservation.
• Control of pollution; measures such as reducing smoke emission, control of pesticide and fertilizer use and prevention of oil spills; to avoid destruction of species and habitats.
• Effective control and monitoring of invasive species population and other introduced species to prevent them from out competing indigenous species.
• Endangered species rescue programmes like breeding in captivity; endangered under controlled conditions before being returned to the wild.
• Implementing conservation strategies e.g afforestation, re-afforestation and swamp conservation.
• Water recycling; reduces demand stress on natural resources; some of which are habitats to several organisms.
• Planned use of land; to restrict human activities that might threaten nature e.g designating land as an Environmentally Sensitive Areas (ESA) or Site of Special Scientific lnterest (SSSI)

Question 42.

(a) Energy enters most ecosystems through the light-dependent reaction of photosynthesis. Describe what happens during the light-dependent reaction. ***(05 marks)***

(b).Outline the reasons for the low efficiency of energy transfer through ecosystems. ***(06 marks)***

(c)(i).Changes in ecosystems can lead to speciation. Explain how a new species of grass can evolve in copper polluted toxic soils. ***(05 marks)***

(c)(ii).Explain the different ways by which nitrogen enters into an ecosystem ***(04 marks)***

(a).

Chlorophyll absorbs light energy; excites electrons / electrons removed (from chlorophyll); Electrons move along carriers /electron transport chain; releasing energy; Energy used to join ADP and Pi to form ATP; Photolysis of water produces protons, electrons and oxygen; NADP reduced by electrons / electrons and protons / hydrogen;

(b).

• Some light is reflected /not of appropriate wavelength;
• Some light misses leaves/photosynthetic tissue / chloroplasts /chlorophyll;
• Heat loss;
• Energy loss via respiration;
• Loss via faeces/undigested food /part of organism not eaten;
• Excretion /named excretory product;

(c)(i).

Due to variation and mutation; some plants have allele to survive/grow/live in high concentration of copper /polluted soils; Differential reproductive success/ adapted organisms reproduce; Increase in frequency of allele; No interbreeding (with other populations)/ separate gene pool/ gene pool differs (from other populations); and over time establish a separate species.

(c)(ii).

Lightening/ electrical discharges from lightening; combines nitrogen and oxygen to form nitrates which are absorbed by plant roots and then converted to amino acids and protein in plants;
Saprophytic organisms; like putrefying bacteria and fungi; cause breakdown of proteins in dead matter to ammonium compounds/decomposes dead decaying organic matter;
Haber process/excretion or urea/application of NPK fertilisers/ sewage discharge also introduces ammonia/ ammonium compounds;
Ammonium compounds/ ammonia is oxidized to nitrites; by nitrifying bacteria like nitrosomonas and nitrococcus; nitrites are oxidized to nitrates; by nitrobacter bacteria; nitrates absorbed by the plant roots;

Question 43.

(a) Distinguish between economic injury level and economic damage threshold with respect to pest populations. ***(02 marks)***

(b) Explain the influence of each of the following factors on natural populations

(i).Diseases ***(05 marks)***

(ii).Predation ***(05 marks)***

(c) Describe how the co-existence of plants and animals in a terrestrial ecosystem is beneficial to each one of them. ***(08 marks)***

(a).

Economic injury level is the smallest number of pests (amount of injury) that will cause yield losses equal to the pest management costs while economic damage threshold refers to the pest density at which management action should be taken to prevent an increasing pest population from reaching the economic injury level.

(b)(i).

Diseases constantly check on the populations by altering the organisms' fitness through affecting their ability to survive, reproduce, compete, grow or defend themselves against intruders. This severely reduces survivorship of the organism. Diseased organisms thus die leaving empty ecological niches thereby reducing overcrowding as well as limiting competition for the available resources;

(b)(ii).

Predation regulates/checks on the prey population; reducing crowding; and competition; promotes co-evolution of preys with more advanced adaptive features for escape, colonization of new localities by preys as well as decreasing intraspecific aggression. Predation on the other hand, avails food to the predators, promotes evolution of selectively advantaged predator species, co-evolution of predators with better hunting adaptive features as well as regulating predator population through constantly checking on it.

(c).

• Plants synthesize organic matter utilized by animals as food; animals in return supply carbondioxide; one of the important substrate of photosynthesis in plants.
• Plants avail oxygen; utilized by animals for respiration; animals in return give carbondioxide; which plants utilize in photosynthesis.
• Mutualistic co-existence of leguminous plants and nitrogen fixing bacteria (rhizobium) enables plants obtain nitrates while bacteria obtains shelter, food and nutrients.
• Mutualistic co-existence of fungi and roots of higher plants (mycorrhizae) enables plants obtain nutrients from the soil as the fungi depend on photosynthesis of the plant to avail organic materials.
• Lichens (algae and fungus); Algae carries out photosynthesis, providing nutrients to the fungus while the algae is protected by the fungi from intense sunlight and dessication.

Question 44.

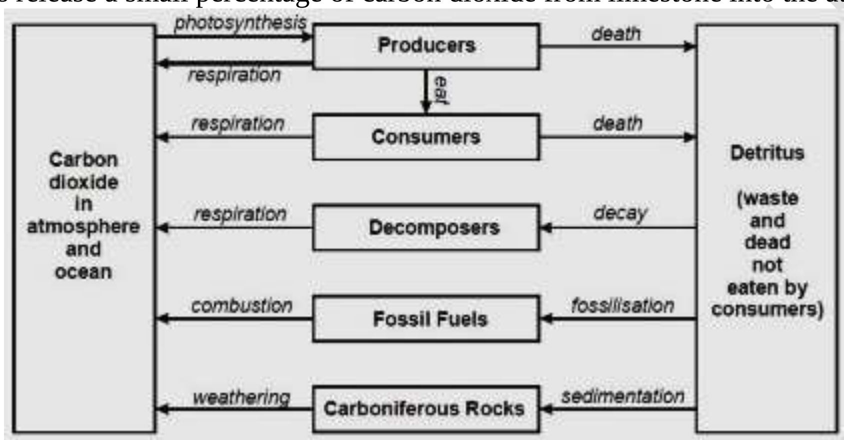
(a).Describe the flow of energy and the cycling of carbon and nitrogen in an ecosystem. ***(07 marks)***

(b).Describe how human population can be regulated by negative feedback mechanism ***(08 marks)***

(c).Why are human populations not naturally regulated by negative feedback ***(04 marks)***

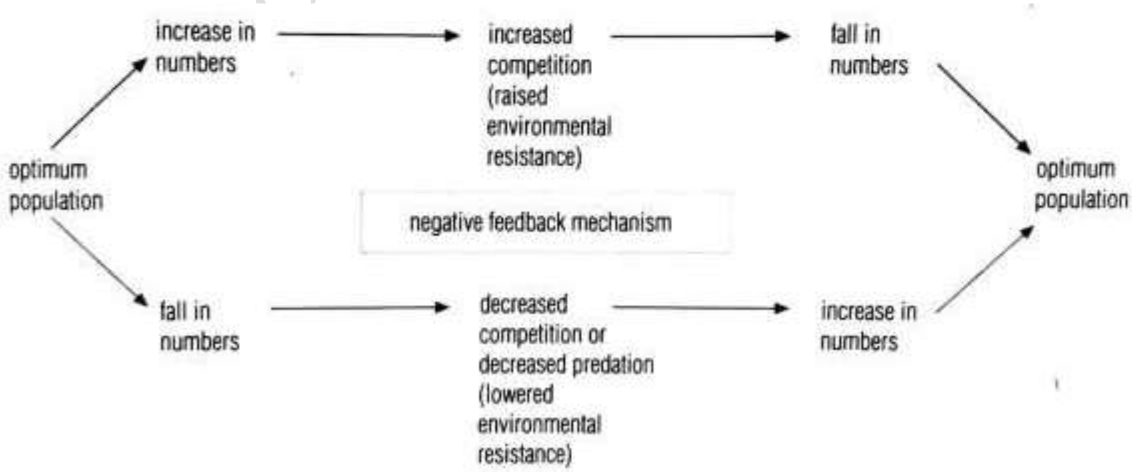
(a).

Based on carbon dioxide gas, making up 0.03% of the volume of the troposphere and is also dissolved in water. Carbon fixation involves the reduction of carbon dioxide to large organic molecules during photosynthesis and chemosynthesis. During aerobic respiration by all organisms, carbon dioxide is returned to the atmosphere or dissolves in water. Over millions of years, buried deposits of dead plant debris and bacteria are compressed between layers of sediment to form the carbon-containing fossil fuels e.g. coal, oil and natural gas, which when burnt release carbon dioxide into air. In aquatic ecosystems carbondioxide may remain dissolved, utilized in photosynthesis or react with water to form carbonate ions and bicarbonate ions. As water warms, more dissolved carbondioxide returns to the atmosphere. In marine ecosystems, some organisms take up dissolved carbon dioxide molecules, carbonate ions and bicarbonate ions and these ions react with calcium ions to form calcium carbonate ($CaCO_3$) to build their shells and skeletons. When the animals with calcium in shells and skeletons die and drift into deep bottom sediments of oceans, immense pressure causes limestone and chalk to form after a very long period of time. Weathering processes release a small percentage of carbon dioxide from limestone into the atmosphere.



(b).

Increase in population results in increased environmental resistance such as increased competition, pests and diseases, stiff predation pressure; accumulation of toxins etc; weak members die; resulting in a fall in numbers; till the optimum/ normal population. Decrease in population lowers the environmental resistance like reducing competetion, decreased predation, reduced susceptibility to diseases, less toxin accumulation etc; numbers rise returning the population to norm.



(c).

- Manufacture of drugs has minimized deaths due to diseases
- Improved standards of living such as good hygiene people increase survival rates of organisms

• Use of contraceptives /birth control methods has controlled population.
• Modern methods of food production have led to production of plenty food hence deaths due to hunger have been minimized.

Question 45.

(a).State the natural causes of extinction of particular living organisms ***(05 marks)***
(b).In what ways have human activities accelerated the rate of extinction in present times ***(05 marks)***
(c)(i).Suggest measures that can be put in place to combat extinction of species ***(07 marks)***
(c)(ii)Explain why large predators like birds of prey are more prone to extinction than their preys/ herbivorous birds ***(03 marks)***

(a).

• Intense competition; where the less adapted fail to reproduce; die or leave a few or no offsprings
• Massive predation pressure
• Natural calamities like earth quakes, fires, glaciation etc
• Diseases; causing massive extermination
• Drastic environmental changes; create new selection pressures such that species cant adapt; die or fail to reproduce

(b).

• Habitat destruction during exploitation of the natural resources
• Direct destruction through hunting for food, trade etc
• Pollution from pesticides/ oil spills/ nuclear reactors
• Artificial selection/Introducing animals with better surviving advantages than the indigenous species
• Resource overexploitation such as over fishing; will rapidly deplete fish species

(c)(i).

• Protecting and restoring habitats
• Reducing the use of pesticides/ use of biological pest control
• Restricting trade in endangered species or their trophies
• Controlling/ reducing the impact of modern intensive agriculture/ control of introduced/ alien species
• Breeding programmes for endangered species
• Establishing seed banks and seed stores to maintain genetic diversity
• Transfer endangered species in threatened habitats to safe ones

(c)(ii).

Large predators exist the end of the food chains/ top trophic levels hence they exist in low numbers which are adversely affected by any disturbance at lower levels in the chains eg toxic effects of bioaccumulation.

Question 46.

(a).State the influence of living organisms in soil formation ***(13 marks)***
(b).Outline the causes of soil acidity ***(07 marks)***

(a).

• Burrowing animals eg rodents break down rocks as they make holes
• Termites feed on dead vegetation, break it down and mix it with soil
• Rodents and termites help in profile mixing
• Plant roots enlarge cracks in the soil
• Bacteria produce acids that break down rocks
• Plant root tips exude acids that corrode rocks
• Man through his activities like road construction/ mining / quarrying
• Hooves of large mammals
• Lichens colonise rocks leading to breakdown
• Living organisms die and decay; forming humus which leads to humic acid.

(b).

• Weathering from acidic rocks
• Presence of humus in the soil; forms humic acid
• Presence of soluble salts
• Water logging

• Rain water that dissolves carbondioxide from the atmosphere (acid rain)
• Application of acidic fertilisers like ammonium sulphate
• Presence of sulphides like hydrogen sulphide

Question 47.

(a).Describe the mutualistic relationships that exist among marine organisms and state how each organism benefits. ***(13 marks)***

(b).Outline ways plants are adapted to overcome water stress. ***(07 marks)***

(a).

Corals and photosynthetic algae; corals provide the algae protection; corals get oxygen in return; Spider crabs and algae; the greenish-brown algae lives on the spider's back; spider in return blends in the ocean; offering camourflage.

Cleaner fish and larger fish; cleaner fish feeds on harmful parasites on the larger fish; the larger fish is freed from such harmful parasites;

Fish and sea anemones; the fish uses the sea anemone for protection from predators; in return the fish occasionally feeds the sea anemone and also its predators.

Boxer crabs and anemones; the stinging anemones offer the crab protection; anemones in return get carry them and make them mobile; increasing their chances of feeding

Several fish species and reefs; fish aggregates and get helped by reefs to get rid of parasites attached on their bodies; reefs in return get food;

(b).

• Possession of thick cuticle; blocks plant pores trapping moisture; reduce water loss by transpiration.
• CAM plants reverse stomatal rhythms; minimize water loss during day.
• Plants possess hairy leaf laminae; insulate against water losses through transpiration.
• Some do periodic shed off of leaves during the dry season; reduce rate of transpiration.
• Possession of glandular trichomes which secretes a resin that coats leaf surface thus limiting water loss
• Possession of an extensive root system; which penetrate deeper layers; to absorb water.
• Xerophytes like cacti are succulent; for reservoir water storage.
• Possession of waxy stems and leaves by drought succulents reduce cuticular water loss
• Leaves are reduced to spines; reducing surface area for water loss through transpiration.
• Small size of the leaves reduce surface area exposed to light
• Produce Abscissic acid; cause stomatal closure; counteracting water stress by reducing transpiration
• Sunken stomata of xerophytes reduce water loss through transpiration.
• Steeper leaf angles parallel to solar radiations reducing direct exposure to the sun;
• Folded/ rolled/ curled in leaves; reduce area exposed to sunlight thus minimizing water loss
• Shiny foliage; increase the plant's reflectance of light; reducing water loss via transpiration.
• Shallow & superficial roots of the desert succulents allowing quick responses to light rainfalls.
• Some do stem photosynthesis at the expense of leaf photosynthesis since stems lose less water.

Question 48.

(a).Explain what is meant by each of the following ecological terms

(i). natural resources ***(02 marks)***

(ii).Indicator species ***(02 marks)***

(b).Discuss the significance of conservation of natural resources in an ecosystem ***(12 marks)***

(c).Explain how indicator species can be used to monitor levels of pollution of particular natural resources

(a)(i).

These are materials provided by the earth that humans can use to make more complex/ human made product. Natural resources include air, coal, minerals, natural gas, oil, sunlight, water bodies, wetlands, flora & fauna.

(a)(ii).

These are species whose distribution is largely determined by some particular factor; the presence or absence of an indicator species therefore gives some measure of the level of that factor. Using the number of indicator species it may be possible to determine the precise level of the factor at one point e.g amount of wave action on a seashore, monitoring of water quality by investigating distribution of water flora and fauna.

(b).

- Conservation is carried out to preserve existing gene pools.
- It is important to ensure the survival of the species.
- Maintenance of the gene pool conserves potentially useful genes for future generations.
- Conservation serves as a defence mechanism against extinction of species.
- Wetlands are catchment areas reducing on the surface flows;
- Wild fauna e.g insects are necessary for biological processes such as pollination and decay
- Wild fauna are source of valuables materials; attract tourists thus a useful source of revenue
- Water bodies are useful source of water for domestic, agricultural and industrial use;
- Plant and animal extracts are sources of valuable medicines e.g. quinine and codeine
- Wildlife contains a complex network of relationships which maintain biogeochemical cycles
- Forests provide habitat to a number of organisms; their destruction compromises biodiversity.
- Forests are carbondioxide sinks, reducing atmospheric carbondioxide; preventing air pollution
- Ensures continous supply of biological resources such as food, medicine and industrial products.
- For maintenance of good climatic conditions/ prevention of environmental degradation.
- Promotion of ecotourism/ biological research
- Maintaining stable biochemical cycles important in nutrient recycling and undisrupted food chains
- Prevents environmental hazards/ calamities like landslides, floods etc
- Water is a means of transport/ medium of reproduction

(c).

In biological monitoring of water quality in a stream/river; discharge of raw sewage into the river; results in fall in oxygen content dramatically; fauna requiring high levels of oxygen are present in low numbers at the point of discharge; Whereas population of sewage fungus, bacteria that survive on organic wastes are high; downstream algal growth increases due to decomposition of organic matter releasing nutrients; complete breakdown of organic matter downstream recovers river fauna; and population of clean water species e.g. stonefly larvae, may fly larvae and caddis fly larvae increases while that of those that depend on polluted condition eg blood worms, rat-tailed maggots and tubbier decline.

Question 49.

(a).Explain the nutritional benefits derived by animals in a symbiotic relationship. ***(12 marks)***
(b).What is the role of soil microorganisms in recycling of inorganic nutrients ***(08 marks)***

(a).

Protozoans and bacteria living in the gut receive food; and protection; they synthesize their own vitamins e.g vitamin K and vitamin of the B group; and any excess is made available to the host animal;
The flagellate protozoans such as Trichonympha; obtain shelter from a pouch in the posterior gut in termites; and in turn produce enzymes essential for the breakdown of wood; to provide nutrients later absorbed by termites;
Blood sucking insects rely on symbiotic bacteria and fungi for essential vitamins, especially vitamin B; which they are not able to synthesise and which are not present in diet;
Symbiotic bacteria, fungi and protozoa living in enlarged caecum and appendix of herbivores; secrete cellulase enzyme; for digestion of cellulose in herbivores;
When the symbionts in the rumen of ruminants die they pass through the digestives system with the food and form an important source of nutrients especially protein; making ruminant digestion more effective;

(b).

Free living nitrogen- fixing bacteria e.g. azotobacter, clostridium; nitrogen fixing blue-green bacteria e.g. Nostoc; and symbiotic nitrogen fixing bacteria like Rhizobium living mostly in association with the root nodules of leguminous plants such as beans, peas and clover; reduce gaseous nitrogen in the atmosphere to ammonia; which they then use to manufacture their amino acids where excess amino acids are translocated to the host tissue; on the death and decay of organisms, saprophytic bacteria and fungi bring about Ammonification (putrefaction) converting phosphates in wastes and remains into phosphates in rocks which erode into oceans, lakes and soils; detritus, human and wastes release carbon dioxide into the atmosphere and dissolved in oceans; nitrogen-rich organic compounds, wastes like urea and dead bodies of organisms into ammonia; ammonia reacts with soil chemicals to form ammonium ion-containing salts which are then converted to nitrates; by free-living chemosynthetic bacteria first to nitrite ions; by Nitrosomonas bacteria; and later to nitrate ions by Nitrobacter bacteria and nitrococcus; anaero-bic bacteria e.g. Pseudo- monas denitrificans and Thiobacillus denitrificans; in water logged soil and deep in oce-an, lake and swamp bottoms convert ammonia and ammonium ions back into nitrite and nitrate ions, and then into nitrogen gas and oxygen; Nitrogen gas is released into the atmosphere; while oxygen is used for the respiration of these bacteria;

Question 50.

(a).Define the term fecundity. ***(01 marks)***

(b).Describe how each of the following affect a natural population.

(i). Diseases ***(03 marks)***

(ii).Predation ***(03 marks)***

(c).Giving examples, explain the various ways in which variation may arise. ***(07 marks)***

(a).

Fecundity refers to the average number of fertilized eggs produced by an organism in an average breeding cycle in the life time of an organism; or the number of young ones produced per female per unit time in mammals.

(b)(i).

Diseases: Functional or structural disorder with the symptoms not result of injury. A high disease incidence decr-eases the population through increased death, emigration and decreased activity. A low incidence on the other ha-nd increases the population through reduced death, less emigration and more immigration & increased activity of organisms including reproduction.

(b)(ii).

Predation; Refers to preying of one animal on other. Low predation incidence increases prey population. Due to reduction in attack from predation; less stress and high prey activity which increases the population of prey. High predation generally decreases the population of prey; due to increased attacks, injury & consumption of prey, more stress and reduced prey attacks. The increase in predation can also be specifically increase the population of the most adopted prey. Due to decrease in competition for the limited resources from the poorly adopted prey varieties which are over fed upon by the predators.

(c).

Isolation in which behavioral, ecological and genetic barriers prevent successful breeding of certain individuals with each other. This prevents gene mixing/flow and concentrate differences among the organisms.

Random pairing of homologous chromosomes during gametogenesis; in prophase I result in different gene combination with in the gametes and consequently in variation among organisms formed from them.

The random assortment of homologous chromosomes; during prophase I of result in the unique gene combin-ation in the gametes and variation among the offspring formed from fusion of these gametes.

Crossing over; involving exchange of chromate sections among homologous chromosomes. Chromatids also cre-ates new gene combination and variation.

Random fertilization; in which each unique hamates and combine with the other gamete from a different sex res-ults in variation among the offspring.

Non-random mating; in which certain variants mate with specific individuals create even gene mixing in a popu-lation and result in variations.

Mutation; which are drastic changes in the genetic material of an organism result in new variation e.g. formation of sickle cells, albinism etc.

Environmental factors; like nutrient availability differences, diseases, inquiry among other result into variations among organisms of species

Question 51.

(a).Explain how limiting factors regulate the growth of populations? ***(14 marks)***

(b).What is the role of natural selection in the evolution of organisms? ***(06 marks)***

(a).

Populations grow by two models ie Exponential/ Intrinsic/ Opportunistic/ Boom & Bust growth with J-shaped cu-rve; and Logistic/ Equilibrial growth with sigmoid or S-shaped curve;

In the short run, intrinsic growth is density-independent in which abundance of resources in new or undisturbed habitats; enables population boom/ rapid production of offspring; due to absence of competition for food and oth-

er resources; Afterwards, exponential population growth stops abruptly and the population busts/ crashes; due to environmental resistance caused by food depletion (water fleas and bacteria)/ inadequate photosynthetic light (algal blooms)/ oxygen depletion (bacteria); etc.
Logistic population growth starts out slowly and then proceeds rapidly to a maximum (carrying capacity) after which the population stabilizes / fluctuates slightly above and below the carrying capacity with time; due to environmental resistance caused by the simultaneous interaction of density-dependent and density-independent factors; like: Inadequate light intensity unsupportive to photosynthesis; death due to unfavourable temperature; death due to accumulation of toxic wastes; starvation due to stiff competition for food; breeding failure due to overcrowding; increased predation due to overcrowding; fast spread of disease and parasites due to overcrowding; habitat destruction by fire; suffocation due to oxygen depletion; reduced reproductive potential; etc

(b).

Natural selection refers to the differential survival and reproduction of individuals due to differences in their phenotype. The phenomenon avails a mechanism of evolution by arresting that incase of any of any change in the environment , selection pressure arises among the variants, the ones possessing more favourable phenotypes are selected for reproductively and the unfavorable ones selected against, the reproductively selected for concentrate their adaptive genetic features which subsequently increased their gene frequency of the selected against decrease forming a population of the most adopted individuals which is evolution.

Question 52.

(a).Explain what is meant by biodiversity ***(02 marks)***
(b).Describe the methods of protecting the endangered species ***(18 marks)***

(a).

Biodiversity is the range of habitats, communities and species in an area & the genetic variation that exists within the populations of each species.

(b).

Habitat conservation; For example, National Parks & nature reserves, zoos etc can set aside areas of land in which the species is protected.
Captive breeding programmes; This involves collecting together a small group of organisms of a threatened species and encouraging them to breed together. In this way, extinction can be prevented. The breeding programme tries to maintain or even increase genetic diversity in the population by breeding unrelated animals together using in vitro fertilisation.
Reintroduction programmes; The best captive breeding programmes work towards reintroducing individuals to their original habitat, if this can be made safe for them.
Control of pollution; measures such as reducing smoke emission, control of pesticide and fertilizer use and prevention of oil spills; to avoid destruction of species and habitats.
Effective control & monitoring of invasive species population; and other introduced species to prevent them from out competing indigenous species.
Ecological study of the threatened habitats and endangered species; prompt better management.
Implementing conservation strategies; e.g afforestation, re-afforestation and swamp conservation.
Water recycling; reduces demand stress on natural resources some of which are habitats to several organisms.
Planned use of land; to restrict human activities that might threaten nature e.g designating land as an Environmentally Sensitive Areas (ESA) or Site of Special Scientific lnterest (SSSI)
Advocating for natural methods of pest control; such as biological pest control
Incorporation of renewable and environmentally friendly energy sources; e.g solar energy.
Community sensitization; about the importances of the environmental conservation.
Legislation to protect wildlife; to combat extinction of the endangered species.

Question 53.

(a).Explain how changes in population density of a named k-species affects its growth rate ***(10 marks)***
(b).How do r-species survive in their habitats ***(10 marks)***

Chapter 7; Gaseous exchange and respiration

Table l shows percentages by volume of some gases in inspired air, expired air and alveolar air in a resting human being.

Table 1.

Gas	Percentage volume (%)		
	Inspired air	**Expired air**	**Alveolar air**
Oxygen	20.90	15.30	13.90
Nitrogen	78.60	74.90	No data
Carbondioxide	0.03	3.60	4.90
Water vapour	0.47	6.20	No data

Figure l(a) and (b) show effects of increased carbondioxide concentrations in inspired air, on the volume of air breathed in and out per minute and on the breathing rate respectively.

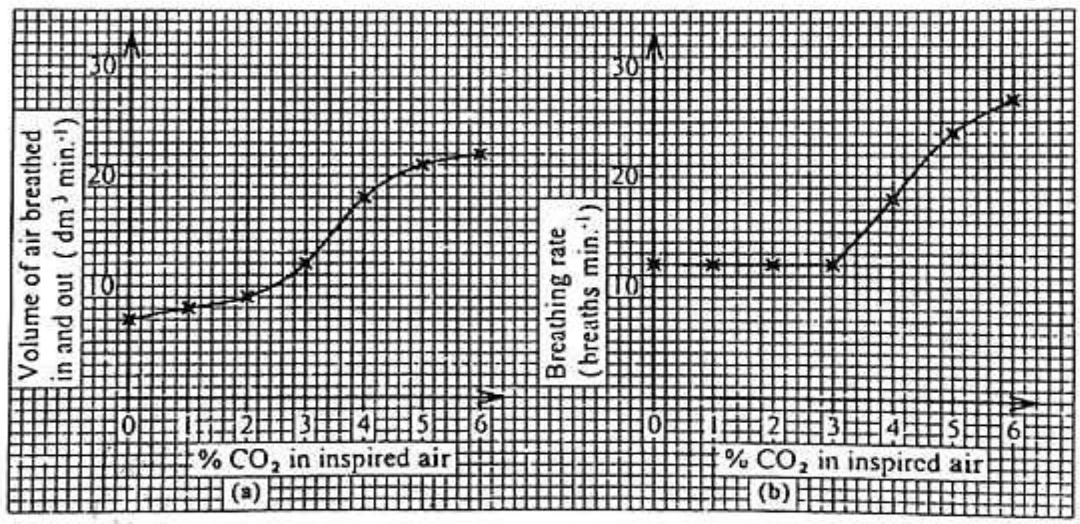


Fig. 1

(a).Explain why

(i).the percentage volume of oxygen in expired air is intermediate between the inspired and alveolar values.

Alveolar air has a lower percentage volume than inspired because oxygen diffuses into the blood stream; and the remaining air in the alveolus mixes with fresh air that is incoming; thus expired air is intermediate between inhaled and alveolar air/ dead space/ alveolar air.

(ii) there is a difference in percentage volume of nitrogen between inspired & expired air ***(04 marks)***

The percentage of nitrogen in expired air is less than that in inspired air because some oxygen is extracted for use by the body while more carbondioxide is expelled; water vapour is also more in expired than in inspired air; hence the remaining percentage composition of nitrogen is reduced.

(b)(i).Using the information in figure 1, calculate the mean volumes of a single breath in and out at different carbondioxide concentrations in inspired air as indicated in table 2. ***(04 marks)***

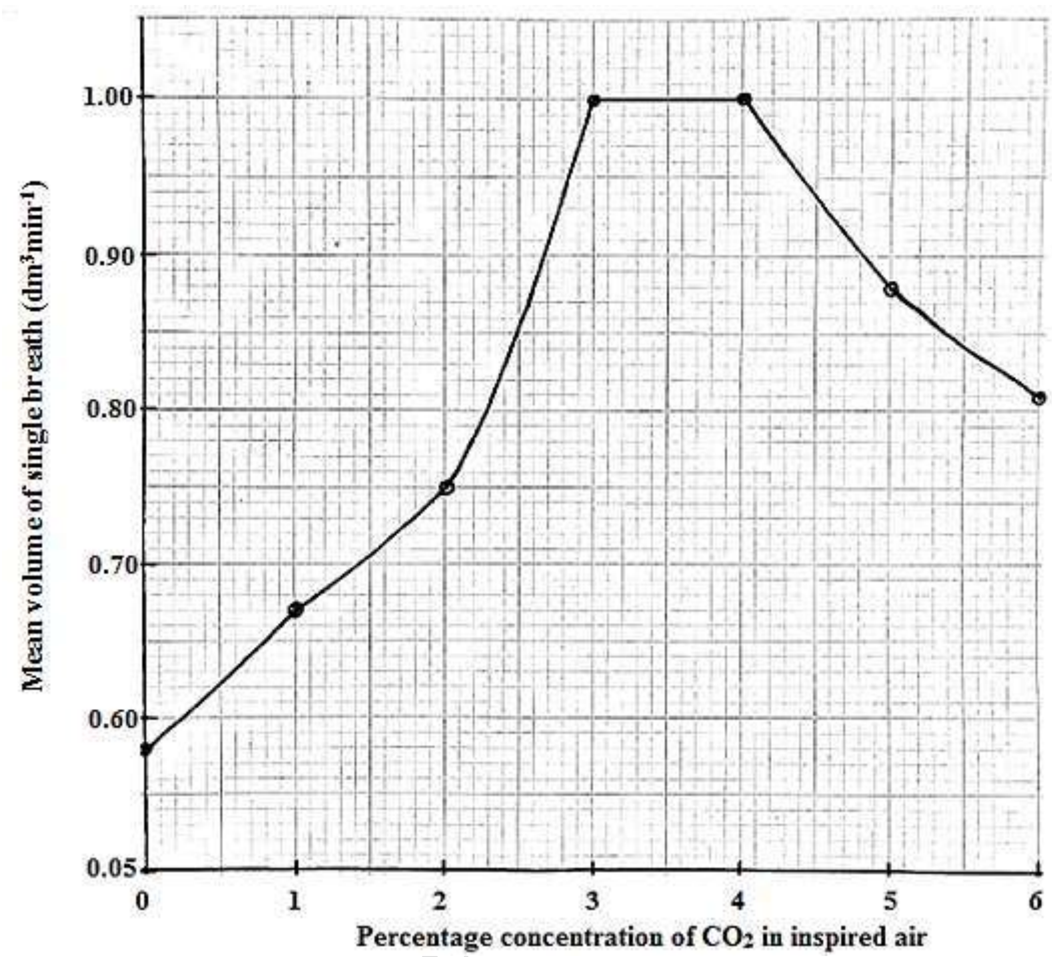
Table 2

% concentration of CO_2 in inspired air	0	1	2	3	4	5	6

Solution

% concentration of CO_2 in inspired air	0	1	2	3	4	5	6
Mean volume of single breath($dm^3 min^{-1}$	7/12 (0.58)	8/12 (0.67)	9/12 (0.75)	12/12 (1.00)	18/18 (1.00)	21/24 (0.88)	22/27 (0.81)

(ii).Plot a graph showing the mean volume of a single breath against percentage concentration of carbondioxide in inspired air. ***(04 marks)***



(c).Describe the effect of the increase in carbondioxide concentration in inspired air on the;

(i) volume of air breathed in and outer minute. ***(03 marks)***

Volume of air breathed in and out increases gradually up to 3%; then increases fast up to 4%; then gradually up to 6%

(ii).breathing rate. ***(03 marks)***

Breathing rate remains constant up to 3%; then increases very fast up to 5%; then slightly decreases up to 6%

(iii).mean volume of a single breath in and out. ***(03 marks)***

Mean volume of a single breath in and out increases rapidly up to 3%; remains constant up to 4% and then decreeses gradually up to 6% carbondioxide.

(d).Explain the effect of the increase in carbondioxide concentration in inspired air on the

(i).volume of air breathed in and out per minute. ***(02 marks)***

Volume of air breathed in and out per minute of carbondioxide; percentage below 3% is low because at this concentration, it is not harmful; but as the percentage increases beyond 3%; it increases the depth of breathing inorder to remove a lot of carbondioxide.

(ii).breathing rate. ***(02 marks)***

Between 0 and 3% carbondioxide concentration; the rate of breathing s constant because chemoreceptors are less stimulated. Increase in carbondioxide percentage beyond 3%, the carotid and aortic bodies of the blood system are stimulated to send impulses to the inspiratory centre; which sends impulses to the respiratory centre; which send impulses via the intercostal nerve causing the intercostal muscles and diaphragm to increase the rate of inspiration or breathing.

(iii).mean volume of a single breath in and out. ***(02 marks)***

As volume of air breathed in and out per minute increases, the rate of breathing remains a constant; there- fore the mean volume of a single breath increases; and when the rate of breathing increases with volume between 3% and

4%; mean volume remains constant while the mean volume decreases slowly as the rate of breathing declines slowly with decrease of volume taken in and out per minute between 4% and 6%.

(e).Outline the physiological effects in the body, of breathing in excess

(i).carbondioxide. ***(04 marks)***

In excess CO_2, there is low pH; which encourages the dissociation of oxyhaemoglobin to release oxygen that will be utilized by body tissues.

(ii).oxygen ***(04 marks)***

In excess oxygen, pH is high so haemoglobin combines with oxygen readily and lowers the ability of oxyhaemoglobin to dissociate

Question 2.

In experimental setup 1, two experiments were carried out in which a suspension of active mitochondria was incubated. in experiment A the mitochondria were kept in buffer solution containing sucrose and inorganic salts in experiment B, succinate, a kreb‘s cycle intermediate was included and malonate added 6 minutes after the experiment had begun . Concentration of dissolved oxygen in the buffer solution was measured using electrodes and results of the experiments are as shown in table 1 below.

Time (minutes)	**Concentration of dissolved oxygen (arbitrary units)**	
	Experiment A	**Experiment B**
0	100	100
2	97	89
4	94	78
6	92	66 (malonate added)
8	89	61
10	86	57
12	83	53

In another experimental setup 2 similar to experiment B, sodium azide was added instead of malonate, the results obtained are shown in figure 1 below

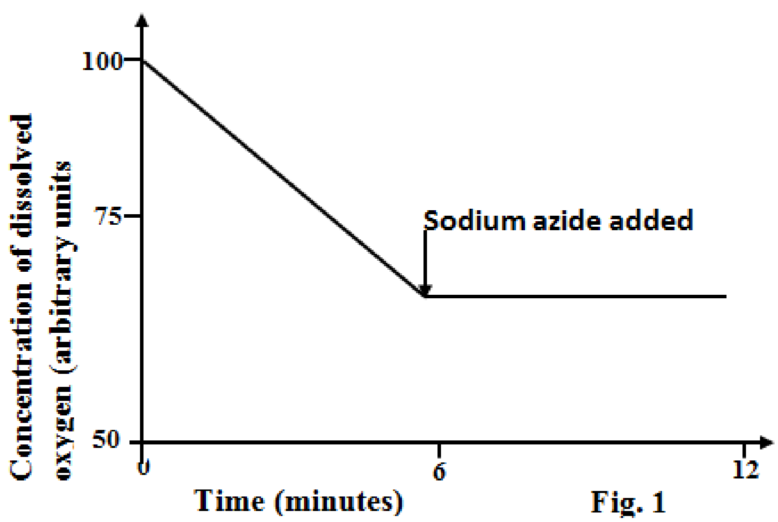
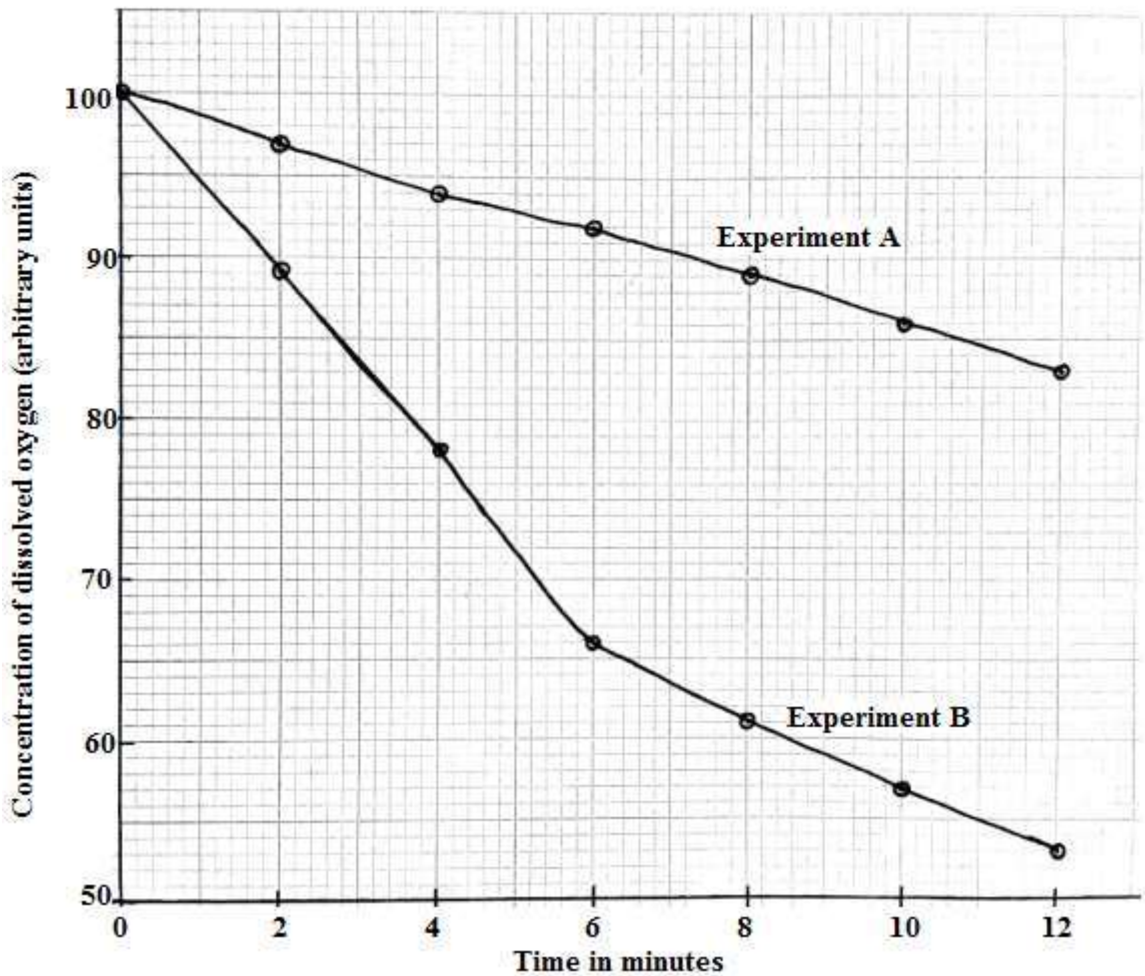


Fig. 1

(a).Represent the information provided in table 1 graphically ***(06 marks)***

<u>A graph showing the variation of the concentration of dissolved oxygen in experiment A and B with time</u>



(b).Using the graph in (a), explain the changes in concentration of oxygen in experiment B ***(10 marks)***

From 0 to 6 minutes, concentration of dissolved oxygen decreases rapidly; oxygen is rapidly used up in aerobic respiration/ oxidative phosphorylation; where it combines /accepts hydrogen to form water; oxidizing $FADH_2$ to FAD; facilitating the breakdown / conversion of succinate to fumarate/ malate; From 6 minutes to 12 minutes concentration of dissolved oxygen decreases gradually ; malonate a competitive inhibitor added competes with succinate for the active site on the enzyme (succinate dehydrogenase); reducing on the rate of dehydrogenation of succinate to malate; fewer FADH2 molecules are formed reducing on the rate of oxidation of hydrogen by mitochondrial oxygen.

(c).Basing on the graph obtained for experiment B in setup 1, suggest explanations for the differences observed between concentration of dissolved oxygen in experiment B and;

(i). Experiment A ***(04 marks)***

Rate of utilization of oxygen is higher in B than A/ concentration of oxygen decreases faster in experiment B than A; succinate is a Kreb's cycle intermediate; readily dehydrogenated (oxidized) to provide hydrogen atoms; that reduce oxygen to water; while sucrose is not a Kreb's cycle intermediate; needs to be first converted into one of the intermediates of Kreb's cycle for its dehydrogenation; producing less hydrogen atoms reducing less oxygen to water;

(ii).Similar experiment in setup 2 ***(04 marks)***

After 6 minutes, concentration of dissolved oxygen remains constant in similar setup2 while experiment B decreases gradually; sodium azide added is a non-competitive inhibitor of cytochrome oxidase; stops oxidation of hydrogen to water; while malonate added in expt. B is a competitive inhibitor competes with succinate for the active site on an enzyme; few hydrogen atoms are obtained due to reduced dehydrogenation of succinate hence resulting in a slow reduction of oxygen to water

(d).State any two(2) vital stages involved in energy production that occur in the mitochondrion, in each case indicate the exact site where each takes place ***(02 marks)***

• Kreb's cycle that takes place in the matrix;
• ETS/HTS/ respiratory chain that takes place in the cristae;

(e). How is the mitochondrion adapted to perform its function(s)? ***(05 marks)***

• Bound by envelope to isolate its reactions from those of the cytoplasm increasing efficiency;
• Matrix contains numerous enzymes to catalyse oxidative processes in the matrix;
• Ribosomes to synthesize their own proteins;
• Cristae to increase the surface area for the electron transport system;
• Permeable envelope for exchange of materials with the cytoplasm;

(f).State the ways in which is energy production in mitochondrion is comparable to that in chloroplast

Similarities

Both
• Involve action of ATPase enzyme;
• Involve electron transport along carriers;
• Involve use of pigments at some stage;
• Require energy from hydrolysis of ATP to occur;
• Occur in inner membranes;

Differences

Energy from mitochondrion	Energy from chloroplast
Energy utilized comes from oxidation of organic compounds	Energy utilized is obtained from the sun
Utilizes oxygen	Releases oxygen
Products are ATP and water	Products are only ATP in cyclic phosphorylation and oxygen, $NADH_2$ and ATP in non-cyclic photophosphorylation
Electrons come from hydrogen	Electrons come from water in non-cyclic and chlorophyll in cyclic photophosphorylation
Hydrogen acceptors are FAD and NAD	Hydrogen acceptor is NADP
Can take place in absence of light	Only take place in presence of light

Question 3.

Part A

An investigation was carried out into the effects of athletic training on respiration in human muscle. A group of athletes and non-athletes exercised at different levels. The levels of exercise expressed as rates of energy expenditure) min^{-1} kg^{-1} of body mass. At each level, rates of oxygen consumption and lactic acid production were measured. The results are shown in table 1 below. Figures in the table are the means of measurements made for each group.

Rate of energy expenditure ($Jmin^{-1}$ kg^{-1})	Rate of oxygen consumption in cm^3min^{-1} kg^{-1}		Rate of lactic acid production in $mgmin^{-1}kg^{-1}$	
	Athletes	Non-atheletes	Atheletes	Non-atheletes
600	30	29	0	0
800	40	39	0	0
1000	50	44	0	185
1200	57	45	45	350
1400	58	45	45	590

(a).Plot graphs to show the relationship between the rate of oxygen consumption and lactic acid production against the level of activity in the two groups.

(b) Using your graphs in (a), describe the effect of increasing the level of exercise on rates of oxygen consumption and lactic acid accumulation in;

(i). Athletes

An increase in level of exercise gradually increases the rate of oxygen consumption up to activity at 1000 $Jmin^{-1} kg^{-1}$ thereafter rate of oxygen consumption is slower and tends to level off; No lactic acid production occurs at activity in the range 60-100 $Jmin^{-1} kg^{-1}$; there after lactic acid production rapidly increases.

(ii).Non-Athletes

Increase in level of exercise, in the range 600 to 1000 $Jmin^{-1} kg^{-1}$ increases gradually the rate of oxygen consumption; thereafter the increase is slower and then levels off from 1200 $Jmin^{-1} kg^{-1}$ and above. No lactic acid production occurs at exercise level in the range of 600-800 $Jmin^{-1} kg^{-1}$ thereafter lactic acid production increases rapidly.

(c).How do the two groups of people compare in their abilities to consume oxygen and accumulate lactic acid during exercise?

In both groups, lactic acid accumulates rapidly at very high level of exercise

Athletes have higher rate of oxygen consumption than the non-athletes;

Athletes produce less lactic acid and hence accumulate less lactic acid than the non-athletes;

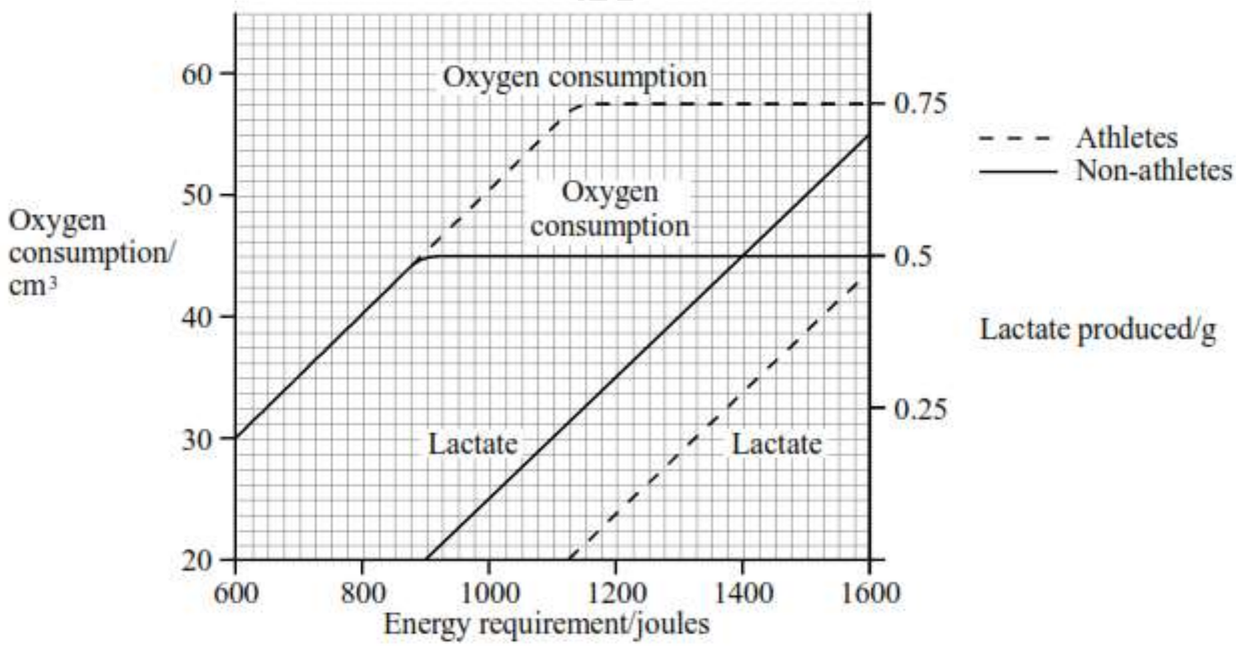
(d) Using the data provided, suggest any advantages an athlete has over a non-athlete.

Athletes consume more oxygen allowing more aerobic respiration; providing more energy from the same amount of foot as compared to the non-athlete; thus athletes can run faster than non-athletes. Lactic acid does not accumulate easily in the muscles of athletes due to complete aerobic respiration; lactic acid is poisonous and leads to muscle pain which the non-athlete experience more easily;

Fatigue of musces doesnot occur rapidly in athletes hence can exercise for a longer time than the non-atheletes; who can experience oxygen debt very rapidly and fatigue easily.

Part B

An investigation was carried out to find the effect of exercise on oxygen consumption and lactate production in athletes and non-athletes. The graph shows the results of this investigation. All units are per kilogram of body mass per minute



(i). Use the graph to find the difference in lactate production between athletes and non-athletes at an energy requirement of 1200 joules per kilogram per minute.

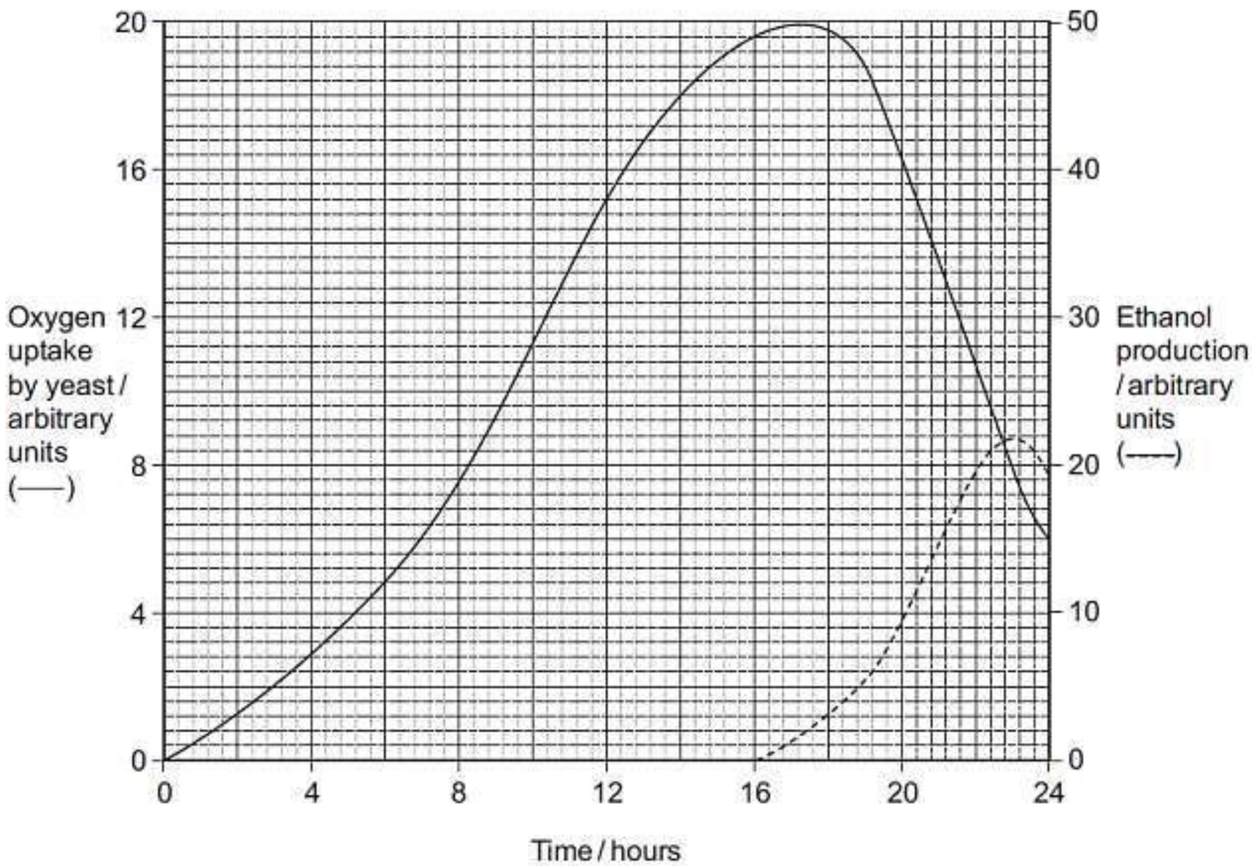
0.225g (per kilogram of body mass);

(ii) Compared with non-athletes, athletes can run at a rate that has a higher energy requirement before lactate production begins. Use information provided in the graph to explain how athletes can sustain a higher energy requirement before lactate production commences.

Lactate is produced during anaerobic respiration; Athletes take in more oxygen (at higher intensities of exercise); Anaerobic respiration delayed / aerobic respiration lasts longer; Aerobic respiration provides more energy

Question 4.

Yeast is a single-celled (unicellular) organism. A student investigated respiration in a population of yeast growing in a sealed container and presented the results as shown in the graph below.



(a).Calculate the rate of oxygen uptake between 2 and 4 hours. ***(03 marks)***

Rate of oxygen uptake = $\frac{\text{change in oxygen uptake}}{\text{Change in time}}$

Rate of oxygen uptake= $\frac{3.2-1.2}{4-2}$

Rate of oxygen uptake = 1 arbitrary unit per hour (Range 0.8-1.2 arbitrary units per hour);

(b).Account for the changes in oxygen uptake during this investigation. ***(11 marks)***

Oxygen uptake very low initially; rapid increase; to maximum at 17 hours; rapid decrease thereafter; This was due to aerobic respiration of glucose; by very few yeast cells; Increased yeast cell growth / reproduction /division; causes increased uptake (of oxygen); Glucose/nutrients/oxygen decreases/becomes limiting; Anaerobic respiration occurs; to form Ethanol/toxins; and much heat released; Cells die.

(c).Explain the changes in production of ethanol during this investigation. ***(11 marks)***

No ethanol till the 16th hour; rapid increase; to maximum at 23 hours; rapid decrease thereafter. This is because of the few yeast cells in first 16 hours; sufficient oxygen; Increased yeast cell growth/ reproduction /division; results in anaerobic conditions; hence anaerobic respiration yields ethanol from pyruvate; (Ethanol/ anaerobic respiration) increases as oxygen (uptake/concentration) decreased; Decreases as glucose is used up/ ethanol kills cells;

(d) Sodium azide is a substance that inhibits the electron transport chain in respiration. A student repeated the investigation but added sodium azide after 4 hours. Suggest and explain how the addition of sodium azide would affect oxygen uptake and the production of ethanol. ***(04 marks)***

Oxygen uptake decreases/stopped;
Oxygen is final (electron) acceptor/combines with electrons (and protons); Ethanol produced sooner/ more ethanol produced;

(e) Briefly explain the main biochemical processes of respiration which lead to the formation of ethanol.

Phosphorylation of glucose; by ATP to form glucose-6-phosphate;
Isomerization of glucose-6-phosphate; to form fructose-6-phosphate; Phosphorylation of fructose-6-phosphate by ATP to form fructose-1,6-bisphosphate;
Splitting of fructose-1,6-bisphosphate; into glyceraldehyde-3-phosphates (3-phosphoglyceraldehyde)
Dehydrogenation of 3-PGAL by nicotinamide adenine dinucleotide (NAD^+) to form reduced nicotinamide adenine dinucleotides (NADH); followed by phosphorylation to form 1,3-bisphosphoglycerate which later loses the phosphate to form 3-phosphoglycerate;
Isomerization of 3-phosphoglycerate to 2-phosphoglycerate; dehydration to form 3-phosphoenolpyruvate and finally loss of a phosphate to form pyruvate; Decarboxylation of pyruvate to yield carbondioxide; conversion to acetaldehyde then reduction by NADH to form ethanol;

(f) Compare the biochemistry of respiration in yeast cells before and after 16 hours. ***(06 marks)***

Similarities:

Both
• Form ATP
• Involve glycolysis
• Use NAD+ as the oxidizing agent that accepts electrons
• Are carried out by same yeast cells

Differences:

Aerobic respiration	Anaerobic respiration
Final electron acceptor is oxygen;	Final electron acceptor is acetaldehyde;
Yields much energy;	Yields less energy;
Occurs in mitochondria	Occurs in cytoplasm;

(g) Give other commercial applications of experiments similar to this investigation ***(03 marks)***
• Leavening of bread i.e. baking of raised bread
• Manufacture of milk products like sour milk, yoghurt and cheese
• Manufacture of organic acids like citric acid, oxalic acid and butyric acid which have industrial applications in food processing.

Question 5.

Part A.

During germination of maize seeds, the volume of carbon dioxide (cm^3) evolved and oxygen (cm^3) consumed by the seed embryo, were established with time and recorded in the table shown below. Study the table and answer the questions that follow:

Time(days)	0	2	4	6	8	10
Volume of carbon dioxide (cm^3)	8.4	7.2	8.0	8.5	9.4	6.8
Volume of oxygen (cm^3)	6.0	6.0	8.0	8.49	10.4	11.3
Respiratory quotient						

(a) Define the term respiratory quotient. ***(02 marks)***
Respiratory quotient is the ration of the volume of carbondioxide evolved to that of oxygen utilized in a respiratory process.

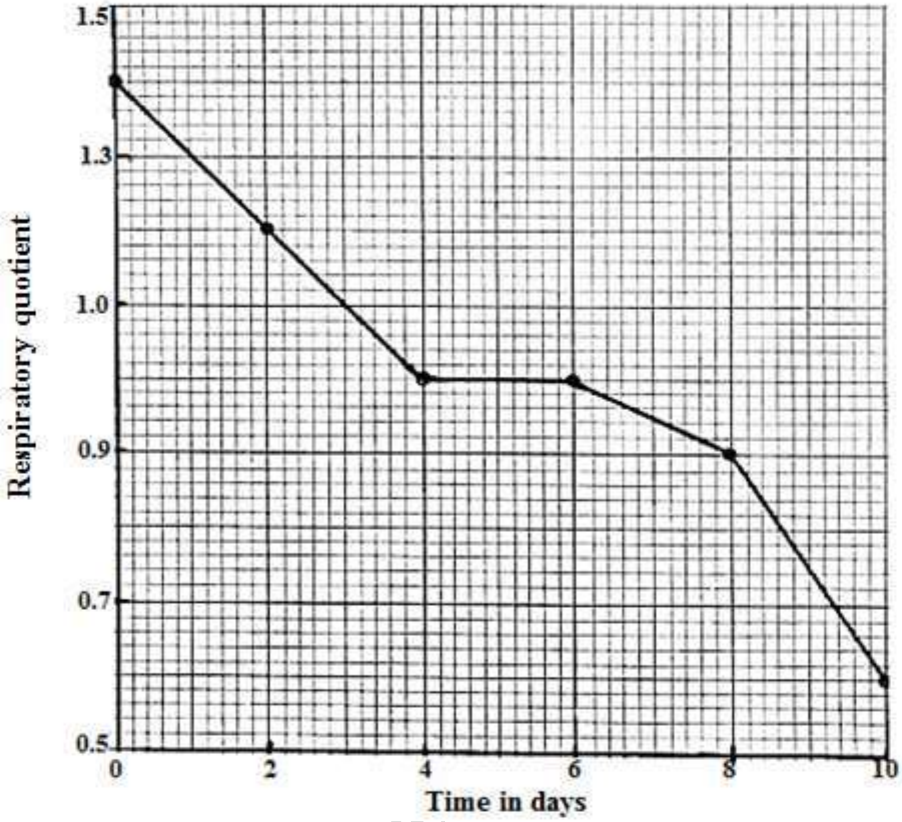
(b) Calculate the respiratory quotients and fill in the values in the table you have copied ***(03 marks)***

$$RQ = \frac{\text{Volume of carbondioxide}}{\text{Volume of oxygen}}$$

Time(days)	0	2	4	6	8	10
Volume of carbon dioxide (cm^3)	8.4	7.2	8.0	8.5	9.4	6.8
Volume of oxygen (cm^3)	6.0	6.0	8.0	8.49	10.4	11.3
Respiratory quotient	1.4	1.2	1.0	1.0	0.9	0.6

(c).Draw a graph to show the variation of respiratory quotient with time. ***(05 marks)***

A graph showing the variation of the respiratory quotient of the embryo with germination time of maize grains



(d) Describe the variation of the respiratory quotient of the seedling with time. ***(05 marks)***

Initially the RQ was high and above 1.0; from 0 to 4 days, the RQ decreased rapidly/ steeply to 1.0. From 4 to 6 days, the RQ remained constant. From 6 to 8 days, RQ decreased slowly; For 8 to 10 days; the RQ decreased rapidly to the minimum RQ of 0.6

(e) Account for the variation respiratory quotient of the seedling with time. ***(10 marks)***

RQ was initially above 1 indicating that the carbondioxide produced was higher than oxygen used due to low oxygen supply to the seed embryo since it is having an intact seed coat which is impermeable to oxygen. This resulted in both aerobic and anaerobic breakdown of glucose to produce ATP for the embryo. RQ reduced to 1.0 and remained constant because the seed coat had ruptured; oxygen supply was sufficient and carbohydrates were aerobically broken down. RQ decreased below 1.0 from the 6th day to the 10th day; because the seedling had developed leaves and had started using internally produced carbondioxide from respiration for photosynthesis which then resulted in production of oxygen as a byproduct. Hence the low RQ below 1.0 is indicative of the volume of carbondioxide evolved being far lower than of oxygen used.

(f). Mention the two aspects determined by the respiratory quotient. ***(02 marks)***

Nature of the substrate metabolized (carbohydrates has RQ=1, proteins has 0.8-0.9& lipids have RQ< 1.0)

Type of respiratory metabolism; whether aerobic or anaerobic

(g) Account for the changes in the respiratory quotient of:

(i) Fattening mammals. ***(03 marks)***

Fattening mammals is associated with RQ above 1 since the conversion of carbohydrates to fat is accompanied by liberation of more carbondioxide than the oxygen consumed during the process.

(ii) Hibernators. ***(05 marks)***

Towards hibernation, the RQ increases above 1.0, reflecting that carbondioxide evolved is higher that the oxygen consumed; because a lot of ingested carbohydrates are being converted into brown fats and stored in the adipose tissues; more carbondioxide is produced than the oxygen used. The brown fats are then stored. During hibernation the RQ reduces below 1.0 because of being inactive such that the organism's tissues breakdown the stored brown fats for their respiratory activities; resulting in less carbondioxide evolved than oxygen consumed.

(h) Explain the variation of basal metabolic rate with:

(i) Sex. ***(03 marks)***

The BMR of males is higher than that of females because the male bodies are less insulated/ have less fats for adequate insulation per unit body mass and surface area. So the male bodies lose heat faster than those of the females; so a higher BMR is required to generate more heat than in females; whose insulation with body fat is greater.

(ii) Age. ***(02 marks)***

In young individuals, BMR is high because a lot of energy is needed for biosynthesis of cellular components/ organogenesis/ growth of body parts. Adult organisms have less biosynthesis in their bodies hence lower BMR.

Part B.

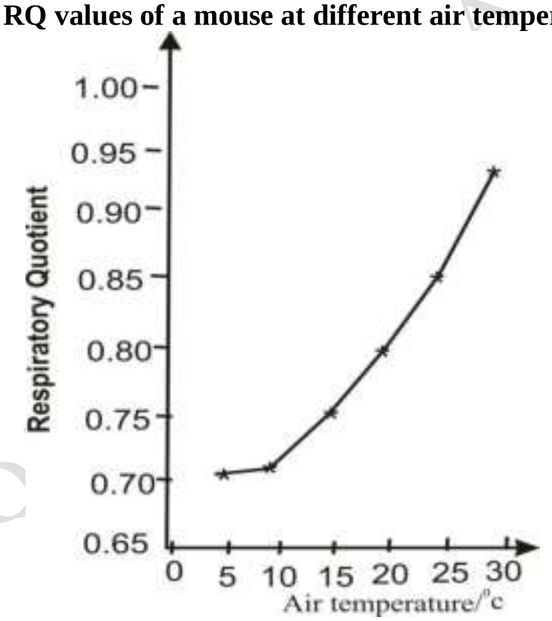
Carbohydrates and lipids are useful energy sources in cells

(a)(i).Explain the difference in the energy values of carbohydrates and lipids as energy sources ***(05 marks)***

Lipids have a higher energy value than carbohydrates per unit mass; Oxidative phosphorylation and ATP production; needs supply of hydrogen; to form reduced NAD/FAD; Lipids have more, hydrogen/ hydrogen-carbon bond; produce more acetyl coenzyme A and go through more turns of Krebs cycle/ more oxidation cycles More ATPs made; Lipids offer insulation; and their metabolism releases much needed water on respiration.

(ii).Explain why a hibernating animal first converts carbohydrates to lipids before hibernation

(b).The graph below shows the RQ values of a mouse at different air temperatures



Using the information in the graph, explain the relationship between RQ and air temperature.

As the temperature increased to 10°C, the RQ of the mouse was low and relatively constant: implying that at low temperatures, the high temperature gradient between the organism and the surrounding resulted into more heat energy loss to the surrounding. In order to replace the much energy lost, lipids that produce alot of energy were respired. As the air temperatures increased, the temperature gradient between the organism and its surrounding became less resulting into less heat energy loss to the surrounding; and the organism hence respired the proteins and carbohydrates which produce less energy and a relatively high RQ on anaerobic respiration

(ii) Explain circumstances under which RQ would rise over 1.01.

• In preparation for hibernation during which the carbohydrate are converted to lipids a process that evolves much carbondioxide, leading to fattening.

• During vigorous activity or early germination which are associated with anaerobism and some aerobic forms of respiration

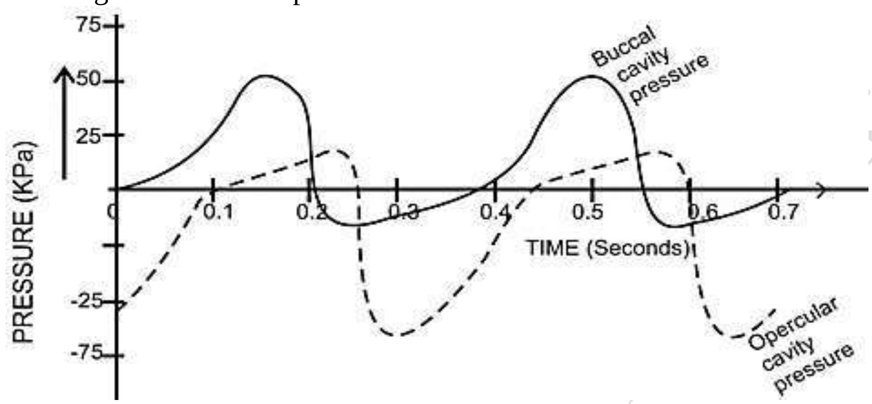
• During the night when the rate of photosynthesis is low/ no photosynthesis reducing carbohydrate use

(ii). Explain, in outline only, how you could test your suggestion. ***(04 marks)***

• Label glucose and determine its failure to enter mitochondria;
• Break mitochondrial membrane (to allow entry of glucose);
• Release appropriate enzymes from mitochondrion;
• Add glycolytic enzymes/ cytoplasm to medium in advance;

Question 6.

The figure below shows the pressure changes in the buccal and opercular cavities of a teleost fish that were obtained using hypodermic tubing connected to a pressure recorder:



The table below summarizes the features of gills in three species of teleost fish A, B and C:

Species of fish	Lamellae thickness/ µm	Interlamellar distance/ µm	Distance between blood and water/ µm
A	35	75	6
B	15	40	3
C	5	20	1

Use the information in the figure and table to answer the following questions:

(a) Compare pressure changes in the buccal cavity and opercular cavity in the first 0.4 seconds. ***(03 marks)***

(b) Account for the observed changes in pressure in the buccal and opercular cavities from 0.2 seconds to 0.6 seconds. ***(16 marks)***

(c) What is the physiological significance of the difference between the pressure in the buccal and opercular cavities? ***(04 marks)***

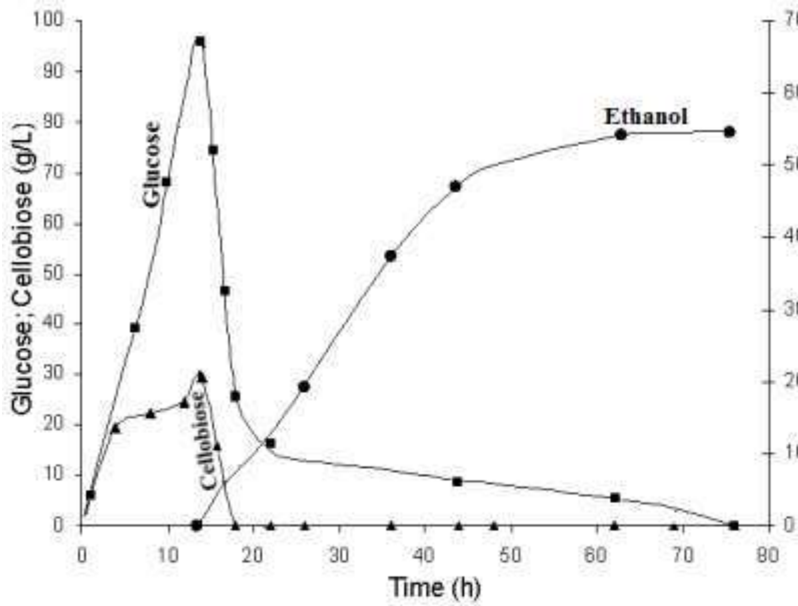
(d) From the table explain how thickness of lamellae is related to extent of activity of the fish. ***(09 marks)***

(e) Blood in the Lamellae flows in opposite direction to that of the water. Comment on the efficiency of this mechanism of gaseous exchange. ***(05 marks)***

Question 7.

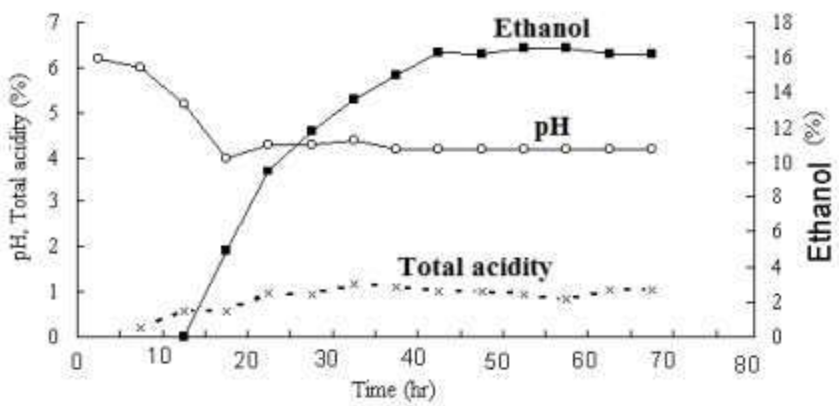
Figure I shows results from the experiment of simultaneous saccharification and fermentation of steam- pretreated sugarcane (Saccharum officinarum) bagasse by Saccharomyces cerevisiae, a strain of yeast. Bagasse, the fibrous residue obtained after extracting juice from sugar cane consists approximately of 50% cellulose, 25% hemicellulose, and 25% lignin.

Figure I



During the experiment, temperature of the medium was maintained at 37°C, and initial pH adjusted to 6.1. Nitrogen was flushed into the reaction vessels at the beginning of the experiment
Figure II shows changes in pH and total acidity during the same period of time.

Figure II



(a) From figure I:
(i) Describe the changes in the concentration of sugars and ethanol. ***(10 marks)***
(ii) Explain the changes in the concentration of sugars and ethanol. ***(10 marks)***
(b) Explain the necessity of the following in the experiment:
(i) Steam-pretreatment of sugarcane bagasse ***(05 marks)***
(ii) Adjustment of pH to 6.1 ***(02 marks)***
(iii) Flushing nitrogen into the reaction vessel. ***(02 marks)***
From figure II:
(c) Explain the observed changes in pH and total acidity of the medium during the experiment. ***(07 marks)***
(d) Suggest one reason for the observed efficiency of the experiment. ***(04 marks)***

Question 8.

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

Time in minutes	Volume of oil displaced in cm^3
0	0

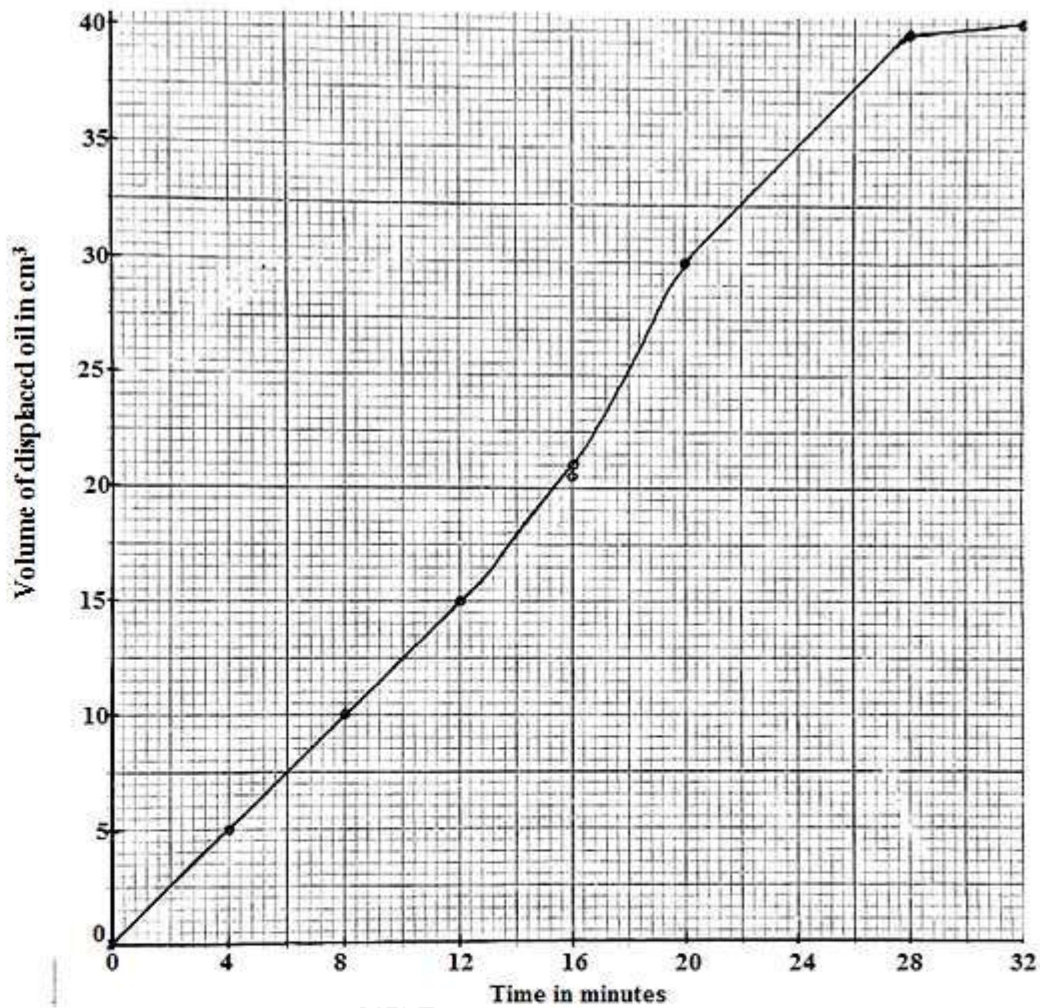
4	5
8	10
12	15
16	21
20	30
28	40
32	41

In another experiment, the ability of the yeast to metabolize a range of different carbohydrates, all at the same conditions, was estimated by measuring the volume of oil displaced by carbondioxide evolved, after 20 minutes of running each experiment. The results are shown in the table 2 below;

Type of carbohydrate	Volume of displaced oil (cm^3)
Glucose	8.7
Sucrose	5.9
Lactose	0.9
Maltose	6.1
Starch	0.9
Fructose	8.9
No carbohydrate	0.9

(a).Plot the data in table 1 in an appropriate graph

Graph showing the variation of the oil displaced by carbondioxide evolved from metabolism of glucose by yeast cells with time



(b).What is the relationship between the concentration of:

(i).carbondioxide evolved and the volume of oil displaced

Carbondioxide concentration demonstrated a sigmoid variation with time. When the carbondioxide concentration is low, the volume of oil displaced is also low and when the concentration of carbondioxide is high, the volume of oil displaced is also high. This indicates that carbondioxide displaces the oil.

(ii).carbondioxide evolved and the rate of metabolism

When rate of metabolism is low, the carbondioxide evolved is low and when the rate of metabolism is high, the concentration of carbondioxide is also high. This is because carbondioxide is produced as a by-product of metabolism.

(b)(i).Describe the variation of oil displaced with time

Initially, there was no oil displaced from 0 to 14 minutes; there is a gradual increase in the volume of the oil displaced. From 14 to 16 minutes, there is a steep/ rapid increase in the volume of oil displaced and from 16 minutes to 20 minutes, there is a steeper increase in the volume of the oil displaced. From the 20th to the 28th minute, the increase in the volume of oil displaced was gradual giving a maximum of 41cm^3

(b)(ii).Account for the variation of oil displaced with time, described in 1(c)(i) above

Initially there was no carbondioxide evolved because the yeast cells had not started metabolizing glucose. From 0 to the 14th minute, increase in volume of oil displaced was gradual because the rate of metabolism was still low due to little time allowed for enzyme activity hence low carbondioxide production to displace the oil. Steep increase in the volume of oil displaced was due to sufficient time for optimum enzyme activity to metabolize glucose at a high rate; hence high rate of carbondioxide was evolved. Gradual increase in the volume of the oil displaced from the 20th to the 28th minute was due to the decrease in the glucose concentration which results in low rate of glucose metabolism hence low rate of carbondioxide evolution. From 28th minute to the 32nd minute, the more gradual increase in the volume of the oil displaced was due to the very little glucose left, which keeps the rate of metabolism very low hence very low carbondioxide evolved.

(c)(i). Predict what would happen to the shape of the graph, if the experiment had been continued beyond 32 minutes

It would remain constant

(c)(ii).Give reasons for your prediction

Due to the great decrease in the concentration of glucose until it gets depleted. As the concentration of glucose goes on decreasing, the rate of metabolism decreases until the metabolism stops with total depletion of glucose, hence no more carbondioxide will be evolved. Evolution of ethanol can also poison the yeast cells; suppressing any further metabolic activity.

(d).From the table 2 above, suggest four factors which must be standardized in this investigation

- Temperature
- Concentration of the substrates
- pH of the solution
- Same species of the yeast sample used.

(e).What was the purpose of the experiment without carbohydrate?

- To establish whether there was metabolism or not
- To act as a control for comparing rates of carbondioxide evolution from metabolism of carbohydrates & that from non-carbohydrates.

(f).Glucose and fructose have exceedingly high concentration of oil displaced during their metabolism. Explain the values obtained for:

(i).sucrose and maltose

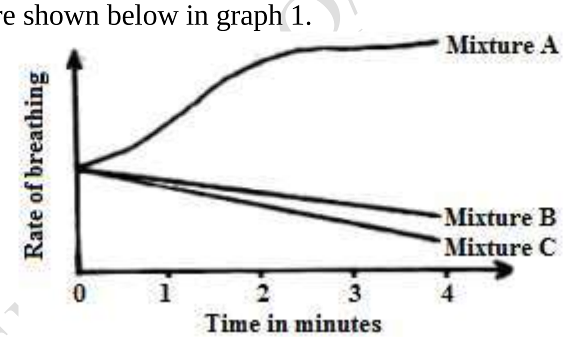
Sucrose and maltose have lower volume of evolved carbondioxide than for glucose and fructose because, being disaccharides, 20 minutes time was not sufficient for their hydrolysis by the enzymes into simple sugars and then metabolized to produce carbondioxide. For glucose and fructose, they are monosaccharides/ simple sugars; easily metabolized to produce carbondioxide at a faster rate.

(ii) starch and lactose

Starch being a larger molecule/ polymer/polysaccharide, the time was not enough for amylase to hydrolyse it into simple sugars; hence no carbondioxide evolved since starch was not metabolized. Lactose was not metabolized to produce carbondioxide because yeast cells lack the enzyme lactase to hydrolyse lactose into simple sugars.

Question 9.

In an experiment, a subject was given various mixtures to breathe and the rate of breathing was measured. The results are shown below in graph 1.



KEY
Mixture A= 90% oxygen + 10% carbondioxide
Mixture B= Normal atmospheric air
Mixture C= 100% oxygen

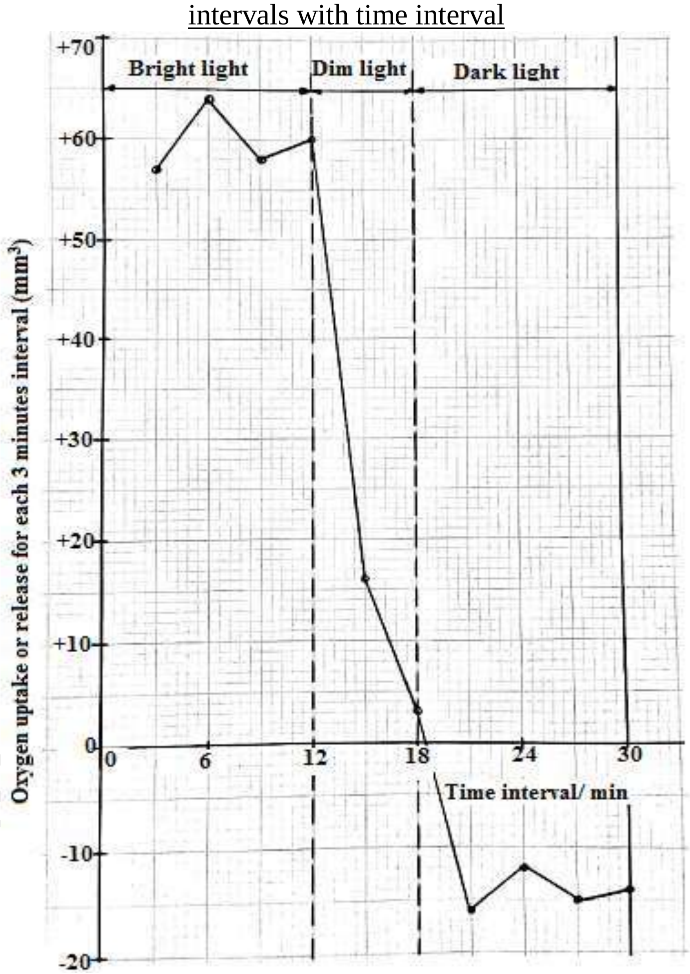
Five small discs cut from spinach leaves were floated on a small volume of buffered hydrogen carbonate solution in a flask attached to a respirometer. The discs were first exposed to bright light, then to dim light and finally left in the dark. Oxygen release was recorded as positive values and oxygen uptake as negative values. The results obtained from this experiment are given in table 1.

Light intensity	Time interval in minutes	O_2 uptake or release for each 3 minutes interval in mm3

Bright light	0–3 3–6 6–9 9–12	+57 +64 +58 +60
Dim light	12–15 15–18	+16 +3
Dark	18–21 21–24 24–27 27–30	- 16 - 12 - 15 - 14

(a)(i).Present the data in suitable graphical form ***(06 marks)***

<u>A graph showing the variation of oxygen uptake or release for each 3 minutes interval under different light intervals with time interval</u>



(a)(ii).Calculate the mean rate of oxygen release in bright light ***(03 marks)***

Total oxygen released= 57 + 64 + 58 + 60= 239 mm^3

Period over which oxygen is released= 12 minutes. Rate of oxygen release= 239/ 12= 19.9 mm^3

(iii).Explain the significance of the results obtained from this experiment. ***(08 marks)***

Oxygen release is a measure of photosynthesis. The rates of oxygen uptake in the dark and release in bright light are both fairly constant because: In bright light, some factor other than light intensity is limiting the reaction (eg CO_2 concentration) and therefore additional light has no further effect: In the dark there is no photosynthesis and the rate of respiration is unaffected by light intensity. In dim light the light intensity is the limiting factor and therefore a small change in light intensity produces a marked change in the rate of photosynthesis and hence oxygen release. The point where the line crosses the horizontal axis is called the compensation point and represent light intensity at which oxygen released in photosynthesis is exactly counterbalanced by that taken up in respiration.

(b).Explain what the data in graph 1 shows on how the rate of breathing is controlled ***(10 marks)***

Normal atmospheric air contains 21% oxygen and 0.04% carbondioxide. When the carbondioxide concentrations increased to 10% (mixture A), the breathing rate increases and when it is decreased to 0.0% (mixture C), the rate decreases. This suggests that it is the concentration of carbondioxide in inspired that controls the breathing rate. It is not the oxygen concentration in inspired air since when this is higher than normal at 90% the breathing rate increases but when it is even higher at 100%, the rate decreases there; and hence doesnot therefore seem to be a straight forward relationship between the oxygen concentration n inspired air and breathing rate.

(c).In the light of the information provided by graph 1. Show why mouth to mouth resuscitation is a better means of artificial respiration than pressing on the chest wall. ***(04 marks)***

During mouth to mouth resuscitation expired air contains about 4%carbondioxide and this stimulates an increase in the patient's respiratory rate and aids recovery. Pressing and releasing he chest wall will cause atmospheric air with only 0.04%. carbondioxide to enter the patient's lungs. With its lower carbondioxide level this air is not as effective in stimulating the patient's own respiratory rate and recovery is therefore slower.

(d).Why is it more dangerous to rebreathe expired air if it is passed through soda lime? ***(06 marks)***

If expired air is rebreathed its oxygen content decreases & the carbondioxide content progressively increases. The breathing rate is therefore increased due to the rise in the carbondioxide concentration of the air. This faster breathing rate to some extent compensates for the lowering of the oxygen concentration and also acts as a warning to the person because the faster breathing rate causes distress. if the expired air is passed through lime, the carbondioxide is completely absorbed and when rebreathed this air no longer stimulates faster breathing. Thus, although the oxygen concentration of the air continues to fall, there is neither a compensatory increased breathing rate nor a warning of the danger and so unconsciousness and death may follow.

(c).Explain the use of the following in the experiment above: ***(03 marks)***

(i) Five small leaf discs, not one.

Leaf strips of equal dimensions were used to have comparable photosynthetic rates; and generate comparable results for accuracy/ minimising experimental errors. **OR** To ensure uniformity/ accuracy in the results; and avoid other factors that could affect the rate of photosynthesis.

(ii).HCO_3^- solution

Provides carbondioxide; an important photosynthetic substrate

(iii).Buffered solution

Provide optimum pH conditions for the action of photosynthetic enzymes

Question 10.

In an experiment, two healthy human subjects A and B at rest were made to breathe in and out through a spirometer filled with pure oxygen. In the spirometer of subject A, the carbondioxide absorber was left in place while in that of subject B, the carbondioxide absorber was removed. The results were obtained using a recording paper and the ventilation rate of the subjects recorded over a period of 7 minutes. The table below shows the data collected.

Time in minutes	**Subject**	0.0	1.0	2.2	3.0	4.0	5.5	6.0	7.0
Ventilation rate in dm^3min^{-1}	**A**	19	17	16	22	21	25	23	19
	B	15	16	20	28	40	57	74	-

(a).Represent the data in the table above graphically ***(04 marks)***

(b).What are the effects of composition of air on the ventilation rate?

Re- breathed air/ air with increasing carbon dioxide concentration; increases the ventilation rate gradually at first and then rapidly; Air free of carbondioxide has little/ no effect on the ventilation rate; this oscillates along the mean

(c).Explain how changes in composition of air results in changes in the ventilation rate as observed from the graph

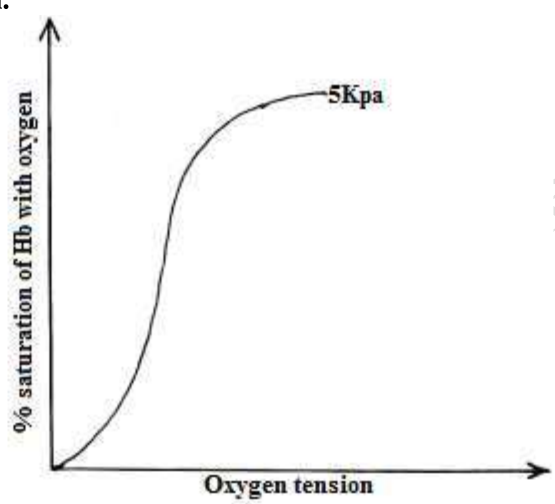
For subject A; removal of carbondioxide from the air in the spirometer; reduces the stimulatory effect of carbondioxide on the medulla of the brain with the remaining oxygen concentration however, much is below the critical level to cause significant change in ventilation rate of the subject.

For subject B; re-breathing of expired air; gradually increases the carbondioxide concentration in the spirometer; the gas taken into the lungs gets richer and richer in carbondioxide; increasing carbondioxide concentration in the blood; chemoreceptors in the medulla and in carotid and aortic bodies are stimulated; impulses are sent to the inspiratory center in the medulla of the brain; which then sends impulses via the external intercostal muscles and diaphragm causing them to increase the rate at which they contract; increasing the rate of ventilation to take in more air as the body tries to get rid of the accumulating carbondioxide.

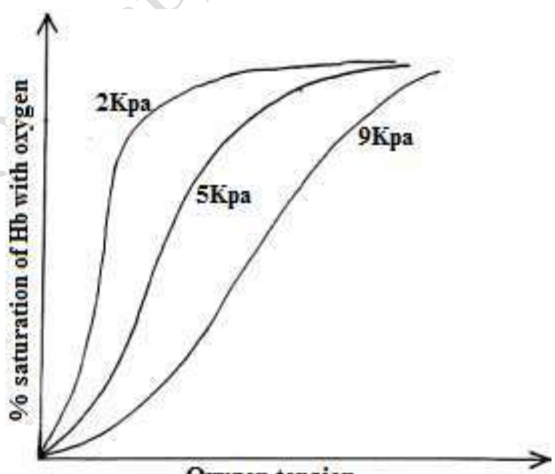
(d).Suggest why breathing in excess oxygen by divers at a pressure higher than atmospheric pressure can be fatal

Tissues metabolize very rapidly at first to keep pace with the oxygen supply; continued uptake leads to oxygen build up; which inhibits enzymes such as cytochrome oxidase in the ETC; entering with cellular respiration hence oxygen poisoning; evidenced by muscle twitching; nausea, dizziness, impaired hearing and vision, confusion, lack of co-ordination and finally convulsions and death.

(e).The figure below shows the changes in percentage saturation of haemoglobin with oxygen at two different carbondioxide concentration.



(i).Taking 5Kpa carbondioxide partial pressure as normal partial pressure of carbondioxide in humans, redraw the graph to show percentage saturation of haemoglobin with oxygen tensions for carbondioxide concentration at 9Kpa and 2Kpa.



(ii).Explain the significance of the relative position of the curves at 2Kpa and 9Kpa carbondioxide to that of the normal carbondioxide partial pressure of humans

At 2Kpa, the oxygen dissociation curve (ODC) is to the left showing that Hb has a higher affinity for oxygen readily loads/picks oxygen from the environment where oxygen concentration is higher. At 9Kpa the ODC is displaced to the night and downwards; haemoglobin has a low affinity for oxygen to the tissues with low oxygen tension for their metabolism.

(iii)Why do organisms like the arenicola that live in environments with low oxygen tension don't show Bohr effect?

Habitats frequently has a higher level of carbondioxide, Bohr effect would cause their oxygen dissociation curve to shift to the night reducing haemoglobin's affinity for oxygen preventing them from taking out enough oxygen for their survival.

Question 11.

A study was carried out on germinating maize seeds to determine the rate of ethanol production by intact seeds and in seeds whose testa had been removed (non-intact seeds). The results are shown in table 1.

Time /days	Rate of ethanol production in arbitrary units	
	Intact seeds	Non-intact seeds
0	0.00	0.00
2	0.15	0.25
4	0.25	0.40
6	0.35	0.60
8	0.45	0.75
10	0.45	0.75
12	0.45	0.75

In another experiment involving maize seeds, the changes in mass of starch and amylase concentration, as the seeds germinate, at a two day interval was determined. The results are shown on figure 1 below. Use the above information to answer the questions that follow

(a)(i). Represent the results in table 1 in a suitable graphical form. *(07 marks)*

(ii).Compare the trends of ethanol production in a (i) above. *(05 marks)*

(b)(i).Explain the differences in the rate of ethanol production observed in a (ii) above. *(08 marks)*

(ii). During the first seven days of germination, the respiratory quotient for intact seeds was found to be higher than for non-intact seeds. Suggest an explanation for this difference. *(05 marks)*

(c).Explain the relationship between the mass of starch and concentration of amylase,

(i).In the first two days. *(03 marks)*

(ii).After day two. *(07 marks)*

(d). From figure 1 and table 1, what conclusion can you draw about the process of germination in maize?

(e).State two internal factors that could affect the results of the second experiment.

Question 12.

An experiment was carried out to investigate the rate of respiration of yeast cells mixed with three differrent carbohydrates (glucose, sucrose and lactose), using methylene blue as an indicator. (Methylene blue is in alkaline condition and colourless in acidic condition.).

1 cm^3 of 0.1M methylene blue was added to a mixture of 5 cm^3 of suspension of yeast in 10 cm^3 of 0.5% glucose solution in a boiling tube. The boiling tube was placed in a water bath at 30^oC for 20 minutes. The rate of respiration was measured as a percentage of the intensity of the blue color at the beginning of the experiment, at intervals of 2 minutes. The experiment was repeated using 0.5% sucrose and lactose. The results are shown in figure 1. Study the figure and answer the questions that follow.

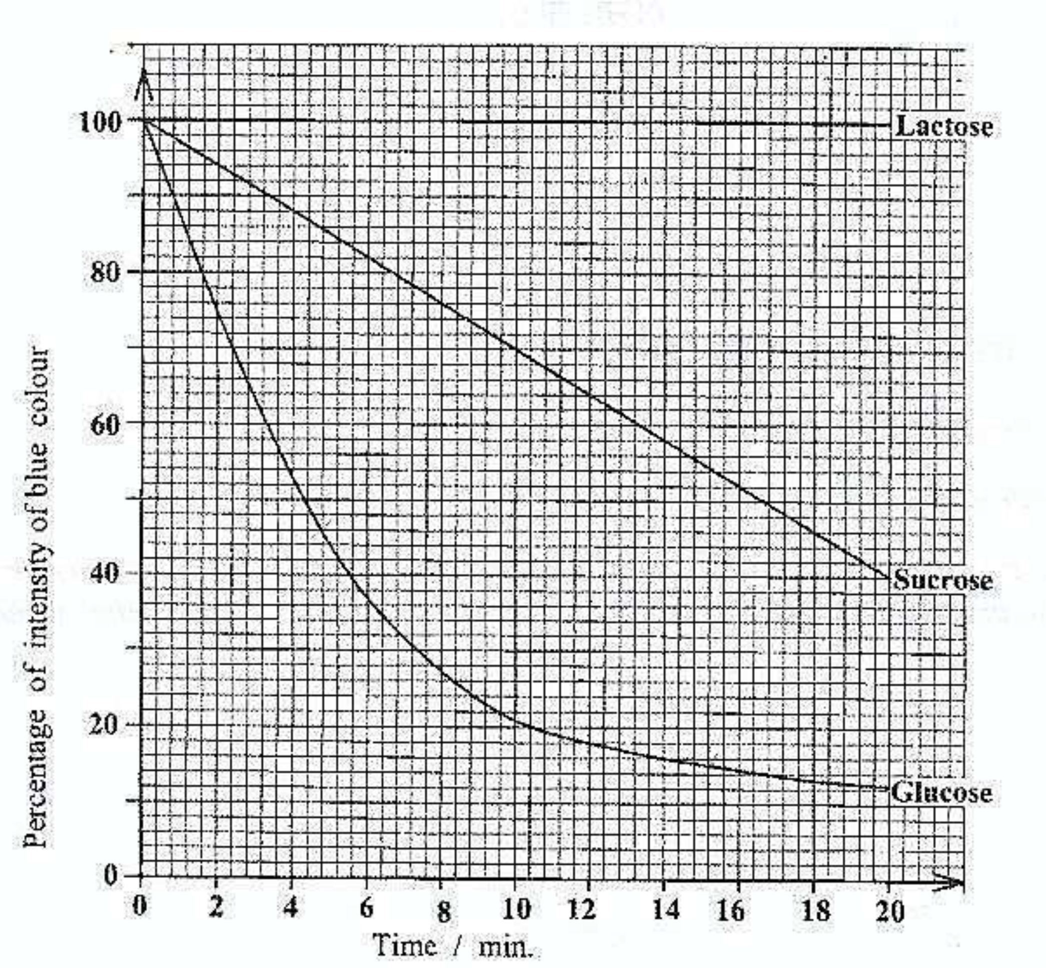


Fig. 1

(a). Calculate the average rate of respiration of yeast in glucose solution during the first four minutes in terms of percentage intensity of the blue color. ***(03 marks)***

(b).Describe the change in the intensity of the blue color with time, for each carbohydrate. ***(05 marks)***

(c)Explain the relationship described in (b) for each carbohydrate.

(i).Lactose ***(03 marks)***

(ii).Sucrose ***(05 marks)***

(iii).Glucose ***(08 marks)***

(c).Suggest what would happen to the color for glucose and sucrose if the experiment continued for 10 more minutes. Give an explanation in each case. ***(10 marks)***

(d).Explain why the boiling tubes were

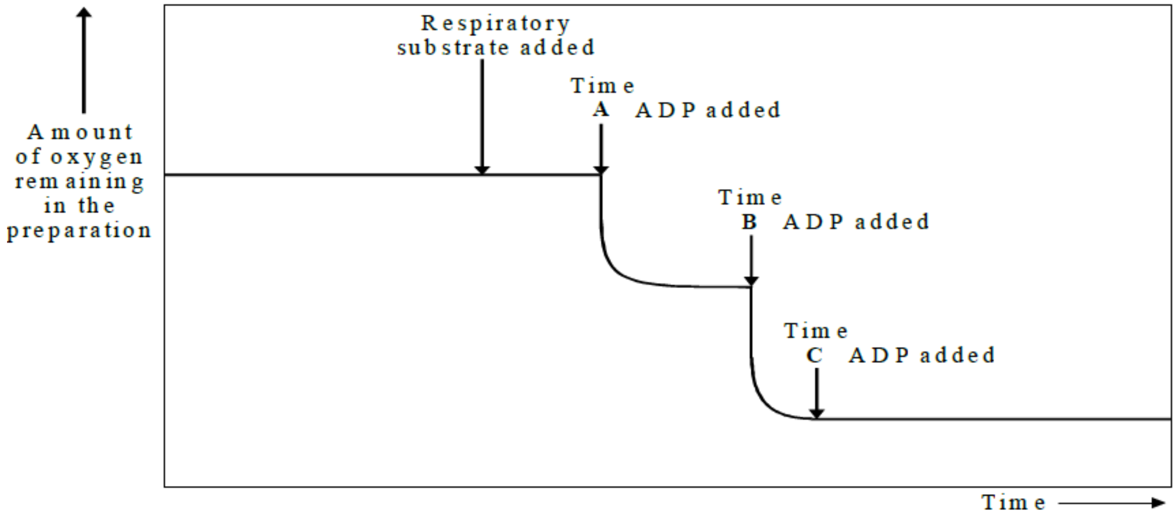
(i).Kept covered during the experiment ***(03 marks)***

(ii).Placed in a water bath at 30ºC ***(03 marks)***

Question 13.

Part A

A preparation of mitochondria was made from liver tissue. Substances were added to this preparation and the amount of oxygen in the preparation was monitored over a period of time. The diagram shows the trace obtained and the times when the different substances were added.



(a).Suggest why the respiratory substrate added to this preparation was a molecule from Krebs cycle and not glucose. ***(04 marks)***
Mitochondria have enzymes for Krebs cycle substrates; have specialized channels for Influx of these molecules but lack specialized transmembrane proteins for glucose Influx; lack glycolytic enzymes that incorporate glucose; do not use glucose as a substrate.

(b). What additional substance, other than those mentioned on the diagram, would need to be added to this preparation in order to get the results shown? ***(02 marks)***
Inorganic phosphate, NAD, FAD^+

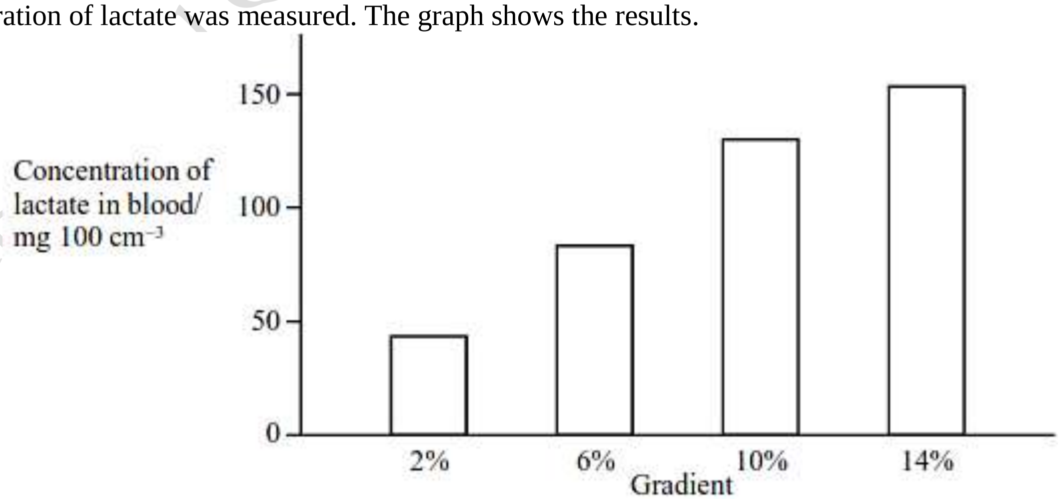
(c) Explain:

(i).why the amount of oxygen fell between lines A and B; ***(03 marks)***
Oxygen is a reactant in oxidative phosphorylation; thus started off Krebs cycle & oxidative phosphorylation. Oxygen is final electron and proton acceptor in the process to form water.

(ii).the shape of the trace after time C. ***(02 marks)***
Reduction in concentration of substrates (or being used up); and accumulation of end products (ATP) which led to end product inhibition.

Part B.

Another investigation was carried out to find the effect of exercise on the concentration of lactate in the blood. Four treadmills were placed at different gradients, ranging from 2% to 14%. A different athlete ran at a constant speed on each treadmill for five minutes. Three minutes after each run a blood sample was taken from each athlete and the concentration of lactate was measured. The graph shows the results.



(a).Name the process that produces lactate during exercise. ***(01 marks)***
Anaerobic respiration

(b).Describe the relationship between the intensity of exercise and the concentration of lactate in the blood.
Increase in the intensity of exercise increases concentration of lactate
(c).Suggest ways in which the design of the investigation could be improved to give more reliable results.
• Athletes are the same gender/ use same athlete;
• Athletes are same age;
• Athletes have similar fitness/ body mass; increase number of athletes/ repeat investigation more gradients;
• Control to measure lactate concentration (at rest).
(d).Suggest why the blood samples used to measure lactate concentrations were not taken from the athletes until three minutes after completion of a run. ***(01 marks)***
Time required for lactate to diffuse into blood (from muscle)
(e).The athlete running on the treadmill at a gradient of 14% suffered from muscle fatigue. Explain what causes muscle fatigue. ***(03 marks)***
• Increase in lactate / lactate produced;
• Fall in (blood) pH / increase in hydrogen ions;
• Effect on enzymes / muscle proteins.

Part C.

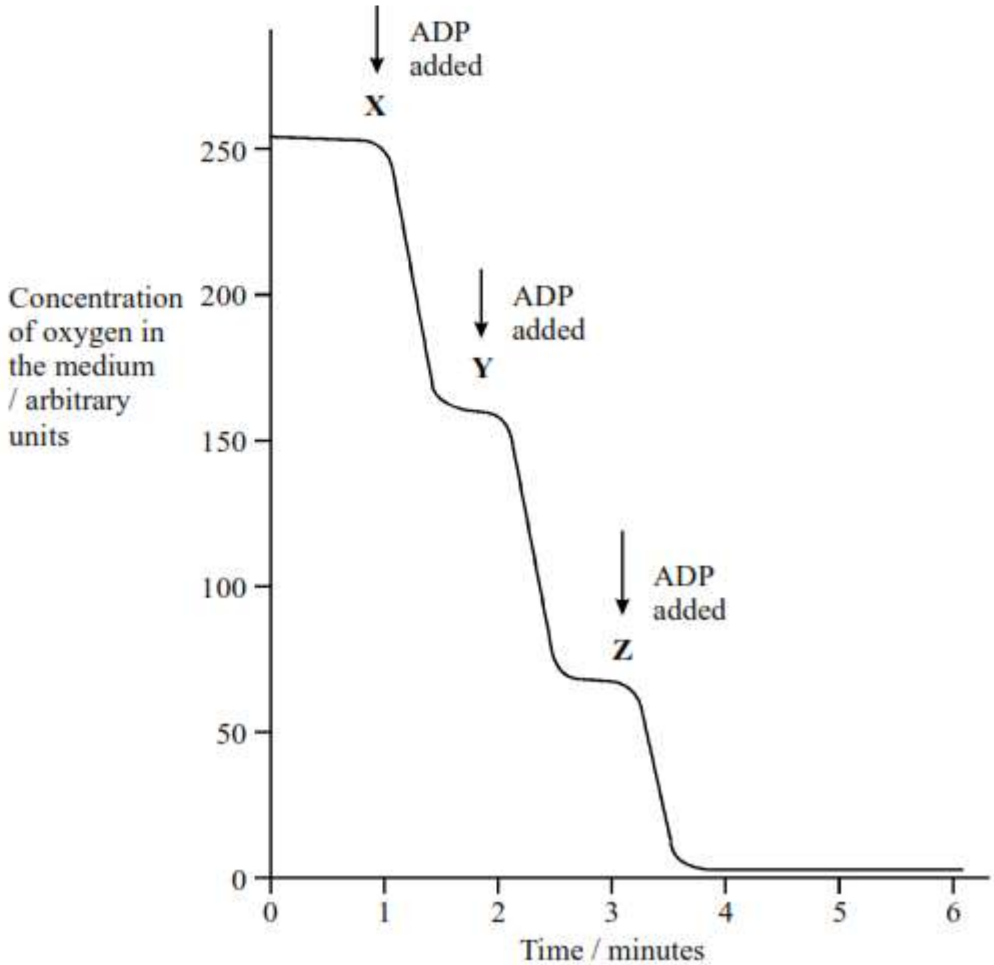
In another investigation, athletes ran as fast as they could for 3 different periods of time. The percentage of energy derived from aerobic and anaerobic respiration during each test was measured. The table shows the results.

Length of test / s	Energy obtained from	
	aerobic respiration/%	anaerobic respiration/%
10	3	97
30	28	72
90	46	54

(i) The world record for the 100m sprint is 9.84s. A top-class sprinter does not need to breathe in during a 100m sprint. Use information in the table to explain why. ***(02 marks)***
(Almost) entirely anaerobic respiration (under 10s); no oxygen used in anaerobic respiration/ needed from breathing
(ii) In the test that lasted 90s, the speed at which the athletes ran decreased before the end of the test. Suggest and explain one reason why their speed of running decreased. ***(04 marks)***
Low energy release from anaerobic respiration; oxygen/ glucose not supplied fast enough for aerobic respiration Or build-up of lactate/ lactic acid causing muscle fatigue or pain/ stiffness/ disruption of enzymes; Or glycogen stores used up; no/ slow supply of glucose to replace.

Question 14.

In an investigation of aerobic respiration, isolated mitochondria were added to a prepared medium containing succinate and inorganic phosphate. Succinate is a 4-carbon compound, which occurs in the Krebs cycle, and can be used as a respiratory substrate. The medium was saturated with oxygen. Equal amounts of ADP were added at one minute intervals, and measurements were taken of the oxygen concentration in the medium. The graph shows the results.



(a).Why was inorganic phosphate added to the medium? ***(01 marks)***
Needed to make ATP / for phosphorylation;
(b). Explain why the oxygen concentration in the medium decreased after adding ADP at X. ***(04 marks)***
Oxygen is needed for formation of ATP/ phosphorylation; thus used so its level falls; Oxygen reacts with protons/ hydrogen ions to produce water; In the electron transport chain/ at terminal acceptor; allows recycling of reduced coenzymes/ NAD/ FAD.
(c) Explain why the fall in oxygen concentration was the same following the addition of ADP at X and at Y.
Because equal amounts of ADP were added;
(d) Explain why the fall in oxygen concentration, following the addition of ADP, was less at Z than at Y.
Less oxygen available in medium at Z than at Y OR because oxygen all used up / 'runs out';
(e). Fresh mitochondria were isolated from cells and a similar experiment was carried out. This time the medium contained glucose instead of succinate. Again, the medium was saturated with oxygen & excess ADP was added. However, there was almost no fall in oxygen concentration, even after 10 minutes.
(i) Suggest and explain a reason for this observation. ***(03 marks)***
Glucose cannot enter mitochondria because too large to enter/ no carrier system for it; OR glucose cannot be metabolized/ equivalent because necessary enzymes not present;

ESSAY QUESTIONS

Question 1.
Describe how the gaseous exchange structures suited for function in the different organisms ***(20 marks)***
Cell surface membrane in unicellular organisms e.g. amoeba

• Their cell surface membrane has a large surface area to volume ratio enables efficient diffusion of gases.
• Being aquatic, the cell membrane is always moist to dissolve respiratory gases to enable their diffusion.
• The cell surface membrane is permeable to respiratory gases.

Entire body surface e.g. skin of earthworms

• Skin surface is moist to enable dissolving of respiratory gases for efficient diffusion.
• Skin is thin to reduce the diffusion distance increasing rate of diffusion of respiratory gases.
• Epidermal tissue is highly vascular to carry respiratory gases; A high concentration gradient is maintained

Across the surface of flattened body e.g. flatworms

• The flatness increases the surface area to volume ratio to increase the rate of diffusion of respiratory gases.

Lung-books in spiders

• The internal cavity increases the surface area for exchange of respiratory gases.

External gills in young tad poles and lugworms

• There is increased surface area for diffusion of respiratory gases.

Tracheoles in insects

• Tracheae are kept open by circular bands of chitin to enable continued movement of air in and out of tracheoles.
• Tracheae branch to form tracheoles that reach every cell to delivered oxygen directly to cells and take away CO_2
• Ends of the tracheoles are moist to enable dissolution of respiratory gases for increasing their diffusion

Internal gills in fish

• Gill filaments have folds called secondary lamellae that increase the surface area for gas exchange.
• Gill lamellae contain a network of capillaries; carrying away oxygen or bringing in carbondioxide for expulsion.
• There is counter current flow i.e. water and blood in the gills flow in opposite directions to maintain a steep concentration gradient for diffusion of respiratory gases.
• Gills are moist to enable dissolution of respiratory gases for efficient diffusion.
• Gills are thin-walled & in close contact with water to provide a short distance for diffusion of respiratory gases.

Inner alveolar surface of lungs in mammals

• Lungs have many tiny alveoli which provide a large surface area for gas exchange.
• Alveoli and capillary walls are only one cell thick reducing diffusion distance.
• Epithelial cells are flattened so are very thin; reducing the diffusion distance.
• Capillaries are pressed against alveoli further reducing diffusion distance.
• The moistened alveolar surface enables dissolution of respiratory gases to increase the rate of diffusion.
• The gas exchange system is internal to reduce water loss by evaporation.
• There are high concentration gradients of the gases, maintained by ventilation and flow of blood in the capillaries.

Cell walls of cells in the leaf mesophyll and cortex of root and stem

• Open stomata, exchange of oxygen and CO_2in the leaf is sufficient to maintain a steep concentration gradient
• Large intercellular air filled spaces in the spongy mesophyll act as a reservoir for gaseous exchange.
• The cortical air spaces of roots and stems are continuous up and down and also in a sideways direction, thus allowing gas transport throughout the stem and root tissues.
• Root hairs lack a waxy cuticle and have moist surfaces to facilitate rapid diffusion of gases through the cell wall.
• Mangrove species that grow in water logged soils with less air content develop breathing roots above the ground level to increase gas exchange.
• Root hairs are numerous to increase the surface area for gas exchange.
• In the stem, lenticels consist of loosely packed cells at the opening to enable diffusion of respiratory gases.

Question 2.

(a)Explain what is meant by lung ventilation ***(01 marks)***
(b).Describe how;
(i). lung ventilation, ***(10 marks)***
(ii).heart beat is regulated ***(05 marks)***
(c).Describe the different forms of phosphorylation that result in ATP production in cell ***(04 marks)***

(a).

Lung ventilation refers to the tidal exchange of air (mainly gases O_2 and CO_2) between the lungs and the atmosphere‘s ambient air that occurs during breathing.

(b)(i).

Lung ventilation is regulated involuntarily by the medulla, carbondioxide being the main determinant. High CO_2 levels is sensed by chemoreceptors in the medulla, carotid and aortic bodies; send impulses to the inspiratory centres in the medulla; which respond by firing impulses via the external intercostal and phrenic nerves to the external intercostal muscles and the diaphragm; increase their rate of contraction; thereby raising the inspiratory rate. Lung inflation following inspiration stretches the proprioreceptors in the bronchial tree; impulses are sent to the expiratory centre by the vagus nerve; trigger reflexes like Hering Breuer reflexes; temporarily inhibiting the inspiratory centre and inspiration. The external intercostal muscles therefore relax, elastic recoil of the lung occurs; expiration occurs. Forcible expiration is achieved by contraction of the internal intercostal muscles. Pneumotaxic and Apneustic centres coordinate the speed of ventilation; the former sends inhibitory impulses to the inspiratory centre; finetunes ventilation while the latter sends stimulatory impulses to the inspiration centre so it activates & prolongs inhalation (deep breaths). Within limits, the rate and depth of breathing is under voluntary control by the cerebral cortex;

(b)(ii).

Intrinsically heart beat is controlled by a set of specialised cardiac cells which initiate and distribute electrical signals myogenically throughout the heart; The SAN as the pacemaker; spreads electrical excitations to atria; making them contract; excitation wave then reaches the AVN; which delays and relays signals through purkyne tissue & the bundle of His; to the ventricles; which then contract.

Extrinsically by the autonomic nervous system; Sympathetic nervous system releases noradrenaline facilitates depolarization of cardiac muscles; increases cardiac activity; Parasympathetic nervous system (vagus nerve); releases acetylcholine; hyperpolarizes cardiac tissue; decrease cardiac activity;

Other extrinsic controls include baroreceptor activity, hormones like thyroxine, age, exercise & body temperature.

(c).

Substrate level phosphorylation occurs when a phosphate group and its associated energy is transferred to ADP to form ATP. The substrate molecule (the molecule with the phosphate group) donates the high energy phosphate group. Such phosphorylation occurs during glycolysis.

Oxidative phosphorylation occurs when a phosphate group is added to ADP to form ATP, but the energy for the bond does not accompany the phosphate group. Instead, electrons in the electron transport chain of oxidative phosphorylation supply the energy. That energy is used to generate the H^+ gradient which, in turn, supplies the energy to ATP synthases to generate ATP from ADP and a phosphate group.

Question 3.

(a)Compare aerobic and anaerobic respiration ***(04 marks)***

(b)Briefly explain the major steps involved in production of energy from glucose ***(16 marks)***

(a).

Similarities

• In both ATP is formed
• Both take place in living cells
• Both are catabolic reactions

Differences

Aerobic respiration	Anaerobic respiration
Uses oxygen which is the last electron acceptor in oxidative phosphorylation.	Occurs without oxygen; rather uses electron transport chain (ETC);
Releases lots of energy (38 ATP molecules per glucose molecule)	Produces1ess energy(Net; 2 ATP molecules per glucose molecule)
Complete glucose breakdown incomplete glucose breakdown CO_2 and H_2O formed	Lactic acid and ethanol are the main products in animals and plants respectively.
Predominant form of respiration in higher plants and animals.	Predominant mainly in microbes like some plants and animal, bacteria, some yeast cells, prokaryotes.
Takes a longer time to release energy	Shorter time to release energy

Goes through glycolysis, Kreb's cycle and oxidative phosphorylation	Glycolysis; then goes straight to the anaerobic pathway (pyruvate to lactate or ethanol)
Occurs in the cytoplasm and mitochondria	Only occurs in the cytoplasm

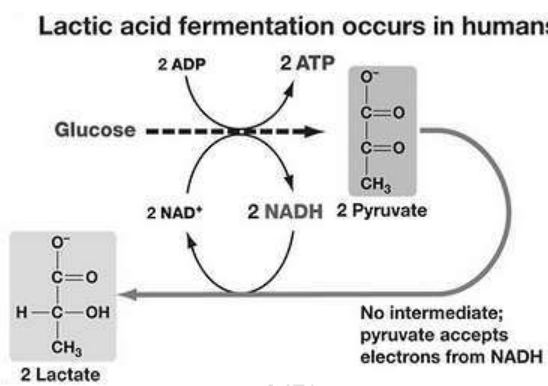
(b).

Glycolysis; first process of glucose breakdown; occurs in both aerobic and anaerobic conditions within the cytoplasm of cells. Two molecules of 3 carbon compound pyruvate are produced from each glucose molecule. Two ATP molecules are used in phosphorylation of the six carbon sugar while four ATP molecules and two NADH molecules are produced by substrate level phosphorylation from each glucose molecule. A net gain of two ATP molecules is yielded per glucose molecule.

Under anaerobic conditions;

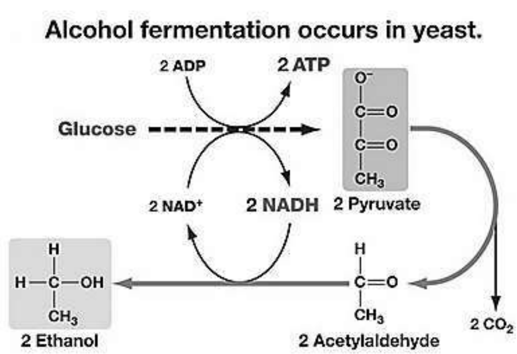
In animals e.g in muscles; the pyruvate in cytoplasm is reduced by NADH to lactic acid catalyzed by the enzyme lactate dehydrogenase.

Lactate pathway



In fungi like yeast; pyruvate is decarboxylated to ethanal and carbon dioxide under catalysis of pyruvate decarboxylase; ethanal is then reduced by NADH to ethanol; process catalyzed by alcohol dehydrogenase.

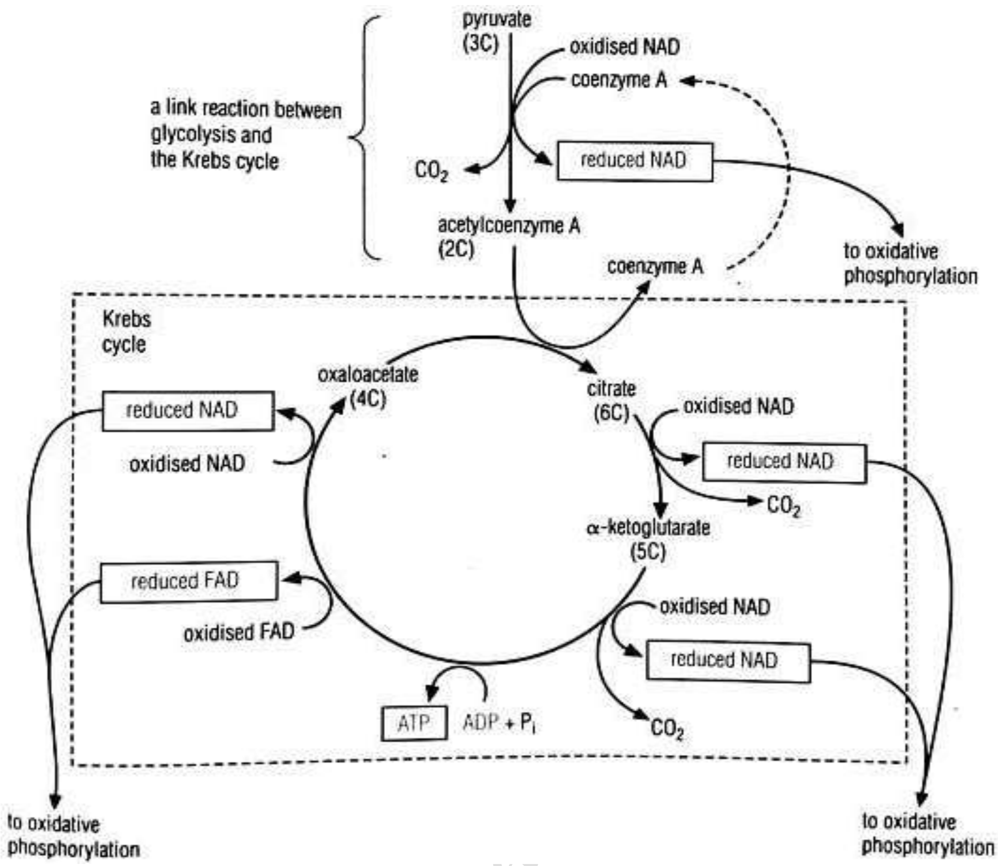
Ethanol pathway



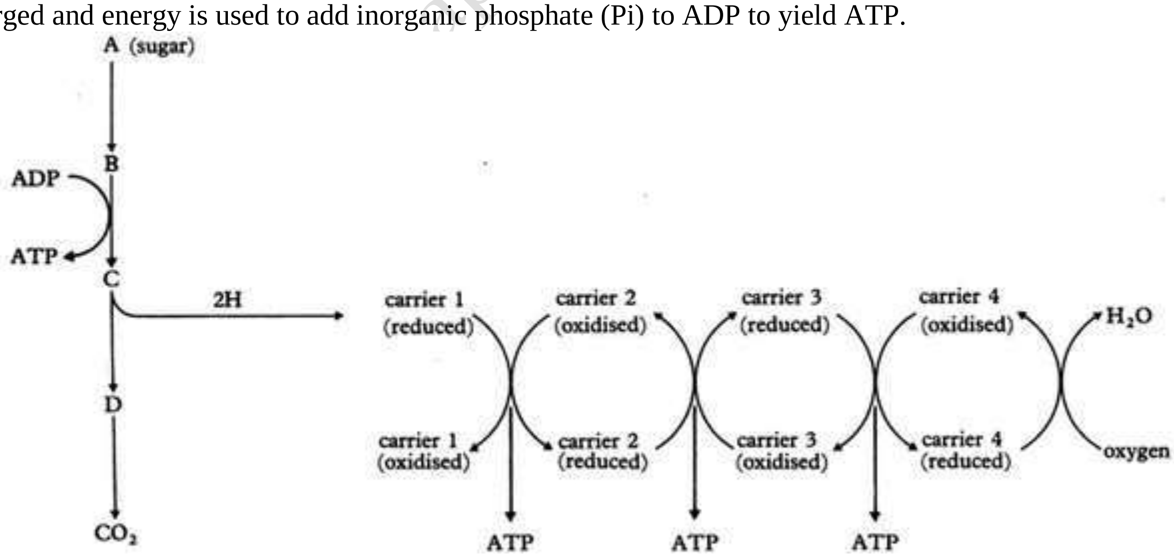
No ATP molecules are produced from the anaerobic fate; thus only 2 ATP molecules from glycolysis are produced.

Under aerobic conditions

Pyruvate is oxidatively decarboxylated (hydrogen and CO_2 are removed) to a 2 carbon acetyl co-enzyme A (acetyl coA); then incorporated into the Kreb's cycle. Tricarboxylic acid cycle (TCA) in the matrix of mitochondria. Acetyl CoA combines with a 4 carbon oxaloacetate; forms a 6 carbon Citrate. Citrate and some of the other subsequent intermediates of the cycle undergo a series of enzymatically controlled oxidative decarboxylations. This reduces oxidized electron carriers NAD and FAD producing 3NADH and FADH for each Acetyl CoA molecule respectively. These then get incorporated into electron transport system Substrate level phosphorylation in the cycle yields one ATP.



Electron transport chain/Oxidative phosphorylation; occurs in inner mitochondrial membranes; electron is transferred along a series of electron carriers downhill in terms of energy until it reaches oxygen; the final electron acceptor. The electron transfer is accompanied by active pumping of protons from the mitochondrial matrix into the inter-membranal space creating a proton gradient. When oxygen accepts the electron, the proton gradient is discharged and energy is used to add inorganic phosphate (Pi) to ADP to yield ATP.



These together with the Kreb's cycle yield 36 ATP and a total of 38 ATPs is produced for every glucose molecule oxidized aerobically.

Question 4.

(a).Write short notes on the following

(i). Respiratory quotient *(04 marks)*

(ii) Oxygen quotient *(02 marks)*
(iii)Oxygen debt *(05 marks)*
(b).Describe the structure and the roles of Adenosine Triphosphate (ATP) in cellular function *(09 marks)*

(a)(i).

Respiratory quotient is the ration of the volume of carbondioxide produced by an organism during respiration to the volume of oxygen consumed. A theoretical calculation of the RQs involved in complete oxidation of different food stuffs predicts a value of 1 for carbohydrates, approximately 0.8 for proteins and approximately 0.7 for fats. RQ values are sometimes rendered ambiguous by certain metabolic states eg interconversion of food stuffs (especially conversion of carbohydrates to fats, which produces an abnormally high RQ) and the creation and discharge of an oxygen debt.

(a)(ii).

This is the rate of oxygen consumption of an organism or tissue. It is measured in microliters of oxygen per mg dry weight per hour.

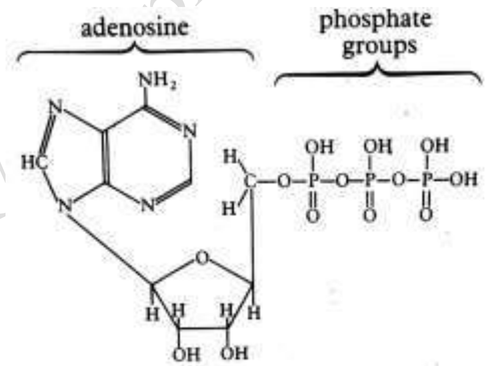
(a)(iii).

It is a physiological condition that occurs in normally aerobic animals during periods of temporary anoxia (lack of oxygen) in which intermediary metabolism is switched to an anaerobic pathway producing compounds that can be stored until sufficient oxygen becomes available to complete the oxidative process. In the presence of insufficient oxygen eg during a vigorous exercise, pyruvate dehydrogenase is activated and pyruvate is converted anaerobically to lactate; building up an oxygen debt. When aerobic metabolism is restored, the debt is paid off as lactate is oxidized by the liver to carbondioxide and water.

(b).

Structure of ATP

Each ATP molecule is a nucleotide composed of three smaller components. The first component is a five-carbon sugar, ribose, which serves as the backbone to which the other two subunits are attached. The second component is adenine, an organic molecule composed of two carbon-nitrogen rings. Each of the nitrogen atoms in the ring has an unshared pair of electrons and weakly attracts hydrogen ions. Adenine, therefore, acts chemically as a base and is usually referred to as a nitrogenous base. The third component of ATP is a triphosphate group (a chain of (3) three phosphates).



Roles of ATP

• Provides energy important in cell division
• Provides energy utilized in active transport of materials.
• Provides energy for muscle contraction and ciliary movement.
• Provides a phosphate molecule for activation of glucose molecules by phosphorylation of glucose in glycolysis
• Provides energy for secretion of cell materials.

Question 5.

(a)(i).Compare the efficiency of air over water as a gaseous exchange medium *(04 marks)*
(a)(ii)Give two reasons why mammals need lungs rather than exchanging gases via skin *(02 marks)*
(b).Describe the tracheal system of an insect *(08 marks)*
(c).How does ventilation and gaseous exchange occur in a terrestrial insect *(08 marks)*

(a)(i).

Advantages of air over water as gas exchange media

- Air has a much higher oxygen concentration than water
- Diffusion occurs more quickly so less ventilation of the surface is needed
- Less energy is needed to move air through the respiratory system than water.

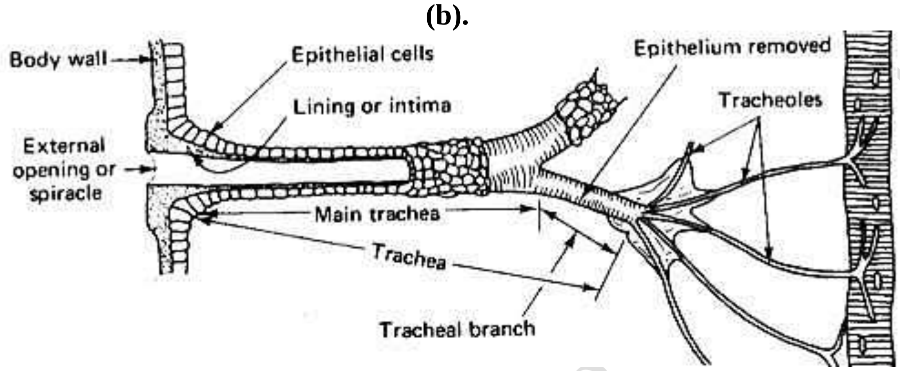
Disadvantage of air as a gas exchange medium

- Water is continuously lost from the gaseous exchange surface by evaporation so the gaseous exchange surface is folded into the body to reduce water loss.

(a)(ii).

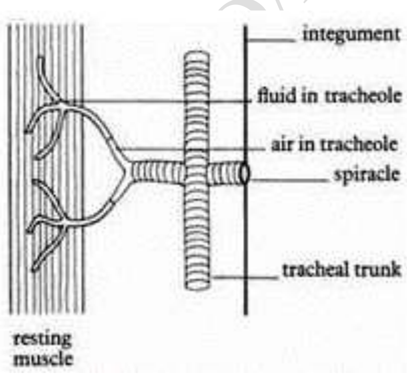
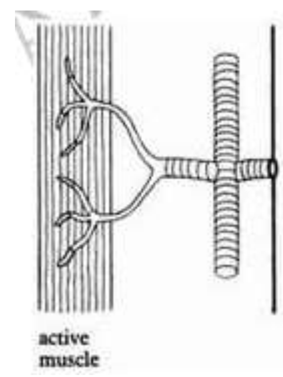
- The skin would not provide a sufficiently large surface area for gaseous exchange
- Gaseous exchange through the skin would result in excessive water loss

(b).



The tracheal systems of various insects consist of variable pairs of spiracles, located laterally on the body surface. Of these, some are thoracic and the others are abdominal. The spiracles are guarded by fine hairs to keep the foreign particles out and by valves that function to open or close the spiracles as required. The spiracles open into small spaces called the atria that continue as air tubes called the tracheae. The tracheae are fine tubes that have a wall of single layered epithelial cells. The cells secrete spiral cuticular thickenings called taenidia around the tube that gives support to the tubes. The tracheal tubes branch further into finer tracheoles that enter all the tissues and sometimes, even the cells of the insect. The ends of the tracheoles that are in the tissue are filled with fluid and lack the cuticular thickenings. The main tracheal tubes join together to form three main tracheal trunks- dorsal, ventral and lateral. At some places, the tracheae enlarge to form air sacs which are devoid of cuticle and serve to store air.

(c).

<table>
<tr><th>Tracheoles with fluid during expiration</th><th>Tracheoles without fluid during inspiration</th></tr>
<tr><td>
</td><td>
</td></tr>
</table>

Increased CO_2 is detected by chemoreceptors, causing relaxation of the abdominal muscles and lowering of pressure. The spiracles valves open and air rich in oxygen is drawn into the tracheal system. Spiracles valves then close and oxygen is forced along the tracheal system into the fluid-filled tracheoles, which are in direct contact with the tissue fluid. Gaseous exchange takes place due to difference in concentration gradients of oxygen and carbon dioxide. Air is expelled out when muscles contract and flatten the insect body, decreasing the volume of the tracheal system. During increased metabolic activity, the water potential of tissue lowers causing osmotic efflux of water from the tracheoles; and hence air replaces the fluid of the tracheoles. In resting tissues, the water potential of tissue fluid increases resulting in the diffusion of much water into the tracheoles.

Question 6.

(a).How does the structure and physiological conditions of the respiratory system in higher animals make exchange efficient? ***(06 marks)***

(b).State the circumstances under which anaerobic respiration may occur in;

(i). Yeast ***(02marks)***

(ii) Flowering plant ***(03 marks)***

(iii).Mammal ***(09 marks)***

(a).

• Thin epithelial lining of the respiratory surface; reduces the diffusion distances of gases.
• Permeable epithelial lining; allows efficient gaseous diffusion across the surface
• Large surface area of the respiratory surface aims at satisfying the gaseous exchange needs of the organism.
• Moisture present on the respiratory surface dissolves gases; making diffusion efficient.
• Closeness to the vascular system aids efficient transport of respiratory gases maintains a steep diffusion gradient.
• Well ventilated respiratory surfaces; allow efficient exchange of gases.

(b)(i).

• In covered stagnant solutions.
• Centre of decomposing fruits and other organic matter.
• Young seeds, centre of fruits or large stems.

(b)(ii).

• In roots within compacted or water logged soils.
• In aquatic plants growing in stagnant waters e.g in ponds.

(b)(iii)

• Inefficiency of lungs e.g emphysema, asthma
• Reduction in blood supply/ poor tissue perfusion e.g after hemorrhage (severe bleeding)
• Low oxygen carrying capacity of blood e.g anemia, bone marrow disease, cyanide and CO poisoning.
• Low cardiac output e.g slow heart rate, coronary thrombosis.
• Capillary network inadequacy poor organ perfusion e.g in ischemic heart disease.
• High oxygen demands like in strenuous exercises, pregnancy
• Hibernation
• Un-acclimatized state like at high altitude.
• Sperm motility in the oviduct.

Question 7.

(a).Describe various mechanisms of ventilation utilized by adult frogs in different environmental conditions

(b).Compare gaseous exchange in teleosts and that in elasmobranches ***(05 marks)***

(c).Explain the advantages of confining pigments to cells. ***(03 marks)***

(a).

Cutaneous ventilation; Air from the atmosphere diffuses through the moist thin skin; it into the dense capillary below the skin. Gases are exchanged by diffusion along the steep concentration gradient. This type of ventilation is controlled by the capillary density, amount of blood flow and blood vessel radius.

Buccopharyngeal ventilation; it is applied when on land but also actively in water and here gases are exchanged between the buccal cavity and the pharynx through rapid pulses of the throat. The moist lining of the mouth allows diffusion of oxygen into the blood stream and diffusion of carbondioxide back into the environment.

Pulmonary ventilation; Here breathing occurs through the lungs when on land. During inspiration, floor of the buccal cavity lowers; skin sacs of the throat get inflated; so it expands. Nostrils open; allow air into the enlarged mouth. Nostrils then close; floor of the buccal cavity rises after contraction of its muscles; positive pressure is created; air in the mouth is forced into the lungs. On expiration, floor of the buccal cavity lowers; draws air out of the lungs into the mouth; Finally nostrils open and the floor of the mouth is moved up; pushing air out of the nostrils.

(b).

Similarities

• In both gaseous exchange occurs via the gills.
• In both, the gill lamellae project from skeletal branchial arches oriented vertically to the wall of the pharynx

Differences

Gaseous exchange in teleost fishes	Gaseous exchange in elasmobranches
Has opercular chamber (operculum, opercular cavity and opercular valves)	Has parabranchial chamber made up of parabranchial cavities and branchial valves
Aseptal gills (lack septa) allows water pass in between gill plates; but gill bars anchor the gill filaments	Have septal gills i.e have septum that anchor the gill filaments; vertical septum also deflects water so that it passes over the gill plates
Water enters the pharynx through the mouth	Water enters the pharynx through the spiracles
Water leaves the gills via the opercular opening	Water leaves the gills via the gill slits
Opercular valves; suck water through the gill pouches.	Role is played by the branchial valves.
Lamellae in the gill pouches project outwards at right angles to each other; allowing more efficient counter flow exchange	Gill lamellae in the gill pouches are arranged parallel to each other; allow parallel flow exchange instead of counter flow mechanism

(c).

• Confining pigments separates them from the highly variable intracellular and extracellular environments.
• Enclosed pigments do not affect solute potential of plasma thus the pigments have no osmotic effects on plasma
• Enclosing the pigment reduces the viscosity of blood so that less energy is expended when the heart is pumping blood around the heart.
• Confinement of water soluble pigments like anthrocyanins prevents them from being lost in solution within the extracellular compartment.
• Confinement of pigments to cells increases their surface area to reception to stimuli e.g rhodopsin and iodopsin.

Question 8.

(a).Describe the advances of bird's respiratory surface over that of humans. ***(10 marks)***
(b).Explain the role of surfactant in alveoli of a mammalian lung ***(06 marks)***
(c).Explain the need for special respiratory structures and pigments in higher animals ***(05 marks)***

(a).

• Avian respiratory system has relatively smaller lungs to minimize weight and a system of nine air sacs that fill and empty differentially during inspiration and expiration. Human lungs on the other hand are larger.
• The air sacs in avians permit unidirectional flow of gases through the lungs; air moving through the lungs is thus largely fresh and has higher oxygen content unlike in mammals where air flow is bidirectional; form mixed air having less oxygen.
• The avian respiratory system is partitioned heterogeneously in that the function of ventilation and gaseous exchange are separate in the air sac. In mammals, gaseous exchange and ventilation are performed homogenously in the alveoli.
• Birds lack diaphragm; instead air is moved in and out of the respiratory surface by pressure changes in air sacs. On the hand, intra-thoracic pressure changes created by the diaphragmatic movements in mammals are responseble for the inspiratory and expiratory movements in mammals.
• Birds' lungs do not expand or contract; gaseous exchange occurs in tiny branching air sacs; surrounded by a profuse network of blood capillaries. Mammals on the other hand use alveoli.

(b).

Surface tension causes collapse of the alveoli; creates a positive pressure that pushes air out of the alveoli making it less effective at gaseous exchange. Surfactant; released by type II alveolar cells; contain a complex mixture of several phospholipids, proteins and ions; that reduce surface tension of water in lungs by dissolving in the fluid lining the alveolar surface while the remainder spreads over the surface of the water in the alveoli. By lowering surface tension, effort needed by respiratory muscles to expand the lungs reduces. Surfactant also speeds up oxygen and carbondioxide transport between the air and the fluid in the alveoli. Any bacterial agents foreign in the alveoli are killed by the bactericidal effects of surfactant.

(c).

• Higher animals are multicellular with increased body sizes; so they have decreased surface area to volume ratio; make simple diffusion over the body surface inadequate; to provide oxygen or remove carbondioxide from tissues that are not in direct contact with the surrounding medium
• Higher animals have increased metabolic activities; cells thus consume more oxygen and to cope with this, specialized respiratory surfaces with large SA and heavy vasculature have been evolved.
• Transport structures provide a link between respiratory surfaces and all the other tissues.
• Pigments like haemoglobin further increase the efficiency of blood's oxygen carrying capacity.
• Special ventilatory movements assist in ensuring rapid exchange of gases between the animal & the surrounding by maintaining a steep diffusion gradient.

Question 9.

(a).Describe the structure of a gill of a cartilaginous fish *(06 marks)*
(b).How is gaseous exchange carried out in an amphibian larva *(04 marks)*
(c).Briefly explain factors that affect the rate of gaseous exchange at the respiratory surfaces of organisms

(a).

Each gill consists of several leaf like lamellae, projecting horizontally from the skeletal branchial arch & oriented vertically in the walls of the pharynx. The lamellae are held in position by vertical septum which project beyond the distal end as the branchial valves. On the upper and lower surface of each lamella are numerous vertical gill plates. At the base of each gill close to the gill arch is the afferent branchial artery. The base of the gill also contains a pair of efferent branchial arteries interconnected within each lamella by an elaborate system of tiny vessels and capillaries. An epibranchial artery conveys blood from each efferent loop to the dorsal aorta above the roof of the pharynx.

(b).

An amphibian larva (tadpole) uses gills for gaseous exchange. Tadpole opens its mouth; takes in water. As mouth closes, buccal muscles contract; increases pressure within the buccal cavity; forces water onto the gills; oxygen is extracted out by the gill lamellae and CO_2 is added to the water by passive diffusion. Oxygen is then taken to the blood stream. However tadpole can also rise to the surface and gulp oxygen from the air.

(c).

Surface area of the respiratory surface; Rate of diffusion and that of gaseous exchange are directly proportional to the surface area.
Thickness of the respiratory surface; a thin respiratory surface membrane has a reduced diffusion distance from the respiratory gases and thus increases the rate of gaseous exchange.
Concentration gradient; this is the difference in the concentration of diffusing gases across either sides of the respiratory surface. Rate of gaseous exchange is directly proportional to the concentration gradient.
Temperature of the medium; the rate of gaseous exchange across the respiratory surface increases with increase in temperature because of the increase in the kinetic energy of the diffusing molecules increasing the rate of diffusion across respiratory surfaces.
Size of the diffusing gaseous molecules; rate of diffusion increases with decrease in the size of the diffusing molecules.
Degree of moistening at the respiratory surface; rate of diffusion is directly proportional to degree of moistening of the respiratory surfaces.
Solubility of the gaseous molecules; the more soluble the gaseous molecules, the higher is the rate of diffusion across the surface and so is the rate of gaseous exchange.
Extent of vascularization of the respiratory surfaces; highly vascular respiratory surfaces favour a higher rate of gaseous exchange; due to the steep concentration gradient created;

Question 10.

(a).Compare the structures of chloroplast and the mitochondria *(07 marks)*
(b).How does anaerobic respiration in plants differs from that in animals *(02 marks)*
(c).Describe the process of anaerobic respiration in the plants. *(11 marks)*

(a).

Similarities
• Both have double membrane envelope

• Both are small in size having a thickness of 0.5-1.0 microns and 2.0-4.0 microns
• Both contain nucleic acids
• Both have enzyme systems located in the matrix
• Both have the electron transfer system located in the membrane.

Differences

Chloroplast	Mitochondria
Has chlorophyll and carotenoids:	Lacks pigments
Contains grana and stroma	Contains folded inner membranes
Have enzymes for carrying out anabolism	Enzymes for catabolism
Disc shaped	Is rod shaped
Site of photosynthesis	Site of respiration
Contains thylakoid membranes	Lacks thylakoid membranes.
There is light generated ATP production.	ATP production by oxidation of organic molecules
H+ gradient across thylakoid membrane	H+ gradient across inner membrane
Cristae absent	Cristae present.
Larger size	Smaller size

(b).

Anaerobic respiration in plants	Anaerobic respiration in animals
Ethanol produced	Lactic acid produced
Carbondioxide produced	No carbondioxide produced

(c).

Anaerobic respiration in plants begins by glycolysis in which glucose in plants is phosphorylated by ATP. The phosphorylated sugar (glucose) is split into two molecules of 3-carbon (triose sugars). Two hydrogen atoms are removed from triose sugar and are accepted by NAD to form NADH an event that takes place in the cytoplasm outside the mitochondria. The triose sugar is converted to pyruvic acid; and two molecules of ATP are produced for every triose sugar used. In the absence of oxygen, pyruvic acid is first converted to acetaldehyde which is then reduced by the hydrogen atom to form ethanol; with release of carbondioxide.

Question 11.

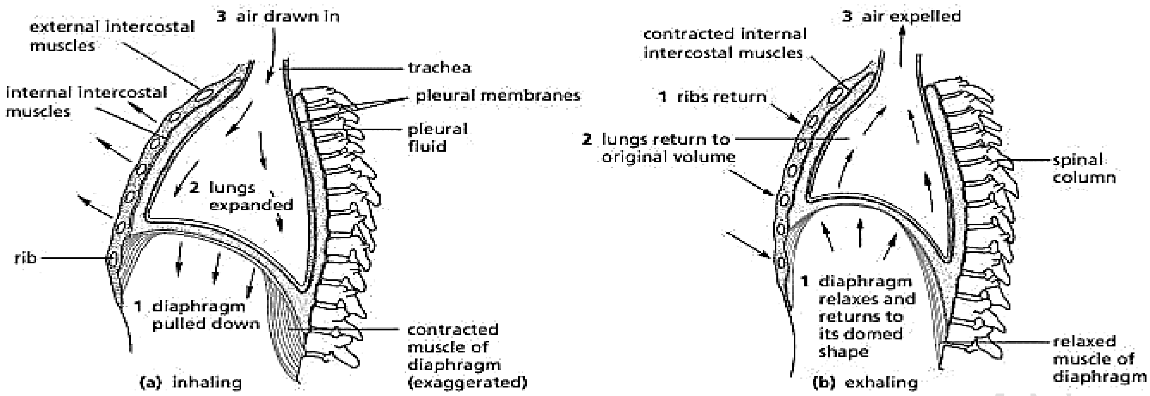
(a).Compare inhalation and exhalation in mammals ***(10 marks)***
(b).Describe the role played by the nervous system in the control of ventilation in mammals ***(10 marks)***

(a).

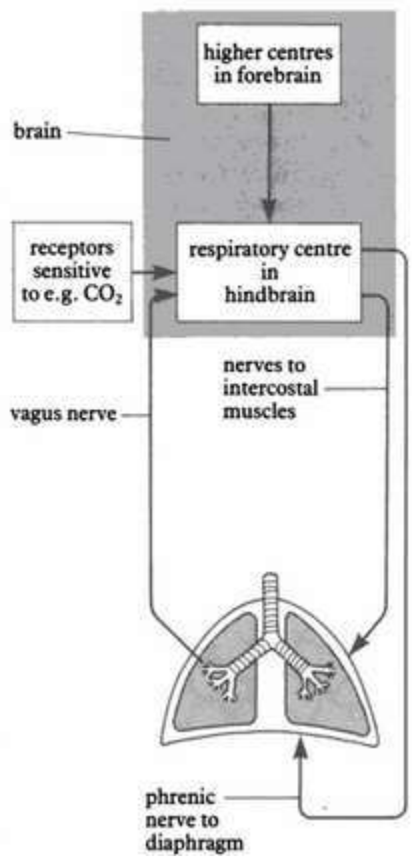
Similarities.
• Both are involuntary processes
• Both are ventilatory processes of the respiratory airway tract
• Both involve volume and pressure changes.
• Both involve contraction and relaxation of the intercostal muscles.

Differences

Inhalation	Exhalation
External intercostal muscles contract while internal intercostal muscles relax	External intercostal muscles relax while internal intercostal muscles relax.
Ribs and sternum move upwards and outwards	Ribs and sternum move downwards and inwards.
Diaphragm muscles contract and diaphragm sheets descend and flatten	Diaphragm muscles relax and diaphragm sheets ascend to attain a dome shape.
Thoracic cavity and the lung volume increase	Thoracic cavity and lung volume decrease
Pressure between pleural surfaces decrease	Pressure between the pleural surfaces increase
Lung pressure falls below atmospheric pressure allowing air in.	Lung pressure rises beyond atmospheric pressure forcing air out of the lungs
Active process	Passive process
Inhaled air has more oxygen than carbondioxide	Exhaled air has more carbondioxide than oxygen.



(b).



Ventilation in mammals is controlled by the respiratory centre in the hind brain; The ventilation movement is initiated by a rise in carbondioxide levels; detected by the chemoreceptors in the aortic bodies, carotid bodies and the respiratory centres in the medulla. Efferent nerves relay impulses to the inspiratory muscles/ diaphragm and the intercostal muscles. The impulses cause the inspiratory muscles to contract. During inspiration, the lungs are inflated and expand causing stimulation of the stretch receptors in the bronchial tubes; impulses are then sent to the respiratory centre; via the afferent nerves/ vagus nerve; alerting the brain of the degree of expansion of the lungs. As inspiration continues, the impulses may reach such a frequency that inhibits inspiration; hence expiration will be initiated. For expiration to occur impulses are relayed from the inspiratory centre; through the Pneumotaxic centres of the brain; to inhibit the activity of the inspiratory centre so the respiratory muscles relax; hence expiration follows passively.

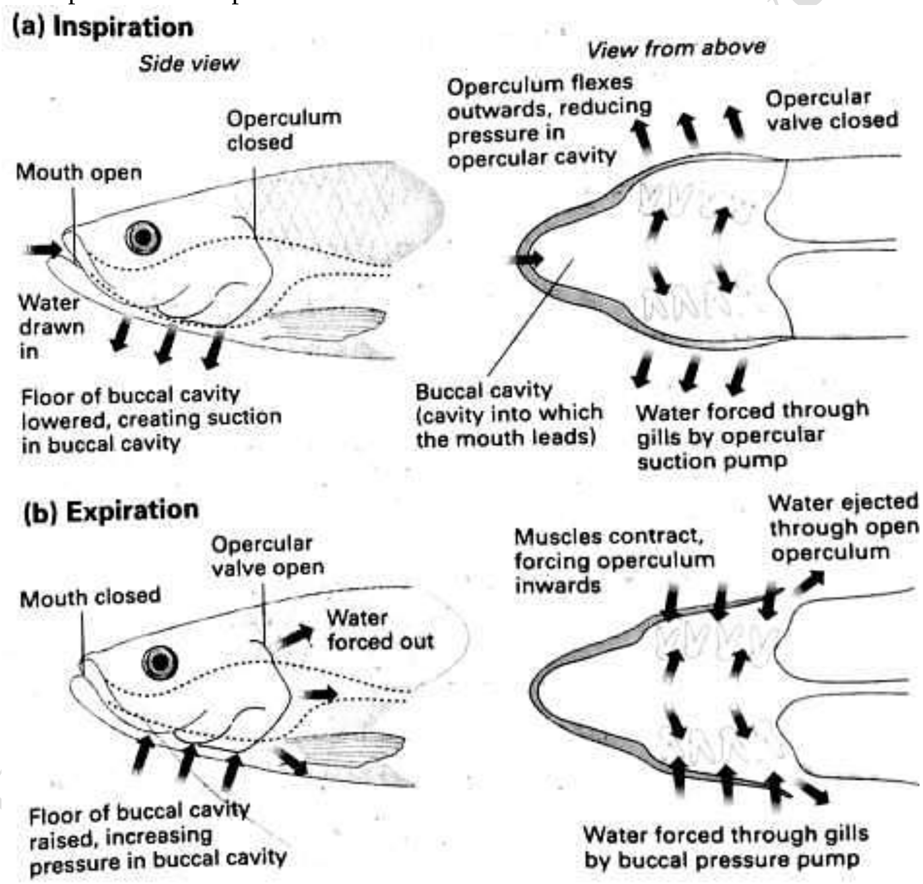
Question 12.

(a).Describe the mechanism of ventilation and gaseous exchange in teleost fish ***(08 marks)***

(b).Compare counter flow system and parallel flow system in fishes ***(04 marks)***
(c).Outline
(i). The advantages of a counter flow system in fishes. ***(02 marks)***
(ii).How has a parallel flow been improved in cartilaginous fish ***(01 marks)***
(d).Explain how efficiency in gas exchange across the gills of a fish is achieved. ***(05 marks)***

(a).

Contraction of the mouth muscles lowers the floor of the mouth, reducing its pressure as the mouth opens. Water (with dissolved oxygen) moves into the mouth and at the same time the operculum remain closed. The operculum muscles relax; causing operculum to bulge open; this increases the volume but lowers the pressure in the gill region as the mouth closes. Water from the cavity mouth moves into the gill region due to the reduced pressure; and bathes the gill filaments in opposite direction to the flow of the blood (countercurrent flow). Oxygen diffuses into the blood capillaries due to its high concentration in the gill region than the blood capillaries; it combines with haemoglobin and is transported as oxyhaemoglobin to the respiring tissues. Carbon dioxide and toxic metabolic wastes, like ammonia which are at higher concentration in the blood than the gill filaments are excreted into the gills and exhaled through the water that moves out when the operculum opens. The higher internal water pressure in gill chamber forces operculum to open to exit the water.



(b).

Parallel flow system	Counter flow system
Predominant in elasmobranches	Predominant in teleost fishes
Blood in the gill lamellae would flow in the same direction and at the same speed as the water passing it reducing until equilibrium is attained	Water flows across the gill lamellae in an opposite direction to the blood flow
The concentration of oxygen gained would not meet the physiological needs of the fish	Oxygen picked is sufficient to meet the metabolic demands of the fish.

Concentration gradient is initially high; keeps	Persistently steep concentration gradient at all

(c)(i).

• Enables blood of the gill lamellae to extract oxygen from the water maximally for the entire period the water flows across the gill filaments than in parallel flow
• Under conditions permitting adequate oxygen uptake, the counter-current fish expends less energy in respiration.
• Fish using countercurrent flow system are more metabolically active than those using parallel flow system.

(c)(ii).

Inhabiting water sources whose flow of water is very rapid compared with that of the blood, to ensure a higher saturation of the blood by the time it leaves the respiratory surface.

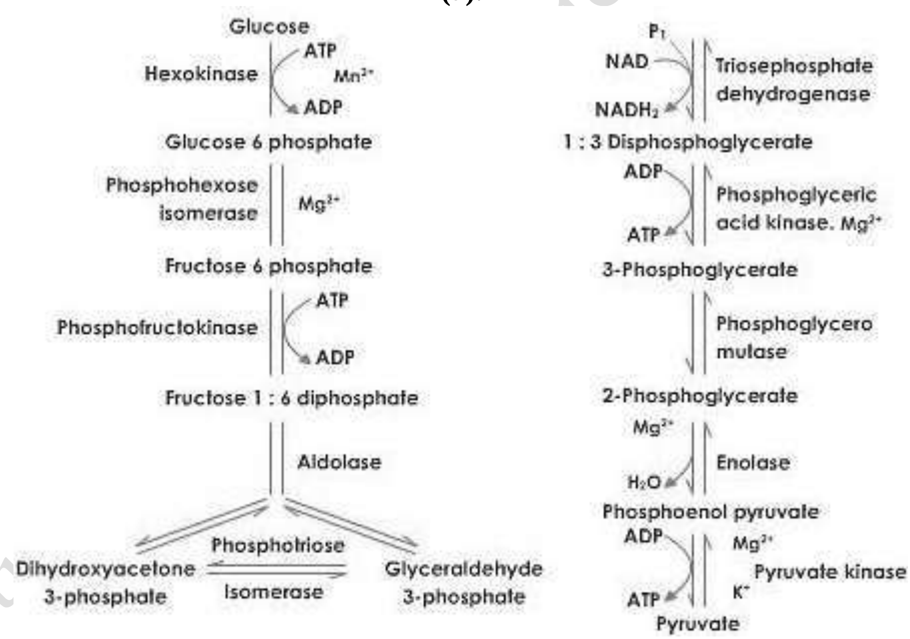
(d).

• Gill filaments have folds called secondary lamellae that increase the surface area for gas exchange;
• There is counter current flow; permits efficient exchange of gases between water and blood via the gills.
• Water and blood in the gills flow in opposite directions; maintains steep concentration/diffusion gradient
• Gills are moist to enable dissolution of respiratory gases for efficient diffusion;
• The gill lamellae contain a network of capillaries for carrying away oxygen or bringing in carbondioxide for expulsion /high diffusion gradient;
• Gills are thin-walled and in close contact with water to provide short distance for diffusion of respiratory gases;

Question 13.

(a).Describe the process of glycolysis in a cell *(12 marks)*
(b).Outline the major steps involved in metabolism of fats as energy stores *(04 marks)*
(c).Outline the role of oxygen in providing cells with energy. *(04 marks)*

(a).



Phosphorylation of glucose; ATP phosphorylates glucose to glucose 6-phosphate catalysed by hexokinase or glucokinase.
Isomerization of glucose-6-phosphate; to fructose 6 phosphate (F-6-P); catalysed by phosphoglucoisomerase or phosphoglucomutase
Phosphorylation of fructose-6-phosphate; ATP phosphorylates fructose-6-phosphate to fructose-1,6-bisphosphate; reaction catalysed by phosphofructokinase. This step is the rate limiting step of glycolysis. Cleavage of fructose-1,6-bisphosphate; to 2 triose phosphate molecules; dihydroxyacetone phosphate (DHAP) and phosphoglyceraldehyde (PGA); reaction catalysed by aldolase.
Isomerization of DHAP to PGA; DHAP converts to PGA; reaction catalysed by phosphotriose isomerase.

Oxidative phosphorylation and dehydrogenation of PGA; PGA is phosphorylated by inorganic phosphates from ATP to form 1,3-bisphoglycerate. PGA is also dehydrogenated and hydrogen ions lost reduce NAD to NADH catalysed by glyceraldehyde-3-phosphate dehydrogenase.
Dephosphorylation of 1,3-bisphoglycerate; phosphoglycerate kinase phosphorylates ADP to ATP using a phosphate group from 1,3-bisphoglycerate. 3-phosphoglycerate is formed.
Isomerization of 3-phosphoglycerate; to 2-phosphoglycerate by phosphoglycerate mutase.
Dehydrogenation of 2-phosphoglycerate; to phosphoenolpyruvate (PEP); reaction catalysed by enolase.
Dephosphorylation of PEP; forming pyruvate with the phosphate being transferred to ADP to form ATP.

(b).

Fats gets hydrolysed to fatty acids and glycerols. Fatty acids undergo β-oxidation in which two carbon fragments are continuously removed from the fatty acids. The two carbon fragments get accepted by acetyl co-enzyme A which then get incorporated into the Kreb's cycle. The much hydrogen atoms generated from the fatty acids during β-oxidation are accepted by NAD forming NADH; which is used in the electron transport system; to generate energy by oxidative phosphorylation. Glycerols on the other hand are isomerized to PGA; a metabolite that continues into the glycolytic pathway.
NOTE; fats are not always the first line respiratory substrates because; besides being harder and more complex than for carbohydrates, oxidation of fats require a lot of oxygen and cannot be respired anaerobically.

(c).

Oxygen is needed for aerobic respiration during oxidative phosphorylation. Oxygen accepts electrons at the end of the ETC; also accepts protons to form water / water formed using oxygen. Allows more electrons along the ETC permitting NAD to be regenerated / reduced NAD to be oxidized. Oxygen allows ATP production; allows a higher yield of ATP from glucose in respiration.

Question 14.

(a).Explain why animals breathe whereas flowering plants do not ***(05 marks)***
(b).State the adaptations of lung system for gaseous exchange ***(11 marks)***
(c).Outline the non-respiratory functions of the lung respiratory system. ***(04 marks)***

(a).

Animals breathe because they use their lungs, diaphragm and respiratory muscles to draw in air. The lungs use this air to oxygenate blood; as the waste air, containing carbon dioxide, is exhaled. Plants on the other hand do not use muscles to draw in air; the exchange of gases occurs passively through stomata.

(b).

• Lungs have numerous alveoli; that provide large surface area for efficient gaseous exchange.
• Squamous epithelium lining the alveoli wall is thin to shorten diffusion distance for gaseous exchange
• The lung is spongy and has numerous alveoli to accommodate large volume of gases
• It is highly supplied with blood capillaries that transport respiratory gases to and from the body tissues
• The alveolar epithelium is moist to dissolve oxygen for easy diffusion into the blood solution.
• The inner passage of air ways is lined with mucus membrane with ciliated cells cleansing respired air.
• Mucus membrane has a rich blood supply which warms & moistens incoming air for easy diffusion in the lungs
• The whole lungs are covered with the pleural membrane which is gas tight thus changes in the pressure within the lungs can occur without external interference
• The walls of the trachea and bronchi are lined by rings of cartilage which prevent them from collapsing and keeps them open for air passage
• The epiglottis and other structures on the top of the trachea prevent food, drinks and other solid particles from going into the trachea during swallowing.

(c).

• The vibration of air flowing across the larynx (vocal chords) in humans allows phonation (speech) & the syrinx, in birds results in vocalization or singing.
• Panting in dogs and some other animals provides a means of cooing body temperature
• Irritation of nerves within the nasal passages or airway can induce coughing and sneezing reflexes.

• Produces angiotensin converting enzyme; aid aldosterone production; important in Na+ /K+ and maintenance of blood volume.

Question 15.

(a).What is meant by oxidative decarboxylation? ***(03 marks)***

(b).Explain the mechanisms leading to formation of ATP that occurs involving the inner mitochondrial membrane ***(10 marks)***

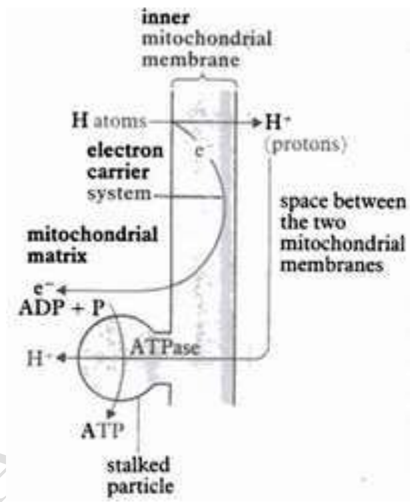
(c).Describe the respiratory metabolism of glycerol in the cytoplasm of the cell. ***(07 marks)***

(a).

Is the removal of hydrogen and carbon atoms; from intermediate compounds of carbohydrate metabolism substrates; in the matrix of mitochondria to form carbon dioxide from oxidation of carbon atoms by oxygen and $NADH_2$

(b).

H atoms in the mitochondrial matrix dissociate into protons and electrons; using energy from electron transport chain; the protons are actively pumped; from the matrix across the inner membrane into the intermembrane space; using energy derived from hydrolysis of ATP in the electron transport chain; this creates an electrochemical proton gradient between the matrix and inter-membrane space of the mitochondria; Protons then diffuse back to the matrix across the inner membrane down a concentration gradient; through specific channels with stalked granules /particles where ATPase enzyme; is used to combine ADP with inorganic phosphate to form ATP; using energy released by the protons;



(c)(i).

Glycerol is phosphorylated to glycerol-3-phospahte and hydrolysis of ATP to ADP which provides phosphate and energy for the process; The glycerol-3-phosphate is then oxidized by NAD to form $NADH_2$ and Phosphoglyceraldehyde interchangeable with dihydroxyacetone then fed into the glycolytic pathway. 3-phosphoglyceraldehyde is then phosphorylated using an inorganic phosphate and oxidized by NAD^+ to form $NADH_2$ and glycerate-1,3-biphosphate; Each glycerate-1,3-biphosphate loses phosphate molecules to form ATP from ADP; glycerate-3-phosphate formed is further dehydrated (loses water molecule) forming ATP and pyruvate; Pyruvate is then taken into the mitochondrial matrix for further production of energy in the Krebs cycle. The formed $NADH_2$ & $FADH_2$ is fed into the electron transport chain generating more ATP;

Question 16.

(a)(i).Explain what is meant by acclimatization ***(01 marks)***

(a)(ii).How does one who has been living at a low altitude acclimatize when moved to a higher altitude

(b).Why is smoking discouraged in pregnancy ***(11 marks)***

(a)(i).

Acclimatization is the process of the body adjusting to the new altitude, climate, temperature or environment.

(a)(ii).

• Increase in respiratory rate; to capture adequate amounts of oxygen
• Increased red blood cell formation; to increase oxygen carrying capacity.

• Increased erythropoietin secretion from the kidneys; command accelerated red cell production
• Angiogenesis and increased capillary density; to avail collateral blood supply.
• Hirsuite chest; increase intrathoracic volume so as to capture enough oxygen every single breath
• Acute reduction in plasma volume; cause haemoconcentration and increases surface area for oxygen carriage
• Increased production of 2,3-diphosphoglycerate; increase dissociation of Hb; hence increase intracellular oxygen diffusion.
• Increased sympathetic activity; inform of accelerated cardiac output and heart rate; to transport the little oxygen at a faster rate to meet the metabolic demands.

(b).

Smoking predisposes the mother and foetus to the following complications and thus must be avoided

Maternal complications of smoking

• Infertility and sub-infertility.
• Placental abruption (placenta peels off the endometrium); cutting fetal blood supply
• Premature rupture of membranes (early breaking of waters);
• Ectopic pregnancy (pregnancy occurs outside the womb)
• Increased risk of cancer of the cervix
• Placenta previa (placenta is low lying and covers the cervical os); impeding descent of baby during labour
• Low birth weight
• Intrauterine growth restriction
• Premature births

Foetal complications of smoking

• Respiratory complications like the respiratory distress syndrome and birth asphyxia
• Congenital heart defects like patent foramen ovale and ductus arteriosus or ventricular septal defects
• Intrauterine fetal death
• CNS defects like cerebral palsy

Question 17.

(a).Discuss the problems encountered by marine organisms in pursuing deep sea diving ***(07 marks)***
(b).How have these problems been practically solved by deep sea divers? ***(05 marks)***

(a).

Pressure increases as on deep descent into the ocean; Sea water is a lot denser and the further you go down, the greater the pressure. Pressure, immediately reduces the volume of the air filled spaces.
Pressure also increases the rate at which gases dissolve into the liquid portions of our blood; If a diving marine mammal tries to return to the surface rising too quickly, those dissolved gases can form bubbles that lodge in blood vessels of critical organs, creating a condition called decompression sickness or the bends, associated with intense joint pain
Difficult oxygen consumption on deeper descent; especially if an organism is deprived of new oxygen
Nitrogen narcosis; Air is 70% nitrogen but under normal atmospheric conditions almost none of it gets dissolved in blood. Under higher pressures, greater levels of nitrogen can dissolve into a diving animals blood causing nitrogen narcosis which eventually becomes toxic.
The ocean is cold; Below 200 meters, ocean water temperatures approach freezing. Warm blooded mammals need to maintain a constant body temperature to survive. In addition, water's high specific heat capacity promote rapid heat loss.
Mammalian bodies float (exhibit buoyancy); because of their great air and fat content. Alot of work is thus done to effect deep diving.

(b).

Increasing pressure: Submarines use closed steel and titanium spherically shaped containers with small thick windows to withstand increasing pressure.
Difficult oxygen consumption: divers use compressed air, or other gas mixtures stored in steel containers.
Nitrogen narcosis and decompression sickness: divers follow strict diving charts with slow assents & descents. Divers who experience nitrogen narcosis or the decompression sickness spend time in specialized decompression chambers.

The Cold: divers wear thick neoprene wet suits or insulated dry suits.
Buoyancy: divers wear lead weights on their belts to help them sink.

Question 18.

(a).There are three stages in the release of energy from a molecule of glucose; glycolysis, the Kreb's cycle and the electron transfer system. What are the essential features of each of these processes? ***(10 marks)***
(b). Explain the following observations
(i). A person who is born and lives at sea level will develop a slightly smaller lung capacity than a person who spends their life at a high altitude. ***(04 marks)***
(ii).When someone living at or near sea level travels to locations at high altitudes (eg. the Rwenzori mountain), that person can develop a condition called altitude (mountain) sickness ***(02 marks)***
(c).Briefly explain the measures taken to avoid altitude sickness ***(04 marks)***

(a).

Glycolysis

- Activation of glucose by phosphorylating it to glucose-6-phosphate.
- Split down of hexose sugars to triose molecules
- Production of ATP directly through substrate level phosphorylation.
- Production of ATP indirectly-via the electron transfer system

Kreb's cycle

- Loss of carbondioxide to give a 2 carbon molecule
- Combination of a 2 carbon molecule and a 4 carbon molecule to give a 6 carbon molecule
- Oxidation of two carbon atoms to carbondioxide to generate a 4 carbon molecule
- Production of ATP directly and indirectly (via the electron transfer chain)

Electron transfer chain

- Progressive transfer of electrons to carriers at lower energy levels.
- The use of energy associated with the electrons to generate ATP from ADP
- Reduction of oxygen to water

(b)(i).

This is because the partial pressure of oxygen is lower at higher altitude which, as a result means that oxygen less readily diffuses into the bloodstream. In response to higher altitude, the body's diffusing capacity increases in order to process more air.

(b)(ii).

This is because their lungs remove adequate amounts of carbon dioxide but they do not take in enough oxygen. (In normal individuals, carbon dioxide is the primary determinant of respiratory drive)

(c).

- Allowing the body to get used to the altitude slowly, a process called acclimatization. The goal of acclimatization is to increase ventilation (breathing) to compensate for lower oxygen content in the air
- Get used to the high altitude before doing a lot of exercise e.g. hiking, skiing, or biking
- Don't drink alcohol at high altitudes. It takes much less alcohol to become drunk at high altitudes than at sea level.

Question 19.

(a).Describe by way of a comparison the key differences between chemiosmosis in photophosphorylation and oxidative phosphorylation. ***(06 marks)***
(b).Account for the changes in the respiratory quotient of:
(i) Fattening mammals. ***(04 marks)***
(ii)Hibernators. ***(06 marks)***
(c).Explain the biological implication of an RQ value less than one ***(04 marks)***

(a).

Chemiosmosis in photophosphorylation	Oxidative phosphorylation
ATP is generated from change in energy levels of electrons in the electron transport chain.	ATP is generated from discharge of the proton gradient produced by ion pumps which pumps protons across inner mitochondrial membrane.

Proton concentration builds up in the thylakoid space	Proton build up in the inter-membrane space
Only one proton pump is involved in the light independent reaction	Three proton pumps which are situated in the electron transport chain.
Has NADP as the final electron acceptor	Oxygen is the final electron acceptor
Photolysis of water is the source of electrons	Glucose is the source of electrons
Uses NADP as the electron carrier	Uses NAD and FAD as the carrier/ co-enzyme

(b)(i).

Fattening mammals is associated with RQ above 1; since the conversion of carbohydrates to fat is accompanied by liberation of more carbondioxide than the oxygen consumed during the process.

(b)(ii).

Towards hibernation, the RQ increases above 1.0, reflecting that carbondioxide evolved is higher that the oxygen consumed; because a lot of ingested carbohydrates are being converted into brown fats; with less oxygen atoms than those of carbohydrates. The brown fats are then stored. **During hibernation,** RQ reduces below 1.0 because of being inactive such that the organism's tissues breakdown the stored brown fats for their respiratory activities; resulting in less carbondioxide being evolved than oxygen consumed.

(c).

A low RQ implies that some or all of the carbondioxide evolved in respiration is being put to some other use such that it appears less than the oxygen consumed. In plants it may be used in building carbohydrates through photosynthesis, and in animals for construction of calcareous shells etc.

Question 20.

(a).How are the alveoli of the mammalian lungs protected from infections? ***(02 marks)***

(b).State the harmful health effects of smoking to humans ***(15 marks)***

(c)(i).Explain why fish suffocate when taken out of water ***(02 marks)***

(c)(ii)Under what circumstances do fish suffocate in the water? ***(01 marks)***

(a).

Alveolar macrophages; phagocytose any intruding microorganism/bacteria in the alveoli.
Surfactant; contains bactericidal agents that kill off the intruding microorganism/ bacteria.

(b).

- Smoking causes stroke and coronary heart disease that can lead to myocardial infarction.
- Smoking damages blood vessels and can make them thicken and grow narrower (arteriosclerosis)
- Smoking predisposes one to formation of internal vascular clots
- Smoking predisposes one to stroke (cerebral vascular accident)
- Cigarette smoking predisposes one to lung cancer.
- Smoking can trigger and worsen an acute asthmatic attack.
- Smoking is a risk factor for most of the cancers like cancer of the colon, bladder, cervix, esophagus etc
- Smoking predisposes to infertility i.e can make it harder for a woman to become pregnant.
- Smoking increases risks for preterm (early) delivery
- Smoking increases risks for stillbirth (death of the baby before birth)
- Smoking increases risks for low birth weight of the baby.
- Smoking increases risks for sudden infant death syndrome (known as SIDS or crib death)
- Smoking is a risk factor for ectopic pregnancy (implantation in the fallopian tubes rather than uterus)
- Smoking increases risks for orofacial clefts in infants such as the cleft lip.
- Smoking increase risks for birth defects and miscarriage.
- Smoking can affect bone health; inform of fractures, osteoporosis etc
- Smoking affects the health of one's teeth and gums and can cause tooth loss, blackening etc.
- Smoking can increase one's risk for cataracts i.e opacification of the crystalline lens of the eye.
- Smoking is a risk factor for emergence of diabetes mellitus.
- Smoking causes inflammation of tissues and decreased immune function.
- Smoking is a cause of joint disease like rheumatoid arthritis.

• Smoking predisposed to lung diseases like Chronic Obstructive Pulmonary diseases which includes emphysema and chronic bronchitis.

(c)(i).

• Their gill arches collapse and there is not enough surface area for diffusion to take place
• Their gill lamellae surface dries and oxygen in air fails to dissolve and diffuse into blood.

(c)(ii).

Depletion of oxygen in the water by another biotic source such as algal bloom, decomposition bacteria etc

Question 21.

(a).Why is Krebs cycle also called the final common pathway of the breaking down of organic compounds?
(b) Explain the different cellular processes that depend on ATP. ***(14 marks)***
(c) Give an account of commercial application of fermentation. ***(06 marks)***

(a).

Because the Kreb's cycle can be activated by other organic molecules (lipids and proteins) and not only by gluco-se. Because breakdown of lipids and proteins, just like carbohydrates; can possibly generate acetyl CoA; a substr-ate that triggers the Krebs cycle, the body is capable of using its energy reserves of fat and protein to cycle the Kr-ebs cycle when experiencing malnutrition or when there is no glucose available for the cells.

(b).

Transportation of materials across cell membranes; such as active transport, transport of vesicles etc
Assembly of the cytoskeleton; ATP is used to assemble smaller molecules into macromolecules.
Intracellular signaling; ATP activates kinase molecules to move the signal throughout the cell.
DNA and RNA synthesis; synthesis of nucleoside triphosphates for assembly into DNA and RNA
Cell division; replication and build-up of food reserves during interphase is an energy intensive process.
Glycolysis; phosphorylation of glucose uses phosphate group from ATP to activate glucose molecule.
Muscle movement (contraction and relaxation); ATP bonds with the myosin head after muscle contraction is complete and is converted to ADP (adenosine diphosphate) with an extra phosphate ion.
Nerve impulse transmission; eg the use of Na-K ATPase pumps; for establishment of a resting potential.
Protein synthesis; joining tRNAs to amino acids for assembly into proteins uses ATP molecules
Beating of cilia and flagella (including sperm); for motility.
Bioluminescence; eg in glow flies

(c).

Production of yorghurt; through the lactic acid fermentation of milk with harmless bacteria.
Industrial manufacture of alcoholic beverages; through alcoholic fermentation of sugars using yeast.
Bakery industry; yeast converts carbohydrates in dough into alcohol & carbondioxide and the bread rises as this gas is being lost.

Question 22.

(a).State how different factors affect lung volumes of humans ***(04 marks)***
(b).How are diving organisms able to endure long periods when submerged under water ***(10 marks)***

(a).

Height of human; taller people have larger volumes while shorter people have smaller volumes.
Effect of smoking; non-smokers have larger volumes while smokers have smaller lung volumes.
Exercise; athletes have larger lung volumes while non-athletes have smaller ones.
Altitude; people living at high altitudes have larger lung volumes than people living at low altitudes

(b).

Overcoming the problem of increasing pressure;

• Most marine mammals lack external ears and sinuses. Without air-filled ears, a diving marine mammal does not suffer the effects of changing pressure.
• Those with ears like fur seals do get their ears filled with a bloody fluid, forcing any air out.
• Most marine mammals have long and tubular lungs that are able to collapse and re-inflate easily. They tend to be long and tubular with built in protective rings to keep valves open.
• Marine mammals have very muscular and efficient lungs which exhale great amounts of air right before a dive. By removing the air from their body, a diving marine mammal has very little problems with changing pressure.

Overcoming the problem of Oxygen Storage and consumption;

• Marine mammals store oxygen in blood, and muscles rather than in their lungs.
• Marine mammals have a very high blood to body volume ratio.
• Marine mammals also have a higher percentage of red blood cells hence more adept at oxygen storage.
• Marine mammals also have a high concentration of hemoglobin in their blood and myoglobin in their muscles which have a high affinity for oxygen and are used to store oxygen in body tissue.
• The mammalian diving reflex allows mammals to lower their heart rate and ultimately survive submerse-on in water for extended periods of time.
• Marine mammals switch to anaerobic respiration while diving without suffering adverse effects of lactic acidosis
• Some marine mammals can stay down without a breath for a longer period of time (90 minutes).

Overcoming the problem of decompression sickness and nitrogen narcosis

• Marine mammals exhale before they dive thus regularly make deep dives and return to the surface very quickly without risks of bends or nitrogen narcosis.
• Many marine mammals have an extensive network of blood vessels feeding into their brain (retia mirabilia) which capture bubbles that may form in the blood stream.

Overcoming the problem of the cold and risk of heat loss;

• Most marine mammals are large and rather; sausage shaped‖ giving them a low surface area to volume ratio to minimize heat loss.
• Most marine mammals have a thick layer of fat known as blubber for insulation against heat and as calorie storage for marine mammals that undergo long periods of fasting.

Overcoming the problem of buoyancy and subsequent difficulty sinking;

• Marine mammals exhale before diving. Removing oxygen from the lungs makes animals slightly negatively buoyant.
• Marine mammals often sink in a sleep-like state during descent of a long dive to save energy during diving.

Question 23.

(a).Explain why blood flowing in the same direction as the water would be a relatively inefficient mechanism for exchange of gases in fish ***(03 marks)***

(b). State the factors responsible for efficient diffusion during gaseous exchange in alveoli ***(07 marks)***

(c). Compare the intermediate steps in the fermentation of a molecule of sugar by yeast with that in a muscle tissue cell. ***(10 marks)***

(a).

When blood and water first meet, the concentration gradient of oxygen between them will be great. However, as blood and water flow along together, the gradient will decrease until blood shows a percentage saturation for oxygen equal to that of water. This would be well below the blood's maximum possible saturation point and thus inefficient.

(b).

• Alveoli have a large surface area.
• Moist lining of the alveoli; facilitates dissolution of gases for easier diffusion
• Alveoli have thin squamous epithelia (one cell thick) reducing diffusion distance for the gases.
• Ventilation maintains a steep diffusion/ concentration gradient
• There are numerous, small and highly folded; providing a large surface area
• Heavy vascularization of the alveoli; maintaining a steep diffusion gradient for gases
• Presence of an oxygen carrying pigment haemoglobin; further potentiates a steep diffusion gradient
• Presence of surfactant in the alveoli; prevents alveolar collapse.

(c).

Similarities

• Both are preceded by glycolysis; that yield two ATP molecules
• In both, precursor molecule is pyruvate; a glycolytic final product
• In both the reducing agent is $NADH_2$
• In both, no ATP is yielded from reduction of pyruvate
• Net ATP molecules produced per glucose molecule are two.

Differences.

Fermentation in yeast	Anaerobic respiration in muscle tissue
Final product is ethanol	Final product is lactic acid
Involves an intermediate step of forming ethanal.	Pyruvate is directly reduced to lactic acid
Ethanal is the substrate reduced by $NADH_2$	Pyruvate is the substrate reduced by $NADH_2$
Mediated by 2 enzymes; pyruvate decarboxylase and alcohol dehydrogenase	Mediated by only one enzyme; lactate dehydrogenase.
Accompanied by production of carbondioxide	Not accompanied by carbondioxide production

Question 24.

(a). List four effects of exercise on the;
(i) Respiratory system ***(04 marks)***
(ii) Cardiovascular system ***(04 marks)***
(b).Give the factors that cause oxygen to be unloaded from blood supplying muscle tissue ***(03 marks)***
(c).Explain briefly how the blood capillaries exchange other materials with the cells ***(09 marks)***

(a)(i).

• Increase in ventilation rate/ respiratory rate
• Increase in the depth of breathing
• Increase in aerobic respiration
• Increase in activity of the intercostals and diaphragm to produce ventilatory movements

(a)(ii).

• Increase in cardiac output (due to increase in heart rate and stroke volume).
• Shunting of blood from the intestines to skeletal muscles
• Increase in percentage of oxygen unloaded from haemoglobin
• Increased myoglobin activity in the muscles

(b).

• High concentration gradient resulting from aerobic respiration of active muscle tissues
• High temperature
• High carbondioxide levels/ low pH

(c).

Capillaries have a single layer of endothelial cells; small gaps between these cells make the wall permeable to water small molecules and ions; capillary networks run close to the cells; capillaries in the kidneys have pores; slow blood flow through capillaries allow time for materials to exchange; down a concentration gradient; In solution, formation of tissue fluid transports materials out of capillaries; at arterial end of capillary network; increased solute concentration/ more negative solute potential of blood at the venous end of the capillary bed; draws tissue fluid back into capillary and with it material that has diffused out of cells.

Question 25.

(a) Outline the process of anaerobic respiration of glycogen in a muscle cell ***(13 marks)***
(b) Explain how varying amount of ATP in the body affects rate of aerobic respiration ***(07 marks)***

(a).

Glycogen is hydrolysed to glucose phosphorylated using phosphate group from ATP to stabilize and make it reactive; forming Glucose-6-phosphate converted to its isomer fructose-6-phosphate; phosphorylated using phosphate group from ATP to make the sugar more reactive; forming fructose-1,6-bisphosphate; this is split into two three carbon sugars, glyceraldehyde 3-phosphate; each glyceraldehyde 3-phosphate molecule is phosphorylated by inorganic phosphate and dehydrogenated by NAD to form glycerate-1,3-bisphosphate; a pair of phosphates are removed forming more ATP, each glycerate 3-phosphate molecule loses a water molecule forming pyruvate; pyruvate from glycolysis accepts the hydrogen atoms from $NADH_2$ forming lactate;

(b).

Amount of ATP greater than ADP/a high ratio of ATP to ADP; inhibits enzyme phosphofructokinase; slows down phosphorylation of fructose 6-phosphate to fructose-1,6-bisphosphate; reducing the rate of glycolysis of sugar to form pyruvate and hence slowing down Kreb's cycle;
Amount of ADP greater than ATP/a high ratio of ADP to ATP; activates enzyme phosphofructokinase; catalysing faster down of phosphorylation of fructose 6-phosphate to fructose-1,6-bisphosphate; pyruvate is formed at a faster rate and hence higher rate of Kreb's cycle;

Question 26.

(a).Compare the process of gaseous exchange and ventilation in bony fish. ***(10 marks)***
(b).Explain how respiratory substrates from lipids enter the Krebs cycle in the cell of a living organism

(a).

Similarities

• In both water is the medium from which oxygen is absorbed and into which carbondioxide is released;
• In both, gill lamellae are the site for gaseous exchange;
• In both respiratory gases are transported in bronchial blood vessels;
• In both, water enters into open mouth during respiration;
• In both, water flows from a region of high into region of lower pressures;
• In both inspiration is as a result of alternate contraction and relaxation of muscles of the buccal cavity (Hypobranchial muscles)

Differences

Gaseous exchange in bony fish	Gaseous exchange in cartilaginous fish
Is by counter current flow	Is by parallel flow;
Water enters through mouth only	Water enters through mouth and spiracles;
Larger amount of oxygen absorbed from water	Less amount of oxygen absorbed;
All gills are ventilated /water passes over all gills	Not all gills are ventilated/ water does not pass through all the gills;
Slower speed of water flow over gill lamellae	Faster speed of water flow over gill lamellae
Operculum valve open and close during ventilation	Bronchial valves (gills slits) open & close during ventilation;
Four pairs of gills are involved.	Five pairs of gills are involved;

(b).

The respiratory substrates from lipids are fatty acids; and glycerols. Fatty acids undergo beta oxidation; a 2C acetyl is formed; which combines with a co-enzyme A to form acetyl co-enzyme A which enters Krebs cycle; Glycerol is phosphorylated by ATP; to form Glycerol-3-phosphate; which is dehydrogenated by NAD to Dihydroxyacetone phosphate; further dehydrogenation of Dihydroxyacetone phosphate by NAD; forms Glyceraldehyde -3- phosphate (phosphoglyceraldehyde); Glyceraldehyde-3-phosphate undergo oxidative dehydrogenation to form pyruvic acid; Pyruvic acids enter mitochondria and undergo oxidative dehydrogenation and decarboxylation to form a 2C acetyl which enters Krebs's cycle.

Question 27.

(a).What is meant by oxidative decarboxylation? ***(04 marks)***
(b).Explain the chemi-osmotic theory of energy formation. ***(07 marks)***
(c).Describe the respiratory metabolism of glycerol in the cytoplasm of the cell. ***(09 marks)***

(a).

Oxidative decarboxylation refers to removal of hydrogen and carbon atoms; from intermediate compounds of substrates metabolism in the matrix of the mitochondria to avoid carbon dioxide; from oxidation of carbon atoms by oxygen and $NADH/H^+$.

(b).

Chemiosmotic theory of energy formation proposes that hydrogen in the mitochondrial matrix are dissociated into protons and electrons using energy produced from the moving electrons down an energy gradient among the cytochromes in the inner membrane of the mitochondria. The energy pumps the formed protons across the inner membrane into the inter membrane space of mitochondrion. The high concentration of protons (H^+) in the inter proton motive force membrane space reduces the PH of space and creates a very high electrochemical proton gradient between the matrix and inter membrane space of the mitochondria. The large electro chemical proton gradient diffuses protons from the inter membrane space via stalked granules rich in ATPase enzyme in the inner membrane of the mitochondria into the mitochondrial matrix. As the protons pass through the stalked granules in the inner membrane, the ATPase enzyme in the granules is activated to catalyses the combination of inorganic phosphate with adenosine diphosphate (ADP) to from ATP; using P.E for protons (adenosine triphosphate)

Consider also in chloroplast.

(c).

Glycerol is phosphorylated to glycerol-3-phosphate and hydrolysis of ATP to ADP avails both the phosphates and energy for the process. The glycerol 3 phosphate is then oxidized using NAD^+ to form $NADH_2$ /$NADH/H^+$ & phosphoglyceraldehyde which is interchangeable with dihydroxyacetone phosphate and at this point the products of glycerol metabolism have joined the glycolytic pathway. The 3-phophoglyceraldehyde is then phosphorylated using the inorganic phosphate and oxidized by nicotinamide adenine di-nucleotide (NAD^+) to form $NADH_2$ & 1,3-diphosphoglyceric acid. The diphosphoglyeric acid molecule is then de-phosphorylated by ADP to form ATP and 3-phosphoglycerate which is dehydrated to phosphoenol pyruvate which dephosphorylates to enol pyruvate forming ATP as well.

Question 28.

(a).What are the properties of a respiratory surface? ***(04 marks)***

(b) Describe how oxygen from the air reaches

(i) liver cells in a mammal ***(10 marks)***

(ii) pith cells in the stem of a flowering plant ***(06 marks)***

(a).

• Large surface area to facilitate high rate of exchange
• Permeable to allow respiratory gases to pass through it
• Thin to shorten the diffusion distance
• Have an efficient transport system/ good blood supply; aids oxygen delivery to & carbon dioxide from the tissues.
• Moist surface for dissolution of respiratory gases
• Well ventilated for efficient delivery of oxygen to and carbon dioxide from the surface

(b)(i).

External intercostal muscles contract while internal intercostal muscles relax; rib cage moves upwards and outwards; diaphragm contracts flattening; these movements increases the volume of thoracic cavity and hence the lungs; decreasing the pressure of air within the lungs below that of the atmosphere; as a result air is drawn into the lungs through the trachea, bronchi and bronchioles; oxygen diffuses across the walls of the alveolus, capillary walls and through walls of red blood cell into a red blood cell; along its concentration gradient; oxygen combines with haemoglobin to form oxyhaemoglobin; moved in this form in blood through the pulmonary vein to the heart; that pumps blood to the liver through the aorta and hepatic artery; upon reaching the liver oxyhaemoglobin is dissociated due the low pH within; forming oxygen and haemoglobinic acid; oxygen then diffuses across walls of red blood cell, capillary walls into the liver cells;

(b)(ii).

At night/ under low light intensity; oxygen concentration in atmosphere is higher than that in inside lenticels; oxygen diffuses down its concentration gradient; into the lenticels within the bark of the stem; oxygen moves through the intercellular air spaces to the internal tissues; dissolves in the moisture around the cells and then diffuses into the pith cells;

Question 29.

(a). Describe the structure and modifications of the features of the mitochondrion that suits their functions.

(b). Explain mechanisms which leads to formation of ATP molecules that occurs involving inner membrane of the mitochondrion. ***(14 marks)***

(a).

• Inner membrane is highly folded to increase surface area for respiratory activity
• Outer membrane is thin to allow passage of materials in and out of mitochondria.

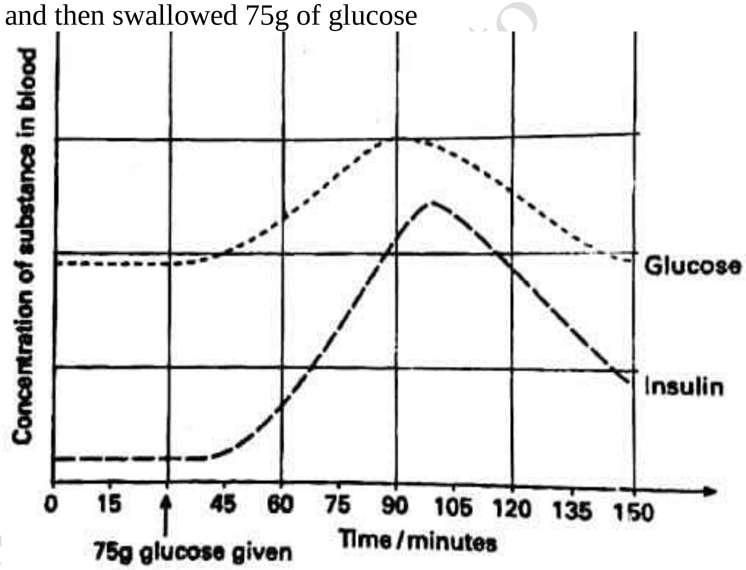
• Compartments between inner and outer membranes with space to contain protons;
• Stalked granules with chemiosmotic channels arranged at different energy levels for passage of protons where in the process energy is emitted for phosphorylation;
• Inner membrane contains protein molecules that actively pump protons into the inter-membranal spaces
• Jelly like matrix; containing enzymes that catalyse ADP and Pi combination to form ATP
• Ribosomes and circular DNA in the matrix for protein synthesis;
• Phosphate granules providing phosphate units that combine with ADP to form ATP.

(b).

Hydrogen atoms is first accepted by a hydrogen acceptor NAD at a higher energy level; to form reduced NAD ($NADH_2$) reduced NAD losses the hydrogen to second hydrogen acceptor FAD at a lower energy level to form reduced FAD ($FADH_2$); energy emitted; is used to combine ADP with a phosphate unit to form adenosine phosphate (ATP); reduced FAD losses its hydrogen atoms to a co-enzyme Q to form reduced Q (Co-enzyme QH_2); the hydrogen atoms dissociate into protons and electrons; The electrons are carried via chains of electron carrier systems placed at different energy levels; energy is emitted and used for synthesis of ATP molecules. The protons are actively pumped into the compartments between the inner and outer membranes; the protons accumulate until a steep proton gradient exists; the inner membrane is impermeable to protons and protons diffuse rapidly only via the chemiosmotic channels in the stalked granules at different energy levels; the energy emitted is used for the synthesis of ATP molecules;

Chapter 8; Homeostasis in living organisms

Figure 1 shows the changes that occur in the concentrations of insulin and glucose in the blood stream of person who had lasted overnight and then swallowed 75g of glucose



(a)(i). Compare the levels of glucose and insulin after swallowing glucose. ***(04 marks)***

Similarities

• Both concentrations rise and fall
• Both concentrations have peaks

Differences

Glucose levels	Insulin concentrations
Peak concentrations attained earlier	Peak concentrations attained later
Higher peak concentration	Lower peak concentration
Higher throughout	Lower throughout

(ii).Explain the changes in the concentration of glucose and insulin ***(12 marks)***

Glucose

Between 30 minutes and 90 minutes; glucose concentration increases gradually due to absorption from the gut; Between 90 minutes and 150 minutes, glucose concentration decreases gradually. It is being converted to glycogen/ fat/increased oxidation by cells OR uptake by cells in presence of insulin

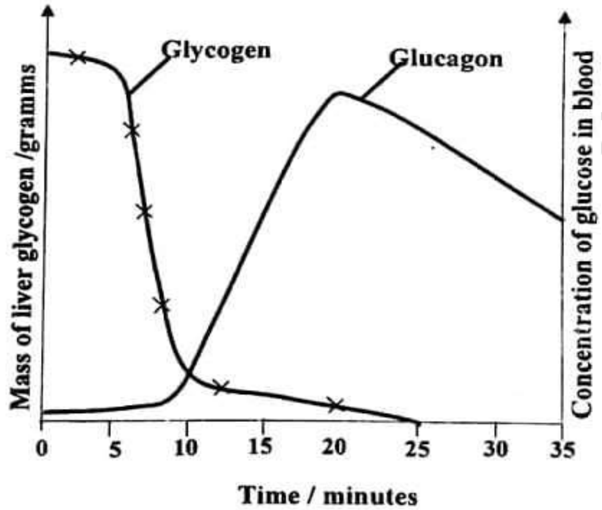
Insulin

Between 45 minutes and 105 minutes. concentration of insulin increases rapidly because the glucose concentration exceeds the set point which stimulates beta cells in the pancreas; to secrete more Insulin: to lower the glucose level back to the normal between 105 minutes and 150 minutes, concentration of insulin decreases slowly because glucose levels are decreasing towards the norm:

(iii).Explain how the concentration of insulin would change if the person engaged in an exercise.

Concentration of insulin would reduce because its secretion from the pancreas would be inhibited; so that there is less/ no glucose converted into glycogen:

(b) Figure 2 shows the changes in the amount of liver glycogen and the glucose concentration in blood of a person during a prolonged exercise



(i).Describe the effect of prolonged exercise on the amount of glycogen and the concentration of glucagon in blood.

Prolonged exercise lowers the amount of glycogen to a minimum but increases the level of glucagon up to a peak; and there after the level reduced.

(ii) Explain the trend in the mass of glycogen and concentration of glucagon in blood ***(14 marks)***

Mass of glycogen

Between 0 minutes and 5 minutes, the mass of glycogen decreases slowly because the glucose concentration in blood is still high; between 5 minutes and 10 minutes. mass of glycogen decreases rapidly because the glucose levels in blood have reduce so much glycogen is converted into glucose: to provide energy for the exercise. Between 10 minutes and 20 minutes, mass of glycogen reduces slowly because glycogen stores in the liver have been exhausted/ depleted or used up.

Concentration of glucagon

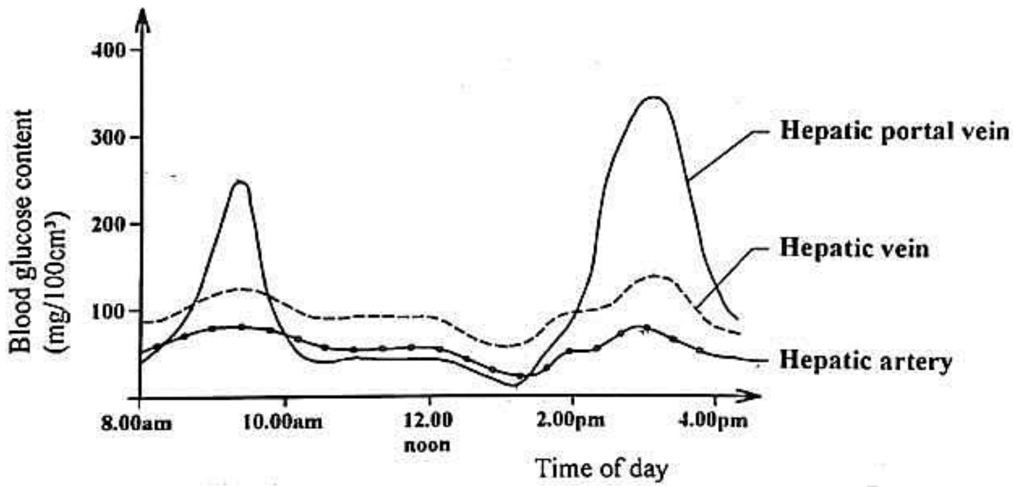
Between 0 minutes and 6 minutes, level of glucagon increases slowly; because the need for its conversion into glucose is low. Between 6 minutes and 20 minutes, the level of glucagon increases rapidly to promote conversion of much glycogen into glucose. Between 20 minutes and 30 minutes, level of glucagon decreases gradually because glycogen stores are depleted

(iii).Suggest how continuous supply of glucose is ensured after the 25th minute (03 marks)

The adrenal glands secrete cortisol hormone: that promotes the conversion of amino acids and glycogen into glucose by the liver cells:

Question 2.

(a).Figure1shows the average blood glucose levels in three major vessels of the liver of an individual who had meals at 7:00 a.m. and 1:00 pm. Use the information to answer the questions that follow.



(i)Compare the levels of glucose in:

Hepatic artery and hepatic vein. ***(04 marks)***

Similarities

- Both rise and fall gradually between 8:00pm and 10:00am; and from 2:00pm to 4:00pm
- Both are almost constant decreasing slowly between 10:00am and 12:00noon.
- Both fall and rise between 12:00pm to 2:00pm to 2:00pm.
- Both have peaks at around 9:00pm and 3:00pm.
- Both peak at the same time at 9:00am.

Differences

- Glucose level for the hepatic vein is higher than that for hepatic artery throughout.

Hepatic artery and hepatic portal vein. ***(04 marks)***

Similarities

- Both peak at the same time of the day
- Both are at the same level at around 8:30am 10:00am and 1:30pm
- In both from noon (12:00pm) to 1:30pm there is a gradual decrease/fall/ almost constant.

Differences

- Glucose level for HPV is level than that HA before 8:30am and between 10:00am and 1:30pm
- Glucose level for HPV is higher between 8:30am to 10:00am and after 1:30pm
- Glucose level for HPV rises sharply while that for hepatic artery rises gradually HPV glucose level fall sharply while falls gradually.

(ii).Explain the differences in the levels of glucose in the:

Hepatic artery and hepatic vein. ***(09 marks)***

Glucose level is higher in the HV than in the HA because of metabolism / respiration in the heart. More glucose is added to the blood due to digestion and absorption of food in the gut which is then transported by the HPV to the liver where glucose level is regulated/ converted to glycogen/glycogenesis take place to establish the normal concentration of glucose level and transported by the hepatic vein.

Hepatic artery and hepatic portal vein. ***(09 marks)***

Between 8:30; the level of glucose is lower because there is little digestion and absorption of digested food; Between 10:00 am and 1:30pm; the level of glucose is lower in the hepatic portal vein because of completion of digestion and absorption; Glucose level in the HPV rises rapidly between 8:30am and 10:00am; and after 1:30pm; because digestion and absorption are at the peak. Glucose levels rises sharply/ rapidly in the HPV due to absorption while it rises gradually in the hepatic artery due to regulation; and respiration in the heart.

(b).Figure 2 shows the blood glucose levels in a normal and diabetic individual, after both individuals were given a sugar solution at 7:00am. Study the information and answer the questions that follow.

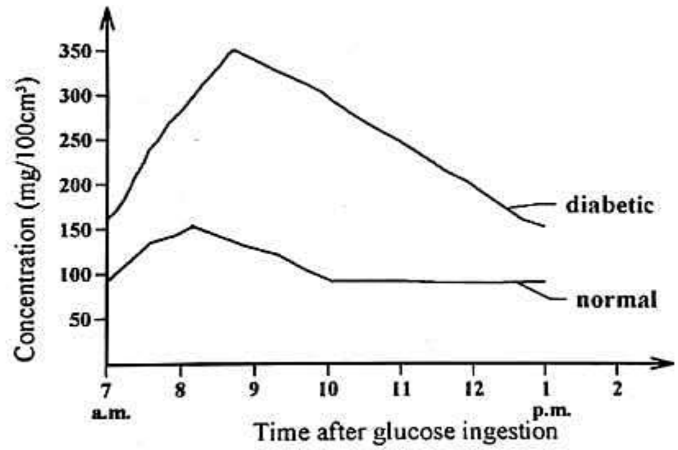


Fig. 2

(i).Compare the levels of blood glucose between the two individuals. ***(05 marks)***

Similarities

• Both concentrations rise
• Both concentrations fall after the rise
• Both concentrations attain peaks
• Generally there is a gradual decrease from 12:00 to 1:30pm

Differences

• Increase for the diabetic is steeper
• Glucose level in a diabetic is higher throughout and lower for a normal person.
• Peak concentration is attained earlier in a normal individual than for a diabetic;
• After 10:00pm, diabetic peak continues to drop whereas the normal person's glucose level remains constant (level off / neither increases nor decreases).

(ii).Give an explanation for the observed pattern of levels of blood glucose in the two individuals. ***(05 marks)***
Increase in glucose concentration is due to absorption after digestion. Peak is higher in a diabetic because of lack of regulation / insulin/ malfunctioning pancreas. Concentration of glucose levels off after regulation is due to homeostatic control of glucose/ release of insulin. Concentration of glucose falls because of lack of regulation and due to excretion of glucose/ removal of glucose in urine (glycosuria)

(c).What is the significance of the physiological process illustrated in figures 1 and 2? ***(04 marks)***
• Glucose is a respiratory substrate for cells eg brain cells/ main metabolite for cells. Less/ lack of glucose results into hypoglycemia/ fainting / ketosis.
• Glucose concentration affects the osmotic relations of cell/ regulation of water and salts
• Excess glucose would result in breakdown of body cells/ muscle tissues /brain cells/ loss of weight/ tiredness.

Question 3.

In an experiment a person who does not have diabetes ate two slices of white bread. The change in her blood glucose concentration was recorded over the next 120 minutes. The experiment was repeated; first with two slices of brown bread and then with two slices of whole meal bread. Figure 1 shows the results of the three experiments.

Fig 1.

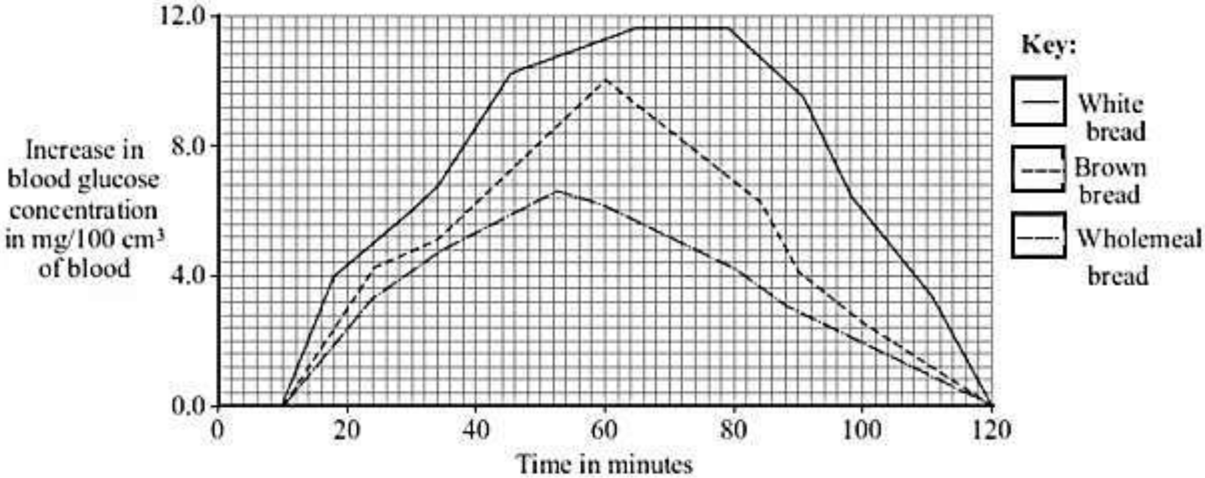
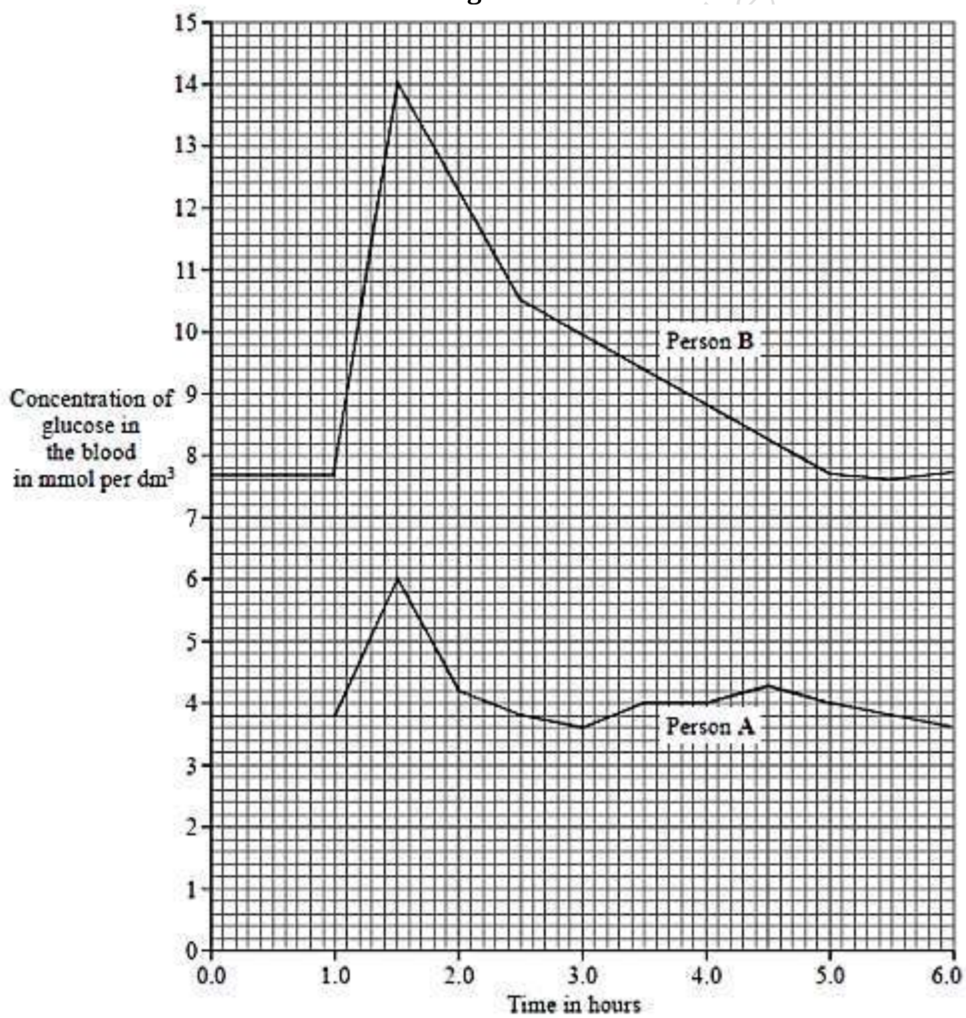


Figure 2 below shows the concentration of glucose in the blood of two people. Person A is non-diabetic. Person B has diabetes. Each person ate 75 grams of glucose at 1.0 hours.

Fig 2.



FROM FIGURE 1:

(a)(i)Which type of bread would be most suitable for a person with diabetes?

(ii) Give two reasons for your answer.

(b) Explain, as fully as you can, the reasons for the changes in blood glucose concentration when the person ate the brown bread.

FROM FIGURE 2:

(c) Explain the observed changes in the glucose concentration in both persons after the meal.

(d)(i) Explain two dangers of having high concentration of glucose in the blood.

(e).Pancreatic cell transplantation is a new treatment for diabetes. Insulin-making cells are taken from up to three dead donors. The cells are kept alive before being injected into the diabetic in a small operation. Cells soon begin to make insulin. In one recent study 58% of recipients of pancreatic cell transplants no longer needed insulin injections. Give the advantages & disadvantages of the new treatment for diabetes compared with using insulin injections.

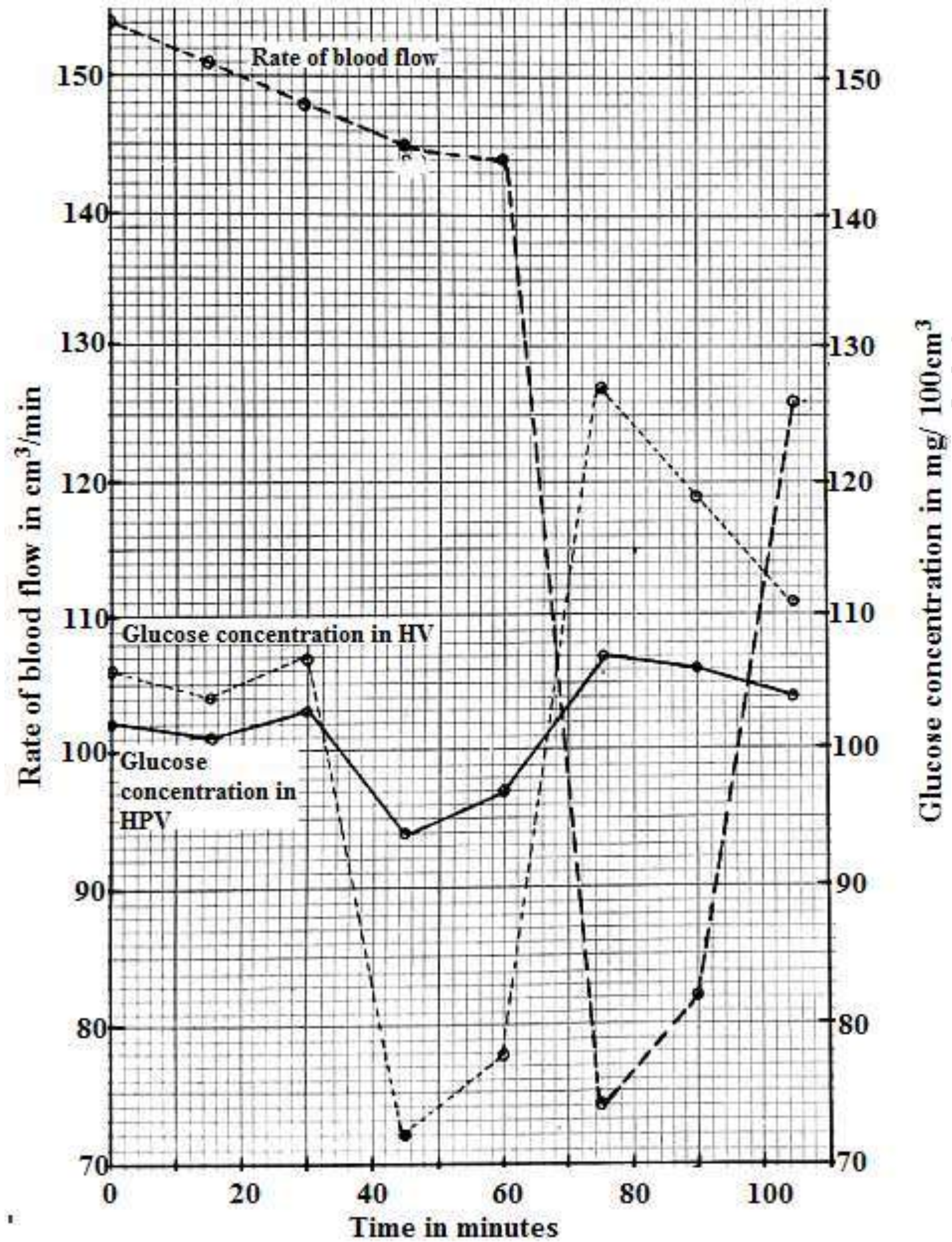
Question 4.

In an experimental animal the hepatic artery was ligatured and the rate of blood flow through the hepatic vein measured. The glucose concentrations in the hepatic portal vein and the hepatic vein were measured at 15 minutes intervals. Presently insulin was injected and subsequently adrenaline.

Time(min)	Rate of blood flow (cm^3/min)	Glucose Concentration (mg/100cm^3)	
		Hepatic portal vein	Hepatic vein
0	154	102	106
15	151	101	104
30	148	103	107
35	Insulin injected		
45	145	94	72
60	144	97	78
65	Adrenaline injected		
75	74	107	127
90	82	106	119
105	126	104	111

(a).Plot a graph showing the changes in uptake or output of sugar by the liver. ***(09 marks)***

Graph showing how the rate of blood flow in the hepatic vein and glucose concentration in both hepatic vein(HV) and hepatic portal vein (HPV) varies with time in an experimental animal whose hepatic artery was ligated and exposed to insulin and adrenaline at different times.



(b).Compare the blood glucose concentration in both veins

(i). Before hormones were administered ***(04 marks)***

Similarities

- Blood glucose concentration is moderately high in both veins initially
- Slow decrease in blood glucose concentration in both veins for the first 15 minutes
- Slow increase in blood glucose concentration in both veins from the 15th to 30th minute.
- Equal glucose concentration in both veins on the 32nd minute.

Differences

- Initially there is a relatively higher concentration in the hepatic vein than in the hepatic portal vein.
- Glucose concentration lower in the HV than in the HPV between the 32nd and 35th minute

(ii).When insulin was administered ***(04 marks)***

Similarities

- From the 35th to 45th minute, both veins experience a decrease in glucose concentration.

• From the 45th to the 60th minute; glucose concentration in both veins increases gradually.
• Same concentration of glucose in both vessels on the 63rd minute
• From the 60th minute up to 65th minute, glucose concentrations in both veins increases.

Differences

• Glucose concentration is generally higher in the HPV than in the HV
• From 35th-45th minute, rapid decrease in glucose concentration in HV; but gradual decrease in the HPV.
• Rapid increase in glucose concentration in HV; but gradual increase in HPV from the 60th to 65th minute

(iii).When adrenaline was administered ***(04 marks)***

Similarities

• In both veins, there is increase in glucose concentration up to 75th minute
• Glucose concentration decreases for both veins between 75th minute and the 105th minute.
• Glucose concentration in both veins is higher on the 105th minute than initially.

Differences

• Glucose concentration in the HV increases rapidly up to 75th minute; that in HPV increases gradually.
• For 75th to 105th minute; glucose concentration in HV decreases rapidly; that in HPV decreases slowly.
• Between 75th to 105th minute; glucose concentration in the HV is higher than that in the HPV

(c).Explain the blood glucose concentration in both veins

(i). Before hormones were administered ***(05 marks)***

In both, glucose concentration was moderate because homeostatic system maintained it with the normal range of 100-110 mg/100cm^3. In both veins there was a slow decrease in the first 15 minutes due to utilization of the glucose in respiration. Slow increase up to the 30th minute was the negative feedback homeostatic response to the decreasing glucose concentration. This involved mobilization of the food reserves like conversion of glycogen to glucose; gluconeogenesis (formation of glucose from non-carbohydrate precursors like proteins, fatty acids and glycerols) under the influence of endogenous hormones like glucagon, cortisol and thyroxine. Glucose concentration is higher in the hepatic vein than in the HPV due to glucose formation in the liver from glycogen and other non-carbohydrate precursors under the influence of the endogenous hormones.

(ii).When insulin was administered ***(05 marks)***

From the 35th minute, decrease in glucose concentration in both veins is because insulin increased glucose uptake into body cells for respiratory breakdown; increased conversion of glucose into glycogen in the liver and muscle tissue and increased conversion of glucose into fatty acids and glycerols in the liver cells. Glucose concentration was relatively higher than in the HPV due to uptake from the gut before insulin regulation in the liver. The slow increase in glucose concentration after 45 minutes was due to insulin degradation in the liver by insulinase enzyme in the liver and onset of other counter-regulatory mechanisms such as glucagon mediated conversion of glycogen to glucose; proteins and fats also converted to glucose.

(iii).When adrenaline was administered ***(05 marks)***

The initial increase in the blood glucose concentration in both veins was because, in the liver, adrenaline accelerates both glycogenolysis (breakdown of glycogen into glucose) and gluconeogenesis (non-carbohydrate precursor molecules like proteins, fats being converted into glucose). The rapid increase in glucose concentration within the hepatic vein was because it is the immediate blood vessel in which the formed glucose in the liver is channeled; lowers in the HPV because of use as a respiratory substrate in the heart and gut. From the 75th minute to the 105th minute; concentration of glucose in both veins decreases due to negative feedback homeostatic regulation; back to the norm through release of insulin which does glycogenesis in liver and muscle cells recruit glucose into cells for respiration; also converts excess glucose into proteins and lipids.

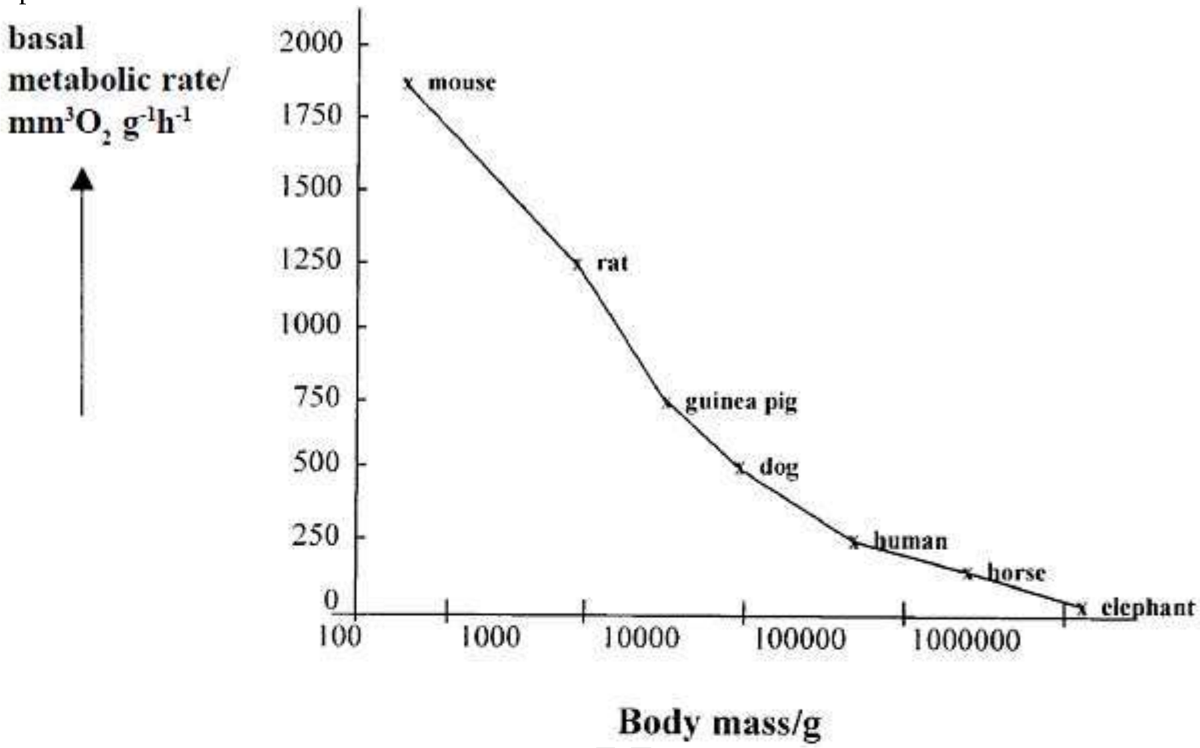
(d).The rate of flow of blood through the renal artery was found to be 1200cm^3/mm; the urea concentration in the renal artery was 32mg/100cm^3 and in the renal vein 24mg/100cm^3. Calculate the quantity of urea which would be excreted by the kidney in one hour. ***(04 marks)***

Blood flow from the kidney = 1200 cm^3/minute
Urea concentration = 32 mg/ 100 cm^3 in the artery and 24 mg/ 100 cm^3 in the vein
Volume of blood through the kidney in 1 hour = (1200 x 60) =72,000cm3
Urea excreted by the kidney/ 100cm^3 of blood= (32-24) cm3 = 8cm^3
Urea excreted by the kidney in 72,000 cm^3 of blood= (8x 72,000/100) =5760 mg of urea

Quantity of urea excreted in one hour is 5760mg/ hour

Question 5.

The graph below shows the basal metabolic rate of various mammals.



(a).What is meant by the term basal metabolic rate? ***(03 marks)***

The minimum energy needed to maintain Vital life processes/ essential metabolism of an organism while at rest eg blood circulation/ temperature control/ventilation.

(b).How is the metabolic rate of different mammals measured? ***(10 marks)***

The animal is allowed time to relax/ get at rest/ acclimatize (for man he has to be naked). The mass of the animal is measured in grammes; the volume of oxygen absorbed, or the volume of carbondioxide evolved by the animal in one hour is also measured using a respirometer. BMR is then computed as expressed as volume of oxygen consumed per gram per hour ($mm^3O_2g^{-1}\ h^{-1}$).

(c).Explain why smaller mammals have higher metabolic rates than large mammals. ***(06 marks)***

Smaller mammals have larger surface areas in proportion to their volume: therefore tend to lose heat more quickly (through skin); also breathe more quickly so tend to lose more heat via respiratory pathways: thus need higher rate of metabolism to compensate for greater heat loss.

(d) How do small animals get enough oxygen to the tissues to maintain a continuous high rate of metabolism?

Have a much faster rate of breathing/higher ventilation frequency/more breaths per minute; frequency of heart be-at is much higher in small mammals/ more beats per minute/ higher relative cardiac output; have a more efficient haemoglobin/dissociation curve of small mammal lies to the left of that of a large mammal.

(e).Discuss the factors that determine basal metabolic rate in organisms. ***(10 marks)***

Age; young ones have higher BMR than old ones since they have a higher growth rate; a process which is highly energy demanding and also have less (not well) developed) insulation structures and mechanisms.

Sex: Males have a higher BMR than females; since they are more muscular (muscles consume much energy in their activity) and less adipose tissue/ fat stores which are body insulators against heat loss.

Size: small organisms have a higher BMR since are they have a higher surface area to volume ratio; thus tend to lose heat more quickly across the body surface than large organisms

State of health: Diseases than result into raised body metabolism like malaria which leads to fever cause a rise in BMR while those that result in low metabolism like those as a result of starvation cause a fall in BMR.

Hormone level in blood; e.g adrenaline thyroxine rise causes rise in BMR.

State of exercise; at rest versus having exercise.
Environmental factors; e.g change in altitude;

Essay questions and answers

Question 1.

Explain what would happen to an individual having malfunctioning liver ***(20 marks)***

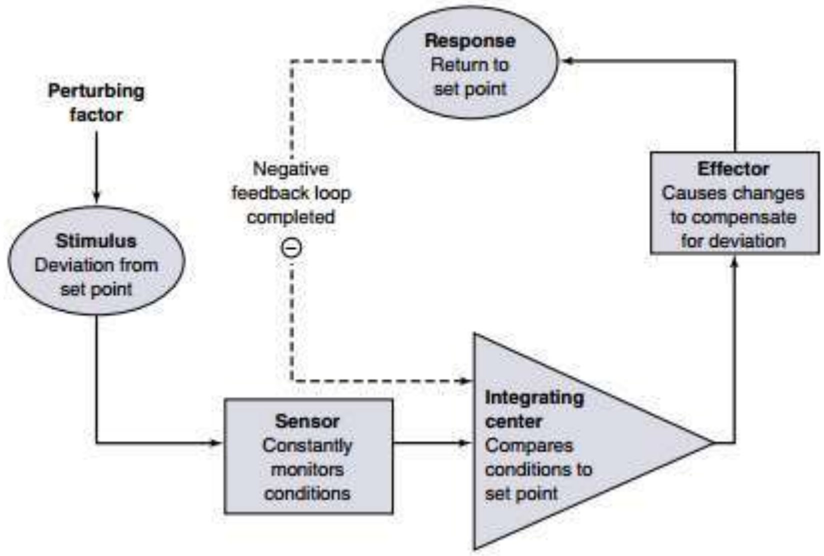
- Jaundice; yellowing of eyes due to increased degradation of RBCs with bilirubin accumulation
- Gall stones; impedes bile flow
- Edema; decreased synthesis of plasma proteins; leads to fluid accumulation in interstitial spaces.
- Drug toxicity and toxin accumulation; due to impaired detoxifying effects of the liver.
- Hyperammonemia; accumulation of ammonia due to impaired deamination
- Hepato-renal syndrome, due to ammonia induced renal cell damage
- Hepatic encephalopathy; ammonia induced neuronal damage following impaired deamination.
- Hepato-pulmonary syndrome; secondary to ammonia intoxication.
- Bleeding disorders due impaired synthesis of clotting factors
- Iron deficiency anemia, due impaired synthesis of apoferritin,
- Fatty food intolerance; Malabsorption of fats due to impaired bile synthesis.
- Steatorrhoea; fatty food intolerance from impaired bile synthesis; leads to fatty stool(faeces)
- Fat soluble vitamin (A,D,E,K) deficiency syndrome; due to impaired absorption
- Ascites; due to fluid accumulation in the peritoneum.
- Poor glycemic control due to impaired glucose metabolism result in hypoglycemia and hyperglycemia.
- Pernicious anemia; impaired synthesis of intrinsic factor impedes absorption of vitamin B12
- Portal hypertension in the esophagus; may present with vomiting blood
- Rectal prolapses; engorged rectal vessels due to portal hypertension.
- Hypoalbuminemia; impaired synthesis of albumin, pre disposes to drug toxicity and edema
- Weakened immune system; due to impaired synthesis of immunoglobulins (antibodies)
- Fatty liver disease (steatohepatitis) due to impaired synthesis of Very low density lipoproteins, agents that transport lipids from the liver to other tissues such as muscles
- Hormonal imbalances especially with estrogen, testosterone and prolactin; lead to gynecomastia (large breasts in males), hyperprolactinemia (continuous milk flow from the breasts), irregular menstrual flows etc
- Others; hypothyroidism, insulin resistance, metabolic syndromes

Question 2.

(a).Explain what is meant by negative feedback in body processes? ***(02 marks)***
(b).Explain how the following affect carbohydrate metabolism
(i). Insulin ***(02 marks)***
(ii).Adrenaline ***(02 marks)***
(iii)Cortisol ***(02 marks)***
(iv)Thyroxine ***(01 marks)***
(c).How is the liver adapted to its functions? ***(11 marks)***

(a).

Negative feedback refers to a homeostatic regulatory mechanism in which whenever there is a deviation from the set point in a given body physiological process; a corrective mechanism is put in place to nullify/ stop further deviation so as to restore back the set point e.g temperature regulation, blood sugar regulation etc



(b)(i).

Insulin converts glucose to glycogen (glycogenesis) for storage in the liver and muscles; also converts excess glucose to fats (lipogenesis); increases rate of oxidative breakdown of glucose to produce energy.

(b)(ii).

Adrenaline cause increase in hepatic glucose production by accelerating glycogenolysis (Conversion of glycogen in liver to glucose) and gluconeogenesis (formation of glucose from non-carbohydrate precursors like proteins) Glucose yielded is broken down during respiration to yield energy. Adrenaline also inhibits glucose disposal by insulin dependent tissues.

(b)(iii).

Cortisol causes gluconeogenesis i.e formation of glucose from amino acids and glycerol when glycogen exhausts, hence increasing glucose concentration in blood.

(b)(iv).

Thyroxine stimulates metabolism e.g. increased glucose breakdown; thereby increasing BMR.

(c).

• The liver is large with numerous lobes to increase the surface area for occurrence of several metabolic reactions as well as creating enough room for blood storage.
• Organ has a dual blood supply i.e from the hepatic artery and hepatic portal vein that keeps a steep concentration gradient for many of the liver metabolites and nutrients.
• Intimate association between the liver cells/hepatocytes with blood capillaries (sinusoids) facilitates an efficient exchange of materials between blood and liver cells.
• Presence of numerous kuppfer cells that phagocytose antigens and old red blood cells (effete RBCs).
• Intimate association between liver cells and bile cannaliculi; ensures efficient bile removal from the liver cells.
• Liver cells have numerous mitochondria, lysosomes & golgi bodies; enabling the organ match with its vast metabolic profile.
• Liver tissue is elastic and can expand to store large volumes of blood.
• Liver has many enzymes; enables it carryout numerous metabolic processes.
• Liver cells are undifferentiated; capable of carrying out numerous metabolic reactions
• Hepatocytes, which are in contact with blood vessels, bear microvilli to increase the surface area for exchange of substances.
• Hepatocytes bear numerous peroxisomes containing catalase and other oxidative enzymes responsible for detoxification of poisonous substances in the liver.

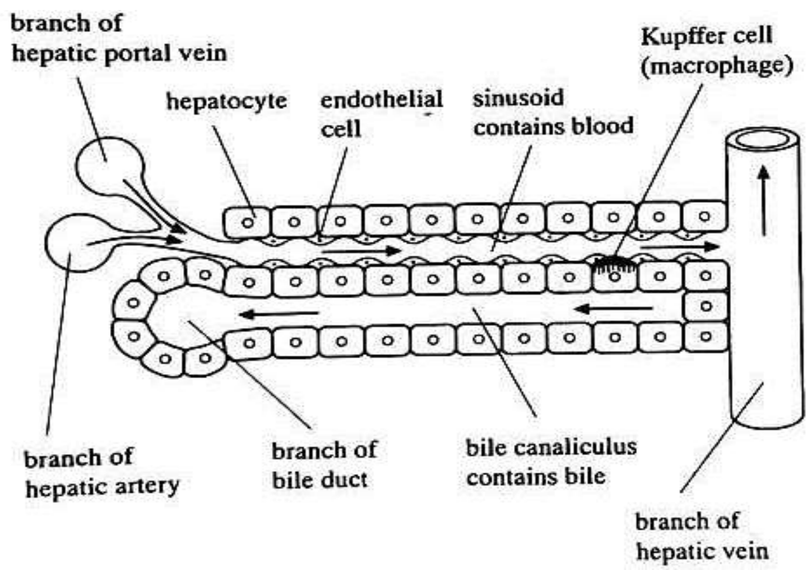
Question 3.

(a).Describe the structure of the liver lobules ***(08 marks)***
(b).How does the mammalian liver deal with;

(i).Excessive fats *(02 marks)*
(ii).Excess proteins *(04 marks)*
(c).Explain the functioning of the kuppfer cells in the mammalian liver *(06 marks)*

(a).

Lobules are functional units of the liver; dominated by one cell type; hepatocytes which are tightly packed cells with prominent nuclei, golgi apparatus, many mitochondria and lysosomes. Between lobules are branches of the interlobular vessels (hepatic artery, hepatic portal vein) and bile duct. At the centre of each lobule is branch of the hepatic vein (central/ intralobular vein) Hepatic vein is connected to the hepatic artery and hepatic portal vein by sinusoids; which are blood spaces; hepatocytes have microvilli that are in intimate association with sinusoids. Sinusoids also have a lining of thin endothelial cells and are perforated; sinusoids do alternate with bile cannaliculi; carry bile to the branches of the bile ducts. Attached to the wall of the sinusoids also are kupffer cells; which are liver phagocytes.

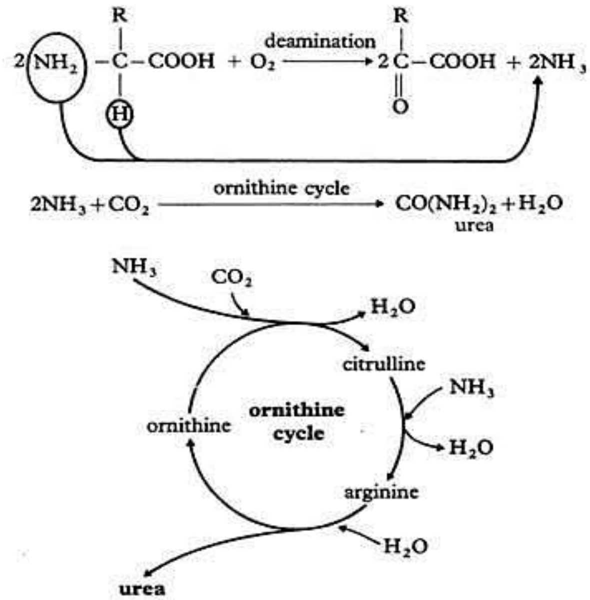


(b)(i).

Excess carbohydrate is converted to fat, stored fats are de-saturated prior to oxidation, synthesizes; degrades phospholipids and cholesterol as well as synthesizing lipid transporting globulins. Excess cholesterol in blood is excreted into bile by the liver.

(b)(ii).

Excess protein are deaminated; amino acid is oxidized by oxygen; resulting in removal of the amino group; The acidic component left is then incorporated into the Kreb's cycle; get used as a source of energy from cellular respiration; The amino group is converted to ammonia during deamination; Ammonia is then detoxified to less toxic urea in the urea/ ornithine cycle; within the liver cells. Urea is lost by renal excretion; The amino group (NH_2) of an amino acid is removed and reacts with hydrogen to form ammonia. The liver also carries out transamination i.e it transfers amino groups ($-NH_2$) from amino acids to other organic compounds to form amino acids that are deficient in the diet.



(c).

Kupffer cells which is part of reticulo-endothelial system found in the liver phagocytose old red blood cells (effete RBCs) and foreign antigens. In this, the plasma membrane invaginates to enclose the tiny particles (old red cells or antigens); fuse at the point of contact; small vesicles enclosing the particles pinch off the plasma membrane in-ward into the into cytoplasm vesicles degraded by lytic enzymes to release content into intracellular fluid.

Question 4.

(a)(i).Explain what is meant by homeostasis *(01 marks)*
(a)(ii).Using an example, explain the components of a homeostatic control system *(14 marks)*
(b).Distinguish between an efficient and an inefficient homeostatic system *(04 marks)*
(c).Explain why positive feedback mechanisms are few in biological systems *(02 marks)*

(a)(i).

Homeostasis: the maintenance of (near) constant internal conditions or the maintenance of internal conditions around cells within narrow limits.

(a)(ii).

Using temperature regulation;

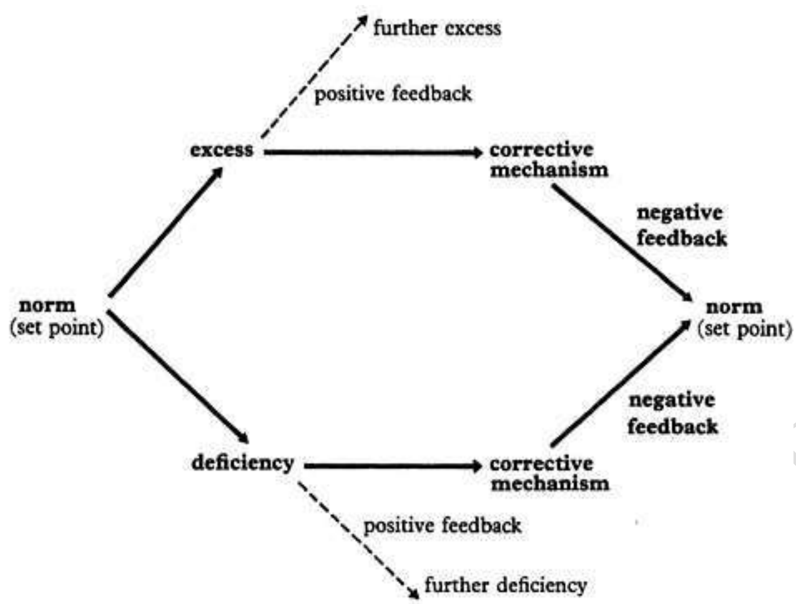
Receptors /detectors; these are parts of the body that constantly monitor and detect changes from the norm in the internal environment and then signal the deviations e.g temperature receptors in the skin provide information on variations in temperature of external environment

Control centre; this is usually the brain that coordinates the information received from various receptors and sends out instructions which will correct the deviation e.g variations in temperature of external environment are conveyed to the hypothalamus of the brain.

Effectors/ responding organs; these are parts of the body that bring about the necessary changes needed to return the system to the reference point / norm e.g the hypothalamus initiates corrective responses in effectors like blood vessels and skin to restore the conditions to normal

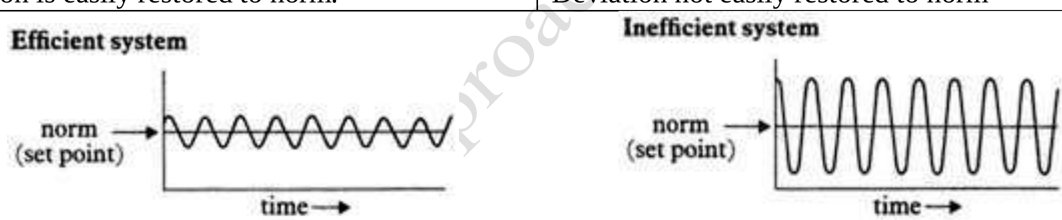
Reference point /norm; refers to set level at which the system operates e.g the average body temperature of 37ºC in humans.

Feedback loop; the hormones and or nerve impulses that inform the receptor of any change in the system as a result of the action by the effectors.



(b).

Efficient homeostatic system	Inefficient homeostatic system
Minimal deviation from the set point/ norm	Great deviation from the set point/ norm.
Deviations are short lived	Deviations are long lived
Deviations rapidly detected	Deviations slowly detected
Fluctuates close to the norm	Fluctuates far away from the norm
Deviation is easily restored to norm.	Deviation not easily restored to norm



(c).

It is because positive feedback mechanisms cause larger deviations from the normal set point and may lead to unstable conditions and extreme states.

Question 5.

(a).Explain what is meant by a feedback mechanism ***(01 marks)***

(b).Describe the process of formation of tissue fluid in living organisms ***(12 marks)***

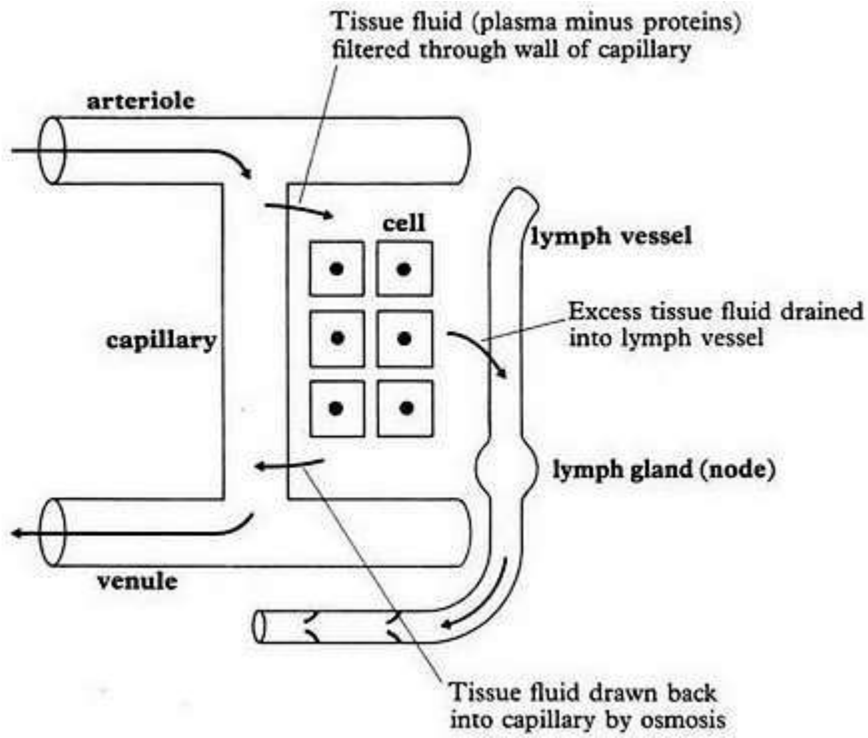
(c).Describe how unicellular organisms and cells of multicellular organisms control their internal environment ***(07 marks)***

(a).

A mechanism in which an input stimulus causes an output response that feeds back to the initial input.

(b).

This is by the process of ultra-filtration. At the arterial end of a capillary bed, hydrostatic blood pressure due to heart pump, being higher than osmotic/ oncotic pressure of blood, results in forced exit of tissue fluid into the interstitial spaces via fine pores on the basement membrane of arterioles. Tissue fluid contains all the other components of plasma apart from plasma proteins and RBCs which are not permitted to go through the capillary pores. Tissue fluid midway along the capillary bed where the blood pressure is lower, the two forces of blood pressure and osmotic pressure essentially cancel each other and no net movement of tissue fluid occurs. At the venule end of a capillary bed, hydrostatic blood pressure is lower than osmotic pressure of blood, resulting into entry of tissue fluid. However, the total amount of fluid exiting capillaries at the arterial end exceeds that entering at the venule end because the osmotic pressure causing entry of fluid at the venule end is lower than the blood pressure causing exit of fluid at the arterial end, resulting into failure of some fluid flowing in capillaries, forming what is called tissue fluid.



(c).

• At cellular level, the internal environment of a cell is its cytoplasm; while the cell's immediate surrounding constitutes the external environment.
• Tissue fluid in most animals and sap in plants constitute the external environment of cells of multicellular animals and plants respectively, but form internal environments of these organisms.
• The constituents of a cell cytoplasm are modulated by the partial permeability of its cell membrane and the level of activity of its enzymes.
• The cell surface membrane selectively allows entry and exit of molecules at a strictly controlled rate by diffusion gradient, osmotic gradients, and active transport etc.
• The nature and amounts of materials synthesized by cells is controlled by rates of protein synthesis and they catalyse most catabolic and anabolic reactions within cells.
• Therefore, relative constancy of the cell's internal environment depends on supply of metabolites, utilization of cellular material or output through activity of the modulators.

Question 6.

(a).Compare positive feedback and negative feedback mechanisms ***(07 marks)***
(b).Explain how the liver and pancreas interact to regulate sugar levels in blood ***(08 marks)***
(c)(i).State the importance of good glycemic control in living organisms ***(05 marks)***
(c)(ii).Explain briefly the advantages of having two corrective mechanisms that regulate blood glucose concentration rather than one ***(02 marks)***

(a).

Similarities

• Both feedback mechanisms are triggered by a deviation from the norm physiological set point.
• Both feedback mechanisms involve the joint activities of the detector, controller and effectors.

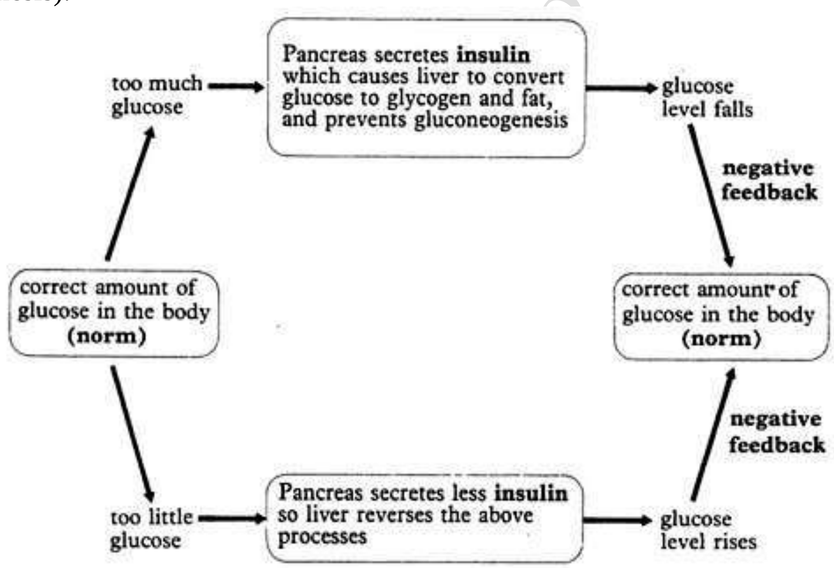
Differences

Positive feedback	Negative feedback

Corrective mechanisms continuously amplify the deviation from the physiological set point	Corrective mechanism nullifies/stops further deviation from the norm.
Aim is to potentiate further deviation from the Norm	Aim is to restore back the physiological set point (norm).
Detector always switched on; recognizes deviation the deviation; and continuously alert the controller	Detector gets switched off such that the controller is no longer alerted of the deviation.
Few in biological systems	Common in biological systems.
Examples include the clotting cascade, oxytocin release, nerve impulse transmission.	Examples include blood sugar regulation, regulation of hormones like anterior pituitary hormones, enzyme activity etc

(b).

A rise in blood glucose level above the norm (hyperglycemia) stimulates beta cells of the islets of Langerhans in the pancreas to secrete the hormone insulin into blood. Insulin binds to body cells with insulin receptors and causes processes which reduce glucose concentration, e.g Increased cellular respiration in muscle and liver cells to form carbondioxide and water, increased glycogenesis (glycogen formation from glucose) in muscle and liver cells. Increased conversion of glucose to fat and protein in adipose tissue and increased uptake of glucose in muscle cells. A decrease in blood glucose level below the norm (hypoglycemia) inhibits insulin secretion but stimulates alpha cells of the islets of langerhans in the pancreas to secrete the hormone glucagon into blood. Being the only cells with glucagon receptors, glucagon binds to liver cells causing them to increase blood glucose level through: Increased glycogenolysis (hydrolysis of glycogen to glucose), increased formation of glucose from amino acids and glycerol (gluconeogenesis).



(c)(i).

• Good glycemic control ensures glucose supply in rightful amounts especially to tissues and organs that are entirely glucose dependent such as the brain, retina, and germinal epithelium of the gonads.
• Glucose can exert a large amount of osmotic pressure in the extracellular fluid, and if the glucose concentration rises to excessive values, this can cause considerable cellular dehydration.
• An excessively high level of blood glucose concentration causes loss of glucose in the urine.
• Loss of glucose in the urine also causes osmotic diuresis by the kidneys, which can deplete the body of its fluids and electrolytes.
• Long-term increases in blood glucose may cause damage to many tissues, especially to blood vessels.
• Good glycemic control protects against both micro and macro vascular disorders.
• Good glycemic control protects against both central and peripheral neuropathies.
• Good glycemic control protects against nephropathies (diseases of the nerves).
• Good glycemic control protects against retinopathies (diseases of the retina).

(c)(ii).

Two separate mechanisms controlling deviations in different directions from the set point give a greater degree of control.

Question 7.

(a).Describe how secretions from pancreas & adrenal glands affect metabolism of absorbed carbohydrates

(b).Under what circumstances may blood sugar;

(i).appear in urine ***(03 marks)***

(ii).level be higher in the hepatic artery than in the hepatic vein ***(03 marks)***

(c) Explain why:

(i).muscle cells do not have receptors for glucagon ***(02 marks)***

(ii).there are second messengers for insulin and glucagon ***(02 marks)***

(ii).insulin and glucagon have different second messengers. ***(02 marks)***

(a).

A rise in blood glucose level above the norm (hyperglycemia) stimulates beta cells of the islets of Langerhans in the pancreas to secrete the hormone insulin into blood. Insulin reduces glucose concentration by increasing cellular respiration in muscle and liver cells, increasing glycogenesis (glycogen formation from glucose) in muscle and liver cells. Increased conversion of glucose to fat (lipogenesis) and protein in adipose tissue and increased uptake of glucose in muscle cells. A decrease in blood glucose level below the norm (hypoglycemia) inhibits insulin secretion but stimulates alpha cells of the islets of langerhans in the pancreas to secrete the hormone glucagon into blood. Being the only cells with glucagon receptors, glucagon binds to liver cells causing them to increase blood glucose level through increased glycogenolysis (hydrolysis of glycogen to glucose). Need for more glucose but with exhaustion of the glycogen stores triggers release of cortisol which stimulate gluconeogenesis (synthesis of glucose from non-carbohydrate precursors like amino acids, fatty acids and glycerols.

(b)(i).

Glycosuria occurs when serum glucose concentration exceeds renal threshold for glucose reabsorption.

Such conditions include;

- Diabetes mellitus; Insufficient insulin production or insensitive insulin receptors.
- Faulty/ malfunctioning pancreas; so that there is insufficient insulin secretion
- Reactionary hyperglycemia due to disturbance of metabolism such as in burns, infections or fractures
- Pregnancy due to latent diabetes mellitus
- Pancreatic disease
- Central nervous system damage

(b)(ii).

When an individual is at rest; there is reduced conversion of glycogen in the liver into glucose; also glucose metabolism in the heart reduces greatly, these make more glucose to be transported in the hepatic artery than in the hepatic vein.

(c)(i).

Muscle cells need their glycogen stores to provide glucose for respiration; there is no point in them releasing glucose into the circulation.

(c)(ii).

Insulin and glucagon are proteins that cannot cross the cell surface membranes of their target cells. There needs to be another substance (a second messenger) to transmit their message throughout the cytoplasm.

(c)(iii).

Insulin and glucagon both have liver cells as their target cells. If they had the same second messenger, they would both have the same effect rather than having opposite effects on glycogen.

Question 8.

(a).Explain why the bicarbonate buffer system;

(i).Is not as powerful as the other buffer mechanisms in maintaining pH of body fluids ***(01 marks)***

(ii)Plays a more important role in maintaining pH of fluids than the other buffer systems ***(05 marks)***

(b).Describe the mechanism of action of the bicarbonate buffer in the extracellular fluid ***(07 marks)***

(c).Explain the importance of phosphate buffer in animals ***(08 marks)***

(a)(i).

Its because of the large difference between the pH of the extracellular fluid ECF (7.4) and the pK of bicarbonate buffer system (6.1).

(a)(ii).

It is because the concentration of two components (HCO_3^- and CO_2) of this buffer system is regulated separately by two different mechanisms. Concentration of HCO_3^- is regulated by kidney and the concentration of CO_2 is regulated by the respiratory system. These two regulatory mechanisms operate constantly and simultaneously, making this system more effective

(b).

Hydrogen ions from the acid are buffered by combining with hydrogen carbonate ions from a bicarbonate salt and forms a weak carbonic acid. This carbonic acid in turn dissociates into carbondioxide and water which are cleared off via the respiratory surface.

$$H^+ + HCO_3^- \rightarrow H_2CO_3$$
$$\downarrow$$
$$CO_2 + H_2O$$

Bicarbonate buffer system also prevents the increase in pH in a fluid to which a base Normally, when a base is added to a fluid, pH increases. It is prevented by adding carbonic acid which dissociates into hydrogen ions and bicarbonate ions. The hydroxyl group of the base combines with hydrogen ions and forms water.

(c).

Phosphate buffer system is more powerful than bicarbonate buffer system as it has a pK of 6.8, which is close to the pH of the body fluids, i.e. 7.4. In addition for being used in intracellular fluid, phosphate buffer is useful in tubular fluids of kidneys also because more phosphate ions are found in tubular fluid. In the red blood cells, the potassium ion concentration is higher than the sodium ion concentration. So, the elements of phosphate buffer inside the red blood cells are in the form of potassium dihydrogen phosphate (KH_2PO_4) and dipotassium hydrogen phosphate (K_2HPO_4).

Question 9.

(a).Explain why deoxygenated haemoglobin is a more powerful protein buffer than the oxygenated haemoglobin ***(02 marks)***

(b).Describe the role of the respiratory system in regulation of the acid-base balance ***(10 marks)***

(c)(i).Outline the three main stages of blood clotting ***(03 marks)***

(c)(ii).Describe the role of positive feedback mechanism in coagulation/ clotting of blood ***(04 marks)***

(a).

Deoxygenated hemoglobin, unlike the oxygenated haemoglobin has a higher pK that is closer to the pH of the body fluids; easily binds with H^+, which are released when CO_2 enters the capillaries.

(b).

Lungs play an important role in the maintenance of acid-base balance by removing carbondioxide which is produced during various metabolic activities in the body. This CO_2 combines with water to form carbonic acid. Since carbonic acid is unstable, it splits into hydrogen ions and hydrogen carbonate ions.

$$CO_2 + H_2O \rightarrow H_2CO_3 \rightarrow H^+ + HCO_3^-$$

Entire reaction is reversed in lungs when carbondioxide diffuses from blood into the alveoli of lungs.

$$H^+ + HCO_3^- \rightarrow H_2CO_3 \rightarrow CO_2 + H_2O$$

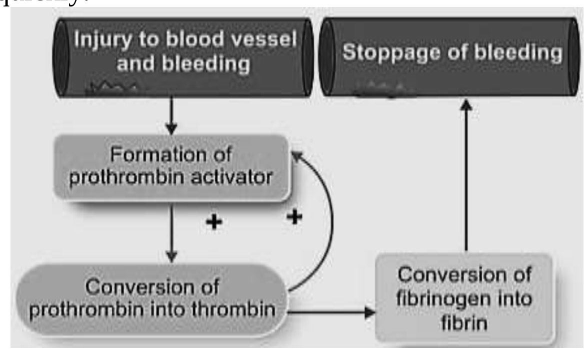
The carbondioxide is then blown off by ventilation. When metabolic activities increase, more amount of carbondioxide is produced in the tissues and the concentration of H^+ increases as seen above. Increased H^+ concentration increases the pulmonary ventilation (hyperventilation) by acting through the chemoreceptors. Due to hyperventilation, the excess of carbondioxide is removed from the body.

(c)(i).

- Formation of prothrombin activator
- Conversion of prothrombin into thrombin
- Conversion of fibrinogen into fibrin.

(c)(ii).

Thrombi stimulates the formation of more prothrombin activator in addition to converting fibrinogen into fibrin. It causes formation of more and more amount of prothrombin activator so that the blood clotting process is accelerated and blood loss is prevented quickly.



Question 10.

(a).Describe the immediate environment of a typical cell within the body of a mammal. ***(08 marks)***
(b).Explain why it is important that the internal environment of a mammal is carefully regulated. ***(02 marks)***
(c)(i).Explain how stimuli, receptors, central control, coordination systems & effectors are involved in maintaining the internal environment of a mammal ***(08 marks)***
(ii).Distinguish between the input and the output in a homeostatic control mechanism. ***(02 marks)***

(a).

The immediate surroundings of most cells in the body is tissue fluid. Blood cells, however, are surrounded by plasma. The composition of tissue fluid, just like blood plasma is mostly made up of water, with a variety of substances dissolved in it. These solutes include ions, nutrients such as glucose and protein molecules. Proteins in plasma are plasma proteins, that remain in the blood all the time. Tissue fluid however contains far fewer protein molecules than blood plasma. Other components of tissue fluid and plasma include waste products such as urea.

(b).

Cells function efficiently if they are kept in a constant environment. Maintaining constant conditions, such as pH, temperature and water potential, ensures that enzymes within cells may function at a constant rate.

(c)(i).

Receptors; detects changes in physiological factors, such as temperature, are the stimuli
Control centre; Directs an appropriate corrective response. The hypothalamus is the central control for many homeostatic mechanisms.
Coordination systems; transfers information from receptors to the central control and from the central control to effectors. Information is transferred as nerve impulses travelling along nerve cells and as hormones in the blood.
Effectors; are muscles and glands that respond to information from the central control by changing the physiological factor.

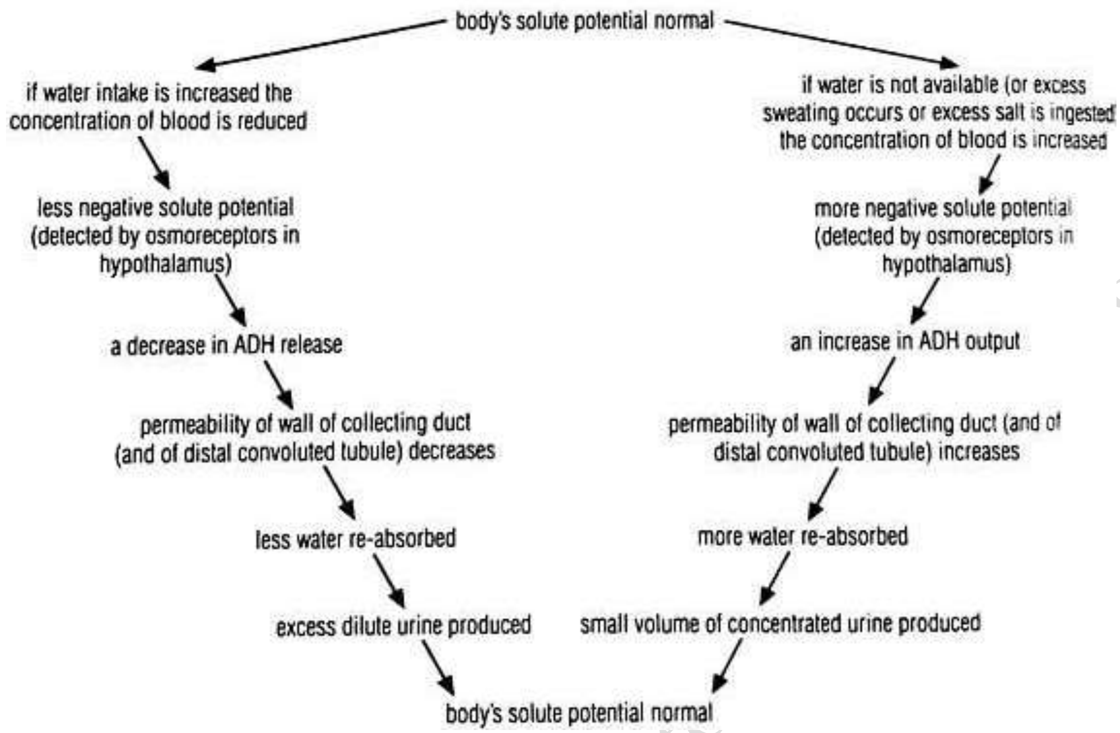
(c)(ii).

Input refers to sensory information from receptors about changes in physiological factors; this information goes to a control centre while the output are corrective actions carried out by effectors that return the physiological factor to its normal value.

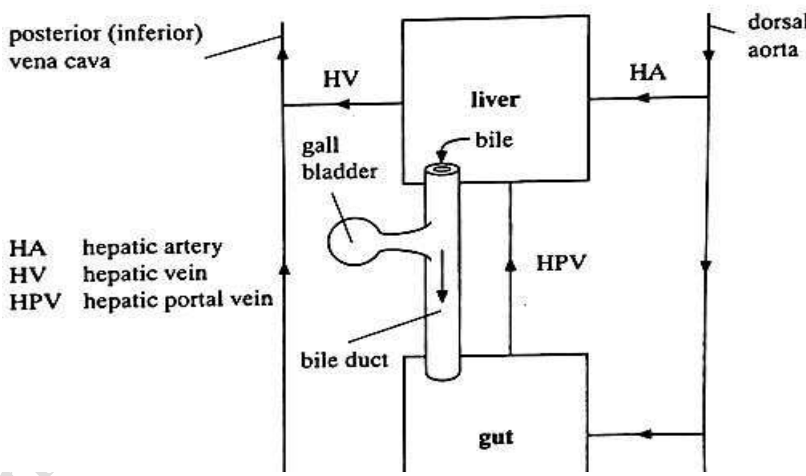
Question 11.

(a).Describe the negative feedback control of osmotic concentration of blood ***(10 marks)***
(b)(i).Describe the blood supply of the liver ***(03 marks)***
(b)(ii).Explain the importance of the liver's dual blood supply ***(04 marks)***
(c).Explain how cells lining the proximal convoluted tubules are adapted to give large surface area

(a).



(b)(i).



Liver receives dual blood supply. Hepatic artery supplies oxygenated blood from the heart; also receives nutrient rich blood from the ileum through the hepatic portal vein. Venous drainage from the liver occurs through the hepatic vein.

(b)(ii).

The hepatic artery carries oxygenated blood to the liver; the hepatic portal vein delivers blood from the intestines to the liver so that substances absorbed from the gut can be processed before they enter the general circulation.

(c).

- A high density of mitochondria; generate sufficient ATP for active selective re-absorption.
- Numerous microvilli; increase surface area for re-absorption
- Indented cell membrane; increase surface area forming large area of intercellular spaces bathed with fluid.

Question 12.

(a).Describe the series of events likely to occur if glycogen stores within in mammalian liver are depleted
(b).Explain the roles played in osmoregulation by specific protein molecules secreted in humans
(c).What are the advantages & disadvantages of a mammal excreting nitrogenous wastes in form of

(i). Ammonia *(03 marks)*
(ii)Trimethylamine *(03 marks)*

(a).

Glucose level in blood reduces below the normal; the hypothalamus detects and stimulates the pituitary gland to secrete adrenocorticotrophic hormone (ACTH); which stimulates the adrenal cortex; to secrete glucocorticoid hormone cortisol; this stimulates the liver to convert amino acids and glycerols into glucose; the levels at glucose brought back to normal.

(b).

The hormone anti-diuretic hormone (ADH)/ vasopressin is a protein hormone. When salt concentration in blood is high, the anterior lobe of the pituitary gland secretes antidiuretic hormone into the blood stream. In kidneys, ADH (Anti-diuretic hormone), stimulates the walls of the collecting duct and distal convoluted tubule to become more permeable to water and urea; causing more water to be re-absorbed back into the blood stream. When the blood volume increases/ an overload of Na^+, atrial natriuretic peptide is secreted antagonizes the effects of aldosterone by reducing circulating levels of renin. The hormone causes natriuresis, (loss of sodium ions) and diuresis (loss of excessive water).

(c)(i).

Advantages of excreting nitrogenous waste inform of ammonia.
• Ammonia is excreted by simple diffusion which is a passive process that doesnot utilize energy.
Disadvantages of excreting nitrogenous waste inform of ammonia.
• Ammonia is very soluble and highly toxic thus requires a lot of water for excretion.

(c)(ii).

Advantages of excreting nitrogenous waste inform of TMO
• It is soluble but less toxic & thus less water is required for its excretion; so it conserves water in the body of marine bony fishes
Disadvantages of excreting nitrogenous waste inform of TMO.
• It accumulates in the body of dead fish; giving off a characteristic unpleasant smell/ odour

Question 13.

Haemoglobin and amino acids acts as a buffer in the blood.
(a) Describe how haemoglobin and amino acids act to reduce the concentration of hydrogen ions in the blood.
(b).Discuss the various causes of Bohr effect. *(12 marks)*

(a).

Hemoglobin: In red blood cells, carbon dioxide reacts with water forming carbonic acid. Carbonic anhydrase causes its dissociation into bicarbonate ions which diffuse out of the cell and protons which accumulate in the cell. Increased acidity causes Bohr effect. Oxyhaemoglobin dissociates to release its oxygen and haemoglobin reacts with the hydrogen ions forming haemoglobinic acid.
Amino acids: In solutions exist as zwitterions with anionic (COO^-) and cationic (NH_4^+) ends. At lower pH/ greater acidity, the molecule reacts with the proton at its anionic end removing the ions from solution and the molecules become more positively charged.

(b).

Bohr effect is the shift of the oxygen dissociation curve downwards and to the right due to increase in the partial pressure of carbon dioxide in blood. Haemoglobin becomes less efficient at taking up oxygen. But more efficient at releasing it.

CAUSES

Low pH/ high acidity: Decreases the affinity of Hb for oxygen. Hb releases more oxygen to respiring tissues to support the increased cellular respiration to break down acids
High carbondioxide concentration; which dissolves in water forming carbonic acid which later dissociate into H^+ and HCO_3^- in the RBC. Excess H^+ lowers affinity of Hb for oxygen. HbO_2 dissociates to avail more oxygen to respiring tissues.
High temperature: Increases metabolic rate/cellular respiration which process evolve carbondioxide. This lowers blood pH. This decreases affinity of Hb for oxygen.

Low oxygen concentration in blood: A small drop in oxygen partial pressure will bring about a comparably large fall in the percentage saturation of Hb for oxygen. When tissues utilize oxygen at a faster rate, oxygen tension falls since much has been utilized by tissues, the haemoglobin responds by giving up more of its oxygen. thus the ODC shifts to the right and downward.

Question 14.

(a).What is meant by positive feedback? *(05 marks)*

(b).Explain positive feedback mechanism during;

(i).Reduction of blood pressure when a person loses substantial amount of blood *(05 marks)*

(ii).Activation of pepsinogen *(05 marks)*

(iii).Control of body metabolism after the high critical temperature *(05 marks)*

(a).

Positive feedback refers to a physiological process whereby initial deviation from the norm of a given homeostatic parameter triggers a further increase in deviation. Usually occurs in period of emergency processes in organisms; and is aimed at driving the process to completion. Under normal homeostasis, if negative feedback control mechanism breaks down say due to impairment of detecting organ, then positive feedback results eg in the case of type 1 diabetes in man; when blood sugar rises above the norm; pancreas does not detect the rise; thus the rise in sugar levels continue rising beyond the norm.

(b)(i).

Upon severe blood loss, blood pressure drops and blood cells including heart cell receive less oxygen and functions less efficiently. If the blood loss continues, the heart receives less blood; the pumping action reduces further and blood pressure continues to fall leading to death if no medical intervention.

(b)(ii).

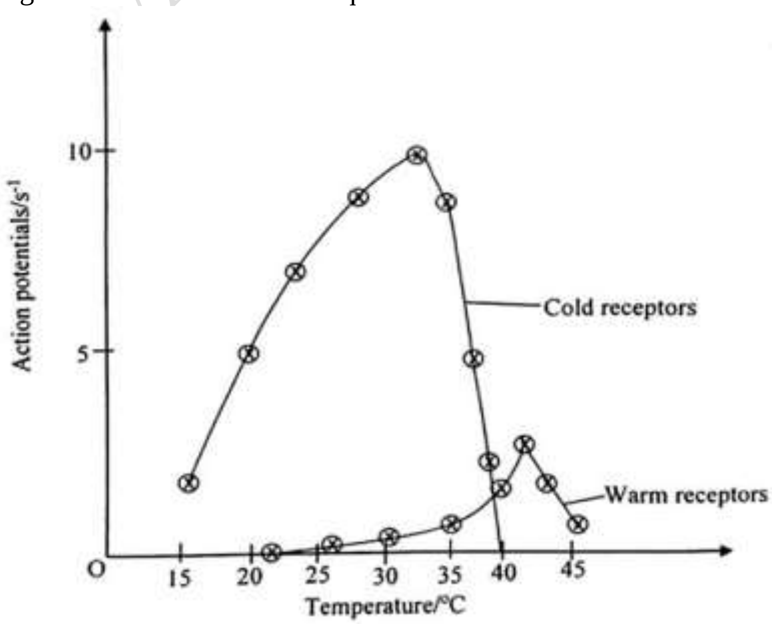
Pepsinogen is partially activated by HCI to pepsin. which then activates the remaining pepsinogen.

(b)(iii).

Once the high critical temperature is exceeded, the metabolic rate starts to rise and continues to rise as long as the ambient temperature continues to rise, chemical reactions in the body double their rate for every 10ºC rise in ambient temperature generating more heat which raises the metabolic rate further. This is repeated until hyperthermia occurs.

Subtopic I; Thermoregulation in living organisms

An experiment was conducted to measure action potentials generated by cold and warm receptors found in the skin of a mammal. Study the figure below and answer the questions that follow.



(a).Describe the response of the receptors with change in temperature

(i). Cold receptors ***(05 marks)***

From 15ºC to 23ºC, increase in temperature cause a rapid increase in action potentials; From 23ºC to 33ºC; increase in temperature causes gradual increase in action potential up a maximum of 10 action potentials per second. From 33ºC to 35ºC, there is a gradual decrease in action potentials. From 35ºC to 40ºC, further increase in temperature causes a rapid decrease in action potentials; up to a minimum of 0 action potentials per second.

(ii).Warm receptors ***(04 marks)***

Initially at 21ºC, the action potential is zero. From 21ºC to 35ºC; the increase in temperature causes gradual increase in action potentials. From 35ºC to 42ºC; increase in temperature causes rapid increase in action potential up to a maximum. From 42ºC to 46ºC; increase in temperature cause a rapid decrease in action potentials to a minimum of 1action potential per second.

(b).Explain the response of the receptors to changing temperature

(i). Cold receptors ***(08 marks)***

Between 15ºC to 23ºC, increase in temperature (stimulus) increases the number of action potentials fired; because many cold receptors are stimulated as they have a low threshold value; many enzymes are activated and there is faster diffusion. Between 23ºC to 32ºC, increase in temperature (stimulus intensity) increases number of action potentials gradually because some of the receptors are adapted; thus few ones firing off action potentials. Between 32ºC, there is decrease in the number of action potentials generated. Action potential generation is an enzyme controlled reaction; the optimum temperature for enzymes in the cold receptors is around 32ºC; beyond which the enzymes are denatured; thus the gradual decrease occurs as few receptor enzymes are denatured. Beyond 35ºC, more receptor enzymes are denatured; thus a rapid decrease in the number of action potentials fired.

(ii)Warm receptors ***(08 marks)***

Between 20ºC to 35ºC, there is a gradual increase in the number of action potentials by the warm receptors because few receptors are stimulated; as their threshold is high. Between 35ºC to 42ºC, the rapid increase in action potentials is due to increase in temperature which activates more enzymes; thus increasing diffusion of ions. Beyond 42ºC, the optimum temperature for warm receptor enzymes is exceeded; the number of action potentials decreases due to denaturation of enzymes.

(c).Suggest how the response of the receptors would vary with changing temperature if;

(i). The organism was sprayed with water before the experiment ***(05 marks)***

In both receptors, initially no action potentials would be fired because temperature is below threshold as temperature increases; water on the surface of the organism evaporates cooling the animal. Once water completely evaporates, the body would gain heat; and both receptors are stimulated. Eventually both receptors would get adapted. Cold receptors get easily adapted; than warm receptors.

(ii).The organism was given iced water before the experiment ***(04 marks)***

Pattern of action potentials would be the same; as in the graph; iced water has no effect on both receptors since they are found on the skin. Iced water only affects thermoreceptors in the hypothalamus.

(d).Outline the responses of mammals towards increasing environmental temperature ***(04 marks)***

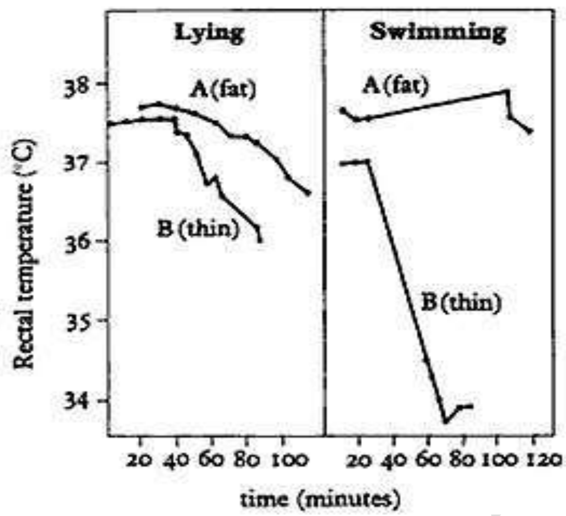
Physiological responses	Behavioural responses
• Sweating/ panting • Relaxation of erector pili muscles/ falling of hairs. • Vasodilation • Reduction in metabolic rate • Increase in body surface area (lying stretched out) • Decreased muscular activity	• Desire to consume cold food/ drinks • Cold bath/ swimming • Aestivation

(e).State the advantages of endotherms over ectotherms ***(05 marks)***

• Enzyme controlled reactions proceed more efficiently since an optimum temperature is provided.
• Metabolic rate is higher and allows greater activity and faster response to stimuli.
• Can live in a wide range of temperatures; hence can live in a wide range of habitats**;**
• Can move long distances**;**
• Can easily obtain food since they are always active**;**
• Young ones have higher survival rate since they are born active**;**

Question 2.

Figure 1 below shows the results of an experiment on the body temperature of two human subjects, A and B.A is fat whereas B is thin, both subjects had their body temperature recorded at intervals while immersed in water at C. Results obtained first with the subjects lying still, and then while the subjects were swimming.



(a)(i).From the figure above, state any two factors that affect body's ability to regulate body temperature of an individual. ***(02 marks)***

• Thickness of the body's subcutaneous fat/ body surface area to volume ratio

• Body activity/ dynamic exercise of the subject in cold water.

(ii).Describe the effect of change in each of the factors above on the rectal temperature

Effect of thickness of subcutaneous body fat in subjects;

Lying stationary in cold water

Thick subcutaneous fat of a fatty subject lying in cold water generally result in a gradual decrease in rectal temperature as time increases. Thin subcutaneous fat of a thin subject lying in cold water generally result in rapid decrease in rectal temperature as time increases

Swimming in cold water

Thick subcutaneous fat of a fatty subject swimming in cold water generally results in a gradual increase in rectal temperature as time increases. Thin subcutaneous fat of a thin subject swimming in cold water generally results in a rapid decrease in rectal temperature as time increases.

Effect of body activity/dynamic exercise in cold water on the rectal temperature of

Fatty subjects

Lying of a fatty subject in cold water generally results in gradual decrease in rectal temperature as time increases. Swimming of a fatty subject in cold water generally results in a gradual increase in rectal temperature as time increases;

Thin subjects

Lying of a thin subject in cold water generally results in gradual decrease in rectal temperature as time increases. Swimming of thin subject in cold water generally results in rapid decrease in rectal temperature as time increases;

(iii).Give an explanation for the results described in a (ii) above. ***(15 marks)***

Subjects lying in cold water are subjected to a constant temperature gradient; and thermal insulation predominantly depends on thickness of the subcutaneous fat layer; A fatty subject, due to small surface area to volume ratio is conferred greater insulation against heat loss; has lower thermal conductivity from the skin & other subcutaneous tissues; conductive heat loss from the body thus occurs at a slower rate; accounting for the gradual decrease in rectal temperature. Thin subjects lying in cold water due their large surface area to volume ratio; are offered minimal insulation against heat loss; lose heat at a faster rate; accounting for the rapid decrease in their rectal temperature; Swimming subjects are subjected to an increasing temperature gradient; sufficient thermoregulation is thus achieved by both the insulative effect of the subcutaneous fat layer and intrinsic heat production; Swimming is associated with a raised metabolic rate; and hence increased heat production; Such heat production augments the insulative effect of the subcutaneous fat in a swimming fatty subject and this exceeds conductive heat loss causing a general gradual rise in rectal temperature when the subject is swimming. For a swimming thin subject, conductive heat loss far much exceeds heat conserved by insulation and that generated intrinsically through raised metabolism; rectal temperature thus generally decreases rapidly;

(b).Explain;

(i).Why rectal temperature and not skin temperature was used in the experiment ***(04 marks)***

Rectum, unlike the skin, is very highly vascular; and provides the most closed cavity; that limits heat exchanges between the body and the surrounding; thus provide the most accurate measurement of body temperature approximating the core body temperatures; Skin temperature, unlike rectal temperature significantly varies in different parts of the body;

(ii).The effect of increasing water temperature to 25ºC ***(03 marks)***

Increasing water temperature to 25ºC proportionally slows down the rate of reduction in rectal temperature of both subjects; Increasing water temperature to 25ºC reduces the temperature gradient between the body and the surrounding water; The surrounding temperature being still lower than the body temperature prompts heat loss to the surrounding but at a slower rate;

(iii)Why prolonged exposure to severe cold of the living cell at the tips of the finger may die? ***(02 marks)***

Finger tips, due to their large surface area to volume ratio and poor thermal insulation; are subjected to extensive heat loss once exposed to severe cold; Compensatory onset of vasoconstriction slows down flow of warm blood from the core of the body to the finger tips; and prolonged exposure to cold eventually leads to formation of ice crystals in tissues; that cause cellular damage and death (frost bite injuries);

(c).State the structural and physiological changes that occurred in the body of the thin human throughout the time of experiment. ***(04 marks)***

Structural changes	Physiological changes
• Erection of the skin hairs.	• Cutaneous vasoconstriction • Shivering thermogenesis • Dilation of the shunt vessels • Contraction of the erector pilli muscles/ piloerection • Elevated basal metabolic rate • Decrease in body surface area (huddling) • Increased muscular activity • Inhibition of sweating

(d).How can thin bodied organisms survive in conditions of low temperature? ***(03 marks)***

• Insulative acclimatization through development of fur or subcutaneous fat.
• Metabolic adjustments such as long term increase in basal metabolism, brown fat metabolism
• Habituative adaptations such as long term change in blood flow patterns inform of persistent superficial vasoconstriction.
• Behavioural acclimatization inform of seasonal migration, hibernation, sun bathing, basking, burrowing in warm areas etc.

Question 3.

Heat losses (-) and gains (+) were monitored and recorded, of a naked human being at varying environmental temperatures. The heat losses and gains by the internal body environment (body core) heat losses and gains by the skin surface as a result of radiation and convection and also heat losses as a result of evaporation, with varying environmental temperature, are show in figure 1 below

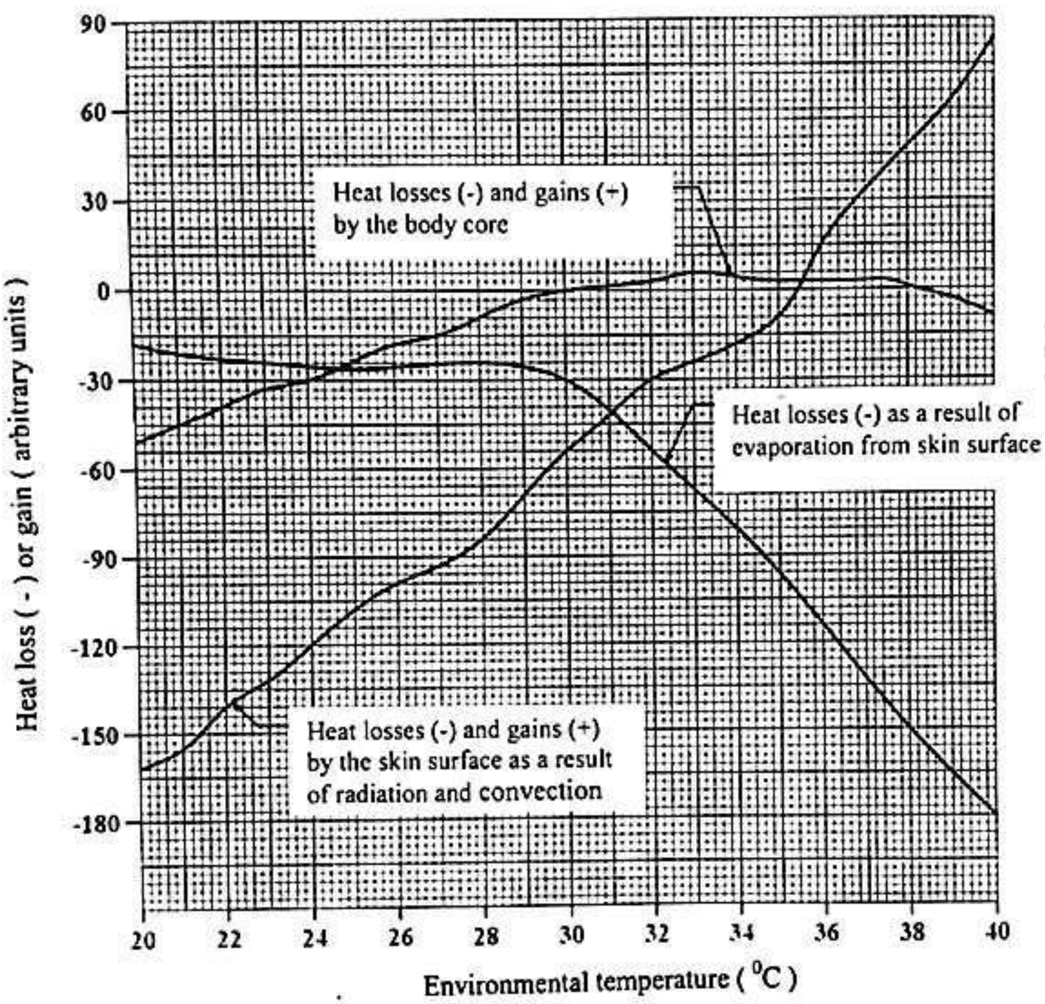


Fig. 1

(a).Describe the relationship between the heat loss and gain by the skin surface as a result of radiation and convection and heat loss as a result of evaporation from the skin ***(04 marks)***

(b).How does the relationship in (a) above affect the losses and gains of heat by the core body ***(03 marks)***

(c).Explain the trend of heat losses and gains by the

(i).Skin surface as a result of radiation and convection ***(10 marks)***

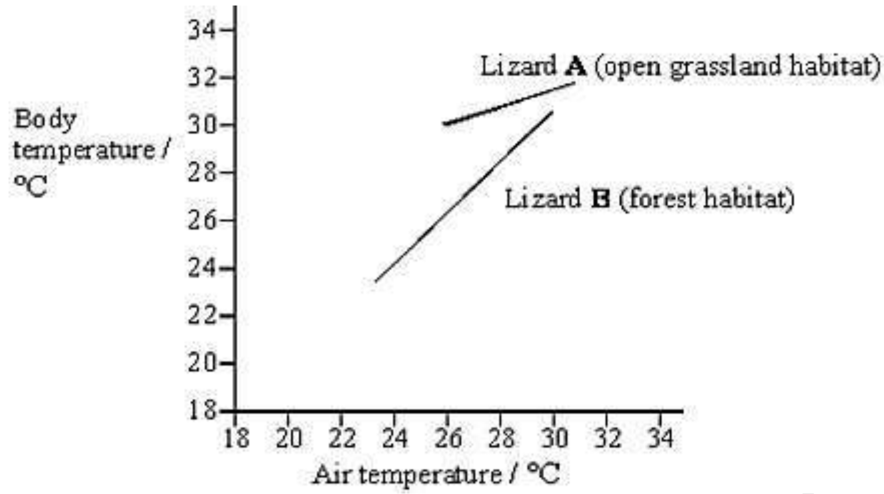
(ii)Skin surface as a result of evaporation ***(08 marks)***

(iii)body core ***(12 marks)***

(d).What is the importance of maintaining body temperature in animals ***(03 marks)***

Question 4.

The graph shows results of an investigation into the relationship between air temperature and body temperature for two lizards living in different habitats. The investigation took place on a hot sunny day over a period of four hours



(a) Explain the relationship between the air temperature and the body temperature for lizard B.
At low air temperature, body temperature is low. Increase in air temperature causes a rapid rise in body temperature since lizard B is an ectotherm; does not metabolically regulate body temperature; but instead is dependent on external air temperature. It thermodynamically gains heat from rising air temperature causing rise in its body temperature.

(b).Suggest an explanation for the different pattern shown by lizard A.
Increase in air temperature causes a slight rise in body temperature; Body temperature of lizard A is higher than of lizard B since lizard A is partly endothemic. In addition to the slight gain of heat from the rising air temperature of the surrounding it also metabolically regulates its body temperature.

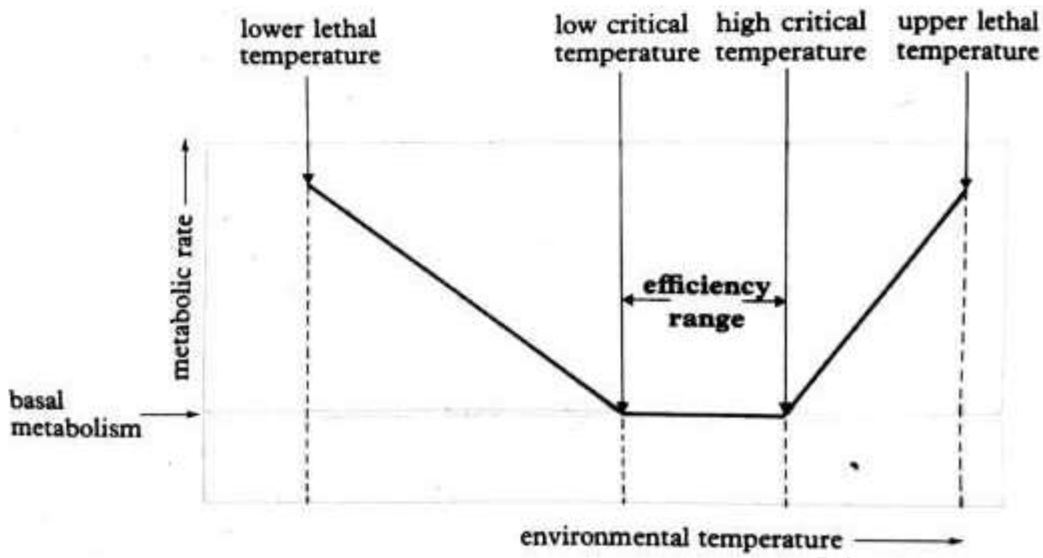
(c) Lizard B moves more slowly when its body temperature is 24°C than when it is 28°C. Explain what causes the slower movements at the lower temperature.
At lower temperature, body temperature is also low; thus low rate of body metabolism since low body temperatures renders body enzymes involved in metabolism inactive.

(d) Discuss the physiological adaptations of a camel to survive in desert environment
- Growth of longer loops of Henle; increase surface for absorption of much water from glomerular filtrate
- Less water is filtered out across the fewer nephrons in their kidney
- Developing body tissues tolerant to dehydration; thus can take long periods without drinking water
- Use metabolic water from oxidation of food reserves/ fats in their humps.
- Has high urea concentration in blood; which aids reabsorption of water across the kidney tubules.
- Developing water-proof integument; to prevent evaporation through the skin
- Growth of dense hairs in nostrils; to prevent water loss by evaporation in breath
- Development of heat tolerant tissues; which can withstand high body temperature.
- Growth of scanty fur and depositing little fat under the skin; to reduce insulation against heat loss

Essay questions

Question 1.

(a).Differentiate between the following
(i). Low critical temperature and high critical temperature *(03 marks)*
(ii).Lower lethal temperature and higher lethal temperature *(03 marks)*
(iii)Hyperthermia and hypothermia *(02 marks)*
(b).Briefly describe thermoregulation in;
(i). Endotherms *(05 marks)*
(ii).Ectotherms *(05 marks)*
(c).Outline the roles of thermoregulation in living organisms *(02 marks)*



(a)(i).

Low critical temperature is the low temperature below which physical mechanisms of heat generation such as vasoconstriction and erection of hairs can no longer regulate the body temperature triggering a rise in metabolic rate to maintain temperature constant while high critical temperature is the highest temperature above which physical mechanisms of cooling can no longer regulate body temperature.

(a)(ii).

Lower lethal temperature is the extremely low temperature at which metabolic mechanisms of heat generation break down and lose ability to regulate the body temperature; and in such a case the victim dies of cold intolerance and hypothermia while upper lethal temperature is the extremely high environmental temperature at which the excessively generated heat from the risen metabolism can no longer be counteracted by the body's mechanism of cooling and here the subject dies of heat intolerance and hyperthermia.

(a)(iii).

In hyperthermia, the body's core temperature rises above 41^oC whereas in hypothermia, the body core temperature falls below 32^oC

(b)(i).

Endotherms generate heat from within the body and thus the body temperature is independent of the changes in the environmental temperatures. Endotherms rely entirely on physiological means rather than behavioural means. Behavioural responses to cold include covering in warm materials e.g heavy clothes, taking warm drinks or food and orientation of the body into the sun; whereas behavioural response to the hot include withdrawal from the sun, shade resting, swimming, taking a cold bath or cold drink/food. Physiological responses to the cold include; increased metabolic rate, vasoconstriction of the skin vessels, contraction of erector pilli muscles with raising of skin hairs), shivering thermogenesis, reduced sweating and development of thick fur and subcutaneous fat. Physiological responses to hot include; skin hairs fall, vasodilation, sweating/ panting, metabolic rate falls and less subcutaneous fat.

(b)(ii).

Ectotherms gain heat from the environment; thus the body temperature varies directly with changes in the environmental temperature. Ectotherms thus predominantly rely on behavioural means of thermoregulation. Behavioural responses to cold include; varying their relative positions to the sun, thermogapping, basking, migration to hotter areas and hibernation. Behavioural responses to hot include; burrowing, migration to cooler areas, thermodancing, thermo salivation, aestivation and eye bulging.

(c).

- Thermoregulation maintains optimum temperature for enzyme activity
- Ensures environment independence.
- Ensures efficient response to stimuli.

Question 2.

(a).Explain the necessity of thermoregulation in living organisms ***03 marks)***

(b).State the advantages and disadvantages of;

(i). Endothermy ***(06 marks)***

(ii).Ectothermy ***(03 marks)***

(c).Describe the role of the brain in thermoregulation ***(08 marks)***

(a).

Most body enzymes act efficiently within a narrow temperature range of 35–38°C. Excessive temperature exceeding 45°C denatures enzymes and other proteins and below that range inactivates enzymes, both of which are fatal. Excessively high or too low temperature disorganizes the structure and functioning of cell surface membranes, and consequently affects entry and exit of substances resulting into death of the organism.

(b)(i).

Advantages of endothermy

• Animals are able to exploit various environments regardless of the existing temperatures.
• Enzyme controlled reactions proceed more efficiently since an optimum temperature is provided.
• Metabolic rate is higher and allows greater activity and faster response to stimuli.

Disadvantages of endothermy

• Hgh food intake during low environmental temperatures to support the metabolic reactions that liberate heat.
• There is need to depend on foods of high calorific values such as fats for both energy production and insulation; which is a variant between individuals.
• Enzyme controlled reactions are slowed during low temperature because enzymes become inactive.
• It requires efficient cooling mechanisms during hot temperatures to avoid overheating of the body, and efficient insulation when the external temperature is too low.

(b)(ii).

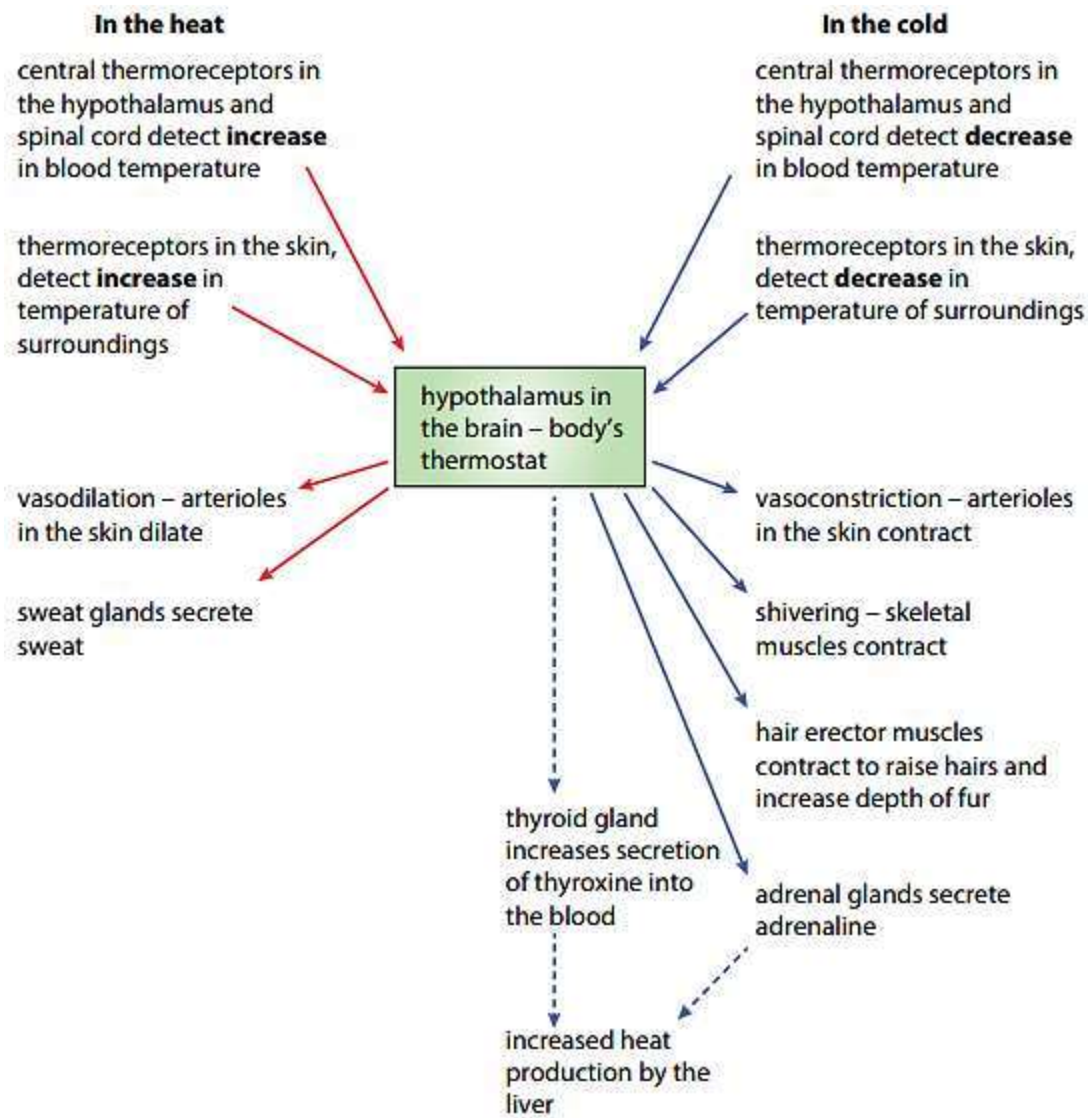
Advantages of ectothermy

• There is low food intake since regulation is by behavioural means and from the environment.
• They keep their internal temperature relatively constant by behavioural means.

Disadvantages of ectothermy

• Dependence on external temperature limits activity of these organisms.
• Their activities are limited during instances of extreme temperatures.
• Organisms exploit a narrow range of environments limiting migrations.
• Low metabolic rates means low response to stimuli and activity especially with decreasing temperatures.

(c).



The thermoregulatory centre in the hypothalamus of the brain is responsible for temperature regulation in the body. Variation in body temperature is directly monitored by heat receptors in the hypothalamus and indirectly by receptors in the skin. Receptors in the skin monitor variation of external temperature. If the temperature of blood flowing through the hypothalamus drops, the heat gain centre is stimulated to send impulses to the liver and muscles to raise metabolic rate so as to generate heat, and to the skin to cause vasoconstriction to reduce heat loss at the skin surface, reduction in sweat production, contraction of erector pili muscle and shivering. The overall result is increased body temperature to normal. If the temperature of blood flowing through the hypothalamus rises, the heat loss centre is stimulated to send impulses to the skin to cause vasodilation to enable more heat loss at the skin surface, increased sweat production to enable more evaporation, relaxation of erector pili muscles to lower the hairs to avoid air insulation, and to inhibit shivering to minimize heat production by metabolic reactions.

Question 3.

(a).Explain what is meant by the term efficiency range in thermoregulation ***(04 marks)***

(b).State the adaptations of living organisms to extremes of low temperature ***(11 marks)***

(c).Outline the functions of the skin in living organisms ***(05 marks)***

(a)

Efficiency range also known as the thermoneutral zone is external temperature range at which the body's physical mechanisms are capable of maintaining temperature constant. In man this is 27 to 31^{o}C. It varies according to the environmental temperature in which the animal inhabits because animals have the ability to acclimatize. If the environmental temperature is high, acclimatization is by raising the upper critical temperature and if low, acclimatization is by lowering lower critical temperature.

(b).

• Possession of thick fur/hair for trapping a layer of air that insulates the body against heat loss.
• Possession of thick layer of subcutaneous fat for insulation against heat loss
• Development of countercurrent heat exchange systems in limbs to enable heat conservation.
• Small sized animals hibernate e.g. bats, dormice, hamsters, hedgehogs, and rodents like mice.
• Brown fat is conserved and used up rapidly at the end of hibernation to quickly raise the metabolic heat
• Some animals migrate to warmer places e.g. birds like swallows.
• Small body extremities to reduce the surface area over which heat is lost
• Large sized; thus small surface area to volume ratio; reducing amount of heat lost to the surrounding
• Tissues tolerant to extreme changes in temperature; maintaining their normal functions in the body
• Enzymes work under a high optimum temperature range to maintain metabolism during day and night
• Gathering in groups to warm themselves e.g penguins

(c).

• It is the major organ involved in temperature regulation in the body.
• It provides protection against mechanical damage, radiations, microorganism invasion & water loss of underlying tissues.
• It is a sense organ, containing sensory nerve endings for detecting temperature, touch, pressure and pain.
• It is an excretory organ of urea, salt and excess water.
• It manufactures vitamin D when exposed to sun light. The dermis contains lipids called sterols which are converted by ultraviolet light into vitamin D.

Question 4.

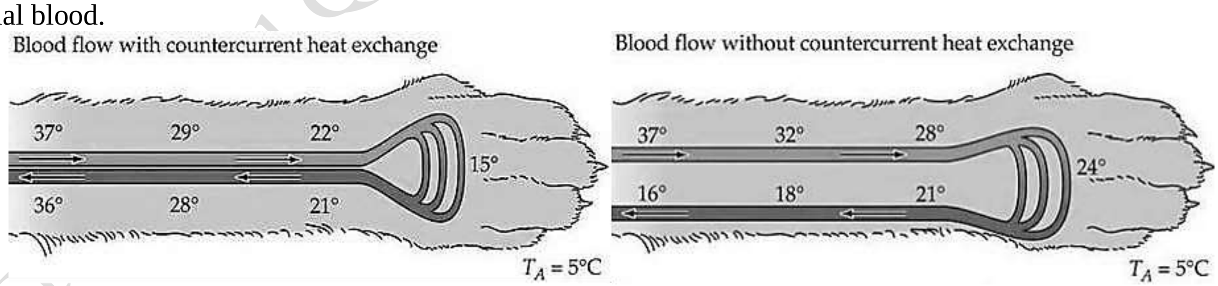
(a)Explain what is meant by counter current heat exchange system *(02 marks)*
(b)Describe how counter current heat exchange occurs in a lower limb of an organism *(04 marks)*
(c).How do plants avoid over-heating and over cooling in different environments *(07 marks)*
(d).Explain how heat can be gained and lost by a living organism *(09 marks)*

(a).

Countercurrent heat exchange system is heat conservation in limbs where there is effective heat transfer at all levels to the periphery of the limb, by conduction from the incoming warmer arterial blood to the outgoing colder venous blood.

(b).

The artery and the vein are in a close proximity and do run parallel to each other. At each level, heat energy is transferred from the artery to the vein such that by the time venous blood exits the limb, it is almost as warm as the arterial blood.



(c).

Plants avoid overheating by

• Transpiration; as the water evaporates into the atmosphere, plant bodies cool down.
• Wilting; parenchyma cells lose turgidity and drop to reduce the surface area of leaves and stems exposed to the sun, hence avoiding much heat gain.
• Possession of shiny cuticle on leaves to reflect heat (sun‘s radiation) and avoid overheating.
• Possession of small needle-like leaves in some plants also reduces excessive heat gain from the sun‘s rays.

Plants avoid overcooling by

• Producing spores or seeds, which are very temperature resistant.
• Losing the easily damaged leaves when external temperature is low e.g. during winter in temperate plants.
• Orientating leaves to take maximum advantage of light at any one time so that they do not shade each other.

(d).

Heat is gained as a by-product of metabolism from exothermic reactions. Heat may be gained from or lost to the environment by radiation where energy is transferred in form of electromagnetic waves. Heat may also be gained from or lost to the environment by convection in which heat is transferred by currents in air or water. Heat may be gained from or lost to the environment by conduction where heat is transferred by the collisions of molecules. Conduction is particularly important between organisms and the ground or water, since air does not conduct heat well. Heat is lost by the evaporation of water from body during sweating and from body surfaces like mouth and respiratory surface of land dwelling animals.

Question 5.

(a).State different mechanisms utilized by homeotherms in cold environment to regulate body temperature
(b).Explain the challenges associated with maintenance of a constant high body temperature in mammals
(c).Explain why prolonged exposure to coldness is frequently fatal ***(05 marks)***
(c)(ii).Explain the occurrence of symptoms of fever accompanied by shivering and chills in terms of the mechanism of control of body temperature ***(03 marks)***

(a).

Short term mechanisms
• Cutaneous vasoconstriction; limit superficial blood flow and hence minimizing heat loss.
• Shivering thermogenesis; permit intrinsic generation of heat
• Dilation of the shunt vessels; diverts blood from the body extremities.
• Elevated basal metabolic rate; generates heat to compensate for the heat lost.
• Contraction of the erector pilli muscles/ piloerection; cause erection of the skin hairs; trap an insulative air layer
• Behavioural mechanisms like taking warm food/ drink, putting on heat conserving wears like jackets.

Long term adjustments
• Insulative acclimatization through development of thick fur or subcutaneous fat.
• Metabolic adjustments such as long term increase in basal metabolism and brown fat metabolism
• Habituative adaptations such as the long term change in the blood flow patterns inform of persistent superficial vasoconstriction
• Behavioural acclimatization inform of seasonal migration, hibernation, sun bathing, basking, burrowing in warm areas etc.

(b).

• Slowed enzyme controlled reactions because of enzyme denaturation
• Dependence on an efficient cooling mechanism; which puts the organisms at risk of dehydration.
• Greater food requirement to support the high metabolic rate that liberates heat.
• Dependence on foods of high calorific values such as fats which are a variant among individuals.
• High energy expenditure to maintain high body temperature puts the organism at risk of starvation.

(c)(i).

Prolonged exposure to coldness results in massive inactivation of enzymes; thereby grossly lowering down the body's metabolic rate to levels that are life incompatible. Besides, the extensive heat loss that occurs more from the extremities results in a compensatory onset of vasoconstriction which slows down flow of warm blood from the core of the body to the body extremities and eventually leading to formation of ice crystals in tissue that cause cellular damage and death (frost bite injuries);

(c)(ii).

Fever is due to resetting of the thermostat‖ at a higher temperature. Until the core body temperature rises to that temperature, the normal body temperature is too low and the body reacts as if it has been cooled. In these conditions, the body responds by shivering and body continues to feel cold until the core temperature reaches the temperature of the thermostat in the hypothalamus.

Question 6.

Endotherms respond to excessive environmental heat by panting while others do so by sweating

(a).State the advantages of panting over sweating *(04 marks)*
(b).Explain why panting can result in the following conditions
(i). Excessive alkalinity of blood *(03 marks)*
(ii).increased heat production *(03 marks)*
(c).How are organisms adapted to survive in areas of extremes of cold *(10 marks)*
(d).Suggest why a person with a dry skin in a hot environment might be in danger? *(03 marks)*

(a).

• Faster cooling of the head and its constituent organs like the brain
• Relatively less water is lost; reduce risks of dehydration
• Not associated with salt loss; reduce risks of electrolyte/ ionic imbalances in the body.
• Panting is not affected much by environmental conditions eg relative humidity.

(b)(i).

Panting is associated with increased ventilation rate; results in greater loss of carbondioxide; raising the blood pH.

(b)(ii).

Panting is associated with increased muscle contraction which generates more heat and adds to the heat load of the body.

(b)(ii).

• Having tissues that are tolerant to large temperature fluctuations between day and night e.g. the camel
• Bodies are thinly insulated with fat to increase heat loss.
• Some animals aestivate e.g African lungfish burrows into mud till the dry season ends.
• Large body extremities e.g ear lobes; to increase surface area over which heat is lost.
• Small sized; to increase the surface area to volume ratio, for heat loss
• Some animals like the camel, have long skinny non-fatty legs to increase heat loss during locomotion
• Little or no fur to reduce on insulation, and increase amount of heat lost
• Enzymes work under a high optimum temperature range to maintain metabolism during day and night.
• Most are nocturnal, i.e most active at night, when temperatures are relatively low
• Movement with some body parts raised to minimize direct contact with hot grounds e.g desert snakes
• Salivation of the neck and legs; increasing heat loss by evaporation e.g in tortoise

(d).

A dry skin in hot weather may indicate that there is a breakdown in the thermoregulatory mechanism because of a disrupted sweating mechanism. The buildup of heat in the body may denature proteins in the body; an event that is fatal.

Question 7.

(a)(i).Explain what is meant by shunting *(01 marks)*
(a)(ii).Why is shunting important in thermoregulation *(04 marks)*
(b).Why is the camel a superbly adapted animal to hot dry climate? *(08 marks)*
(c).Compare the functions of the heat loss and heat gain centres of the hypothalamus *(07 marks)*

(a)(i).

Shunting is the diversion of blood from one region of the body to another.

(a)(ii).

Blood is shunted to the surface so that heat can be radiated away from the body when the body becomes too hot. During cold, blood remains confined in the deeper layers, insulated by fat, when the body needs to retain heat.

(b).

• Possession of tissues tolerant to large temperature fluctuations between the day and night
• Loses heat be conduction, radiation and convection at night; optimizing heat loss by evaporation.
• Possession of fur which is an efficient insulating barrier; reducing heat gain as well as water loss.
• Has tissues tolerate to dehydration; in excesses of temperature rise; limits fall in blood volume
• Ability to maintain hydration state using metabolic water from oxidation of fat in the hump.
• Possession of long skinny non-fatty legs to increase heat loss during locomotion
• Ability to sweat at higher temperature i.e it begins sweating at 41^{o}C contrary to the normal 34^{o}C.
• Drinks vast volumes of water in short time; enable rehydration of tissues after a long period of severe dehydration.

(c).

Heat loss centre	Heat gain centre
Situated in the anterior hypothalamus	Situated in the posterior hypothalamus
Activated by increase in temperature of the hypothalamus	Activated by nerve impulses from cold receptors in skin or decrease in temperature of hypothalamus
Increases vasodilation	Increases vasoconstriction
Increases heat loss from the skin by radiation, convection and conduction	Decreases heat loss from the skin by radiation, convection and conduction
Increases sweating and panting	Decreases sweating and panting
Decreases metabolic activity	Increases metabolic activity
Relaxes erector pili muscles/ flattening hair	Contracts erector pili muscles/ erects the skin hairs.

Question 8.

(a).What advantages do endotherms have over ectotherms? *(03 marks)*

(b) Explain the body responses of endotherms to cold environmental conditions. *(08 marks)*

(c) Describe the role of the following in temperature regulation.

(i). Thermoreceptors. *(04 marks)*

(ii) Hypothalamus. *(05 marks)*

(a).

• Enzyme controlled reactions proceed more efficiently since an optimum temperature is provided.
• Metabolic rate is higher and allows greater activity and faster response to stimuli.
• Can live in a wide range of temperatures; hence can live in a wide range of habitats**;**
• Can move long distances**;**
• Can easily obtain food since they are always active**;**
• Young ones have higher survival rate since they are born active**;**

(b).

• Metabolic rate increases; generating more heat;
• Hairs stand erect; trap a layer of air; which insulates the skin;
• Skeletal muscles contract/shivering occurs; generating more heat;
• Sweating ceases; reducing heat loss; through evaporation;
• Decrease in body surface area/huddling; reduces heat loss;
• Skin arterioles vasoconstrict; less blood flows near skin surface reducing heat loss by convection or radiation or conduction;

(c)(i).

Thermoreceptors in the skin; detect temperature changes; Cold thermoreceptors detect decrease in temperature & heat/hot thermoreceptors detect increase in temperature; Thermoreceptors are connected to the brain by nerves; & therefore send impulses to the brain/control centre about changes in skin temperature; and the control centre sends stimulate appropriate corrective measures; to return the temperature back to norm;

(ii).

The hypothalamus in the brain; detects changes in temperature of blood passing through the brain; When temperature increases above norm stimulates the heat loss centre; in the (anterior) hypothalamus that stimulates corrective measures; to decrease temperature back to norm; Decrease in temperature of blood flowing through the brain below norm stimulates the heat gain centre; in the (posterior) hypothalamus; which stimulates corrective mechanisms that increase heat gain; to raise temperature back to norm;

Subtopic II Excretion and Osmoregulation

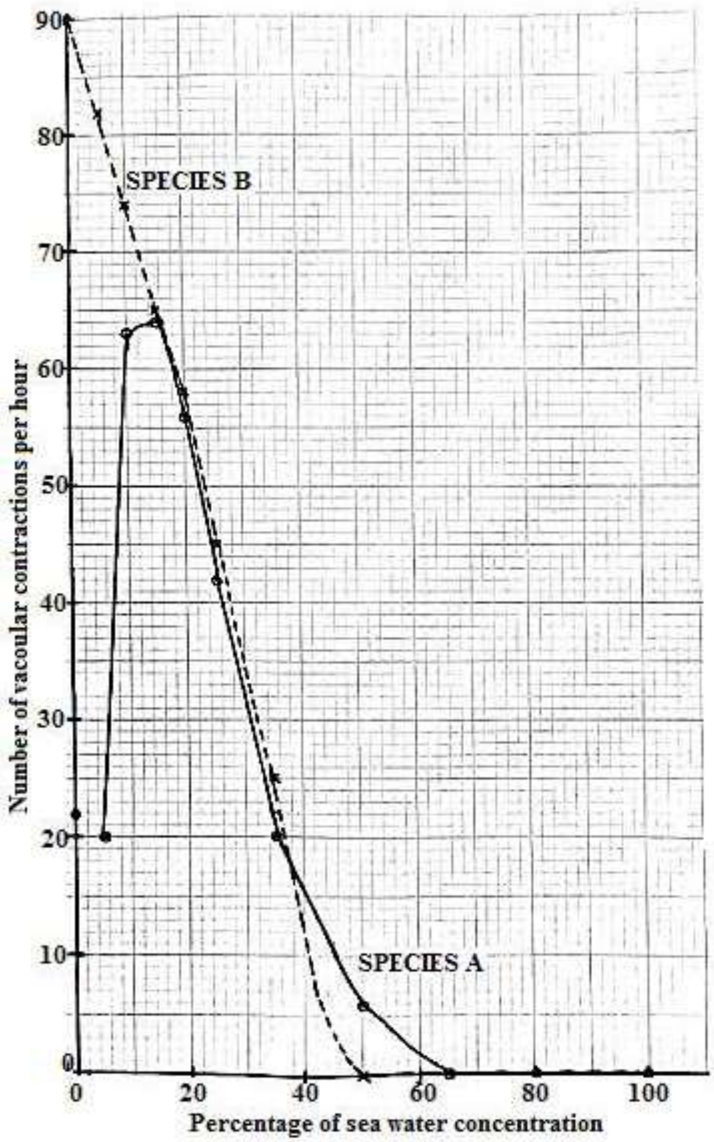
In an experiment, two species of protozoan A and B were exposed to dilutions of sea water for one hour and the number of vacuolar contractions counted. The following results were obtained.

Concentration of sea water (%)	Number of vacuolar contractions per hour	
	Species A	**Species B**
100	0	0

80	0	0
65	0	0
50	6	0
35	20	25
25	42	45
20	56	58
15	64	65
10	63	74
5	20	82
0	22	90

(a).Represent the information above on the same axes ***(10 marks)***

<u>A graph showing the relationship between concentration of sea water and the number of vacuolar contractions per hour of two protozoan species A and B.</u>



(b).Account for the effect of concentration of sea water on the vacuolar contractions per hour in the two different species

(i).Species A ***(20 marks)***

From 100%-65%, sea water concentration, there is no vacuolar contraction; This is due to a higher external osmotic pressure beyond that of internal hence water molecules move out of the protozoa/ vacuoles by osmosis. Further dilution of sea water from 65% to 35%, cause a gradual increase in the number of vacuoles contracting resulting from a higher Opi than the Ope; hence small quantities of water enter the protozoa/ vacuoles by osmosis. From 35 % to 15% sea water concentration, there is a rapid increase in the number of vacuolar contractions due to a rapid decrease in the Ope; and rapid increase in the Opi causing large amount of water to enter the protozoa/ vacuoles by osmosis. Beyond 15% up to 10% sea water concentration; vacuolar contraction gradually decreases because of active extrusion of little salt; by the protozoa lowering Opi; hence reducing the amount of water that enters the protozoa/ vacuole by osmosis: From 10%-5% sea water concentration; vacuolar contraction per hour decreases rapidly; This is due to much salt being actively expelled by protozoa; lowering Opi more rapidly below Ope such that much water leaves protozoa/vacuoles by osmosis; Also concentration gradient between seawater and protozoa reduces rapidly; to reduce amount of water entering protozoa/ vacuoles by osmosis; From 5% to 0% seawater concentration; there is a slight increase in vacuolar contraction; as Ope has reduced to minimum below Opi; hence water enters the protozoa/vacuoles by osmosis again;

(ii). Species B ***(04 marks)***

From 100 to 50% dilution of sea water; there is no vacuolar contraction/ zero vacuolar contraction; since the Opi is lower than that external; Hence water molecules flow out of protozoa/vacuoles by osmosis: Decreasing the dilution of sea water from 50% to 0% rapidly increases the vacuolar contractions of species B because of large amounts of water entering the protozoa by osmosis due to a rapidly decreasing Ope below the internal.

(c).State one advantage species A has over species B ***(02 marks)***

Species A can osmoregulate in decreasing osmotic potential external; Hence can survive in both sea and fresh waters above 5% concentration; But species B cannot osmoregulate in decreasing Ope hence cannot survive in fresh waters as it may die at minimum Ope;

(d).Suggest an explanation for what would happen in another experiment where small quantities of mercury were added to 15% sea water concentrations containing the specimens ***(05 marks)***

Mercury is a metabolic poison which inhibits enzyme activity during respiration; leading to an insufficient energy production, hence contraction of vacuoles which requires energy ceases; this kills both species of protozoa.

Question 2.

Two species of amoeba were transferred from their natural habitats to different dilutions of sea water, and each individual was given time to adjust to its new environment. The table below shows data about the rate of vacuolar contractions with varying solute concentrations.

	Number of vacuolar contractions per hour	
Sea water concentration in % (normal sea water = 100%)	***Species A***	***Species B***
5	82	20
10	74	63
15	65	64
20	58	56
30	34	31
40	14	13
50	0	6
60	0	0

(a) Present the results of the experiment graphically.

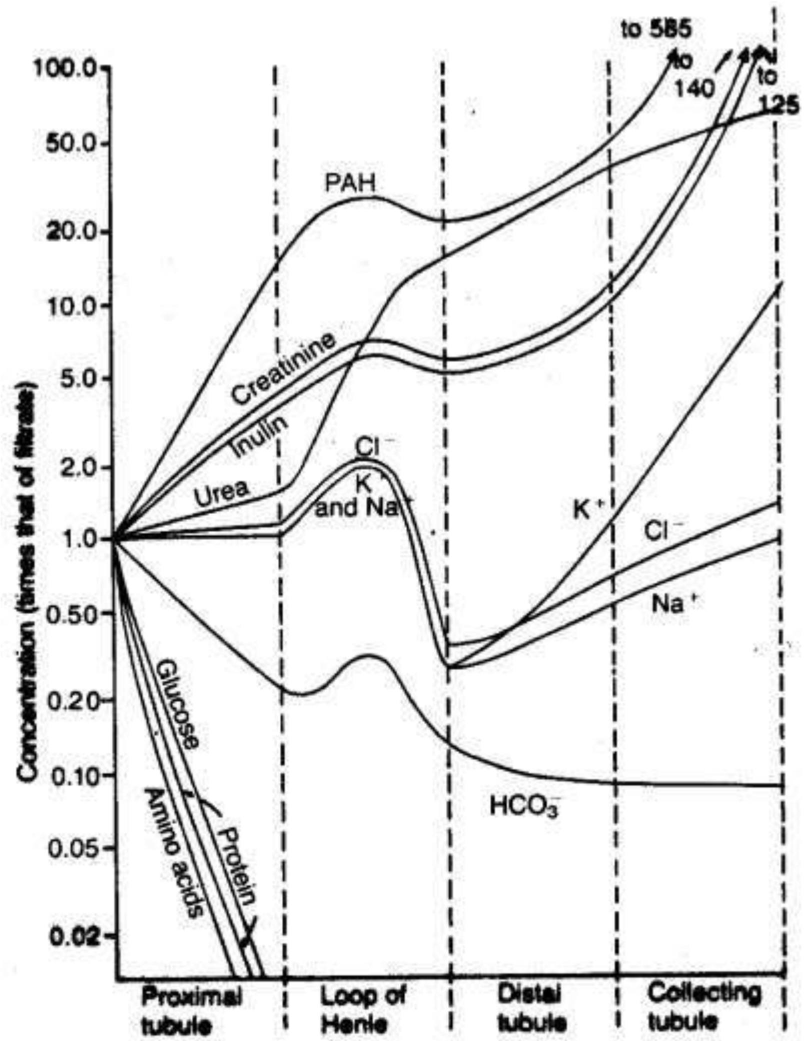
(b) Describe the activity of contractile vacuoles with changes in salinity.

(c) Explain by reference to the data, the difference in vacuolar contraction in the two species of amoeba when placed in the higher concentrations of seawater.

(d) What information may be deduced about the natural habitats of the two species from the rates of vacuolar contractions?

Question 3.

The figure below shows variation in concentration of cations (K^+, Na^+), inorganic anions (HCO_3^-, Cl^-), organic anion (p-aminohippurate-PAH), inulin, (a fructose Polymer), excretory wastes (Urea and creatinine; a product of muscle metabolism derived from creatine phosphate), and metabolites (glucose, amino acids and protein of low molecular weight) along the different regions of the nephron. Inulin is not synthesized, destroyed, or stored in the kidneys.



(a) Explain the concentration of the following along the different regions of the nephron:
(i) Ions
(ii).Metabolites
(iii).Excretory wastes
(b) Explain the:
(i) Absence of cells, immunoglobulins, and large molecular weight proteins in glomerular filtrate.
(ii) Clinical importance of selective filtration of cells, immunoglobulins, and large molecular weight proteins.
(c) Explain why the:
(i) Rate of plasma ultrafiltration in the kidney glomeruli far exceed that in all other capillary beds.
(ii) Proximal tubular fluid is essentially iso-osmotic to plasma.
(d) What is the significance of producing concentrated urine osmotically to a named land dweller?

Question 4.

(a) The table below shows changes in percentage of total excretory material of an amphibian with age.

Age of tadpole or frog(days)	Percentage of total excretory material	
	Ammonia	Urea
50	92	8
55	88	12
65	84	16
75	83	17
90	68	32
95	20	80
100	13	87
110	12	88

(i) Represent the tabulated data graphically *(08 marks)*
(ii) Describe the change in the ammonia percentage of total excretory material. *(05 marks)*
(iii) With a reason, identify the period when the animal leaves water. *(02 marks)*
(iv) Explain the need to change the excretory product on transitioning from water to land. *(06 marks)*
(v) State two structural changes that accompany the change in excretory product. *(01 marks)*

Question 5.

An investigation was carried out to determine the effect of a strong saline solution on the rate and concentration of urine produced by a dog. The experiment begun with the dog first being allowed to drink water to its full. Then minutes later, it was injected with a strong saline solution through the carotid artery. The dog was then monitored closely and the relevant measurements taken. The table below shows the results obtained. The rate of urine production was expressed in cm^3 per minute while the corresponding concentration of the urine produced was expressed in arbitrary units. Study the table and the answer the questions that follow:

Time (minutes)	0	10	20	30	40	50	60
Rate of urine production (cm^3/min)	6.5	7.3	1.0	2.0	3.3	5.0	6.5
Concentration of urine (arbitrary units)	2.0	2.0	8.0	6.0	3.7	2.0	2.0

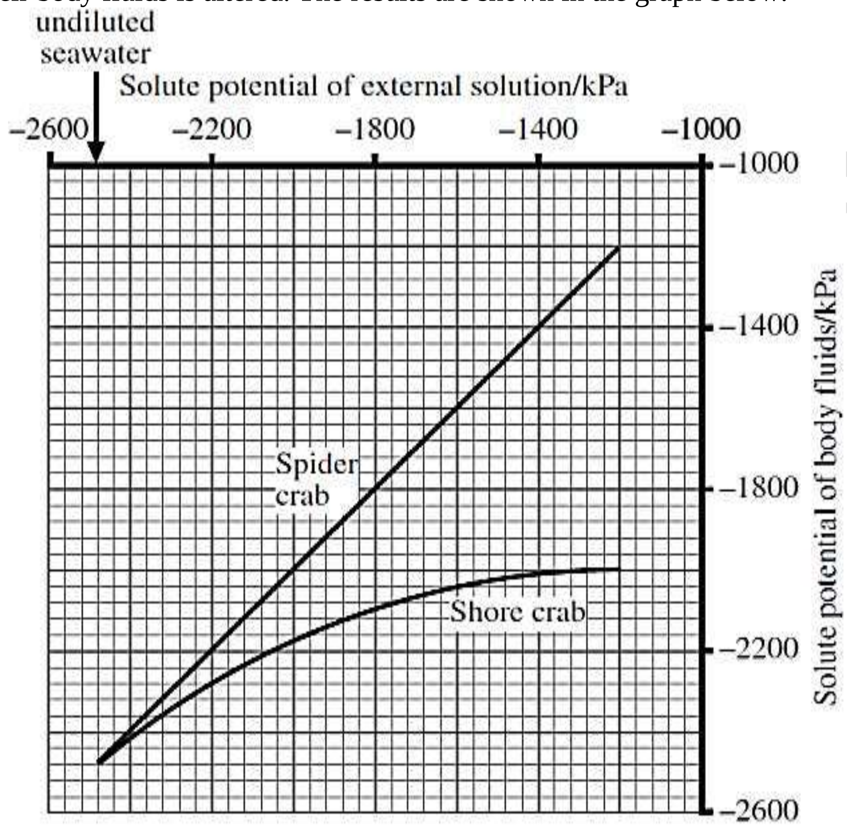
(a) Using appropriate scales and the same axes, draw graphs to reflect these results. *(09 marks)*
(b) Explain the inclusion of measurements recorded at time zero (0) in this investigation *(02 marks)*
(c) Comment briefly on the effect of saline solution on:
(i) The rate of urine production
(ii) The concentration of urine produced by the dog during this investigation *(08 marks)*
(d) Account fully for the observed changes in (c) above. *(13 marks)*
(e) Give the main structural and physiological advantages the animals living in arid habitats have for water conservation. *(11 marks)*

Question 6.

(a) Explain what is meant by;
(i). Osmoconformer?
Osmoconformers: these are organisms that do not have body osmoregulatory mechanism to maintain their internal osmotic pressure independent of that of the surrounding seawater, thus their OPi is always in equilibrium with OPe. They we behavioral means by migrating to regions with suitable OPe. They Include all marine invertebrates.
(ii).Osmoregulator?
Osmoregulators: these are organisms that have internal body osmoregulatory mechanisms they use to maintain their internal osmotic pressure constant as external osmotic pressure fluctuates. They include stenohaline that osmoregulate over a narrow range of change in Ope like freshwater fish; and euryhaline organisms like salmon fish that osmoregulate over a wide range of change in OPe; they can exploit both marine water and fresh water at the same time.
(b).Describe the role of contractile vacuole in fresh water protists.
Osmoregulatory organ in fresh water protists that ensures OPi is always higher than OPe. In this way they can take up water osmotically from the surrounding retain ions that enter the organism across the plasma membrane by pinocytosis and eliminate excess water. Pinocytic vesicles form enclosing water with dissolved solutes/ions that has been osmotically taken in energy from mitochondrial ATP used to pump solutes/ions out of vesicle into the

cytoplasm and then vesicles which is now almost titled with purely water fuses with the contractile vacuole and empty their water into it. The vacuole is impermeable to water thus goes on filling and swells to a certain size & then it moves actively to the plasma membrane with which it fuses, and a pore is formed through which excess water released to the outside by exocytosis.

(c). The spider crab (Maia) lives in the sea at a depth of over 30 metres while the shore crab (Carcinus) lives in estuaries as well as along the shoreline. When the two species of crab are placed in dilute solutions of seawater the solute potential of their body fluids is altered. The results are shown in the graph below.



(i).Explain the effect of diluting seawater on the solute potential of the body fluids of the spider crab
Leads to reduction in the solute potential of body fluid, this is because the spider crab lacks osmoregulatory mechanisms to keep its internal solute potential independent and above that of that of the surrounding water.
(ii).When the shore crab is placed in dilute solutions of seawater, it absorbs salt through its gills from surrounding solution. What is the effect of absorbing salt on the solute potential of the body fluids?
It increases and makes it to be above that of the surrounding water
(iii).What is the evidence from the graph that the shore crab absorbs salt when placed in dilute solutions of seawater?
As sea water continuously gets diluted the solute potential of body fluid does not reduce with the same magnitude and there comes a moment when its solute potential becomes constant.

Essay questions

Question 1.

(a).Explain what is meant by osmoregulation ***(02 marks)***
(b).Explain the importance of osmoregulation in living organisms. ***(08 marks)***
(c).Explain the different physiological mechanisms by which water and salt content of the mammalian body is regulated ***(10 marks)***

(a)

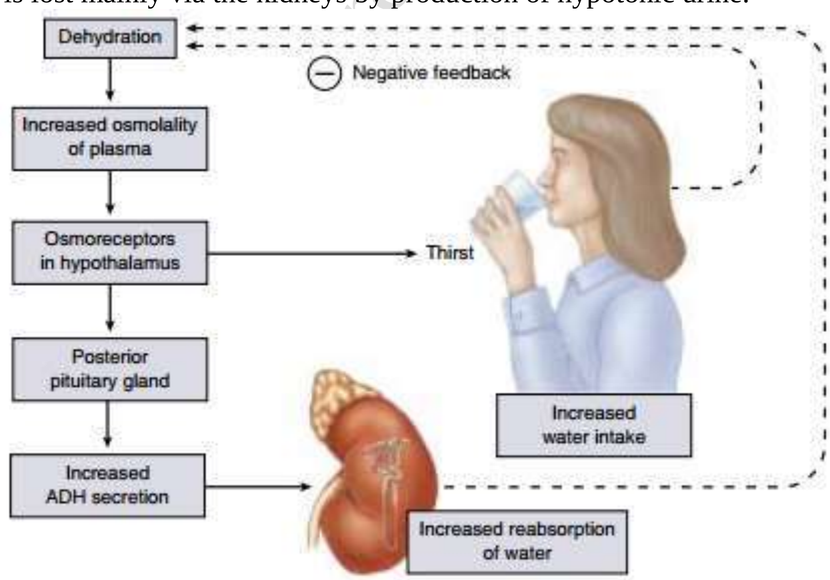
Osmoregulation is the maintenance of a constant internal osmotic environment of an organism irrespective of the changes in the external osmotic environment.

(b).

- Maintains a constant fluid-electrolyte (ion) homeostasis preventing osmotic bursting or shrinkage of cells
- ensures environmental independence of the organisms i.e organisms are capable of safely surviving in their different osmotic environments
- Constant fluid-electrolyte balance ensures efficient metabolic and physiologic processes in the body e.g enzyme activity, nervous conduction, membrane permeability etc.
- Osmoregulation maintains constancy in body fluid pH; preserving enzyme activity.
- Maintenance of constant body fluids is required in cells that lack a rigid cell wall; for maintenance of their structural framework.
- It regulates the water content of body fluids.
- Enables removal of excess nutrients that are taken in that if allowed to accumulate would interfere with cell activities.

(c).

Thirst induction; low water content of the blood passing the hypothalamus stimulates the thirst centre; that calls for an increased urge to take water.
Hunger induction; low water content and deficient electrolytes in blood passing the hypothalamus stimulates the hunger centre; leads to an increased urge to take food so as to utilize the water and ions therein.
Anti-diuretic hormone (ADH) system; switched on in response to concentrated blood; facilitates water retention via the kidney tubules to dilute the blood. Reduced osmotic pressure calls for a switch off of the ADH system, by negative feedback.
Renin-Angiotensin-Aldosterone system (RAAS); long term response switched on in response to low water content or low Na and high K concentration in blood. Aldosterone increases sodium retention; and potassium ion loss followed by water re-absorption via the kidney tubules;
Atrial Natriuretic peptide hormone; antagonises aldosterone; thus released in response to a high blood water content. Excess water is lost mainly via the kidneys by production of hypotonic urine.



Question 2.

(a).Describe osmoregulation in a terrestrial insect ***(04 marks)***
(b).Explain the factors that influence the type of nitrogenous wastes excreted by animals ***(16 marks)***

(a).

Terrestrial insect is liable to water loss; has impermeable exoskeleton that is coated with wax; produces uric acid; a non-toxic and insoluble excretory product; that requires little water for its excretion. Water is re-absorbed by the malpighian tubules and rectal glands; resulting in formation of concentrated urine/uric acid.

(b).

Toxicity profile of the nitrogenous waste; ammonia is highly toxic; requires plenty of water thus excreted by fresh water animals. Urea is less toxic; requires less water thus excreted by some terrestrial animals and marine fishes. Uric acid is non-toxic; requires little or no water for the excretion; thus excreted by animals in very arid terrestrial conditions.

Nature of the habitat of the organism; dictates the need and extent to which the organism has to conserve water. Fresh water animals excrete ammonia because of their very limited need to conserve water. Marine organisms and terrestrial organisms need to conserve water thus excrete TMO and urea or uric acid.

Osmotic potential of the body fluids relative to that of the external environment (Opi vs Ope); if Opi >Ope, organism takes in water thus excretes ammonia like in fresh water fishes. Where Opi <Ope, suffers a physiological drought; thus TMO, urea or uric acid are excreted e.g in marine organisms

Solubility of the nitrogenous waste; highly soluble excreta like ammonia require a hypo-osmotic water environment like in a fresh water environment. Less soluble excreta like TMO, urea and uric acid are opted for by marine and terrestrial organisms.

Question 3.

(a).Explain the significance of excretion in living organisms ***(02 marks)***

(b).Outline some of the excretory products in plants ***(05 marks)***

(c).Explain why plants lack complex/elaborate excretory systems as those seen in animals ***(13 marks)***

(a).

• Enables removal of toxic products of metabolism; maintaining the body's steady state/ equilibrium.

• Removes toxic wastes that if accumulated would affect the metabolic activities of organisms e.g. may act as enzyme inhibitors

(b).

• Carbondioxide, Water and Oxygen from respiration and photosynthesis respectively.

• Anthocyanins stored in petals, leaves, fruits, barks.

• Tannins deposited in dead tree tissues like wood and barks

• Calcium oxalates, calcium carbonates and Latex (rubber)

• Alkaloids like quinine, cannabis, cocaine, caffeine, morphine etc.

(c).

• Toxic wastes do not accumulate because they are utilized by the plant e.g CO_2 and water are raw materials for photosynthesis while oxygen participates in respiration.

• Extra gaseous wastes are removed from plant bodies by simple diffusion through the stomata and lenticels.

• Most of the organic waste substances formed in plants are non-harmful and can be stored in the plant tissues which are removed periodically e.g. leaves and bark.

• Some plants store other wastes such as resins in organs that later fall off e.g. leaves.

• Excess water and dissolved gases are removed by transpiration through the stomata.

• Some plants remove wastes products by exudation e.g gums, resins, latex and rubber.

• In some plants guttation occurs i.e excess water with dissolved salts ooze out through hydathodes at leaf surfaces

• Organic acids which would be harmful to plants often combine with excess cations and precipitate as insoluble crystals which can be safely stored in plant cells e.g. excess Ca^{2+} combines with oxalic and pectic acids to form the non-toxic calcium oxalate and calcium pectate

• Plants synthesize all their organic requirements according to demand, leaving no excess of protein hence very little excretion of nitrogenous waste substances occurs.

• The rate and amount of catabolism is much slower and much less than that of animals of similar weight, and as a result the waste products accumulate more slowly.

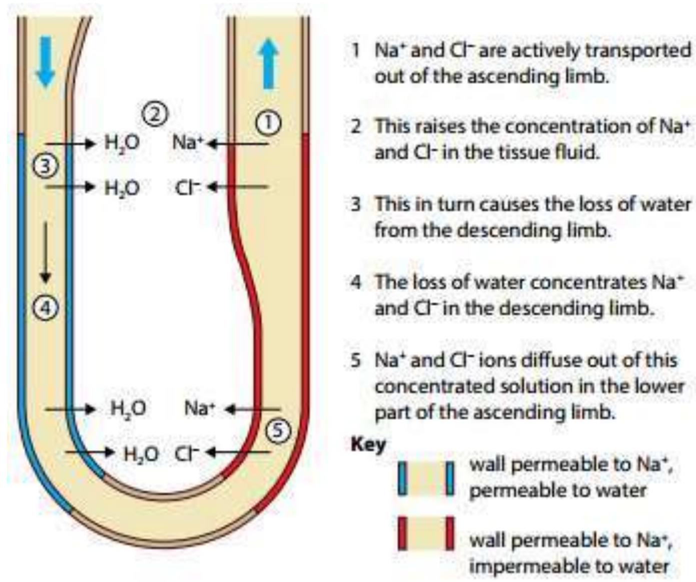
Question 4.

(a).Describe how the loop of Henle operates as a counter-current multiplier ***(08 marks)***

(b).Explain how the different animals have solved their osmotic challenges ***(12 marks)***

(a).

Ascending limb is permeable to Na^+ but impermeable to water. The descending limb on the other hand is permeable to both water and Na^+. Na^+ and Cl^- actively pumped out of the upper part of ascending limb but diffuse from the lower part; Concentration of Na^+ and Cl^- in the interstitial fluid raised; that in the ascending limb lowered; Th-is concentration gradient allows osmotic loss of water from the tubular fluid in the descending limb into the inter-stitial space; concentrating Na^+ and Cl^- in the descending limb; concentration of solutes builds to maximum at the bottom of the loop.



(b).

Terrestrial animals like land mammals, arthropods, birds
- Body covering like fur, feathers, water proof cuticles; keratinized skin epithelia; prevent dehydration
- Excretion of water conserving excreta like urea, uric acid, TMO
- Metabolic water from stored fats e.g in camels.
- Nocturnal behaviour; minimize water loss through evaporation
- Migratory behaviour in response to seasonal changes.
- Elongated loop of Henle in birds/ mammals like the kangaroo cat.
- Hyper secretion of ADH by mammals.
- Possession of numerous malpighian tubules rectal glands;
- Possess tissues tolerant to water stress;

Fresh water teleosts
- Copious amounts of dilute urine/ have large glomerular and renal capillary network.
- Excrete water soluble excreta like ammonia
- Chloride secretory cell; pump salts into blood; raise the Opi

Marine teleosts like cod, mackerel
- Produce little concentrated urine/ small glomeruli
- Drink plenty of salty water
- Excrete TMO
- Chloride secretory cells; excrete excess salts
- Antenna glands; excrete excess nitrogenous wastes

Marine elasmobranches like dog fish, sharks
- Urea retention through having gills impermeable to it
- Renal re-absorption of urea;
- Tissue and enzyme tolerance to too high urea concentration.
- Highly toxic urea detoxified to TMO.

Migratory fishes like salmons and eels.

Switch osmoregulatory mechanisms depending on the current habitat. Such as changes in the glomerular filtration rate, reversal of the direction in which chloride secretory cells transfer salt; i.e take in salts in fresh water and pumps out salts in marine waters.

Question 5.

(a)(i).Explain what is meant by counter current exchange ***(03 marks)***
(a)(ii)Why is it important that the ascending limb of the loop of Henle is impermeable to water ***(02 marks)***
(b).Describe the different forms of counter current exchange systems in vertebrates highlighting their significances ***(15 marks)***

(a)(i).

Counter current exchange is a highly efficient, naturally occurring mechanism by which some property of a fluid e.g heat or a chemical substance is transferred from one fluid across a semi permeable membrane or a thermally conductive material to another fluid flowing in opposite direction. The two oppositely flowing fluids do so in close proximity to each other. Counter current exchange creates a very steep concentration gradient for exchange of materials.

(a)(ii).

To prevent water from leaving the ascending limb by osmosis; otherwise if water followed by salts leaves the ascending limb, an osmotic gradient could not be created between the fluid in the descending limb and the surrounding tissue fluid.

(b).

Counter flow system across gills of fishes; in which blood and water flow in opposite direction. Oxygen rich water meets oxygen deficient blood flowing in opposite direction, a steep concentration gradient is maintained across the respiratory surface; maximizing gaseous exchange
Countercurrent heat exchange system in extremities; Present in extremities of many aquatic animals e.g in flippers of whales, legs of birds, fingers of humans etc. The system is important in minimizing heat losses to the surrounding. Heat exchange occurs between blood vessels in close proximity whose blood flow occurs in opposite direction i.e in the capillary bed. Warm arterial blood transfers heat to the cold venous blood; thereby conserving heat.
Countercurrent multiplier system in the kidneys; present in the loop of Henle of juxtamedullary nephrons; important in electrolyte re-absorption mainly Na^+ and Cl^-, water retention and eventual urine concentration. Active re-absorption of Na^+ and Cl^- in the thick ascending limb combined with the thick limb impermeability to water ca-use increased medullary interstitial osmolality; calls for an osmotic influx of water from the thin descending limb. Sodium ion concentration in the descending limb keeps increasing towards the apex of the loop; then decreases tip the ascending loop. At a particular level, this is the unit effect and the sum of all the unit effects along the entire length of the loop constitutes the countercurrent multiplier effect. Fluid passage around the hair pin is accompanied by NaCl loss into interstitium by passive diffusion. Thus tubular fluid reaching the distal tubules gets more hypo-osmotic.
Counter current exchange in nasal passages of desert rodents; emerged as an evolutionary intervention to minimize heat and water loss during exhalation. A single nasal passageway facilitates inhalation of dry, cool air and exhalation of warm moist air. The two fluids (incoming and outgoing air) are not spatially separated but rather temporally separated. This exchange system works by temperature changes within the narrow nasal passages that feature a large surface area. The tip of the nose is the coolest; several degrees below ambient air, moving up the nasal passages, temperature gradually increases; reaches core body temperature; cool dry inhaled air cools the walls of the nose; water evaporates into the moist nasal mucosa. During exhalation, warm moist exhaled air passes over the previously cooled nasal surfaces; exhaled air gets cooled; and warm moisture within gets condensed; air is made less saturated with humid air exhaled.

Question 6.

(a) How is the structure of the Bowman's capsule related to function? ***(06 marks)***
(b) Describe the process of forming hypertonic urine ***(10 marks)***
(c) How is osmoregulation in a marine fish different from that of a fresh water fish? ***(04 marks)***

(a).

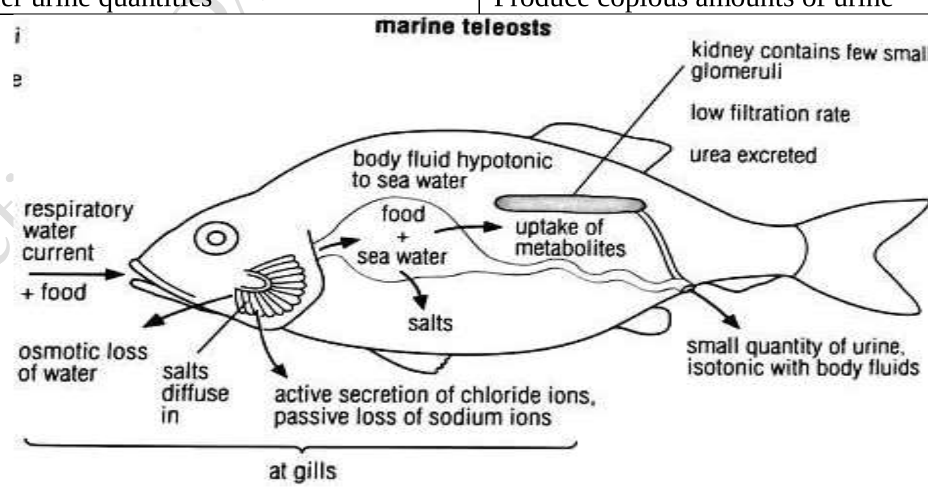
• Numerous podocytes; which are specialized cells with long thin processes; increase surface area for ultra-filtration to occur
• Major processes from different podocytes interlock leaving narrow slits; that form gaps large enough to permit selective passage of blood plasma components.
• Minor processes connect podocytes to basement membrane leaving narrow spaces; permit selective passage of blood plasma components.
Fenestrated capillary endothelia; does selective permeability of materials.
• Double walled capsule; provides an efficient sieve membrane via which materials within plasma are filtered.
• Basement membrane; forms a continuous membrane between blood and the capsular space; and has smaller holes thus impedes larger plasma components such as protein from filtering.
• Wide capsular space; cavity that accommodates large amounts of the ultra-filtrate.
• Afferent arterial entering the Bowman's capsule has wider lumen than that of efferent arterial leaving it, resulting into high hydrostatic pressure that causes ultrafiltration to occur.
• The glomerular capillaries are highly coiled to increase the surface area for ultrafiltration to occur.
• The Bowman's capsule is funnel-shaped to direct the renal filtrate into the proximal convoluted tubule.

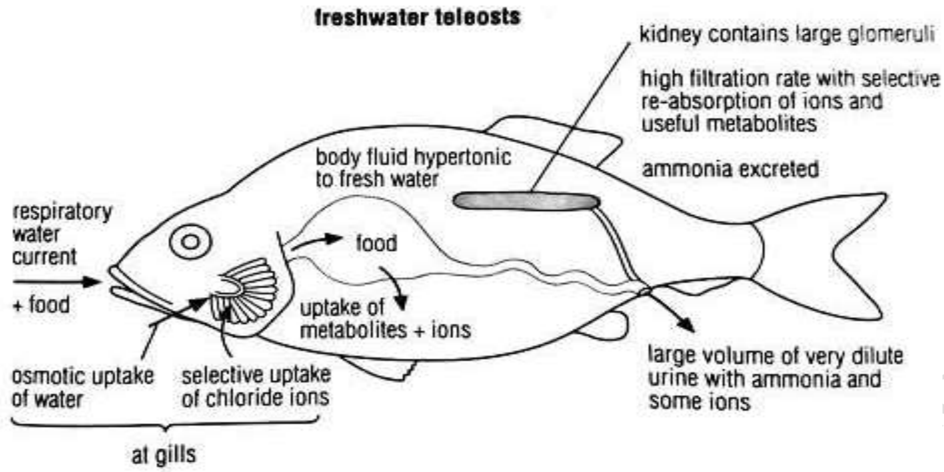
(b).

Urine concentration follows creation of a hyperosmotic medullary interstitium and the effect of ADH system. A hypertonic medullary interstitium follows the counter current multiplier effect of the loop of Henle involving parallel and opposite flow of renal fluid in the descending and ascending limbs. Active pumping of Na^+ and Cl^- from the ascending limb into the interstitium increase medullary concentration and this prompts osmotic loss of water from the descending limb into the medulla; which is taken to the blood stream by the vasarecta. The counter current exchanger effect of vasarecta maintains a steep concentration gradient. At the distal convoluted tubule and collecting ducts; ADH secretion causes more water retention; further water deficits prompt passive re-absorption of urea from the collecting ducts; into the medullary interstitium and this is followed by osmotic intake of water; little concentrated urine s thus produced;

(c).

Osmoregulation in marine fishes	Osmoregulation in fresh water fishes
OPi is less than the Ope	OPi is greater than the Ope
Counteracts tissue dehydration	Counteracts tissue over hydration
Fewer and small glomeruli; lower GFR	More and larger glomeruli; higher GFR
Excrete TMO to retain water	Excrete ammonia; lose plenty of water
Chloride secretory cells pump out salts from the body	Chloride secretory cells pump salts into blood stream
Produce smaller urine quantities	Produce copious amounts of urine





Question 7.

(a).The distribution of stomata & other leaf modifications in plants are indicative of their habitats. Discuss.
(b).Describe the osmoregulatory survival of migratory fishes. ***(04 marks)***

(a).

Mesophytes; Plants that live in moist places on land e.g clover, lilac, goldenrod etc;
• Leaves and fewer on the upper surface;
• Leaf surfaces are hairy to reduce evaporation of water.
• Some shed their leaves in winter or summer so as to conserve more water
• Broad leaved; increase surface area for trapping light

Hydrophytes; are plants that live in water; e.g water lilies, water hyacinth
• Have numerous stomata on the upper leaf surfaces and a few or none on the lower leaf surface;
• Possess hydathodes for exuding water
• Their leaves are broad and spongy enabling them float on water.

Halophytes; plants living in areas of high salinity e.g Spartina alterniflora (smooth cord grass).
•Their leaves have reduced stomata on both sides for water conservation;
•Have tissues tolerant to water stress, store water in their succulent tissues.
•Have buoyant leaves

Xerophytes; plants found in dry areas; e.g cacti
•Have fewer or no leaves;
•Leaves have reduced stomatal number;
•Possession of fleshy succulent stems & leaves; store water in large parenchyma cells e.g bryophylum & cactus.
•Rolling / curling / folding of leaves to reduce transpiration e.g. marram grass (Ammophila)
•Some have their leaves reduced to spikes; with sunken stomata.
•Some have shiny leaf surfaces which reflect light to avoid overheating.
•Some xerophytes especially CAM plants such as cacti; have reversed stomatal rhythms i.e stomata open at night;
•Possession of extremely deep roots to obtain water from deep down below the water table e.g. acacia and Oleander.
•Shallow root system for absorbing moisture even after slight showering e.g. cactus
•Possession of stomata sunken i. hairy leaf surface to tap air and reduce on transpiration.
•Hairy epidermis for reflecting solar radiation and trapping humid air next to leaf surface and reduce transpiration.
•Possession of thick cuticle, which is impermeable to water e.g. prickly pear (Opuntia).

(b).

Migratory fishes such as salmons cope with both marine and fresh water environments due to their ability to switch osmoregulatory mechanisms in a variety of environments They raise their filtration rate in fresh water environments; produce large volumes of dilute urine while in marine environments, filtration rate is lowered and little volumes of concentrated urine is produced. Chloride secretory cells in a fresh water environment do pump salts from the water into blood; activity of the same cells is reversed in a marine environment where salts are rather pumped out of the fish's blood to water. Fish drinks plenty of sea water in a marine environment terminates plentiful drinking in a fresh water environment. Migratory fishes switch excretory products; ammonia in a fresh water environment and TMO in a marine water environment.

Question 8.

(a).Compare the structural and physiological functioning of the ascending and descending limb of the loop of Henle in the Kidney nephrons ***(06 marks)***

(b).Describe the role of the kidney in acid-base balance ***(09 marks)***

(c).How is the structure of the urinary bladder adapted to function ***(05 marks)***

(a).

Similarities

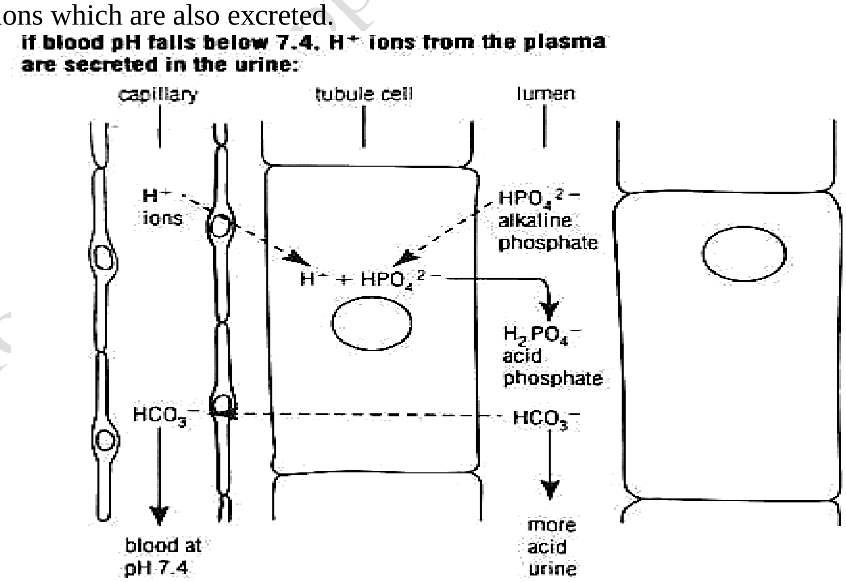
- Both limbs have thin and thick walled segments.
- Both are involved in bringing about the counter current multiplier effect cause of urine concentration.
- In both, maximum concentration of the ions is attained at the apex of the loop (hair pin)

Differences

Descending limb	Ascending limb
Highly permeable to water	Impermeable to water
Impermeable to solutes and ions e.g Na^+ and Cl^-	Active re-absorption of Na^+ and Cl^- in the thick segment and passive re-absorption of the same ions in the thin segment.
Concentration of ions keeps on increasing down the descending limb	Concentration of Na^+ and Cl^- keeps decreasing up the loop.

(b).

Kidneys control the level of hydrogen ions through the phosphate and ammonium buffer systems. Carbondioxide diffuses into the renal tubular cell; combine with water forming carbonic acid, which partially dissociates into hydrogen ions and hydrogen carbonate ions. The hydrogen ions are pumped into the lumen of the renal tubules in exchange for sodium ions from the phosphate compound Na_2HPO_4 found in the luminal fluid. Bicarbonate ions diffuse into the renal Interstitium (blood stream) and these are followed by sodium ions via the Na^+/K^+ pumps to maintain electroneutrality. Luminal hydrogen ions are buffered by the phosphate salt $NaHPO_4$ get excreted in form of NaH_2PO_4. In case renal fluid is too acidic, the excess hydrogen ions combine with ammonia from glutamine to form ammonium ions which are also excreted.



(c).

- Urinary bladder is lined by a transitional epithelium that is stretchable; and distends when subjected to tension; allows the bladder to temporally accommodate large volumes of urine.
- Has powerful detrusor muscles; whose contractions and relaxations over long lengths bring about urinary filling and expulsion.

• Has internal and external sphincters; whose contractions and relaxations regulate urinary expulsion.
• Bladder contains stretch and pain receptors; which when stimulated triggers the urge to void/urinate.
• The sub-mucosa of the bladder has lots of fibrous connective tissues, blood vessels and nervous tissues that support and control the surrounding tissue layers.

Question 9.

(a).Briefly explain the different environments and their osmotic challenges *(08 marks)*
(b).Describe the process of osmoregulation in a named fresh water protozoan *(06 marks)*
(c).Outline the physiological adaptation of xerophytes to survival *(06 marks)*

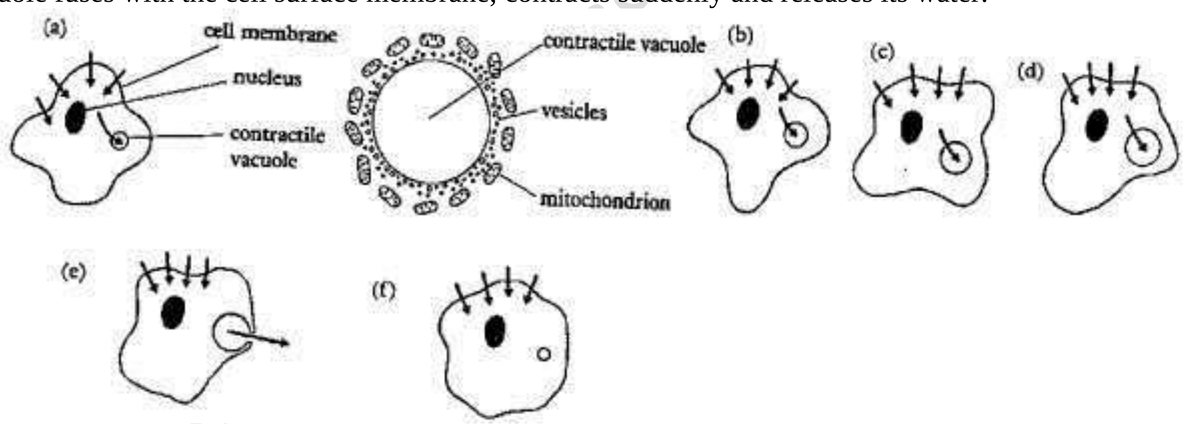
(a).

Sea water; the solute concentration is extremely variable, but average salinity is 34.5 parts per thousand. Organisms suffer osmotic water loss and salt gain by diffusion
Fresh water; water freshness varies but any water with salinity of less than 0.5 parts per thousand may be considered as fresh. Problems include osmotic water gain and salt loss by diffusion
Brackish water; this is water with salinity between 0.5 and 30 parts per thousand (between fresh water and sea water). It includes estuarine water and intertidal zones. Osmotic problems are variable
Terrestrial environment; this is land environment. Osmotic problems include water loss by evaporation.

(b).

Amoeba/paramecium

Contractile vacuoles carry out osmoregulation in fresh water protozoa. Since the cell contents are hypertonic to the surrounding, and the cell membrane is partially permeable, there is constant influx of water into the cytoplasm by osmosis. Small vesicles in the cytoplasm fill up with fluid from the cytoplasm and pump salts back into the cytoplasm by active transport, using energy provided by ATP from the numerous mitochondria surrounding the vesicles. The vesicles containing water fuse with the contractile vacuole which gradually expands. The impermeability of the vacuolar membrane to water prevents osmotic out flow of water. On reaching critical size, the contractile vacuole fuses with the cell surface membrane, contracts suddenly and releases its water.



(c).

• Increased levels of Abscissic acid, which induces stomatal closure so as to reduce water loss.
• Leaf fall in deciduous trees so as to cut down transpiration
• Survival of drought as seeds or spores that are highly dehydrated and protected within a hard coat.
• Have desiccation tissues tolerant e.g low solute potential of cytoplasm & production of resistant enzymes
• Reversal of the normal stomatal rhythm in some plants e.g. opening stomata at night and closing during day time so as to reduce on water evaporation.

Question 10.

(a).Distinguish between osmoconformers and osmoregulators *(02 marks)*
(b).Describe the different forms of osmoconformers and osmoregulators *(06 marks)*
(c).Describe the mechanisms of osmoregulation in marine invertebrates *(14 marks)*

(a).

Osmotic conformers (Osmoconformers) are animals whose osmotic concentration of body fluids fluctuates according to that of the environment e.g fresh water lower animals while Osmoregulators are animals that maintain or regulate condition of their internal body osmolarity within normal limits despite environmental change e.g most marine vertebrates, higher fresh water animals (they remain hyperosmotic).

(b).

Euryhaline osmotic conformers (tissue tolerant species): species that tolerate wide external and therefore internal osmotic fluctuations.

Stenohaline osmotic conformers: species that tolerate only limited external and therefore internal osmotic fluctuations. Such organisms' habitats are limited to environments of constant concentration e.g. the hagfish is strictly marine and stenohaline, its body fluids are iso-osmotic (have same concentrations as sea water)

Euryhaline Osmotic regulators: species that maintain within narrow limits the internal body osmolarity over a wide range of environmental changes. E.g. migratory fish like eel (Anguilla bengalensis) which migrate from fresh water to sea water, Salmon (Salmo fario) which migrate from sea to fresh water for spawning,

Stenohaline osmotic conformers: species that regulate the internal body osmolarity over a narrow range of external environmental changes.

(c).

Shore crab (Carcinus maenas); Antennal glands at the base of the antennae excrete excess water and nitrogeneous wastes. Antennal glands are incapable of holding back salts (they eliminate salts and water alike), resulting into production of urine isotonic with blood. Gills absorb salts from the surrounding medium and secrete them in-to blood against a concentration gradient so as to maintain an internal osmotic pressure (opi) higher than external osmotic pressure (ope). Same mechanisms occur in mitten crab (Eriocheir) except that here the inward secretion of salts is sufficient enough to enable the animal to flourish in fresh water.

Crayfish; Here antennal glands are capable of eliminating excess water but reabsorb salts, resulting into production of urine hypotonic with blood and an internal osmotic pressure (opi) higher than external osmotic pressure (ope). Reabsorption of salts occurs as the urine flows along the coiled tubule.

Question 11.

(a).Describe the process of

(i). Osmoregulation, ***(06 marks)***

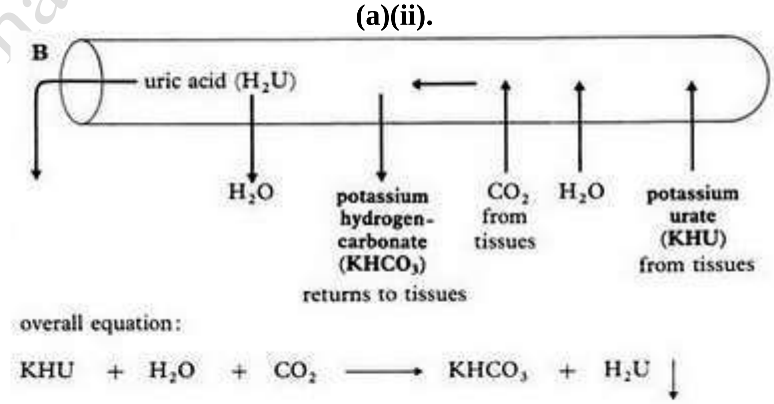
(ii) Excretion in a terrestrial insect ***(06 marks)***

(b).Explain the physiological and behavioural adaptations of terrestrial organisms against water loss

(a)(i).

A terrestrial insect is liable to water loss, which is minimized by an impermeable cuticular covering coated with wax, production of non-toxic and almost insoluble waste product, uric acid which requires little water for its elimination being almost non-toxic, reabsorption of water by malpighian tubules and rectal glands, resulting in very concentrated urine, laying cleidoic eggs such that water loss is prevented during embryo development by a relatively impermeable shell and possession of valve-like structures and hair in the spiracles to reduce on water loss.

(a)(ii).



The peristaltic movements of malpighian tubules stir up the coelomic fluid (blood) enabling epithelial cells to absorb nitrogenous wastes like sodium and potassium urate. Within the tubule cells, Water and CO_2 react with potassium urate to form potassium hydrogen carbonate and uric acid is formed. Potassium hydrogen carbonate is absorbed back into blood while uric acid is deposited in the tubule lumen. As the uric acid moves from distal to proximal end of the malpighian tubule, water is vigorously back into blood while solid crystals of uric acid are deposited in the lumen and later rectum to be passed out.

(b).

Physiological adaptations

• Reduction in glomerular filtration rate e.g. the desert frog, chiroleptes has few and smaller glomeruli than its relatives living in moist temperate regions.
• Production of non-toxic nitrogenous waste e.g. the insoluble uric acid (reptiles, birds and insects) and the relatively less toxic urea (mammals and amphibians) that require little water for removal.
• Extensive water reabsorption from glomerular filtrate (mammals and birds) and rectum (insects) e.g kangaroo rat has an extra-long loop of Henle enabling it to produce hypertonic urine.
• Use of metabolic water from fat through respiration e.g kangaroo rat Dipodomys.
• Possession of tissues tolerant to dehydration e.g a camel
• Ability to sweat at abnormally higher temperature e.g. a camel begins sweating at 41°C from its normal body temperature of 34°C
• Ability to reduce the need for nitrogenous excretion e.g. a camel secretes urea into the lumen of alimentary canal where bacteria convert it to protein, which is then utilized as food.

Behaviuoral adaptations

• Change of habitat depending on the weather conditions.
• Some animals e.g. African lungfish aestivate.

Question 12.

(a).Describe the mechanisms of osmoregulation in
(i). Amphibians ***(04 marks)***
(ii).Reptiles ***(10 marks)***
(b).State the functions of the kidneys in mammals and freshwater fishes ***(06 marks)***

(a)(i).

Amphibians have their body fluids hypertonic to fresh water resulting in osmotic influx of water which is readily lost by the kidneys expelling large volumes of urine and lose salt loss by diffusion which are replaced actively across the skin. During aestivation, amphibia instead of the usual ammonia form urea which is less toxic and therefore can be retained until water is available for excretion. Amphibia also never drink water hence water gain is osmotic via the skin or in food consumed.

(a)(ii).

Reptiles live in diverse habitats: Those living mainly in fresh water e.g some crocodiles possess kidneys like those of fresh water fishes and amphibians. Marine reptiles e.g. some crocodiles, turtles, sea snakes and some lizards e.g iguana possess kidneys similar to those of their fresh water relatives. However, since these kidneys reabsorb salt, marine reptiles cannot excrete a great deal of salt in their urine. Instead, they eliminate excess salt by means of salt secreting glands located near the nose or the eye, hence the turtle shedding tears. Terrestrial reptiles reabsorb much of the salt and water in the nephron tubules of kidneys, helping somewhat to conserve blood volume in dry environments. Like amphibians and fishes, though, they cannot produce urine that is more concentrated than the blood plasma. Reptiles minimize water loss by laying cleidoic eggs with waterproof embryonic membranes & supporting shell, possession of waterproof keratinized skin and scales and kidneys with reduced glomeruli hence low rate of glomerular filtration. They also produce insoluble uric acid which is almost non-toxic and therefore re-quires little water for elimination and absorb water by the cloaca from faeces and nitrogenous wastes.

(b).

• Excretion of metabolic waste products such as urea, excess water, uric acid, ammonia etc
• Regulation of water and solute content of blood (osmoregulation).
• Maintenance of pH of body fluids at 7.4.
• Regulation of blood levels of ions such as Na^+, K^+, Cl^-, Ca^{2+}
• Secretion of the hormone erythropoietin, which stimulates red blood cell production.
• Retention of important nutrients eg glucose & amino acids by reabsorption from glomerular filtrate into blood

Question 13.

(a).Explain the mechanism of;

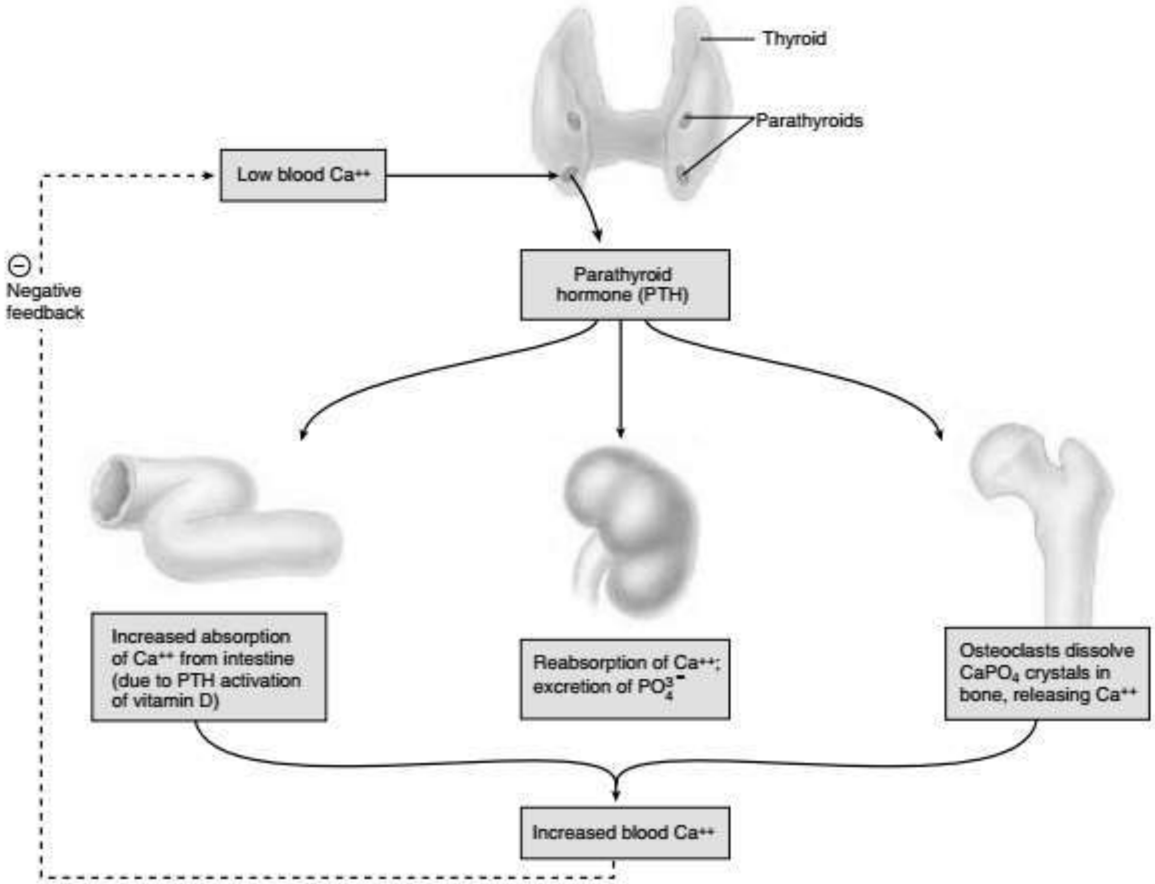
(i). Calcium ion regulation in kidneys ***(06 marks)***

(ii).Regulating water and solute concentration of blood ***(08 marks)***

(b).How is the proximal convoluted tubules are adapted for re-absorption ***(05 marks)***

(a)(i).

Low blood calcium level stimulates the parathyroid glands (surrounding the thyroid gland) to secrete parathormone (parathyroid) hormone which increases the calcium level and decreases the hydrogen phosphate (HPO_4^{2-}) level through promoting bone breakdown by osteoclasts, calcium retention by kidneys, excretion of hydrogen phosphate (HPO_4^{2-}) in urine by kidneys, activation of vitamin D, which in turn stimulates the absorption of calcium from the gut. High blood calcium level stimulates the thyroid gland to secrete calcitonin hormone, which increases bone buildup by osteoblasts so as to reduce calcium level.

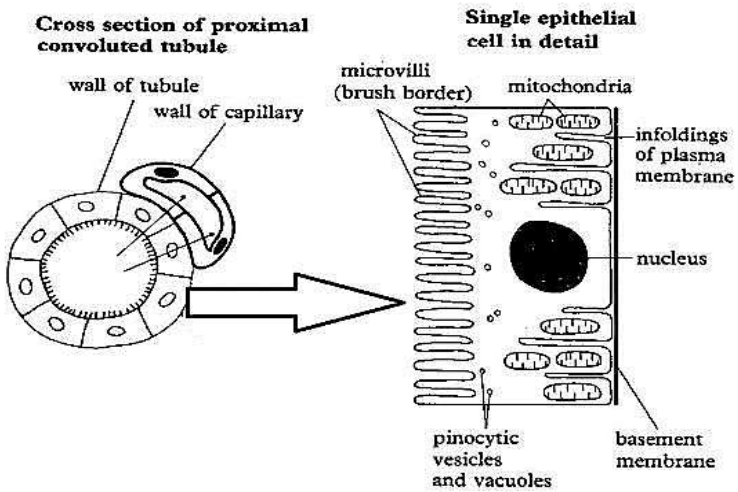


(a)(ii).

Increased concentration of solutes in blood (little water relative to salts) is detected by osmoreceptors in the hypothalamus which stimulate the posterior pituitary gland to secrete antidiuretic hormone (ADH) /vasopressin and at the same time triggering the sensation of thirst resulting in drinking of water. ADH increases the permeability of distal convoluted tubule and collecting duct to water, allowing the osmotic flow of water from the glomerular filtrate into the cortex and medulla hence reducing the osmotic pressure of blood but increasing that of urine. ADH also increases the permeability of the collecting duct to urea, enabling its diffusion from urine into the medulla tissue fluid where it increases the osmotic pressure resulting in osmotic extraction of water from the descending limb. Low solute concentration in blood (too much water relative to salts) inhibits ADH release, tubule walls and collecting duct become impermeable to water, less water is reabsorbed from glomerular filtrate into blood and large volume of dilute urine is passed out hence raising the osmotic pressure of blood.

(b).

• Bear numerous microvilli at the free end to increase the surface area for reabsorption of substances like glucose, amino acids, vitamins, NaCl, water.
• Contain numerous mitochondria to form ATP that provide energy required in active transport of glucose, amino acids, Na^+, $H_2PO_4^-$ and HCO_3^- into the blood capillaries.
• The cell surface membrane is indented to form a large area of intercellular spaces bathed with fluid.
• Contain numerous pinocytic vesicles which enable digestion of small protein molecules from the renal filtrate.
• Form a thin thickness of one cell layer to ease reabsorption of substances.



Question 14.

(a).How is the loop of Henle adapted to function in a the kidney ***(04 marks)***
(b).Describe the roles of the following during urine formation
(i). Ultra filtration ***(07 marks)***
(ii) Selective re-absorption ***(05 marks)***
(c).Why does urine production almost stop after severe bleeding? ***(04 marks)***

(a).

• The loop of Henle is U-shaped with parallel, opposite flows of tubular fluid in its limbs to provide a multiplier effect that create a concentration gradient, which enables increased water reabsorption.
• The capillaries of vasa recta form loops that accompany the loops of Henle resulting into countercurrent exchange of solute and water between ascending and descending blood.
• The capillaries of vasa recta are in close proximity with tubules to increase the reabsorption of useful substances from the filtrate.

(b)(i).

Ultra filtration runs the process of glomerular filtrate formation powered by the high hydrostatic pressure created within the glomerular capillaries because of the narrower efferent vessels compared to the afferent ones. The hydrostatic pressure is opposed by the osmotic pressure of the solutes (oncotic pressure for plasma proteins) leading to retention of plasma proteins in blood. Hydrostatic pressure being greater than osmotic pressures creates a net flux that forces the fluid constituents into the capsular spaces and subsequently into the proximal tubules. Other than the pressure aspect, ultra-filtration is also aided by the filter formed by endothelia of the glomerular capillaries and the epithelia of the Bowman's capsule. Capillary endothelium has pores that allow passage of only blood components smaller than or of the same size as the pore. Spaces between the adjacent podocytes, those between the minor processes of the podocytes and the vascular endothelium enable plasma passage.

(b)(ii).

As the glomerular filtrate (renal fluid) flows along the tubule of the nephron, all glucose, 85% of the water, Na^+, Cl^-, aminoacids, vitamins, hormones, 50% of urea is reabsorbed from the proximal convoluted tubule into the surrounding blood capillaries. Glucose, amino acids and Na^+, H_2PO_4 and HCO_3^- diffuse into proximal tubule cells & then actively transported into the blood capillaries. The active uptake of Na^+ followed by the passive uptake of Cl^- raises the osmotic pressure in the cells enabling entry of water into capillaries by osmosis. 50% of urea is reabsorbed by diffusion but the small sized proteins in the renal filtrate are removed by pinocytosis. As a result of all this activity, the tubular filtrate is isotonic with blood in the surrounding capillaries.

(c).

The amount of urine produced is proportional to the amount of blood flowing through the kidneys. The total blood volume in the body reduces if serious bleeding occurs, resulting into diversion of blood from other tissues (including the kidneys) to the brain to maintain life. Therefore, the volume of blood flowing through the kidneys reduces greatly to the extent that less ultrafiltration and hence formation urine occurs/ reduce glomerular filtration rate.

Question 15.

(a).Explain what is meant by the renal plasma ratio ***(01 marks)***

(b).Explain the significance of vasarecta in the process of urine concentration ***(05 marks)***

(c).Describe how the sodium ions are regulated in the by the body ***(14 marks)***

(a).

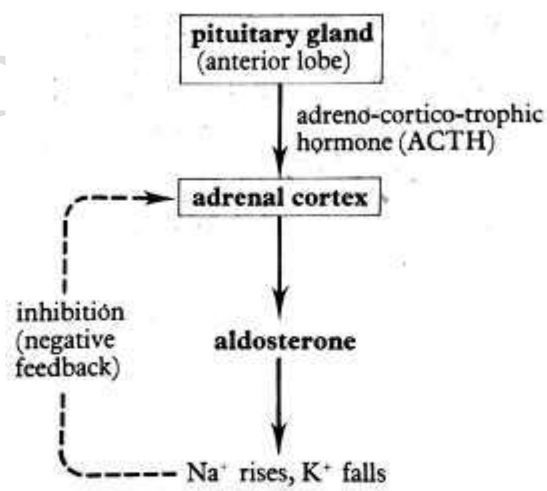
The ratio obtained after dividing the concentration of substances in renal fluid by the concentration of same substances in blood plasma

(b).

The vasa recta serves as the counter current exchanger; continuously transport diluted blood from the medullary interstitium into the main blood stream; maintaining a steep concentration gradient in the medulla for further water absorption. Without the vasarecta, the high solutes concentration in the medullary interstitium would be washed out.

(c).

Low levels of sodium in blood are detected by the hypothalamus, which stimulates the anterior pituitary gland to secrete the hormone adrenocorticotropic hormone (ACTH), which stimulates the juxtaglomerular complex to release the enzyme Renin. Renin catalyses the conversion of angiotensinogen, a plasma protein into a hormone angiotensin which stimulates the adrenal cortex to secrete the hormone. Aldosterone stimulates renal retention of sodium ions and loss of potassium ions in urine. This induces osmotic uptake of water into blood thus increasing both the blood volume and sodium level back to the norm, accompanied by loss of potassium ions. Aldosterone stimulates sodium absorption in the gut and decreases loss of sodium in sweat so as to raise sodium levels to cause an osmotic inflow of water thus increasing the blood volume and pressure. Also stimulates the brain to increase the sensation of thirst. Increased sodium level in blood causes increased blood volume and pressure, less production of renin and angiotensin resulting in less secretion of aldosterone by the adrenal cortex hence less uptake of sodium from the glomerular filtrate occurs, restoring sodium level to the norm.



Question 16.

(a).Discuss how the organisms' environment change both its disposal mechanism for nitrogenous waste and its ability to retain water? ***(08 marks)***

(b).The nephron has a number of adaptations that ensure waste substances are excreted from the body but not the useful ones, what are they? ***(12 marks)***

(a).

• Fresh water environment makes organisms like fish excrete nitrogen as ammonia. Despite being highly toxic the fish are surrounded by water and so after excretion the ammonia is quickly diluted to safe levels. Such fish do not have issues with water conservation as they can easily get water from their surroundings.

• Marine water environment poses a physiological drought to its inhabitant organisms; these thus excrete less soluble and less water requiring trimethylamine oxide; to allow conservation of water.

• Birds and arthropods excrete water insoluble uric acid in their terrestrial environment little water content. Uric acid is not toxic allowing birds to carry the waste for a long time while re-absorbing water.

• Mammals excrete urea; a fairy toxic nitrogenous waste with moderate water requirement for its excretion and can only be tolerated in the body for a short period of time. However, organisms possess special adaptations to conserve water such as long loops of Henle in kangaroo rats, possession of massive reservoirs of metabolic water (fat) in camels etc

(b).

• The efferent arteriole has a smaller diameter i.e long and narrow compared with the afferent which is wide & short creating a strong hydrostatic pressure to permit ultra-filtration.

• The Bowman‘s capsule is funnel-shaped to direct the renal filtrate into the proximal convoluted tubule.

• Constant blood flow from the renal artery, a branch of the aorta ensures the pressure remains constant.

• Numerous podocytes; which are specially adapted epithelial cells with long thin processes; increase surface area for ultra-filtration to occur

• Major processes from different podocytes interlock leaving narrow slits; that form gaps large enough to permit selective passage of blood plasma components.

• Minor processes; connect podocytes to basement membrane; leaving narrow spaces; also permit selective passage of blood plasma components.

• Fenestrated capillary endothelia; does selective permeability of materials.

• Capsule is made up of three membrane; provides an efficient sieve membrane via which materials within plasma are filtered.

• Basement membrane forms a continuous membrane between blood and the capsular space and has smaller holes thus impedes larger plasma components such as protein from filtering.

• Wide capsular space; cavity that accommodates large amounts of the ultra-filtrate.

• Afferent arterial entering the Bowman's capsule has wider lumen than that of efferent arterial leaving it, resulting into high hydrostatic pressure that causes ultrafiltration to occur.

• The glomerular capillaries are highly coiled to increase the surface area for ultrafiltration to occur.

• The Bowman's capsule is funnel-shaped to direct the renal filtrate into the proximal convoluted tubule.

• The proximal convoluted tubule has a large number of mitochondria which generate ATP required for selection re-absorption which is an active process.

• The proximal convoluted tubule has a long length and microvilli in its walls to increase surface area for selective re-absorption of materials.

• Thick and thin parts of the ascending and descending loop of Henle permit counter current multiplier effect of materials; potentiating water retention.

• Possession of a vasarecta which serves as a counter current exchanger between the medulla and the systemic blood circulation.

• Possession of the macula densa which detects changes in the ion concentration especially sodium ions.

Question 17.

Discuss the functioning of each of the following parts of the kidney nephron;

(a).Bowman's Capsule *(10 marks)*

(b).Proximal Convoluted Tubule *(10 marks)*

(a)(i).

Bowman capsule; start of nephron; site of ultrafiltration (where blood is filtered); this occurs between specialised capillaries called glomerulus and Bowman's Capsule; glomerulus located in the middle of an arteriole. Afferent arteriole before glomerulus is wide; efferent arteriole after glomerulus is narrow; so build-up of hydrostatic pressure in the glomerulus pushes fluid and small substances from the glomerulus into the Bowman's capsule. Small substances filtered include; glucose, amino acids, salts, urea; only small substances can pass through the 3 layers (endothelium of glomerulus, basement membrane and podocytes of Bowman's capsule); results in glomerular filtrate in Bowman's capsule. Glomerular filtrate contains water, glucose, amino acids, salts and urea etc.

(a)(ii).

Proximal convoluted tubule (PCT): second part of the nephron: site of selective reabsorption all the glucose /amino acids and some of the salts/water are sent back into blood; (from lumen of PCT; through cells lining PCT, into blood); salts (sodium ions) are actively transported from cells lining the PCT into the blood; this letters sodium ion concentration in the cells so sodium ions diffuse from the lumen of the PCT into the cells; as sodium ions move they pull in glucose and amino acids with them via co-transport; glucose and amino acids build up in the cell then diffuse into the blood; the movement of salt/glucose/ amino acids into the blood, lowers its water potential so water follows into blood by osmosis.

Question 18.

(a).How is the kidney nephron adapted to carry out its functions? *(15 marks)*
(b) Discuss the functioning of the loop of Henle in the kidney nephron *(05 marks)*

(a).

Glomerulus;
• Selectively permeable podocytes for ultrafiltration;
• Afferent arteriole larger than efferent arteriole creates a pressure difference;
• Proximal convoluted tubule;
• Long providing large surface area for glucose re-absorption
• Cells with brush borders/microvilli to increase surface area for selective re-absorption
• Cells with numerous mitochondria; provide ATP for active transport of ions
• Selective glucose carrier proteins in membranes; for pH regulation eg Na_2HPO_4;

Loop of Henle
• U-shaped for counter flow of glomerular filtrate:
• Descending limb with numerous aquaporins for water re-absorption
• Ascending limb with channels permeable to ions/ salts; allowing exchange of ions
• Ascending limb becomes larger away from medulla region to increase surface area for salt re-absorption;
• Numerous mitochondria for active transport of Na, K and Cl ions;
• Countercurrent multiplier system & unit effect creates steep concentration gradient for water reabsorption

Distal convoluted tubules and collecting ducts:
• Membrane proteins whose permeability is regulated by hormones aldosterone and vasopressin.
• Numerous vasarecta to transport away useful substances; creating steep concentration gradient
• Countercurrent flow between contents of vasarecta & glomerular filtrate to maintain steep concentration gradient

(b).

Loop of Henle: third part of the nephron; site of further water reabsorption; occurs by hairpin counterurrent multiplier. Sodium and chloride ions are actively transported out of the ascending limb of the loop of Henle into the surrounding medulla of kidney) this lowers water potential of medulla; so water moves out of the descending limb of loop of Henle (and collecting duct) by osmosis into the medulla; water then moves into the blood, sodium and chloride ions then diffuse into the descending limb of loop of Henle so the above process can be repeated.

Question 19.

(a).What is meant by countercurrent hairpin multiplier? *(03 marks)*
(b).Describe the significance of the countercurrent heat exchanger in organs such as long limbs of birds.
(c).Discuss the functioning of the collecting duct as part of the kidney nephron *(10 marks)*

(a).

An active process in tubules where salts are actively pumped out of the ascending limb into medulla and around descending limb by unit effect; creating a steep concentration gradient for water re-absorption. The continuous flow of renal fluid in opposite direction at different concentrations: creates a concentration gradient; for water to continuously be reabsorbed from the descending loop; which by virtue of its length tends to increase/multiply.

(b).

Transfer of heat from the arterial blood flowing to the extreme end of extremity to venous blood returning from the extremity, as the blood in these adjacent vessels in opposite directions. The flow ensures that at the extreme/ distal end of extremity, blood is at the lowest temperature to ensure that temperature gradient between blood and surrounding is small thus minimizing heat loss to the environment; and venous blood returning back reaches the body core at almost the same temperature as body core temp; thus minimizing heat loss.

(c).

Collecting Duct: final part of nephron; site of further water reabsorption and osmoregulation; end up being left with urine that is sent into the ureter to the bladder, water re-absorption occurs by the hairpin countercurrent multiplier, amount of water being re-absorbed is controlled at this stage i.e osmoregulation by the hypothalamus. If water levels become low (dehydration); osmoreceptors in hypothalamus shrink stimulating the release of ADH from the posterior part of the pituitary gland; ADH stimulates the cells lining the collecting duct to increase the number of aquaporins (water channels); so more water moves from the collecting duct back into blood; so less water is lost in the urine. If water levels become high (over hydration); less ADH released; less aquaporins in collecting duct; less water move from collecting duct into blood. more water lost in urine (reduces over hydration).

Chapter 9; Species and population genetics

In a laboratory population of diploid, sexually reproducing organisms a certain trait was studied. This trait is determined by a single autosomal gene and is expressed as two phenotypes. A new population was created by crossing 51 pure breeding (homozygous) dominant individuals with 49 pure breeding (homozygous) recessive individuals. The table below shows the results obtained after four generations.

Generation	NUMBER OF INDIVIDUALS		
	Dominant	Recessive	Total
1	51	49	100
2	280	0	280
3	240	80	320
4	300	100	400
5	360	120	480

(a) Identify and explain the choice of organism used to perform this experiment. ***(03 marks)***

Drosophila melanogaster

- The fruit fly has a number of contrasting characteristics for a particular trait.
- They are easy to culture under a suitable nutrient medium of glucose on a gel agar.
- They have giant chromosomes that can easily be isolated and the genes located.
- Have a high reproductive rate such that all characteristics of the parent are expressed in many offsprings
- They have a short generation time such that characteristic can be studied together with its mode of trans- mission within many generations but in short period of time.

OR

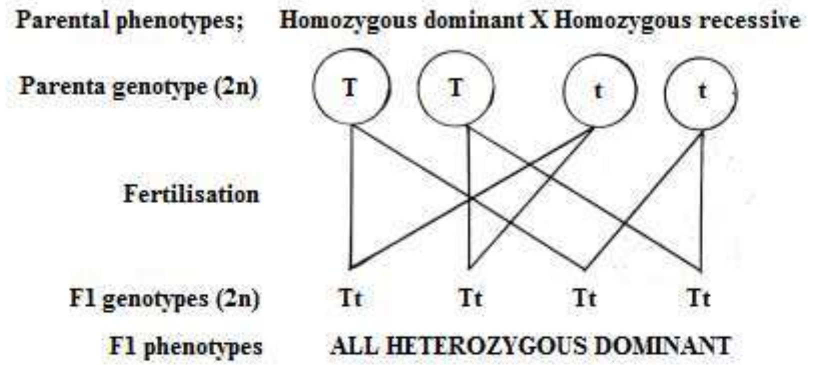
Garden peas

- Peas have clear cut differences in their characteristics of the same trait eg tall vs short for height.
- Peas have a short generation time such that many generations can be studied and many characteristics investigated concerning their transmission within a short time.
- It is easy to grow these plants in an open ground and in pots.
- The flowers could easily be cross pollinated because the stamens can easily be cut off.
- The flowers have stamens and pistils enclosed by petals for effective self-pollination / selfing.
- When hybrids are crossed, the offsprings are fertile.

(b) On the basis of the data in the table, suggest explanation for the change in the phenotypic frequency between the first and third generations. ***(07 marks)***

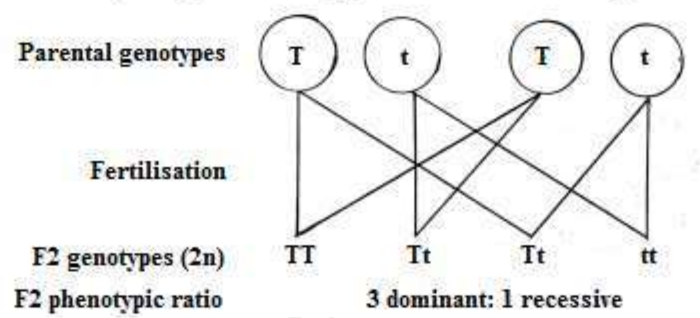
For 1st and 2nd generation (F1 generation); number of dominant individuals increased by 5 folds; that of recessive individuals reduced to zero; because a cross between homozygous dominant and homozygous recessive individuals resulted in a generation of only heterozygous dominant individuals.

Let T represent allele for the dominant trait and t for the allele for recessive trait



Between the 2nd and 3rd generation (F_2 generation); selfing the heterozygous dominant individuals resulted in generation of dominant individuals and recessive individuals in a 3:1 ratio.

Parental phenotypes; Heterozygous dominant X heterozygous dominant



(c).Explain whether or not this population is in Hardy-Weinberg equilibrium. ***(05 marks)***

It is in Hardy Weinberg equilibrium

Explanation

A locus in this population has two alleles T (dominant allele) and t (recessive allele) that occur with initial frequencies of p and q respectively

f(T)= p and f(t)= q

		Female	
		T(p)	**t(q)**
Male	**T(p)**	TT (p^2)	Tt (pq)
	t(q)	Tt (pq)	tt (q^2)

The gene/ allele frequencies are constant and their sum is equivalent to 1

Therefore the sum of all entries is p_2+ 2pq+q^2=1

Also p+q=1 and the binomial expansion of p+q=1; is p^2+2pq+q^2=1

OR

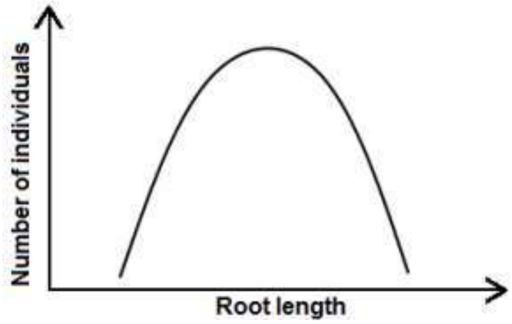
f(T)=f(TT)+ f(Tt)= p^2+pq

f(t)=f(tt)+f(Tt)= q^2+pq

f(T)+f(t)= f(AA)+f(aa)+f(Aa)= p^2+ 2pq+q^2=1

Hence the above population is in the Hardy Weinberg equilibrium

The graph below shows the distribution of root length in a population of a species of grass. The population inhabits an area in which the soil water is held mainly below 20 cm.



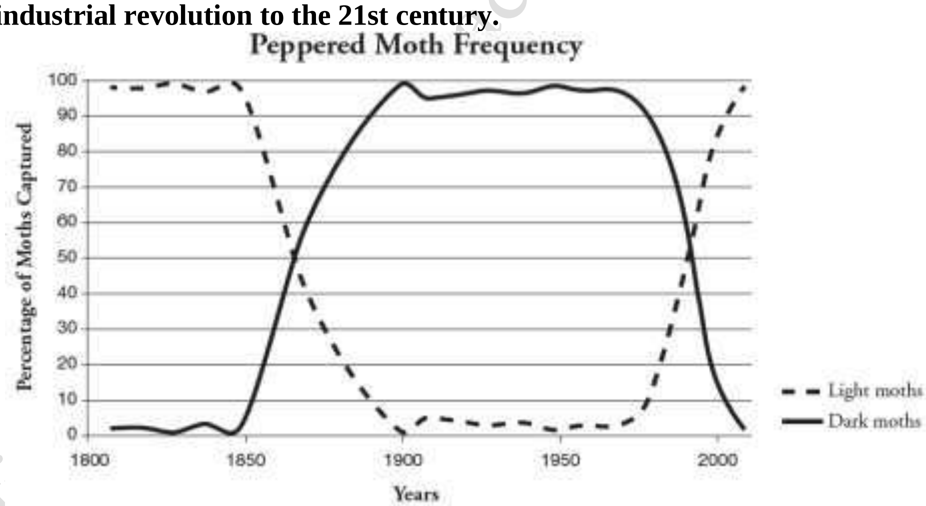
(d) Explain the type of selection in operation from the information given. ***(03 marks)***

Stabilizing natural selection; The plant roots are existing in a stable environment where the extremes bear no selective advantages. Selection pressure (accessibility of the plant roots to water in the soil) favours survival of plants with intermediate root length i.e roots of such plants perfectly exist within the water level. Those with extreme root lengths i.e the extremely shorter and extremely longer ones are selected against as they are denied access to water since their roots fail to reach the water level or go beyond it respectively and eliminates the extremes.

(e).Describe the evolutionary mechanism that cause change in distribution of root length ***(04 marks)***

Accessibility of plant roots to water imposes a selection pressure to plants. Plants with intermediate root length perfectly reach the water level rendering them a selective advantage ably absorb water. Those with extreme root length are selected against as they can't access water i.e either fail to reach the water level or go beyond it hence unable to absorb water. Selectively advantaged plants survive, reproduce and pass on their favourable genes to the next generation and over successive generations; these become the majority of the population and do eventually evolve into new species. The selectively disadvantaged plants die and fail to reproduce & become the minority of the population over. Over successive generations, these get eliminated from the environment.

The graph below shows the change in frequency of two varieties of peppered moths in an urban center, from the period of industrial revolution to the 21st century.



(f) Describe the changes in peppered moth frequency for the period shown. ***(05 marks)***

Light moths

Percentage of the light moths captured was initially high; remained almost constant between 1800 to 1850 then reduced rapidly up to 1900; attained minimum value at 1900; remained almost constant up to 1975; then increased rapidly up to 2000;

Dark moths

Percentage of the dark moths was initially low; remained almost constant up to 1850; then increased rapidly up to 1900 where it peaked; remained almost constant up to 1975; Percentage of light moths then decreased rapidly up to 2000

(g).Explain the observed changes in peppered moth population for the period given. ***(13 marks)***

Before the industrial revolution (1800-1850), most backgrounds were white and the non-melanic (light) moths formed the predominant population. Upon onset of the industrial revolution that was associated with the use of the coal as the major industrial fuel; produced a lot of soot which changed the camouflaging background to black. This trend made the black moths not easily spotted by their predatory birds since the background had turned black and could easily blend with the new background. The allele frequency of the black moths increased while that of the white moths reduced.
Population of the light moths then remained constantly low between 1800 and 1975 because the predation pressure/ death rate was matching with the birth rate. That of the light moths was also constantly high; because further population rise was being limited by density dependent factors like shortage of food/ space/ mates, intense intraspecific competition; accumulation of toxins etc such that death rate matched with birth rate; Dark moths finally decreased in number between 1975 and 2000; because of the overwhelming density dependent factors that made their death rate exceed their birth rate. Population of the light moths increased in return due to reduced intraspecific competition from the dark moths; such that their birth rate started exceeding their death rate.

Essay questions and answers

Question 1.

(a).State Mendel's laws of genetic inheritance ***(02 marks)***
(b).Using meiosis, explain how the laws described in (a) above operate ***(12 marks)***
(c).Explain why Mendel used garden peas for his experiments ***(06 marks)***

(a).

Law of Segregation: The characteristics of a diploid organism are controlled by alleles/ factors that occur in pairs and of each pair of such alleles, only one can be carried in a single gamete.
Law of Independent Assortment; Each of a pair of contrasted characteristics may be combined with either of another pair

(b).

Law of segregation

The stages of meiosis that explain the law of segregation include; Synapsis of homologues (prophase I) and metaphase I during when homologous chromosomes arrange themselves in two rows at the equator of the spindle. Towards the end of metaphase I, homologous chromosomes repel each other and orient towards the opposite poles towards the centromere. Segregation is completed during anaphase I during when the homologous chromosomes part company and more to the opposite poles. Assuming a diploid individual has two alleles for a particular gene, carried on two separate chromosomes (maternal and paternal), the allele on maternal chromosome segregates/ separates from the allele on paternal chromosome (Anaphase I) so that each allele is passed on to different gamete (offspring).

Law of independent assortment

Prophase I; during which crossing over occurs, proceeded by metaphase I; during which homologous chromosomes come to the equatorial plane; arrange themselves in a double row in a purely random fashion and at the end of metaphase part company to opposite poles; a process that is completed in anaphase. Their movement occurs after independent assortment i.e any chromosome can move to rather poles. Assuming an organism has 23 pairs of homologous chromosomes, the maternal and paternal chromosomes of pair 1 separate randomly during anaphase I with respect to maternal and paternal chromosomes of pair 2 or all the other pairs. There is no fixed chance that all the paternal or maternal chromosomes (alleles) will be passed to one gamete. This allows independent assortment of genes and for gametes and thus offspring to be much more genetically variable.

(c).

• Peas have clear cut differences in their characteristics of the same trait eg tall vs short for height.
• Peas have a short generation time such that many generations can be studied and many characteristics investigated concerning their transmission within a short time.
• It is easy to grow these plants in an open ground and in pots.
• The flowers could easily be cross pollinated because the stamens can easily be cut off.
• The flowers have stamens and pistils enclosed by petals for effective self-pollination / selfing.
• When hybrids are crossed, the offsprings are fertile.

Question 2.

(a).Explain what is meant by cross over values

(b).Outline the differences between

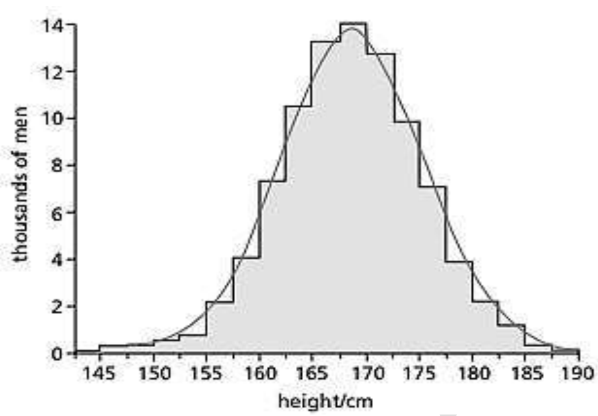
(i) Continuous and discontinuous variation *(07 marks)*

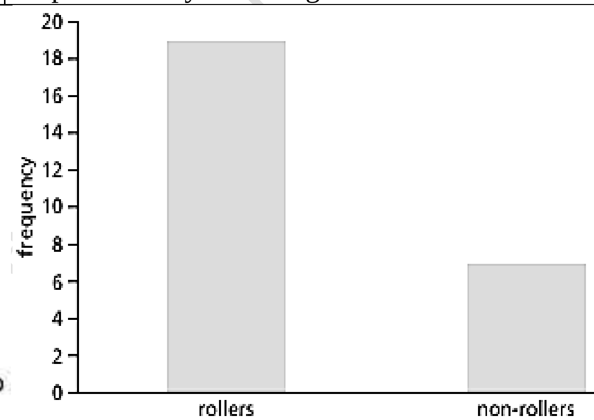
(ii)Monogenic and polygenic inheritance *(06 marks)*

(c).Outline the importances of pedigree analysis in genetics *(07 marks)*

(a)(i).

Continuous variation	Discontinuous variation
Shows grades in characteristics from one extreme through intermediate individuals to another extreme	Not graded with distinct and clear cut differences between individuals with no intermediates.
Has intermediates	No intermediates
Under polygenic control and non-allelic	Under control of few genes that are allelic
Influenced by environment	Not affected by the environment.
Greatly influence the evolutionary process	Less important in evolution.
Examples include weight, height, skin colour, egg yield, milk yield etc	Examples include sex, eye colour, blood group, tongue rolling, height in plants.
Represented by normal distribution curve	Represented by the histograms





(a)(ii).

Monogenic inheritance	Polygenic inheritance
Governed by two or more alleles of the same genes.	Governed by many genes or non-allelic
Controls discontinuous variation	Controls continous variation
Individuals with extreme characteristics are rare.	Individuals with extreme characteristics are more frequent
No intermediates represented	Have intermediates giving smooth gradation in characteristics
Phenotype not influenced by environment	Phenotype influenced by the environment
Also known as qualitative inheritance	Also known as quantitative inheritance

(b).

- Used in filling up possible genotypes by knowing the phenotypes only.
- Helps in the study of the patterns of inheritance of the dominant or recessive traits.
- Helps to identify whether genetic diseases is due to recessive or dominant genes
- Important in genetic counselling about the possibilities of having genetically defective children.
- It helps to identify the genotype of an offspring yet to be born.
- It helps to trace the origin of defective genes in the family.

Question 3.

(a)What is meant by the term gene mutation? *(03 marks)*

(b)Describe the role of mutation in arising of sickle cell anemia in individual. *(09 marks)*

(c).Explain the ecological significance of the existence of sickle cell trait in African population. ***(08 marks)***

(a).

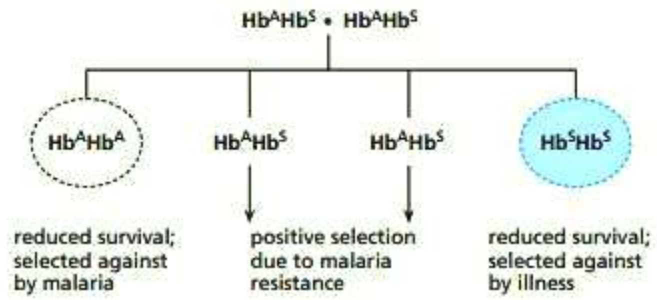
A gene mutation is a permanent alteration in the DNA sequence making up a gene; Gene mutations can be hereditary or acquired(somatic); Gene mutation can be in form of an Insertion; deletion; substitution; or a duplication;

(b).

The base substitution mutation involving substitution of thymine for adenine (from GAG to GTG) on the sixth codon of the genetic sequence; leads to coding of valine rather than glutamate on the sixth position of the beta chain of human adult haemoglobin (HbA); Homozygosity for this mutation renders the hemoglobin molecule insoluble upon deoxygenation ;RBCs containing deoxy-HbS polymers are rigid; less pliable; readily dehydrated; sickle shaped; easily crystallize at low oxygen partial pressures; This reduces red cell life span such that RBCs easily hemolyse in capillaries; causing sickle cell anaemia;

(c).

Sickle cell trait (HbAHbS); is associated with heterozygous superiority/advantage; in which such individuals confer resistance to both sickle cell disease and malaria; selection pressures that are endemic in Africa; Heterozygotes thus outcompete homozygotes; for both normal haemoglobin (HbAHbA) & those with sickler haemoglobin(HbS HbS); Individuals with sickle cell trait thus dominate the population where both selection pressures co-exist; The environmental resistance impacted by malaria is thus minimized in a setting where sickle cell trait dominates;



Question 4.

(a).Define the terms gene and allele and explain how they differ. ***(04 marks)***
(b).Outline how the process of meiosis can lead to Down's syndrome. ***(10 marks)***
(c).Karyotyping involves arranging the chromosomes of an individual into pairs. Describe one application of this process, including the way in which the chromosomes are obtained. ***(06 marks)***
(d).Explain why Mendel used Drosophilla melanogaster (fruit flies) in his experiments ***(05 marks)***

(a).

A gene is a heritable factor/ unit of inheritance composed of DNA that controls a specific characteristic/ codes for a polypeptide/ protein while an allele is an alternative form of a gene. Alleles of a gene occupy the same gene locus/ same position on chromosome and differ (from each other) by one/ a small number of bases(s)/ base pair(s).

(b).

In metaphase I, homologous chromosomes are attached on the spindle fibres in equatorial plane of cell. Homologous chromosomes are separating during anaphase I but one pair doesn't separate/ non-disjunction. In telophase, cells divide into two and cells have either one more / one less chromosome. It can also occur in second division of meiosis in which sister chromatids fail to separate. Fertilization with one gamete/ sperm/ egg carrying extra chromosome results in Down's syndrome which is trisomy of chromosome 21.

(c).

• Sex differentiation (XX = female and XY =male)
• Test for congenital chromosomal anomalies like Down's syndrome (third chromosome 21 indicates Down's syndrome), Klinefelter's syndrome etc.
• Diagnosis of disorders of gonadal development

Procedure

Fetal cells obtained from amniotic fluid/ amniocentesis/ other named source, white blood cells obtained, cells encouraged to divide, accumulated / blocked in metaphase. Slide is taken and chromosomes examined.

(d).

• The fruit fly has a number of contrasting characteristics for a particular trait.
• They are easy to culture under a suitable nutrient medium of glucose on a gel agar.
• They have giant chromosomes that can easily be isolated and the genes located.
• They have high reproductive rate such that all characteristics of the parent are expressed in the many offsprings
• They have a short generation time such that characteristic can be studied together with its mode of transmission within many generations but in short period of time.

Question 5.

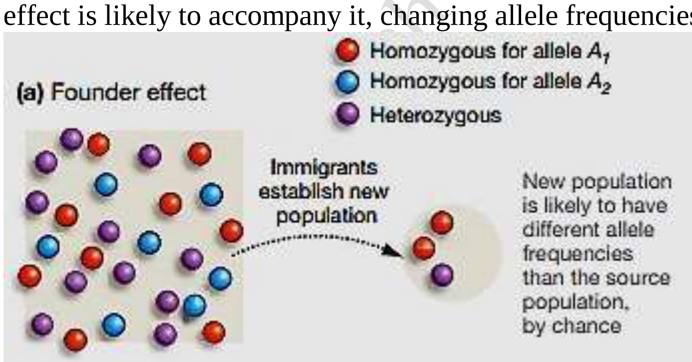
(a)What is meant by genetic drift? *(04 marks)*
(b).Describe the two main causes of genetic drift in natural populations *(12 marks)*
(c).Explain why genetic drift;
(i).Leads to a random loss or fixation of alleles. *(02 marks)*
(ii)Is particularly important as an evolutionary force in small populations *(02 marks)*

(a).

Genetic drift is defined as any change in allele frequencies in a population that is due to chance. When drift occurs, allele frequencies change due to blind luck. Drift occurs in every population, in every generation, but especially in small populations. Genetic drift is random with respect to fitness and the changes in allele frequency that it produces are not adaptive. Over time, genetic drift can lead to the random loss or fixation of alleles.

(b).

Founder effect; When a group of individuals immigrates to a new geographic area and establishes a new population, a founder event is said to occur. If the new population is small enough, the allele frequencies in the new population are almost guaranteed to be different from those in the source population due to sampling error. A change in allele frequencies that occurs when a new population is established is called a founder effect. Each time a founder event occurs, a founder effect is likely to accompany it, changing allele frequencies through genetic drift.



Genetic Bottleneck; If a large population experiences a sudden reduction in size, a population bottleneck is said to occur. Disease outbreaks, natural catastrophes such as floods or fires or storms, or other events can cause population bottlenecks. Genetic bottlenecks follow population bottlenecks A genetic bottleneck is a sudden reduction in the number of alleles in a population. Genetic drift occurs during genetic bottlenecks and causes a change in allele frequencies.

(c)(i).

When allele frequencies fluctuate randomly up and down, sooner or later the frequency of an allele will hit. That allele thus is lost from the population, and the other allele at that locus is fixed.

(c)(ii).

In small populations, sampling error is large. For example, the accidental death of a few individuals would have a large impact on allele frequencies.

Question 6.

(a) Define the following terms as population genetics
(i). Deme *(01 marks)*
(ii) Genetic equilibrium *(01 marks)*
(iii) Reproductive isolation *(01 marks)*
(b). State the Hardy Weinberg's principle of population genetics *(02 marks)*

(c). Describe how genetic equilibrium can be upset in a population ***(05 marks)***
(d). Give an account of how reproductive isolation is brought about ***(10 marks)***

(a)(i).

A deme is an isolated sub-population subjected to selection as an entire breeding unit rather than as individuals. Separate demes are more or less reproductively isolated and limit gene flow.

(a)(ii).

Genetic equilibrium is the maintenance of a constant overall gene frequency of the dominant and recessive alleles of a population.

(a)(iii).

Reproductive isolation is the occurrence of an ecological, behavioural or genetic barrier that prevents individuals/ organisms of a certain population to successfully breed with each other.

(b).

In a large randomly breeding population, the frequency of the dominant and recessive remains constant from generation to generation provided there are no mutations, migrations or selection for particular alleles.

(c).

• **Occurrence of mutations;** may result in loss or gain of alleles; alter gene/allele frequency
• **Occurrence of migrations;** Immigrations may introduce new alleles while emigrations lead to loss of alleles from the population; alter gene/allele frequency.
• **Biased/ non-random mating;** members have unequal chances of passing on their alleles to the next generation. Genes for desired characteristics are favoured; eliminating the undesirable; change the allele/ gene frequency.
• **Small population size;** some alleles fail to be passed on the next generation. Genetic drift (accidental loss of an allele from the population) is high in small populations.
• **Selection for particular alleles;** e.g through artificial selection gives some genes selective advantages over others, genetic equilibrium is compromised.

(d).

Pre-zygotic means; impede fertilization or mating

Behavioral;

Inappropriate courtship displays e.g lack of attractiveness fails to stimulate other organism hence no mating.
Temporal or seasonal isolation; organism of a species may mate/flower at different times of the year e.g Pinus radiata in February and Pinus attenuata in April
Ecological isolation; organisms of species with different habitat preferences e.g Viola aruesis on calcareous soils and Viola trichola on acidic soils
Mechanical isolation; Genitalia incompatibilities prevent successful copulation, failure of sperms to survive in the female genital tract due to much acidity.
Gametic isolation; occurs when male gametes do not survive in the environment of the female gamete (such as in internal fertilization) or when female gametes do not recognize male gametes.
Post-zygotic means; impedes reproductive maturity or general reproduction of the offspring.
Hybrid inviability; occurs when the zygote fails to develop properly and aborts or dies, before reaching reproductive maturity.
Hybrid sterility; occurs when hybrids become functional adults, but are reproductively sterile (eggs or sperm are nonexistent or dysfunctional). The mule, a sterile offspring of a donkey and a horse, is a sterile hybrid.
Hybrid breakdown; occurs when hybrids produce offspring that have reduced viability or fertility.

Question 7.

(a).Explain how the interaction at one locus and between loci can affect the phenotypic variation ***(09 marks)***
(b).How does natural selection increase the adaptation of a species to the environment ***(11 marks)***

(a).

Interactions at one locus

Co-dominance; where alleles express themselves independently and equally in the phenotype e.g allele A and B are co-dominant in blood group AB.
Partial/incomplete dominance; where both alleles express themselves in the phenotype but one does so more than the other.

Dominant and recessive genes; where the presence of dominant genes suppresses phenotypic expression of recessive genes
Multiple allele; like the ABO blood group system where the alleles for A & B are codominant but O is recessive to both.

Interactions between two loci

Polygenes; where many genes interact together to give different phenotypes e.g skin pigmentation
Complementary genes; where one pair of genes complements another pair it interacts with; giving rise to a different phenotype.
Supplementary genes; these apparently have no phenotypic effects but facilitate other genes to bring out a particular phenotype.
Epistatic genes; these mask expression of hypostatic genes in the phenotype e.g coat colour in dogs.

(b).

Organisms with favourable characteristics have selective advantages over others; and these are favoured/ selected for by the environment. They survive up to their reproductive age; breed to pass on their genes for the favoured characteristic to the next generation hence off springs of the subsequent generations are better adapted to survive. However the survival value of an inherited characteristic may change with time and characteristics which were favoured may no longer have selective advantages and other characteristics may be favoured. Favoured characteristics are the passed on to the next generation;

Question 8.

(a).Explain what is meant by sex linked and sex limited traits ***(05 marks)***
(b).Giving examples, discuss the inheritance of sex linked and autosomal traits ***(10 marks)***
(c).Explain using an appropriate example why many sex-linked diseases occur more frequently in men than women. ***(05 marks)***

(a).

Sex linked traits are those whose genes/ alleles are carried on the sex chromosomes hence transmitted along with the sex chromosomes. They are transmitted mainly along X-chromosomes as the Y chromosome carries very few genes other than those determining maleness. Examples of traits carried on the X chromosomes include; colour blindness and haemophilia. They are non-autosomal caused by recessive alleles. Y linked traits include porcupine man.
Sex limited traits are inherited trait carried on autosomal chromosomes; but are expressed phenotypically in only a particular sex. i.e either male or female. These include muscular development in male and beards in males, breasts in females.

(b).

Autosomal recessive traits can only be expressed in homozygous recessive conditions; the expression of which shows no selectivity between the male and female offspring. The trait can be inherited on any chromosome except the sex chromosomes. For an offspring to express an autosomal recessive trait, both parents must atleast carry one recessive allele.
Autosomal dominant traits are expressed when the dominant allele appears in either the homozygous or heterozygous state. Atleast one of the parents must carry the dominant allele. Autosomal traits include; muscular dystrophy, cystic fibrosis, sickle cell anemia etc. Inheritance of sex linked traits is linked to sex of the offspring; male offspring inherits an X chromosome form the mother and Y chromosome from the father; whereas a female offspring inherit X chromosomes from both parents. The human X chromosome is much larger than the Y chromosome; so that males will have alleles present on the X chromosome expressed in the phenotype whether dominant or recessive; since there is no allele to counter the dominance. Sex linked traits are thus predominant in males since they carry as single X chromosome. The mother must be homozygous i.e recessive for a particular or a carrier and the father must express the traits. A female hemophiliac must have a hemophiliac father and a mother who is a carrier or a hemophiliac.

(c).

Sex-linked diseases like haemophilia is transmitted caused by recessive alleles carried on the X chromosome. Females are XX and males are XY hence females have two alleles of the gene and males have only one allele causing the disease. Female would have to inherit the allele from her father who would have suffered from the disease so females can carry the gene but still be normal but males (with the gene) will have the disease.

Question 9.

Both haemophilia and colour blindness are transmitted in the same way.

(a).What are the effects of each disease ***(06 marks)***

(b).Describe the transmission of the diseases ***(10 marks)***

(c).Explain why there are more colour blind individuals than hemophiliacs among human population despite the similar transmission modality ***(04 marks)***

(a).

Hemophilia is a heritable disorder which is sex linked and carried on the X chromosome; due to a fault in the genes responsible for production of clotting factors (factor VIII and IX) that are required for normal blood clotting. It leads to excessive bleeding even from minor injuries. Patients are more prone to bacterial infections due to prolonged healing of wounds. Poor healing makes survival hard and complicates surgical operations.

Colour blindness is a heritable disorder in which an individual cannot distinguish between certain colours eg green and red etc due to the defect in the gene in the codes for the synthesis of one of the three groups of cones in the retina.

(b).

Both are heritable disorders due to recessive gene carried on the X-chromosome; the genes are transmitted along with the sex determining genes during fertilisation and are more common in males. The male who is genetically XY can be normal or has the recessive gene since the Y chromosome doesnot carry the gene, giving a 50% chance of inheriting the disorder. The female who is genetically XX can be heterozygous and hence a carrier giving three possible genotypes for normal, carrier or the individual with the disorder. This gives athird chance in female to inherit the disorder. With haemophilia, a substitution gene mutation leading to a recessive gene on the X chromosome and leads to failure of producing factor VIII and IX in haemophilic individual. With colour blindness, a deletion gene mutation occurs, leading to absence of appropriate colour genes in X chromosomes of colour blind individuals.

(c).

• Haemophilia, unlike colour blindness is potentially lethal and therefore selected against, sufferers being less likely to survive to sexual maturity and so produce offsprings

• Haemophiliacs, unlike colour blind individuals may choose not to have children knowing the risk that their offsprings may suffer the disease

• Haemophiliac females rarely survive to child bearing age; and hence only carriers may pass on the disease. With colour blindness, both the sufferers and the carriers can pass on the condition.

Question 10

(a).Explain what is meant by genetic counselling ***(02 marks)***

(b).Explain the importance of genetic counselling in health care provision ***(10 marks)***

(c).State how non-disjunction in the production of female gametes can result in chromosomal aberrations

(a).

The process of identifying parents at risk of producing children with genetic defects and of assessing the genetic state of early embryos.

(b).

• In the absence of a cure for certain genetic diseases, genetic counselling forms the basis for trying to avoid producing children with these conditions.

• Through genetic counselling, parents at risk of producing children with genetic defects are identified and offered appropriate pre-conception counselling services.

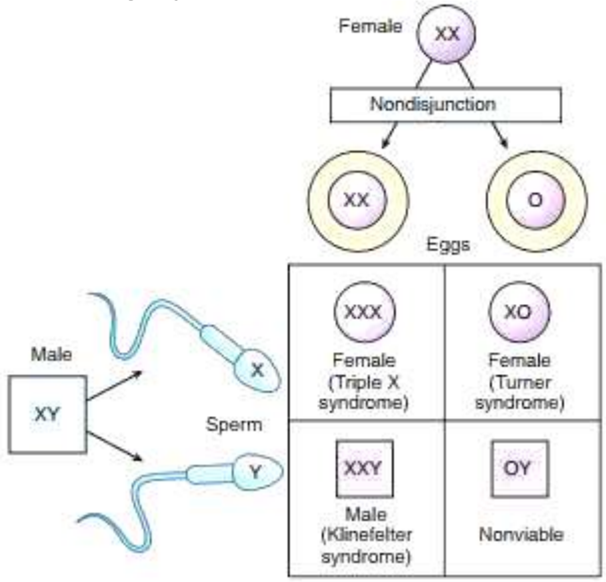
• Pedigree analysis; one of the tools used in genetic counselling enables potential parents determine the likelihood that they carry the allele for certain disorders caused by a recessive allele such as the likelihood that the person is a carrier.

• Assesses high-risk pregnancies like mothers conceiving at more than 35 years old due to increasing risk of genetic anomalies like Down's syndrome with increasing age.

• Through genetic counselling, procedures such as amniocentesis and chorionic villi sampling are performed enabling prenatal diagnosis of many genetic disorders.
• Genetic counselors can look for other associated genetic disorders with known genetic markers. For sickle cell anemia, Huntington's disease etc investigators have found other mutations on the same chromosomes that, by chance, occur at about the same place as the mutations that cause those disorders. By testing for the presence of these other mutations, a genetic counselor can identify individuals with a high probability of possessing the disorder-causing mutations.

(c).

When nondisjunction occurs in the production of female gametes, the gamete with two X chromosomes (XX) produces Klinefelter males (XXY) and XXX females. The gamete with no X chromosome (O) produces Turner females (XO) and nonviable OY males lacking any X chromosome.

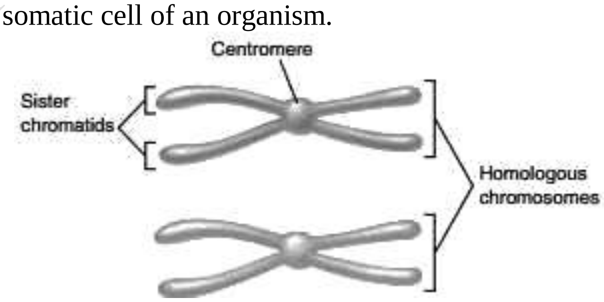


Question 11

(a).Distinguish between sister chromatids and homologous chromosomes ***(02 marks)***
(b).Why is the study of genetics important in the day to day life ***(10 marks)***
(c).Explain the factors that affect crossing over ***(08 marks)***

(a).

Sister chromatids are pairs of chromatids located on the same chromosome while homologous chromosomes refer to structurally similar chromosomes one obtained from the mother and another from the father during fertilization which exist in the nucleus of a somatic cell of an organism.



(b).

• It is used in genetic engineering where better breeds and varieties of plants and animals are produced. This is intended to increase production and improve resistance of diseases and pests. This can be done locally through cross breeding.
• It is used in the legal profession to determine the paternity of the child i.e. genetics is used to settle paternal disputes by confirming who the father of the child is. This can be proved through use of blood groups as these groups

are genetically inherited and can therefore be used to prove the rightful father of the child. If the blood groups fail to prove then DNA analysis can be used.

• They are used in blood transfusion. Genetic principals are used during blood transfusion so that blood being transfused is compatible to avoid blood clotting (agglutination) in the recipient.

• It is used in the control of the transmission of genetic diseases. These diseases are genetically engineered e.g haemophilia, colorblindness, acandroplasia etc can be eliminated from the human population by following the principles of genetics as these diseases are genetically inherited.

• It can be used in crime investigation i.e. use of the DNA finger prints to identify criminals

• It is used in molecular biology to manufacture artificial enzymes, hormones and vaccines.

• Enables humans to choose right partners during marriage by choosing those with favourable characteristics

(c).

The relative distance between the genes on the chromosome; When the genes are far apart from each other on the chromosome, they have high chances of forming chiasmata in between thereby leading to genetic exchange on the other hand when genes are very close to each other on the chromosome, their chances of forming chiasmata is limited.

The position of the centromere on the chromosome; If the genes are very close to the centromere their chances of undergoing genetic exchange are limited. However, if the genes are far away from the centromere, there are high chances that they can be exchanged by crossing over.

Temperature; Crossing over decreases with increase in temperature because the process of meiosis requires suitable temperature that can promote efficient crossing over.

Age of the organism; Increase in age lowers the chances of crossing over. Meiosis is more efficient in grown up adults before menopause stage in females and before senescence in male.

Mutagens; These can decrease or increase the rate of crossing over. The chances of crossing over are greatly reduced by presence of chemical substances that inhibit chiasmata formation thereby preventing cross over e.g. in drosophila flies.

Question 12.

(a).Explain what is meant by gene reshuffling ***(02 marks)***

(b).Explain the causes of gene reshuffling ***(14 marks)***

(c).Why is reshuffling considered to be of little consequence in evolution ***(04 marks)***

(a).

Reshuffling of genes refers to the random orientation of chromosomes at the equator of the spindle during meiosis which changes the positions of the genes on the chromosomes.

(b).

Crossing over: this is the exchange of genetic material between the non-sister chromatids of homologous chromosomes during pachytene stage of prophase I of meiosis. This produces new linkage groups and so provides a major source of genetic recombination of alleles on chromosomes

Independent assortment; During independent assortment in metaphase I, chromosomes are distributed randomly at the equator and segregate (separate). It is by pure chance as to which chromosome from each homologous pair ends up in a daughter cell at the end of meiosis and therefore all sorts of allele combinations are possible in the gametes. This reshuffles the existing alleles thereby producing new genetic recombinations in of the gametes and the offsprings formed from these gametes when they fuse randomly during fertilisation.

Fertilization; Fertilization occurs randomly between the male and female leading to mixing of genes in different combinations.

Mutation; mutations change the genotype of an organism with respect to a specific characteristic as it produces new alleles in the population hence making it to vary due to the combination of mutant and non- mutant gametes during random fertilisation.

Genetic drift; This refers to a loss of genes from a small population or the change of genes of a small population by chance alone and not natural selection which results into the change of the gene frequency of the small population. This changes the phenotypic appearance of the organisms thereby making them to vary.

Cross breeding; This mixes genes from different individuals resulting into the formation of hybrids (heterozygotes) with improved qualities compared to the parents.

(d).

Reshuffling of genes by independent assortment, random segregation, crossing over and fertilisation donot generate significant changes in the genotypes which are necessary for evolution. This is because no new genes are introduced or lost; the genes that are present are the ones that are reshuffled and the established variations may be resolved in the subsequent generations.

Question 13.

Discuss Mendel's laws of segregation and independent assortment with respect to

(a).Genes that are not linked ***(05 marks)***

(b).Sex-linkage ***(05 marks)***

(c).Down syndrome ***(05 marks)***

(d).Turner syndrome ***(05 marks)***

(a).

When the chromosomes align on the metaphase plate during meiosis I, homologous chromosomes are paired. Each homologue migrates to a separate pole and becomes a member of a separate gamete. The migration to separate poles is random that is, either chromosome of a homologous pair can migrate to either pole (Mendel's law of segregation). Different homologous pairs of chromosomes act independently of other homologous chromosome pairs Thus genes that are on different chromosomes (unlinked) migrate independently of genes on other chromosomes (Mendel's law of independent assortment).

(b).

Sex linkage occurs when a gene is located on one of the sex chromosomes, usually the X chromosome. For example, in humans, hemophilia is inherited as a recessive allele on the X chromosome. Females receive two copies of the gene, one on each of their X chromosomes. If they receive two recessive alleles, they are hemophiliacs. If they receive two normal alleles, they are normal, but if they inherit one normal and one hemophilia allele, they will have normal clotting abilities (because the normal allele is dominant) but will be carriers of the disease. Males, on the other hand, inherit only one X chromosome and, thus, only one copy of the allele. If they receive the normal allele, they will have normal clotting; if they receive the hemophilia allele, they will be hemophiliacs. Because they need only one copy of the allele to express the trait, sex linked diseases are more common in males than in females.

(c).

Down syndrome occurs as a result of the nondisjunction of the two number 21 chromosomes. As a result, the homologous pair does not separate and move to opposite poles (as the law of segregation implies), but rather both chromosomes end up at the same pole and in the same gamete. Two kinds of gametes are formed, one with two copies of chromosome 21 and one with no chromosome 21. Only the gamete with two copies of the chromosome is viable. The zygote formed between this gamete and a normal gamete will have three copies of chromosome 21 and the infant will express the Down syndrome phenotype, which consists of physical abnormalities and mental retardation.

(d).

Turner syndrome results from a nondisjunction of the sex chromosomes. This results in a gamete that has either 2 sex chromosomes or no sex chromosomes. If a gamete with no sex chromosomes (O) fuses with abnormal gamete bearing the X chromosome, the resulting zygote will have only a single X chromosome (XO) and express the Turner syndrome phenotype. Turner syndrome individuals are female and exhibit physical abnormalities, including sterility.

Question 14.

(a).How is sex determined in humans? ***(04 marks)***

(b).A woman has four sons, one of whom is a haemophiliac and the other three are normal.

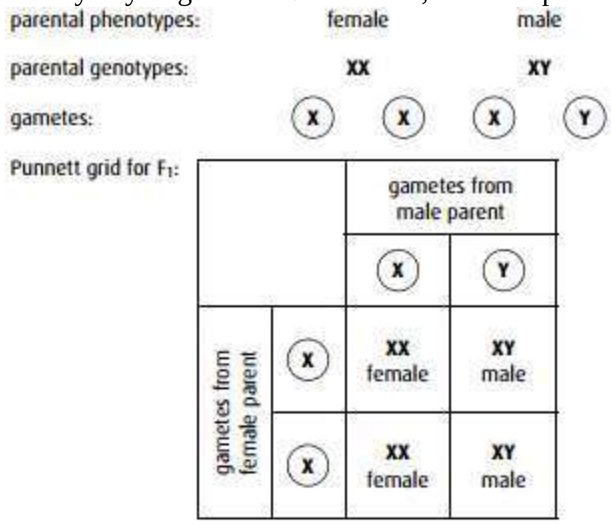
(i). What are the possible genotypes of the woman and her husband ***(12 marks)***

(ii) Is it possible for the couple to have a haemophiliac daughter? Explain your answer ***(04 marks)***

(a).

Sex in humans is determined by a pair of sex chromosomes. An individual has one pair of sex chromosomes either XX or XY, along with 22 other pairs known as autosomes. The X chromosome is longer than the Y and carries more genes. Human females have XX and males have XY. On segregation, the female produces homogametes (two

X chromosomes) while males produce heterogametes (one X and one Y chromosome). On fertilization, a 50% (equal) chance of getting either a baby boy or girl exists. Therefore, the male parent determines the sex of the child.



(b)(i).

The allele for haemophilia is recessive; sex linked and carried on the X chromosome; The sons are XY and the Y chromosome could only have been contributed by the father; the mother only provides the X chromosome. As one son has haemophilia and the allele is carried on the X chromosome, the mother must have one X chromosome that bears the haemophiliac allele. As her other sons are normal, the other X chromosome doesnot carry the allele (i.e the mother is X^HX^h). The genotype of the father could be either X^HY and is normal or X^hY and is haemophiliac. The 25% chance of getting a haemophiliac boy when a carrier woman mates with either a normal man or a haem-ophiliac man could be responsible for the existence of the one hemophiliac boy among the four sons of couple.

Let h represent allele for hemophilia.

Parental phenotypes: Carrier woman x Normal man

Parental genotypes:(2n) X^HX^h X^HY

	X^H	Y
X^H	X^HX^H	X^HY
X^h	X^HX^h	X^hY

F_1 phenotype ratio; 1normal girl: 1 normal boy: 1 carrier girl: 1 hemophiliac boy

OR

Parental phenotypes: Carrier woman x sickler man

Parental genotypes:(2n) X^HX^h X^hY

	X^h	Y
X^H	X^HX^h	X^HY
X^h	X^hX^h	X^hY

F1 phenotype ratio; 1 carrier girl: 1 normal boy: 1 sick girl: 1 hemophiliac boy

Possible genotypes; father's genotype is either X^HY or X^hY; and the mother's genotype is X^HX^h

(b)(ii).

Yes it is possible for a couple whose genotype is X^HX^h (carrier female) and X^hY(hemophiliac male) because a 25 % chance of getting a hemophiliac girl is possible with such genetic constitution of the parents. However, for a couple in which the female is a carrier (X^HX^h) and the male parent is normal (XHY), all females are either norm-al or carriers hence no possibility of having a hemophiliac girl.

Question 15.

(a).Describe the biochemical processes involved in transforming the information stored in a gene into the expression of a physical trait. ***(14 marks)***
(b).Contrast the ways in which bacteria and viruses cause disease. ***(06 marks)***

(a).

Genes are segments of the DNA that contain instructions for producing a specific polypeptide. Expression of physical trait manifests by synthesizing specific proteins. Protein synthesis consists of two parts, transcription and translation. RNA polymerase directs RNA nucleotides to base-pair with the DNA fragment that represents the gene. If a fragment of DNA contained the nucleotide sequence adenine, cytosine, guanine, and thymine, the RNA nucleotides that would base-pair with it are uracil, guanine, cytosine, and adenine, respectively. The mRNA contains the code for the polypeptide. After the removal of noncoding intervening sequences, called introns, mRNA moves to the cytoplasm. In the cytoplasm, ribosomes, consisting of rRNA and proteins, attach to the mRNA. There are three binding sites in the ribosome; one for the mRNA and two for tRNA. In the process of translation, ribosomes direct the pairing of the anticodons of tRNAs with appropriate triplet regions of the mRNA called codons. Each mRNA codon specifies a particular amino acid. The genetic code describes which amino acid is indicated by each of the 64 different mRNA codons. Some codons indicate a stop code. Another codon indicates methionine, the start amino acid. During translation, the ribosome provides binding sites to incoming tRNAs. Each tRNA brings the appropriate amino acid as dictated by the codon sequence on the mRNA. As each new tRNA arrives, the growing polypeptide chain that is attached to the previous tRNA is transferred to the new tRNA. The old tRNA is released; the ribosome moves over one binding site; and the process repeats until the stop codon is encountered. At this point the ribosome separates into two subunits, and the polypeptide is released. Once released, the amino acids in the polypeptide may interact with one another giving the polypeptide secondary and tertiary protein structures. In its final form, the polypeptide can enzymatically regulate a reaction that will produce some end product, or trait.

(b).

Viruses cause disease by destroying cells. Viruses consist of a nucleic acid core (either DNA or RNA) and a protein coat. In the lytic cycle of reproduction, a DNA virus enters a cell and uses the metabolic machinery and raw materials of the cell to manufacture more viral DNA and viral protein coats. The viral DNA and protein assemble into hundreds of new viruses that burst from the cell, killing the cell in the process. In the lysogenic cycle, the virus may temporarily remain dormant as part of the host's genome, to become active only when exposed to radiation or other environmental disturbance. When activated, the viral DNA begins the lytic cycle. Some viruses are RNA retroviruses. These viruses produce the enzyme reverse transcriptase to first manufacture DNA, which in turn, enters a lytic or lysogenic cycle.
Bacteria, in contrast, do not usually cause disease by direct destruction of host cells. Rather, most bacteria cause disease by producing toxins, usually waste products of their normal metabolism. When the toxins affect the normal metabolism of the host, disease results. Some bacteria also cause disease by competing for the same resources as do the host cells. In other cases, the symptoms of a disease are the result of the host's response to invasion by foreign bodies. For example in pneumonia, the mucus that accumulates in the lungs is produced by the lung cells in response to the presence of the bacteria.

Question 16.

(a).Explain why a single base deletion from one Deoxyribonucleic molecule usually causes greater effect than the replacement of one base by another different base. ***(10 marks)***
(b).Using a named example, describe how a gene mutation may affect a phenotype of an organism.

(a).

Deletion of a single base causes forward shifting of bases behind the mutation / frame shift mutation occurs; This alters the triplet codes after the mutation point on the DNA nucleotide sequence in the gene; The base deletion causes a change in the reading frame; During transcription, the codons on the RNA transcribed after the mutation point is also altered; This causes the formation of a different sequence of amino acids in the polypeptide; A faulty or non-functional protein is formed; e.g β-Thalassaemia. On the other hand, if only one base is substituted, only a single genetic code is altered, leading to one altered codon in the transcribed mRNA; So only one amino acid may be different in the polypeptide produced; There is only a slight change in the polypeptide chain; eg in sickle cell disease.

(b).

Sickle cell anaemia is caused by base substitution in the gene; Substitution of the base thymine in CTT in DNA sequence with the base adenine changes the triplet code to CAT; This causes the glutamic acid to be substituted with valine at the 6th position of amino acid in the β-polypeptide chain; This causes formation of abnormal haemoglobin (HbS); At low oxygen concentration, the haemoglobin molecules crystallize in the cells; The red blood cells are distorted into sickle-shaped cells; This causes them to have a reduced oxygen binding affinity; The cells fragment easily, get stuck in blood capillaries, impede blood flow to reduce oxygen supply to tissues like muscles and organs e.g. kidney, heart, brain; Homozygotes (HbSHbS) for the mutated alleles suffer from severe anaemia which may lead to early death; Heterozygotes (HbAHbS) suffer from mild anaemia & more resistant to malaria;

Question 17.

(a)(i).What is meant by genetic recombination? ***(04 marks)***

(a)(ii).State the importance of genetic recombination in the process of evolution ***(01 marks)***

(b).Outline the factors that limit degree of recombination in populations of sexually reproducing organisms

(c).Discuss how Mendel's law of segregation and independent assortment correlate with;

(i).Genes that are linked ***(06 marks)***

(ii).Crossing over ***(04 marks)***

(a)(i).

Re-arrangement of genes that occurs when reproductive cells (gametes) are formed. It results from crossing over of homologous chromosomes and random/ independent assortment of parental sets of chromosomes during meiosis. Mixing of the parental genotypes during fertilisation also forms new gene combinations.

(a)(ii).

Basis of genetic variation; on which natural selection operates; to bring about evolution.

(b).

- Size of the gene pool; Number of chromosomes and hence the genes involved
- Frequency of crossing over at meiosis
- Amount of gene flow between populations
- Length of the generation time
- Type of breeding (self versus cross fertilisation/ single versus multiple breeding)

(c)(i).

When two genes are linked, they are on the same chromosome. If they are on the same chromosome, they migrate together to either pole (unless crossing over occurs). Thus, they violate Mendel's law of independent assortment and are inherited together as if they were a single gene in a monohybrid cross. If the dominant alleles A and B are on one chromosome and the recessive alleles a and b are on the homologous chromosome, they produce only two kinds of gametes, AB and ab. The dihybrid cross AaBb × AaBb would produce a 1:2:1 genotypic ratio for AABB, AaBb, and aabb with a phenotypic ratio of 3:1, not the typical 9:3:3:1 phenotypic ratio Mendel found when using unlinked genes. The 1:2:1 and 3:1 genotypic and phenotypic ratios are those expected from a typical monohybrid cross.

(c)(ii).

Crossing over occurs between linked genes. Instead of producing only two kinds of gametes; say AB and ab exchanges occur between homologous chromosomes, producing some Ab and aB gametes, quantities of which depend on the frequency of crossing over. The frequency of crossing over increases as the distance between the gene loci increases.

Question 18.

(a)(i).How do the different forms of gene interractions differ ***(02 marks)***

(a)(ii).Describe the different forms of epistaxis using relevant examples in each case ***(12 marks)***

(b)(i). What are cross over values and why they are usually computed ***(03 marks)***

(b)(ii) Discuss the conditions that will lead to emergence of polyploidy in a population ***(03 marks)***

(a)(i).

In co-dominance & lethal genes the effect is on one gene locus while in epistaxis and complementary genes, the effects are on two gene loci.

(a)(ii).

In **Epistatic recessive gene;** the presence of recessive alleles of one gene suppresses the effects of another gene; at another gene locus; eg inheritance of fur colour in mice is controlled by two sets of genes; dominant allele of one gene(A) promotes colour while its recessive allele(a) inhibits colour and controls white colour (albinism). The dominant allele for the other gene(B) controls grey(agouti) colour while its recessive allele(b) controls black colour; The genotypes aaBB, aaBb, aabb are all phenotypically white (albinos)
In **epistatic dominant gene;** the presence of the dominant alleles of one gene suppresses the effects of another gene at another gene locus eg the white leghorn fowl, plumage colour is controlled by two sets of genes; dominant allele(W) is inhibiting the white colour while its recessive alleles(w) promotes colour; the dominant allele for the other gene(B) controls black colour; while its recessive allele(b) controls brown colour. The genotypes WWBB, WWBb, WwBB, WwBb and Wwbb are all phenotypically white.

(b)(i).

Cross over values is the proportion of individuals showing new characteristics due to crossing over.
Cross over values are used to determine positions of genes on chromosomes, also show the relationship between genes/ distance apart between genes on the chromosomes.

(b)(ii).

DNA replication and chromosomal duplication occurs during interphase of mitosis but without cytokinesis; resulting in formation of tetraploid (4n)
Failure of spindle fibres to form; lead to non-disjunction; diploid gametes are formed; union/ fusion of the diploid gametes with either diploid ones or normal haploid; gametes produce polyploids such as 3n,4n, 5n.

Question 19.

(a).Describe how
(i). nucleic acids are formed from nucleotides ***(06 marks)***
(ii) gene and chromosome mutations cause change in the structure of DNA ***(10 marks)***
(b).Why is it important for a mutation to occur in asexually produced organisms ***(04 marks)***

(a)(i).

Two nucleotides join together by condesation reaction between the phosphate group of one nucleotide and the hydroxyl group; of the sugar of the nucleotide resulting in the formation of the phosphodiester bond; until a nucleic acid is formed; whose base pairs are held by hydrogen bonds and are complementary (cytosine with guanine and thymine and adenine).

(a)(ii).

Gene (point) mutation; occurs on a single locus on chromosomes
Duplication; where a portion of the nucleotide chain is repeated
Deletion; where a portion of the nucleotide is removed from the sequence
Addition/ insertion; where an extra nucleotide sequence becomes inserted in the chain
Inversion; nucleotide sequence becomes separated; from the chains and rejoins in its original position;
Substitution; one of the nucleotide bases is replaced by another one which has a different organic base
Chromosome mutation; affects more than one locus. Changes to whole sets of chromosomes/ possession of extra chromosome sets; can be auto-polyploidy (occurs within the same species) or allopolyploidy (occurs between different species.

Changes to individual chromosomes

Duplication; repetition of a portion of chromosome
Translocation; a portion of the chromosome separates and reattaches else where
Deletion; removal of a portion of the chromosome
Inversion; reversal of a sequence of genes on a chromosome

(b).

Asexually produced organisms have limited variations; so mutations introduce new genes which increase chances of variations; and if favourable; the organisms will be able to adapt to the changing environment; which promotes evolutionary success.

Question 20.

(a) Distinguish between co-dominance and incomplete dominance ***(04 marks)***
(b) What is the genetic basis of

(i) hybrid vigour/ heterosis? ***(08 marks)***
(ii) Determination of the ABO blood groups. ***(08 marks)***

(a).

Co-dominance is a phenomenon whereby the alleles controlling a particular characteristic have equal powers of expressing themselves in the phenotype in the heterozygote. Therefore, the offsprings produced will have a mixture of the two parental characteristics in the phenotype while **Incomplete dominance** is a condition whereby the characteristics of the alleles blend together to form an F_1 offspring phenotype which is intermediate between the two parental phenotypes. Therefore, the F_1 individuals do not resemble any of the parent.

(b)(i).

Dominance hypothesis: explains heterosis by the complementing action of superior dominant alleles from both parental inbred lines at multiple loci over the corresponding unfavorable alleles, leading to improved vigor of hybrids

Over-dominance hypothesis: attributes heterosis to allelic interactions at one or multiple loci in hybrids that results in superior traits as compared to parents. It states that the heterozygote at one or more loci is superior to either homozygote. Allelic interactions at a single heterozygous locus result in a synergistic effect on vigor that surpasses both homozygous parents.

Epistasis; the interaction of favorable alleles at different loci contributed by the two parents, which themselves may show additive, dominant or over-dominant action

(b)(ii).

Follows multiple allele inheritance. The ABO blood group system is controlled by three alleles of a gene I (isohaemogglutinogen) occur at a single ABO locus. These alleles are A or I^A, B or I^B and O or I^O. These alleles I^A and IB are equally dominant while the allele. I^O is recessive to both. The transmission of three alleles occurs in a normal Mendelian fashion. I^AI^A (AA) is blood group A (homozygous), I^AI^O (AO) is blood group A(heterozygous), I^BI^B (BB) is blood group B (homozygous), I^BI^O (BO) is blood group B(heterozygous), I^AI^B (AB) is blood group AB (co-dominant) and I^OI^O (OO) is blood group O.

Question 21.

(a).Derive the Hardy-Weinberg equation from first principles. ***(10 marks)***
(b).Describe how the following affect the allele frequency of sexually reproducing population;
(i). Random mating
(ii).Genetic drift.
(iii).Geographical isolation ***(10 marks)***
(c). A particular species of insects may occur in either light or dark form. The dark trait is dominant. In a certain population of 5000 such insects, there are 950 which are dark. Using the Hardy Weinberg's equation, calculate and show your working.
(i). The frequency of light allele
(ii).The frequency of the dark allele
(iii).The number in the population which are heterozygote

(a).

Consider a population of monoecious diploids where each organism where each organism produces male and female gametes at equal frequency and has two alleles at each gene locus;

Assumption

Population is large, randomly mating; non-mutating; nether migrating nor experiencing any natural selection.
A locus in this population has two alleles A (dominant allele) and a(recessive allele) that occur with initial frequencies of p and q respectively

f(A)= p and f(a)= q

Using a punnet square

		Female	
		A(p)	**a(q)**
Male	**A(p)**	AA (p^2)	Aa (pq)
	a(q)	Aa (pq)	aa (q^2)

The gene/ allele frequencies are constant and their sum is equivalent to 1
Therefore the sum of all entries is $p^2 + 2pq + q^2 = 1$
Also p+q=1 and the binomial expansion of p+q=1; is p2+2pq+q2=1

OR

$f(A)=f(AA)+ f(Aa)= p^2+pq$
$f(a)=f(aa)+ f(Aa)= q^2+pq$
$f(A)+f(a)= f(AA)+f(aa)+f(Aa)= p^2+ 2pq+q^2=1$

(b)(i).

Random mating brings about a constant allele frequency; Organisms mate randomly with each other within a population without preference for particular genotypes; This gives an equal opportunity for all alleles to be expressed in the genotypes; hence cause no evolutionary change; The allele frequency thus remains constant from one generation to another;

(b)(ii).

When a small population may is isolated from a large population, it may not be truly representative of the original population in terms of allele and genotype frequencies; some alleles may be absent while others may be disproportionally represented; Continuous breeding in the small pioneer population results into loss of some alleles; increase or decrease in the frequencies of other alleles just by chance; in the process, a gene pool that is atypical of the parent population will be produced.

(b)(iii).

A geographical barrier between two populations of the same species prevents them from mixing; isolated demes experience different environmental conditions; the different selection pressures in the new environment; therefore different alleles are selected for; therefore the individuals evolving along different lines/ undergo adaptive radiation to adapt to their respective environments.

(c)(i).

Population of light trait = 5000- 950 = 4050 insects;

Frequency of light trait (p^2) $= \frac{4050}{5000}$

$= 0.81$

$p= \sqrt{0.81}$

p = 0.9

(c)(ii).

p+q=1
q = 1- p;
q = 1- 0.9
q = 0.1

(c)(iii).

2pq;
= 2 x 0.9x 0.1;
= 0.18

Question 22.

(a). Explain the meaning of the following;
(i). Genetic isolation *(02 marks)*
(ii).Reproductive isolation *(02 marks)*
(b).Explain how the gene frequency of population may be altered. *(16 marks)*

(a)(i).

Genetic isolation occurs when mating can occur but fertilization is not possible or even when it occurs, the product is a sterile or inferior offspring. This is due to incompatible genetic constitution between organisms of a population.

(a)(ii).

Reproductive isolation involves failure of interbreeding among organisms of a population. This may be as a result of lack of attractiveness between males and females or non-correspondence of genitals.

(b).

Change in gene frequency of a population occurs when:

There is non-random/ biased breeding; In such cases sexual selection occurs whenever the presence of one or more inherited characteristic increases the likely hood of bringing about successful fertilization of gametes. As a result, the frequency of some genes increases while that of others reduces in the population.

The **population is small** and leads to genetic drift. There is usually chance appearance or disappearance of genes in a small population, leading to change in frequency of the gene in question.

Genotypes are not equally fertile; In this case, the more advantageous (fertile) alleles are transferred to offspring at the expense of other alleles. This leads to change in frequency of such genes.

Gene flow occurs between populations. Interbreeding between populations always leads to flow of genes within the populations involved. This causes instability in the gene frequency of the gene over generation.

Gene reshuffling occurs; During meiosis, crossing over occurs that results in new gene recombination. At fertilization, these altered alleles are transmitted to offspring & over generations the allele frequency of a gene changes.

Question 23.

In *Drosophila,* the gene for wing length and shape or the abdomen are slinked. The gene for long wing and broad abdomen arc dominant over those for vestigial wings and narrow abdomen.

(a).Work out the phenotypes resulting from a cross between a vestigial winged and broad abdomen male & a homozygous long winged and narrow abdomen female fly in the;

(i). F_1 generation. ***(06 marks)***

(ii).F_2 generation. ***(04 marks)***

(b). A cross between a female from the F_1 generation in (a)(i) with a vestigial winged and narrow abdomen male fly gave the following results;

Long winged narrow abdomen flies = 35.
Long winged, broad abdomen flies = 17.
Vestigial winged and narrow abdomen flies = 36
Vestigial winged, broad abdomen flies = 18.

Account for the phenotypes and their relative numbers in the cross. ***(05 marks)***

(c) Explain why *Drosophila* are commonly used in genetic experiments. ***(05 marks)***

(a)(i).

Let B represent allele for broad abdomen;
Let A represent allele for long wing;
Let b represent allele for narrow abdomen;
Let a represent allele for vestigial wing;
Let XX represent the genotype for female drosophila;
Let XY represent the genotype of male drosophila;

Parental phenotypes: Vestigial winged, broad abdomen male x Long winged, narrow abdomen female;
Parental genotypes: $X^{aB}Y$ x $X^{Ab}X^{Ab}$
Meiosis
Gametes: X^{aB} Y X^{Ab} , X^{Ab} ;
Random fertilisation;
F_1 genotypes: $X^{aB}X^{Ab}$ $X^{Ab}X^{aB}$, $X^{Ab}Y$, $X^{Ab}Y$;
F_1 phenotypes; 2 long winged, broad abdomen female flies : 2 long winged, narrow abdomen male flies;

(a)(ii).

F_1 genotypes: $X^{Ab}Y$ x $X^{Ab}X^{aB}$
Meiosis
Gametes: X^{Ab} , Y X^{Ab} , X^{aB}
Random fertilisation;
F_2 genotypes: $X^{Ab}X^{Ab}$, $X^{Ab}X^{aB}$, $X^{Ab}Y$, $X^{aB}Y$
F_2 phenotypes: 1long winged, narrow abdomen female fly;
1long winged, broad abdomen female fly;
1long winged, narrow abdomen male fly;

1 vestigial winged, broad abdomen male fly;

(b).

The lack of 1:1:1:1 ratio is an indication of crossing over between the gene for wing length and that for size of abdomen;

Parental phenotypes: Vestigial winged, narrow abdomen male; x long winged, broad abdomen female

Parental genotypes: $X^{ab}Y$ x $X^{Ab}X^{aB}$

Meiosis:

Gametes: X^{ab} , Y X^{AB}, X^{Ab}, X^{aB} , X^{ab}

Random fertilisation by punnett square:

	X^{AB}	X^{Ab}	X^{aB}	X^{ab};
X^{ab}	$X^{AB}X^{ab}$	$X^{Ab}X^{ab}$	$X^{aB}X^{ab}$	$X^{ab}X^{ab}$;
Y	$X^{AB}Y$	$X^{Ab}Y$	$X^{aB}Y$	$X^{ab}Y$;

Phenotypes: 35 long winged, narrow abdomen flies: 17 long winged, broad abdomen fly: 36 vestigial winged and narrow abdomen fly: 18 vestigial winged and broad abdomen flies; $^1/_2$mark@,

(c).

- Breed quickly/mature faster;
- Breed throughout the year;
- Have only 4 pairs of chromosomes;
- Have giant chromosomes in their salivary glands;
- Sex can easily be distinguished;
- Cheap to culture;

Chapter 10; Selection and evolution

Table 1shows the number of individuals with a given length of fur in a population of a terrestrial mammalian species for two different generations. The prevailing climatic temperature during the two generations changed from 15ºC and 10ºC

Table 1

Length of fur (cm)	**Number of individuals**	
	At 15ºC	**At 10ºC**
1.00	0	0
1.25	25	0
1.50	60	0
1.75	120	20
2.00	155	60
2.25	120	130
2.50	60	155
2.75	25	130
3.00	0	60
3.25	0	20
3.50	0	0

Figure 1shows the variation of resistant strains of bacteria in relation to the amount of antibiotics given during a period of several years in one hospital

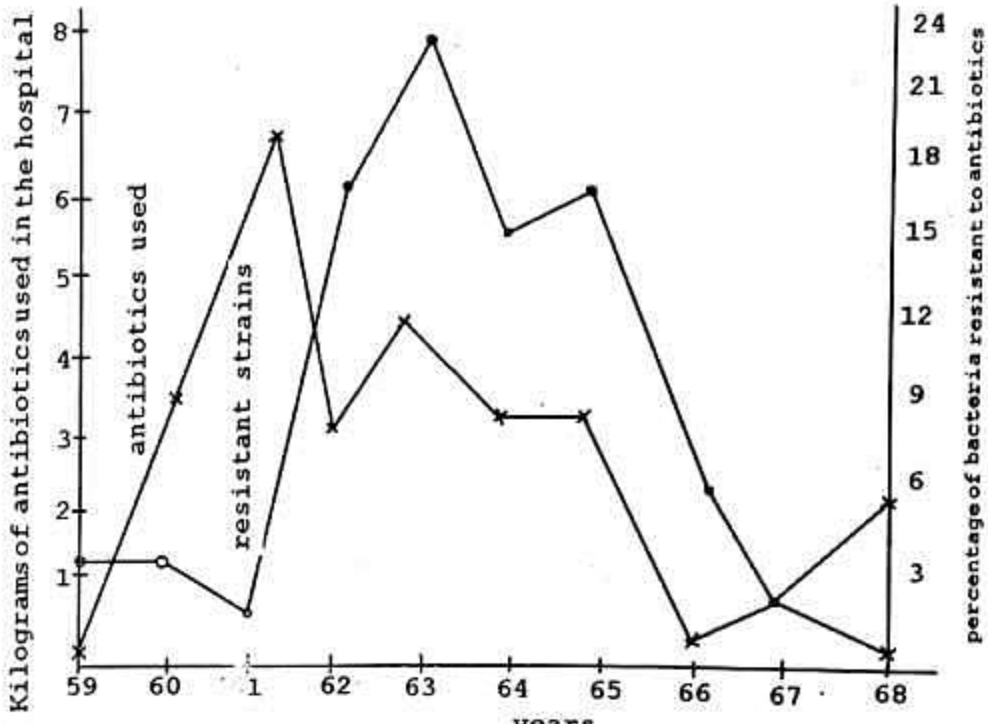


Fig.1

(a)Draw a graph of the relationship between fur length and number of individuals at the two temperatures.
(b).What is the optimum length of fur at each temperature?
(b) At 15ºC optimum length of fur = 2.00 cm
At 10ºC optimum length of fur = 2.50 cm
(c)(i). What is the effect of temperature on fur length among the individuals?
Temperature directly affects fur length among individuals. Low temperature favours growth of long fur; while high temperature favours growth of short fur. At 10ºC individuals have fur length in a range 1.75-3.25cm. At 15ºC individuals have fur length of the range 1.25 -2.75cm;
(ii).Suggest an explanation for the effect of temperature on fur length.
Fur is a structural adaptation in mammals to carryout temperature regulation. In response to cold conditions hair is raised on the body due to contraction of erector pilli muscles; air is trapped between the fur. Air being a poor conductor insulates the body against excessive heat loss from the mammal's body. Long fur traps more air; providing more insulation against excess heat loss favouring survival in more cold environment; where the mammal would lose more heat than in a warmer environment; The temperature exerts a stabilising selection pressure, favouring individuals with optimum fur length at prevailing environmental temperature to survive. Individuals with shorter or longer fur out of the optimum range are gradually eliminated.
(d)(i).From figure 1, describe the trend of resistant strains with the amount of antibiotics used.
Percentage of resistant strains decreased slightly as the amount of antibiotics used increased rapidly from 59-60 years; then resistant strains decreased gradually as amount of antibiotics used increased more rapidly from 60-61 years. Then from 61-63 years, resistant strains increased very rapidly to a peak at 63 years; as the amount of antibiotics used decreased rapidly; Thereafter percentage of resistant strains generally decreased rapidly as the amount of antibiotics used, except in the last year from 67-68 years were resistant strains increased steeply as amount of antibiotics used reduced slightly;
(ii).Suggest an explanation for the observed trend of resistant strains with the amount of antibiotics used.
Initially the antibiotics killed the bacteria and even the resistant strains were slightly killed; The surviving resistant strains reproduced rapidly; their offsprings increased in number yet they are not killed by the antibiotics; The antibiotics could induce more mutations in the bacteria; increasing the percentage of resistant strains further; Competition for food, space and host could limit the further increase in resistant strains; hence the reduction in res-

istant strains with reduced amount of antibiotics used; Final reduction in amount of antibiotics used allowed resistance strains to survive, reproduce and hence the steep rise.

(e) A bacterium is a haploid organism that produces a sexually by fission, twice every minute on average. Using this information, explain the rapid emergence of resistant strains.

A bacterium is haploid due to the single stranded DNA it contains; the antibiotics induce mutations in DNA forming resistant genes on a strand of DNA called plasmid; The plasmids replicate and are passed on to daughter cells; asthe bacteria under goes binary fission; which occurs very rapidly. The plasmid may direct synthesis of proteins that coat the cell surfaceof the bacterium and prevent entry of the antibiotic or a protein that destroys the antibiotic as soon as it diffuses into the bacterium within the host's body cells or tissue fluid; giving the bacteria resistance to the antibiotics. The resistance to antibiotics has a selective advantage over the non-resistant types; therefore resistance strains will rapidly reproduce and their numbers increase;

(f).The data in table 1 and figure 1 illustrate the process of natural selection. State the selection pressure in each case.

Selection pressure in table 1 is prevailing environmental temperature on fur length;

In figure 1 selection pressure is use of antibiotics

(g).Giving a reason in each case, predict what the effect of the following would be.

(i).If the use of antibiotics was stopped for a year.

Number of resistant strains would decrease rapidly.

Reason: In the general population, the resistant strains are normally few given that they are mutants; they appear by chance and have a selective advantage in the presence of antibiotics. The selection pressure is removed once the use of antibiotics is stopped. The non-resistant strains then have a selective advantage, they reproduce and outcomplete the resistant strains; which then reduce as few survive the competition; The number of resistant strains would thus decrease rapidly

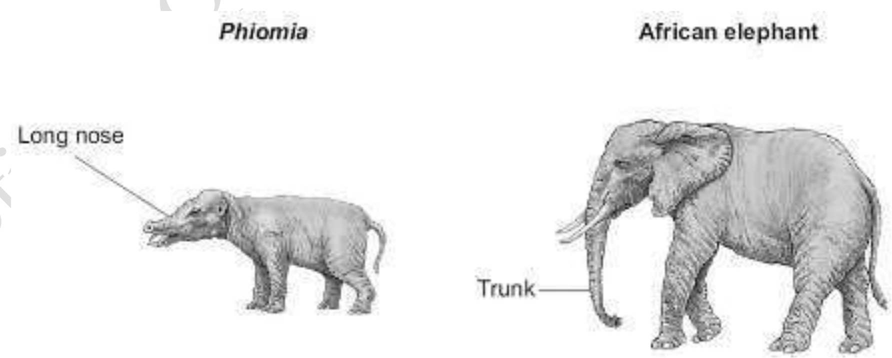
(ii).If the generation of the terrestrial mammal at a prevailing temperature of 10°C was supplied with an abundance of food.

There wouid be a reduction in length of fur;

Abundance of food increases raw materials for metabolism; generating enough heat; to counter the heat loss in the cold environment; a role that long fur was doing. Gradually individuals with shorter fur would increase and optimum fur length would be shorter than the one before abundance of food was provided; long fur would no longer be necessary.

Question 2.

The figure below shows Phiomia, an ancestor of elephants that lived about 35 million years ago and a modern African elephant.



(a)In the 1800s, Charles Darwin and J. B. Lamarck had different theories about how the long nose of Phiomia evolved into the trunk of the African elephant. Explain how the elephant's trunk evolved according to:

(i) Lamarck

Larmack from his principle of use & disuse, the idea that parts of the body that are used extensively become larger and stronger while those that are not used deteriorate; the Phiomia elephants stretched their nose/trunk to reach leaves on high branches and break tree stems and this made the nose/ trunk longer, stronger and larger The Ionger, stronger, broader nose (trunk) that the living elephant evolved over many generation as elephants stretched their noses ever higher was then passed onto offspring; while long nose of Phiomia deteriorated (Principle of Inheritance of acquired character).

(ii) Darwin

Darwin's Natural selection: The two forms (variations) of elephant co-existed in initial population, but long nose type predominant. Food became scarce thus ability to feed high in trees especially during the dry season and the threat of starvation being high (Change in environment) by these two forms provided a selection pressure/ drive for natural selection; trunk type/form effectively obtained food and these reproduced and passed on their character to offspring while the long nose form was over generations/ time weeded out due to starvation.

(b) What is Adaptation?

A species adjusting/ acclimatizing to changes in the environment (e.g new diseases or change in climate) drive by natural selection where most of the individuals in the species will have the favourable allele/ characteristic for that environment.

(c) Describe the process of Adaptation.

There is variation in population of species; (genetic diversity/ genetic variation/ variety in gene pool) new allele arise by random mutation; changing environment applies a selection pressure on the population; those with favourable characteristics/alleles survive the others die by natural selection; the ones that survive will reproduce passing on their favourable alleles (reproductive success); if this happens for many generations then that characteristic will become most common; the favourable alleles will become more frequent (adaptation).

(d) Suggest explanations for the following evolutionary events:

(i) the continual failure to develop a vaccine to give long term protection against malaria plasmodia.

Plasmodia has a very high mutation rate changing nature of the surface antigens; producing new strains Much larger genetic changes occur over time causing major antigenic change producing new species Antibodies against one strain of plasmodia are unlikely to protect against new strains. Plasmodia also reproduces within red blood cells which are devoid of the body immune system thus its very difficult to develop antibodies against them.

(ii) the incompleteness of the fossil record.

Only hard parts/ bones/ exoskeletons/ plant cellwalls stand a chance of fossilisation;

Most dead organisms just rot away/decay/ may be eaten;

Conditions for fossilisation are relatively rare;body needs to be buried in anaerobic conditions to prevent decay;

Peat/ river mud/silt/ sand required where petrification/ impregnation with inorganic salts can occur

Most fossils are still buried/ hidden in rocks thus undiscovered; sections of the fossil record may be destroyed by earth quakes/weathering

(iii) the high prevalence of sickle cell anaemia in the sub-Saharan Africa.

Individuals with the allele in heterozygous state have a selective advantage/ heterozygous advantage over homozygotes in areas infested with malaria; since they do not suffer malaria; (as plasmodia fail to breed sufficiently in their blood) and also donot suffer the adverse pleiotropic effects of the allele in double recessive state but suffer just a mild condition; and tropics have optimal conditions for breeding of mosquitoes; which are the vectors of plasmodia that cause malaria; thus malaria is of high prevalence.

Ignorance of cause/ Poverty; poor health facilities; allele not (usually) screened in newborns and among marriage partners thus no prevention measures

(iv) the development of industrial melanism in peppered moths (Biston betularia) in Great Britain in the mid 1800s.

Original before discharge of industrial effluents: the population of moths was predominantly white; and were well /better adapted/ camouflaged against predation by birds on bark of trees due to lichens on trees while the poorly/ less adapted dark form was easily spotted and fed on by the predators/ birds, hence decreased in their population/ frequency. Tree bark became darker during the industrial revolution due to pollutants/soot and suphurdioxide gas emission that killed the lichens removing the white background. Occasional black mutants appeared in the population/ gene mutations gave rise to melanic form; these were better camouflaged (on the polluted bark) than the normal/ white forms; thus the white forms were predated on and the black forms survived to breed; thus the black/ rnelanic forms were selected for and the population of moths became melanic.

Essay questions and answers

Question 1.

(a).Explain what is meant by
(i).Organic evolution *(03 marks)*
(ii)Biochemical evolution *(02 marks)*
(b)Discuss how the following show that organic evolution is occurring
(i).Resistance to antibiotics *(05 marks)*
(ii).Resistance to antimalarial drugs *(05 marks)*
(iii).Industrial melanism *(05 marks)*

(a)(i).

Organic evolution is the process by which changes in the genetic composition of the populations of the organisms occur in response to environmental changes. This suggests that the organisms living today are the direct but modified descendants of the species that populated the earth in the geological past i.e current life forms have gradually evolved from the pre-existing life forms.

(a)(ii).

Involves changes that occur at molecular levels in living organisms over a period of time. It is also called molecular evolution and involves all mutations.

(b)(i).

Exposure to antibiotics cause mutations in the pathogenic bacteria; the mutant strains thus favoured to survive and are capable of reproducing in a hostile environment; such that the antibiotics fail to kill them; subsequent progeny of mutant pathogenic bacteria become resistant to antibiotics but evolved from previously non-resistant strains.

(b)(ii).

The malaria drugs induce mutations in the plasmodium parasite; forming mutant strains that are resistant to the anti-malarial drugs. Due to their selective advantages, the resistant parasites ably reproduce and produce more identical progeny; their gene frequency increases; evolving into new species of plasmodium that is resistant to anti-malarials.

(b)(iii).

Industrial melanism is the process by which melanic (dark) forms of the species have evolved in areas darkened by industrial pollution. With reference to the population dynamics of peppered moths in the UK, the typical light (grey) peppered moths had a selective advantage affording camourflage in the pre-industrial era; on the light tree trunks and walls. The mutant (black) peppered moths had a selective disadvantage as it could easily be spotted by the predator. However, with increased industralization, the mutant moths gradually increased in number as they could afford camourflage on the darkened backgrounds of the tree backs and walls; covered by soot. On the other hand the light peppered moths could be spotted by predators against the dark background. They selective advantage possessed by the mutant forms made them reproduce more than the light peppered moths; and the black peppered moths eventually became the predominant species.

Question 2.

(a).Describe how abnormal hemoglobin arises in the human population *(07 marks)*
(b).Explain;
(i). the effect of the gene for abnormal hemoglobin in the human population *(05 marks)*
(ii).why people with sickle cell trait do not suffer from malaria *(05 marks)*
(iii)why sickle cell mutation causes hemoglobin to clump *(02 marks)*

(a).

Abnormal hemoglobin arises from mutation or defects of the one or more genes coding for the synthesis of one or more globin polypeptide chain of hemoglogin; **Sickle cell hemoglobinopathies;** arise from base substitution mutation; causing glutamic acid to valine substitution; at the 6^{th} position in the β globin chain of human adult hemoglobin (HbA); Homozygosity for this mutation renders hemoglobin molecule insoluble upon deoxygenation; RBCs containing deoxy HbS polymers are rigid; less pliable; readily dehydrated; sickle shaped; easily hemolyse in capillaries; reduce red cell life span and cause sickle cell anaemia; **Thalassemias;** arise from defect in gene that controls β or α globin synthesis of HbA; β thalassemias occurs when gene defects/ mutations affect production of β globin protein; α thalassemias occurs when gene defects/ mutations affect production of α globin protein;

(b)(i).

Sickle cells anaemia; because the sickle cells are destroyed lowers the amount of oxygen. This leads to;

• Fatigue (weakness) and poor physical development
• Dilation of the heart which may lead to heart failure
• Infections which lead to frequent illness

Interference with circulation of blood as cells get jammed in capillaries and small arteries. This leads to;

• Heart damage which leads to heart failure
• Lung damage which leads to pneumonia
• Muscle and joint damage which leads to rheumatism and pain
• Gut damage which leads to abdominal pain
• Kidney damage which leads to kidney failure
• Liver damage
• Autosplenectomy; increases susceptibility to malarial attacks.

(b)(ii).

• Hb easily crystallizes with reduced oxygen carrying capacity; such hypoxic conditions prevent the plasmodium parasite from thriving.
• Increased rate of phagocytic breakdown of infected sickled RBCs; reduces the parasitic load; making the host tolerant to the parasite.
• Sickle cell hemoglobin induces production of heme oxygenase-I; an enzyme that metabolizes heme with production of carbon monoxide; CO is highly toxic to the plasmodium parasite; This renders the parasite inability to thrive in a sickle shaped red blood cell;
• Micro RNA integration into the parasite; temper with its genome and negatively affects the infectivity of the parasite.

(b)(iii).

The sickle cell mutation changes the sixth amino acid in the hemoglobin β chain (position B6) from glutamic acid (very polar) to valine (nonpolar). The result is that the nonpolar valine at position B6, protruding from a corner of the hemoglobin molecule, fits into a nonpolar pocket on the opposite side of another hemoglobin molecule, causing the two molecules to clump together.

Question 3.

(a).Explain what is meant by mutations *(03 marks)*
(b).Describe the process of the theory of evolution *(07 marks)*
(b).Mutations are normally harmful when in homozygous recessive condition and yet sometimes do not disappear from a population in a few generations. Why is this so? *(10 marks)*

(a).

Mutation refers to a sudden or spontaneous change in the arrangement, structure or amount of genetic material. Mutations that occur in gametes are heritable to subsequent generations while those occurring in somatic cells are only inheritable by daughter cells produced by mitosis and hence not passed on to the subsequent generations.

(b).

The process of organic evolution is based on natural selection of genetically determined characteristics. Mutations, isolations and gene recombinations cause genetic variations. The variations are passed on to offsprings. In large populations, there is competition among individuals in the struggle for existence. Individuals with advantageous variations are favoured to survive, reproduce and pass on their traits. Less adapted individuals have a selective disadvantage; fail to survive and are gradually eliminated.

(c).

Mutations introduce deleterious alleles that can cause harm. They are normally transmitted by recessive genes which are thus only transmitted by recessive genes which are thus only expressed in the homozygous state. They do not disappear from a population in a few generations because sometimes the mutation offers a selective advantage in heterozygous genotypes. This increases their chances of being passed to subsequent generations. Mutant alleles normally co-exist with the normal allele in the population thus exhibit polymorphism eg in humans, sickle cell anemia is due to a recessive gene. In the homozygous recessive state, the condition is lethal. Heterozygous recessive individuals afford protection from malaria and have a selective advantage over the normal individual with homozygous dominant genotype. Consequently, carriers are many and propagate the mutant gene to subsequent generations.

Question 4.

(a) Explain what is meant by;

(i) polyploidy ***(02 marks)***

(ii)artificial selection ***(02 marks)***

(b)Explain how polyploidy arises in sexually reproducing organisms ***(08 marks)***

(a)(i).

Polyploidy is having cell with one or more extra sets of chromosomes in every cell in the organism. Cell is therefore no longer diploid(2n), but can be triploid(3n) if there are three sets, tetraploid(4n) if there are four sets etc The extra set of chromosomes may arise from members of the same species (autoploidy) or from members of different species(alloploidy)

(a)(ii)

Artificial selection refers to the human intervention to ensure that only organisms with desired characteristics are made to breed and pass on their genes to successive generations while those with undesired characteristics are denied chance to pass on their undesired characteristics to the next generation. The main aspect of artificial selection is selective breeding.

(b).

Mitotic chromosomal non-disjunction; secondary to failure of spindle fibre formation which is either natural or artificially induced by colchicine. Somatic doubling of the chromosomes occur; self-fertilization of these forms a tetraploid.

Non disjunction of the sex chromosomes; leads to gametic non-reduction during meiosis. Unreduced 2n gametes are formed. Fusion of these gametes forms polyploids

Polyspermy; in which the female gamete is fertilized by more than one male gamete

Endo-duplication; DNA replication but with failed cytokinesis. Fusion of such cells forms polyploids.

Question 5.

(a).Explain the factors that bring about evolutionary change in the population ***(10 marks)***

(b).How has human activity influenced this change ***(06 marks)***

(c).Explain the role of extinction in evolution ***(04 marks)***

(a).

Variation; Variants with favourable characteristics are selected for by the environment; get inherited by the progeny; and over successive generation evolve to become dominant species. Variants with unfavourable traits are selected against; evolve to become a less dominant species;

Selection (natural or artificial); Individuals with favourable characteristics are selected for by the environment; become the dominant population over successive generations; evolve to form a new species. Organisms with unfavourable characteristics are out competed and selected against by environment. Selection is the only form that produces adaptive evolutionary changes.

Mutations; Mutants with favourable characteristics are selected for; get inherited by the progeny and over successive generations evolve to become dominant species. Mutants with unfavourable traits are selected against; evolve to become a less dominant species;

Isolation; limit gene flow between different demes and each evolves along its own line to form separate species; within the same niche.

Genetic drift; genes are accidentally lost; randomly changes the allele frequency; hence affects the evolutionary potential of a group of organisms especially in small populations.

Genetic load; deleterious alleles are maintained in the heterozygous genotype; which confers a selective advantage eg sickle cell trait.

Gene flow; A very potent agent of change since populations exchange members.

Non-random mating; Inbreeding is the most common form. It doesnot alter allele frequency but decreases the proportion of heterozygotes.

(b).

Selective breeding; man conserves desirable characteristics which would otherwise be diluted by mating with unrelated individuals and out-breeding. In all cases, organisms with favourable features are selected for and over successive generations evolve to form new species
Genetic counselling; targets to stop passing on of unfavourable traits to the next generation; hence this limited gene flow leads to evolution e.g for most genetic diseases like sickle cells
Human activities like industralization, overfishing, habitat destruction etc either impose several selection pressures or cause isolation; lead to evolution;
Medical advances; besides effective clinical management of previously fatal disease selection pressures; others like use of ionizing radiations have facilitated mutations
Technological advances; through genetic engineering, biotechnology and nanotechnology; has led to invention of organisms with favourable traits;
Irrational drug/ antibiotics use; mutations associated with evolution of drug resistant strains
Artificially induced polyploidy; polyploids have high hybrid vigor and are selected for, survive up to their reproductive age; those with an even chromosome number; breed and pass on their genes to the next generation; become the majority of the population and over successive generations evolve to forrn new species.

(c).

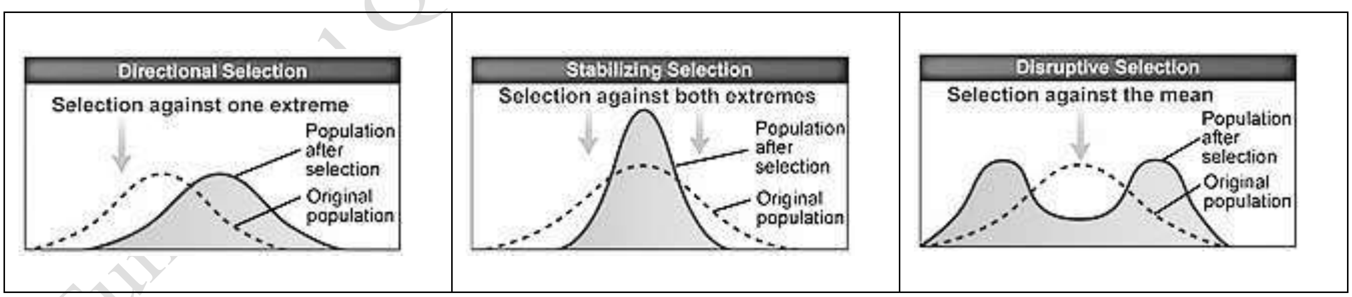
Extinctions reduce biodiversity by eliminating off specific lineages. This creates vacant ecological niches. Over successive generations of natural selection, the new inhabitants evolve new ecological strategies to suit in their new environment so as to utilize the resources therein; Extinctions, through reducing competition also permits success of previously less competitive organisms and makes them diversify and become more prevalent species.

Question 6.

(a).Describe the different forms of natural selection ***(09 marks)***
(b).Explain how the following may lead to evolution of new species
(i) Increased population size ***(05 marks)***
(ii).Isolation ***(06 marks)***

(a).

Directional selection; Involves selection against one extreme with shift of the mean population in the direction of phenotype favoured by the selection pressure
Stabilizing natural selection; Selection pressure favours intermediates of given phenotypes and eliminates the extremes. Occurs in the stable environment where the extremes bear no selective advantages.
Disruptive/destabilizing selection; Selection pressure favours individuals with extreme characteristics; eliminates intermediates; results in discontinuous variation; and gives rise to two or more phenotypic forms (polymorphism). Population exhibits a bimodal distribution.



(b)(i).

Increased population size; imposes several selection pressures including shortage of food, shelter, mates etc & higher disease pre-disposition. Only organisms competitively superior possess better selective advantages ably survive to their reproductive age; breed and successfully pass on their genes to the next generation; with subsequent increase in their numbers. Over successive generations; such organisms become the majority of the population eventually evolve to form new species (speciate). On the other organisms that are competitively inferior die before reaching their reproductive age become the minority of the population and over successive generations may become extinct leaving vacant ecological niches that allow thriving of the competitively advantaged species.

(b).

Isolation forms separate demes; that limit gene flow within different populations. Organisms geographically Isolated due to a certain geographical barrier; undergo adaptive radiation to cope with the new environmental conditions; they survive in these new niches; eventually evolve into separate distinct species each living in separate niches allopatric speciation results. Population groups either reproductively isolated due to lack of attractiveness, genital non-correspondence, gametic failure at the fertilization level or genetically isolated due to gene incompatibilities; or behaviorally isolated due to poor courtship displays, difference in flowering times; make organisms breed independently; each along its own line; form separate species. Population groups are maintained in the same environment despite failure to interbreed;
sympatric speciation results.

Question 7.

(a).Describe how distribution studies provide evidence for evolution ***(14 marks)***
(b).Why are there missing links in the evolutionary history based on fossil studies ***(06 marks)***

(a).

There is discontinuous distribution of both plants and animals; i.e similar organisms are found in different geographical areas. In Africa, the savanna exists, Prairies in North America and Pampas in South America. In the savanna are lions, Prairie dogs in the Prairies and cougars in the pampas. All these animals are fundamentally similar and have a common ancestral background but their minor differences are due to adaptive radiation in response to the varying selection pressures imposed on them by their environments. The African buffalo and the North America's Bisons as well as the African camel and the South America's Llama show great similarity suggesting a com-mon ancestor. The ancestor of the camel and the Llama is from North America and their differences are due to divergent evolution. The unique presence of the marsupials in Australia was due to continental drift and the subsequent land mass separation from the Pangea (plate tectonics or older land mass) before the appearance of placental mammals. Marsupials continued to survive in competition free areas. Elsewhere they were absent because of being outcompeted by placental mammals when they evolved. Darwin's finches on the Galapagos islands show resemblance with those on the main land suggesting a common ancestor.

(b).

- Dead organisms are eaten by scavengers.
- Dead organisms readily decompose or broken down chemically.
- Many organisms are soft bodied thus lack hard parts that can form fossils.
- Very few fossils have been excavated
- Volcanicity and other natural geographical occurrences disorganize the layers of the sedimentary rocks
- Some organisms die in conditions that favour do not fossil formation.
- Remains of animals living in arid or semi-arid habitats are hard to fossilize.
- Hominid fossils that have been found are usually partial and the remainder of the organism must be infered and inferences may not necessarily be correct.

Question 8.

(a).Briefly explain the process of evolution by natural selection according to Darwin ***(07 marks)***
(b).Explain how each of the following supports Darwin's theory of evolution
(i). Industrial melanism ***(05 marks)***
(ii).Resistance to insecticides ***(05 marks)***
(c).State the differences between natural selection and artificial selection ***(03 marks)***

(a).

Darwin asserts that living organisms have arisen by a process of slow and gradual change over a period of successive generations; due to natural selection. He further argued that organisms produce far more off springs than what the environment can support as a result there is struggle for existence as they look for food, space, mates, breeding places etc. Competition between off springs sets in; and individuals with favourable characteristics will have a higher chance of survival in the struggle (survival for the fittest) while the less fit die. The final result is that the well adapted individuals are able to reach reproductive age and give rise to off springs while the less fit/ poorly adapted never reach reproductive age If this selection continues for the successive generations of organisms, a new species evolves/ speciation results.

(b)(i).

Selection pressure resulting from a change in the environment caused a gene for white/grey colour of the peppered moths to mutate; leading to evolution of black peppered moths. Soot deposited on the tree trunks provided camourflage to the black peppered moths against potential predators compared to the white peppered moths. The camourflage provided by the environment was the basis for natural selection through selective predation; that allowed the black moths to survive against the white/ grey moths.

(b)(ii).

Insecticides pose a selection pressure that causes evolution of the mutant strains resistant to many insecticides. The mutant strains have developed enzymes that breakdown insecticides into harmless metabolites; thus the mutant strains get selected for while the non-mutant ones are selected against.

(c).

Natural selection	Artificial selection
Selective agent is the environment of the organism	The selective agent is humans
adaptations to the prevailing conditions are selected	Phenotypes wanted by humans are selected
Many different traits contributing to fitness are selected	Selection may be for a single trait (which may not be advantageous for the organism)

Question 9.

(a).What is meant by natural selection? ***(03 marks)***

(b).Describe the role of each of the following in natural selection

(i). Mutations ***(05 marks)***

(ii).Meiosis ***(08 marks)***

(iii).Fertilization ***(04 marks)***

(a).

Natural selection is the mechanism of evolution where organisms with favourable characteristics survive and contribute more off springs the next generation; while those with unfavourable characteristics are selected against; and their population becomes extinct.

(b)(i).

Mutations cause a change in DNA structure, that lead to genetic variability. Mutants with favourable characteristics are selected for; mature up to their reproductive age; breed and pass on their superior genes to the next generation becoming the majority of the population. Mutants with poor characteristics are selected against and are eliminated.

(b)(ii).

Meiosis leads to formation of variable haploid gametes; whose fusion during fertilization is purely random and thus form new gene combinations. During prophase I crossing over occurs between homologous chromosomes; resulting in formation of new gene combinations; which then randomly assort during metaphase I. Variation upon which natural selection works, results. Variants with favoured characteristics are selected against and pass on their genes to the next generation becoming the majority of the population while the unfavoured ones are selected against and are eliminated from the population.

(b)(iii).

Fertilization involves random union of two different parental gametes; this leads to gene mixing. The resultant organisms with favourable variation are selected for and their gene pool expands while variants with unfavourable characteristics are selected against; get eliminated and their gene frequency within the gene pool decreases.

Question 10.

(a).What do you understand by the following

(i).Convergent evolution ***(02 marks)***

(ii).Divergent evolution ***(02 marks)***

(b).Describe how industrial melanism supports the theory of evolution ***(08 marks)***

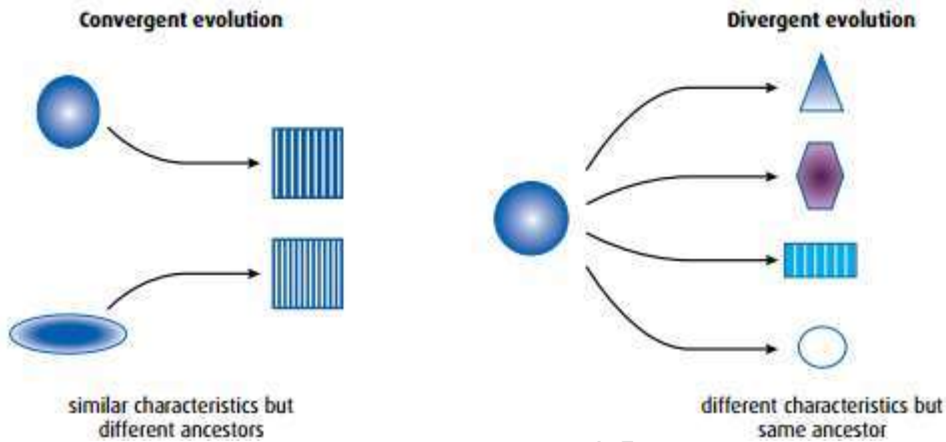
(c).Using Darwin's theory of evolution, explain the slight differences in the fauna in the different parts of the Galapagos islands ***(08 marks)***

(a)(i).

Convergent evolution refers to evolution of structures from different ancestral stock along the same line with structures that seem to be similarly produced. Such structures perform the same function (analogous) e.g wings of a butterfly and birds, legs of insects and those of mammals perform the same function but structural organization and principle of operation is different.

(a)(ii).

Divergent evolution; evolution along different lines; in which there is modification of basic pattern to serve different functions so as to suit a variety of ecological niches e.g pentadactyl limbs in mammals. Divergent evolution leads to adaptive radiation.



(b).

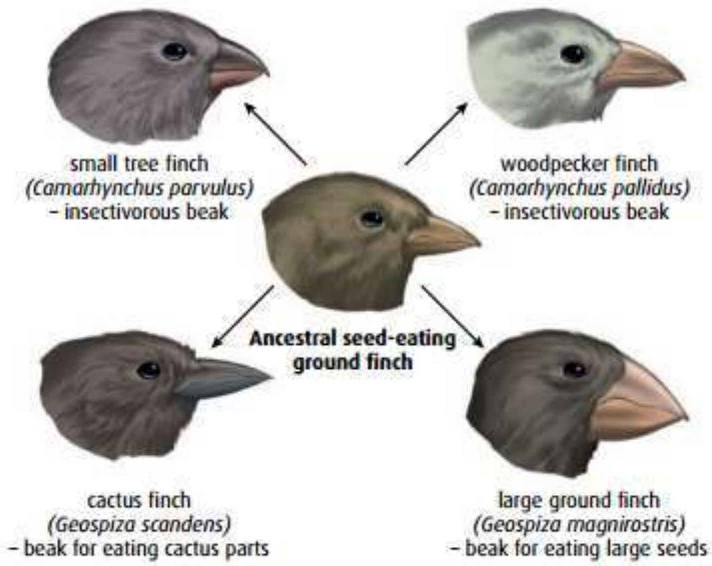
During industrial revolution, two variants of peppered moths existed; mutant melanic (black) peppered moths and the non-mutant light type (white peppered moths). Smoke/soot from the industries blackened the environment; sulphur dioxide from the soot destroyed the white lichens on the tree barks; melanic types of the peppered moths camouflaged and are not easily spotted by the predatory birds. These continue to survive; reproduce to pass on their genes to the next generation and therefore selected for by the environment. The light type becomes conspicuous and easily spotted against the black background. They greatly suffered selective predation most of them died completely wiped out of the major industrial areas. Over several generations the melanic emerged as the new dominant species.

(c).

Modern organisms have a common ancestor which accounts for the resemblance but the slight differences are as a result of a constantly changing nature which leads to a gradual change of the individuals over several successive generations in order to fit in their new environment.

The giant iguana lizards; Darwin found that lizards in the Galapagos Islands are of two types i.e the marine type which inhabited the nearby waters; had hard webbed feet and laterally flattened tails for swimming and the land type which neither had webbed feet nor laterally flattened tails. Marine forms could have evolved from the land form but due to overcrowding and lack of food on land, they developed devices for swimming. Both lizards feed on plant matter; have a common ancestor hence basically similar but the slight differences are due to evolutionary changes to fit in the various niches.

Darwin's finches; Darwin found birds known as finches; these birds were similar basically but with slight modification of their beaks adapted for a particular food type. Wood pecker finches had beaks that bore holes in the wood and aid to climb up tree trunks. Cactus ground finches; have long straight beaks and split tongue for getting nector out of flowers of the pricky pear cactus. Large ground finches; these have short straight beaks for crushing seeds. Insectivorous finches; beak suited for feeding on bettles. All forms of finches are similar showing a common ancestor but slight differences evolved to suit the available ecological niches on these islands.



Question 11.

Explain the five major evidences that support the theory of evolution ***(20 marks)***

Evidence from geographical distribution; plants and animals have a discontinuous and non-uniform distribution throughout the world e.g Africa has savanna inhabited by lions, south America has pampas inhabited by cougars and north America has prairies inhabited by prairie dogs. Both the plant and animal species have a lot in common but with minor differences due to divergent evolution and this shows that these are closely related species suggesting a common ancestor. They originated from a particular area and then dispersed to adjacent land masses before continental drift. Each then evolved to adapt to the prevailing environmental conditions as dictated by the selection pressure.

Evidence from paleontology; bases on study of fossils excavated from sedimentary rocks. Oldest strata of the rock were found to have fossils with simple structures whereas fossils identified in the upper (recent) strata were more complex showing that organisms evolved from simple to complex forms. On comparing the simple forms from the lower strata with the complex forms from the upper strata, they show a general similarity but with minor differences due to difference in the ecological niches and this suggests a common ancestor.

Evidence from comparative anatomy; organisms that show striking similarities in structure and embryonic development are believed to be closely related and thus share a common ancestor. Such organisms have homologous structures i.e structures with a similar basic plan in both the embryo and adult suggesting a common ancestor. Minor differences and modifications are, due to adaptive radiation; a process that results in divergent evolution e.g the pentadactyl limb. Other organisms have analogous structures i.e do perform similar functions in different organisms but fundamentally different in their embryonic development and adulthood as well as their mode of action e.g eyes of insects and those of mammals, wings of insects and of analogous structures is suggestive of convergent evolution. Existence of vestigial organs e.g coccyx in vertebrates which is a remain of a tail suggests common ancestor.

Evidence from embryonic development; embryonic development of all vertebrates shows striking similarities during organ development and cell division; suggestive of a common ancestor. According to the evidence, "Ontogeny recapitulates phylogeny" i.e developmental stages of the embryo tends to repeat the history of the ancestor e.g the two chambered heart with a single circulation in the mammalian embryo is similar to that seen in fish. Mammalian embryo has pharyngeal arches that resemble gill slits seen in fish. Vertebrate embryo also possesses a tail that disappears in adulthood. Bird's embryo begins by excreting ammonia but adult forms excrete ammonia. The above examples suggest that higher animals trace evolutionary origin from fish and amphibians. Seedling of Acassia species have simple leaves but mature forms of the plant have compound leaves suggesting origin of co-mpound leaved plant plants from simple leaved ones.

Evidence from comparative biochemistry; similar biochemical molecules are found in a wide range of organisms e.g cytochrorne, haemoglobin, myoglobin, haemocyanin, phosphocreatine etc and do perform biochemical reactions in an almost similar way. These molecules have similar sequences of their basic monomer units (amino acids); hence suggesting a common ancestor and evolutionary homology. The similarities are even greater for a particular group e.g in primates; the sequences of amino acids are more similar compared to other organisms.

OTHER EVIDENCES

Evidence from comparative cell physiology; physiological processes in living organisms occur in the same way with similar chemical reactions, enzymes and coenzymes involved e.g in all cells; respiration involves glycolysis, kreb's cycle and electron transport system. Protein synthesis follows the central dogma (transcription and translation) in all cells and this suggests common ancestory. Minor differences are due to the different ecological niches and complexity of the organism.

Evidence from classification; hierarchical classification system of Linneus places organisms having structural similarities into the same classification groups e.g all members with dorsal nerve cord and segmented myotomes are placed in phylum chordate. This suggests existence of a common ancestor and an evolutionary relationship between the organisms.

Evidence from plant and animal breeding; ability of man to bring about evolutionary change in a short time through artificial selection/ selective breeding means that it is possible that natural selection can do so given a long time frame say a million years.

Evidence from cell biology; according to the cell theory, all cells divide except mature nerve cells, do carryout similar biochemical reactions with similar pathways, have the same organelles only varying in size, shape and structure but do perform the same function. All these suggest evolutionary relationship and common ancestral origin

Evidence from serological tests; when serum of an experimental animal is introduced into the serum of man, precipitation occurs due to an antigen-antibody reaction Comparative precipitation with sera from different animals reveal that chimpanzees >gorilla > baboons> monkeys>lemur> hedge-hog > pig This therefore suggests that chimpanzees are closest to man thus trace evolutionary origin from the same ancestor while the pig is the least related to man.

Question 12.

(a).Distinguish between polyploidy and aneuploidy ***(06 marks)***

(b).Explain the main features of each of the following evolutionary concepts

(i). Lamarckism ***(07 marks)***

(ii) Neo-Darwinism ***(07 marks)***

(a).

Polyploidy	Aneuploidy
Full set chromosomes is added to the cell	Involves addition or subtraction of an extra set of chromosomes in the nucleus of the cell
Arises from non-disjunction following failure of forming spindle fibres during prophase I	Arises from non-disjunction due to failure of one of the homologous chromosomes to separate during anaphase I of meiosis
Common in plants and rare in animals	Common in animals and rare in plants.
Associated with hybrid vigour	Associated with disadvantageous characteristics to the animal
Cell size increases	Cell size doesnot enlarge
Multiple number of DNA molecules exist in the nucleus	Number of DNA molecules doesnot change or multiply.
Organism can be 3n, 4n, 5n, 6n….	Organism is either 2n+1 or 2n-1

(b)(i).

Sudden change in the environmental conditions to one extreme; cause new needs to arise among individuals of a given population; changing greatly their pattern of behaviour or activity; result in disuse or over use of particular organs. Overuse of a particular organ makes it develop new and better features; increase in size while disuse results in degeneration. Changes acquired throughout life time are inherited by offsprings in successive generations; and new species evolve e.g evolution of the present day giraffes with long necks and legs, blindness in moles and other cave dwellers and limblessness in snakes.

(b)(ii).

Neo-Darwinism is a new concept where new species are formed from pre-existing ones by natural selection of genetically determined characteristics. Sudden mutations occur; resulting in discontinuous variation of the mutant & non-mutant individuals. The non-mutant individuals are the pre-existing ones which become less adapted and are selected against; get wiped out of the environment and their genes are not passed to the next generation. Mutants are better adapted; have better selective advantages; interbreed to pass on their genes to the next generations; this results a new and distinct species;

Question 13.

(a).Explain what is meant by the following
(i). Genetic isolation *(02 marks)*
(ii).Reproductive isolation *(02 marks)*
(iii)Ecological isolation *(02 marks)*
(b).Explain how the environment may influence the process of natural selection *(08 marks)*
(c).How may species get extinct *(06 marks)*

(a)(i).

Genetic isolation occurs due to fundamental differences in the genetic constitution of different individual organisms preventing successful reproduction. The isolation may involve failure of the gametes to fuse, failure of the zygote to develop, failure of the hybrid to develop further, infertile hybrids and hybrid breakdown as the subsequent generations are infertile.

(a)(ii).

Reproductive isolation is brought about by the failure to interbreed among individuals of a population and may be inform of lack of attractiveness between the male and the female, inappropriate courtship displays, incompatibility of the genitalia, failure of cross pollination and self-sterility.

(a)(iii).

This is due to environmental barriers that separate and keep the populations apart. The environmental splits the population into sub populations called demes. Environmental factors affect each sub population differently; bringing new variations, the sub-populations adapt to the different environmental conditions differently (adaptive radiation); gene flow between the sub-populations is prevented forming new species.

(b).

Variation in the environmental factors such as climate, diseases etc that exert a selection pressure and individuals with better suited traits to the prevailing selection pressure survive and breed at the expense of the others that are selectively disadvantaged that eventually get eliminated. The selection pressure may be directional in which the environment favours only one type that dominates as it adapts to the new environment e.g in industrial melanism. The stabilizing selection pressure only favours intermediates and eliminates extremes eg sickle cell trait. Disruptive selection pressure favours presence of more than one phenotype; resulting in bimodal distribution; a basis of polymorphism.

(c).

When gene flow is interrupted & impaired due to reduced population size, a species become extinct; which may be due to;

• Failure to adapt to the prevailing environment rendering a selective disadvantage
• Increased selection pressure due to intense predation, grazing, parasitism, competition etc.
• Intense pollution which can lead to death of inhabitant organisms causing extinction
• Hunting and related human activities that lead to death of many organisms
• Climatic change; new environment may not favour some species
• Natural disasters and diseases that lead to massive deaths and can eliminate some species.

Question 14.

(a).Giving an example, explain what is meant by discontinuous variation *(03 marks)*
(b).Give an account of the different types of mutation and their causes *(12 marks)*
(c).State the role of mutation in evolution *(05 marks)*

(a).

Discontinuous variation is the difference in characters of individuals which shows a drastic transition between extremes with clear cut categories and no intermediates. The characters are controlled by a single gene; and the environment has little or no role on the character. Examples include; blood groups, colour blindness and hemophilia.

(b).

Gene mutations; these occur due to sudden changes in structure, arrangement or amount of DNA; occurring on a single gene. The gene mutation can be deletion, translocation, inversion, insertion or duplication of nucleotides in the DNA strand. These change the sequence of nucleotides corresponding to one gene in the mutant DNA formed.
Chromosome mutation; occur due to sudden change in structure, arrangement or amount of chromosomes. This can take the form of; aneuploidy due to non-disjunction of chromosomes during meiosis; gametes formed carry 1 or more extra chromosomes. Polyploidy, here cell has more extra set of chromosomes. Can be autopolyploidy if chromosomes are from the same species, or allopolyploidy if chromosomes come from individuals of different species.
Causes of mutation include; exposure to high energy radiations like X-rays, exposure to extremes of temperatures, exposure to mutagenic chemicals like nitrous acid, mustard gas, pesticides etc.

(c).

Mutation cause genetic variation; new genes appear and are reshuffled during meiosis and fertilization. The variation resulting from mutations is the basis for natural selection; mutants with desired traits are selected for by the environment; breed and pass on their genes to the next generation with overall increase in their numbers at the expense of those with undesirable traits; who are selectively eliminated in the evolutionary process.

Question 15.

(a).Distinguish between genetic and cultural evolution and state the relative importance of genetic and cultural evolution in the recent evolution of humans. ***(08 marks)***
(b).Explain the Hardy-Weinberg equation and why it is used. ***(06 marks)***
(c).Discuss how biochemical variations can be used as an evolutionary clock. ***(05 marks)***

(a).

Genetic evolution is a product of selection for (adaptive) genes. Genetic evolution produces heritable traits that are physically inherited as genes or coded within DNA. Genetic evolution is affected by random mutation and natural selection determines the likelihood of genetic inheritance. Acquired characteristics are not inherited. Genetic evolution occurs slowly/ as gene pools alter gradually while cultural evolution is inherited from the environment and is inherited independent of DNA. Cultural evolution is (specific) learning/ learning done during one's life time, can be directed, selection determines likelihood of inheritance; and cultural evolution can occur rapidly.

Importances

Genetic evolution continues to produce the phenotype of humans while cultural evolution has played an increasingly greater role in the lives of humans over time
Genetic change happens too slowly to produce the huge changes in human culture but some cultural changes have reduced natural selection pressures.

(b).

Mathematical model for genetic equilibrium from which predictions can be made. It is used for sexually reproducing species whose breeding must be random and for a large population with no migration, selection or mutations. It is used to calculate allele or gene frequency by sampling from a population. Allele or gene frequencies remain constant through generations and if there is an observed change it suggests evolution is occurring therefore population is no longer in equilibrium. $p^2 + 2pq + q^2 = 1$ where p and q represent the frequencies of two alleles of a gene and frequency of alleles adds to 1 (genotype frequencies) i.e $p+q=1$. $p^2$and q^2 are the frequencies of the homozygotes (homozygous dominant and recessive respectively) and 2pq is the frequency of the heterozygotes.

(c).

Methods of using evolutionary clocks:
Differences in nucleotide base sequences/ DNA/ amino acid sequences/ proteins accumulate gradually over time; differences accumulate at (roughly) predictable rates therefore the number of differences can be used as a clock to measure the time since two divergent groups shared a common ancestor e.g. amino acid sequences in globin genes
Problems with using evolutionary clocks:

However, variations are partly due to mutations which are unpredictable chance events so there must be caution in interpreting data and hence need to establish a variety of molecular clocks for reliability.

Question 16.

(a).Distinguish with examples, between analogous and homologous characteristic *(06 marks)*
(b).Explain the biochemical evidence for the common ancestry of living organism *(08 marks)*
(c).Explain how the following can lead to speciation
(i). Disruptive natural selection *(04 marks)*
(ii).Biased mating *(02 marks)*

(a).

Analogous structures are structures that perform similar functions in different organisms but fundamentally different in their embryonic development and adulthood as well as their mode of action e.g eyes of insects and those of mammals, wings of insects and birds are analogous structures and is suggestive of convergent evolution while homologous structures are structures with a similar basic plan in both the embryo and adult but perform different functions in different organisms. Minor differences and modifications are, due to adaptive radiation; a process that results in divergent evolution e.g the pentadactyl limb like dolphin forelimbs and human arms.

(b).

DNA structure is universal with the same four nucleotides with adenine, guanine, cytosine and thymine nitrogen bases. RNA composed of same four nucleotides with adenine, guanine, cytosine and uracil bases. The ribosome structure is universal i.e composed of large and small subunits/ proteins and rRNA/ site for mRNA attachment/ 2 sites for tRNA attachment. Protein structure is universal/ composed of polymers/ made of the same 20 amino acids. Genetic code is universal/ same codons for determining amino acid sequence. ATP is universal energy molecule/ energy source for metabolism, glycolysis is universal/ biochemical pathway producing ATP from glucose and membranes structure is universal/ proteins and phospholipid bilayer. Biochemistry is identical in all organisms, therefore likely related by common ancestry.

(c)(i).

Disruptive selection favours individuals with extreme phenotypes; eliminating the mean population. Given sufficient time, it splits the population into two sub populations. If gene flow is prevented between the two, the two evolve independently along different lines cause a change in gene frequency and over successive generations form new species.

(c)(ii).

Biased mating promotes desirable alleles and eliminates undesirable alleles for a particular trait; leads to a change in gene/ allele frequency. Organisms with favourable traits become the dominant and over successive generations eventually evolve to form new species.

Question 17.

Give an account of the evidence of evolution based on;
(a).Comparative anatomy. *(08 marks)*
(b).Cell biology. *(06 marks)*
(c).species distribution. *(06 marks)*

(a).

Comparative anatomy; Organisms that show striking similarities in structure and embryonic development are believed to be closely related and thus share a common ancestor. Such organisms have homologous structures i.e struct- ures with a similar basic plan in both the embryo and adult suggesting a common ancestor. Minor differences and modifications are, due to adaptive radiation; a process that results in divergent evolution e.g the pentadactyl limb. Other organisms have analogous structures i.e do perform similar functions in different organisms but fundamentally different in their embryonic development and adulthood as well as their mode of action e.g eyes of insects and those of mammals, wings of insects and of analogous structures is suggestive of convergent evolution. Existence of vestigial organs e.g coccyx in vertebrates which is a remain of a tail suggests common ancestor.

(b).

Cells of different organisms are very much alike. Organelles like mitochondria, endoplasmic reticulum and ribosomes are of universal occurrence. This strongly supports the view that all living things have evolved from a common ancestor. Further, all cells are made up of carbon, hydrogen, oxygen, nitrogen and about 70% water and all chromosomes consist of DNA whose basic structure is very similar.

(c).

Distribution of species; It is by no coincidence that places with similar environmental conditions have a similar composition of flora. It is rather reasonable to assume that such organisms have had a common ancestor but were only separated during the process of continental drift. This together with other isolating barriers could have worked on separating organisms from a common ancestral origin which have now developed characteristics to suit their current environments.

Question 18.

(a).Outline five modern examples where evolution can be observed. ***(05 marks)***
(b).Explain the evidence from homologous anatomical structures that supports the theory of evolution.
(c).Discuss the theory that evolution occurs by punctuated equilibrium. ***(05 marks)***
(d).Compare evolution by punctuated equilibrium and that by gradualism ***(05 marks)***

(a).

- Change of beak shape in Galapagos finches
- Resistance to pesticides/antibiotics/ antimalarials
- Bird predation on moths
- Heavy metal tolerance in plants
- Melanism in ladybird beetles

(b).

Homologous structures are various different structures of the same basic plan; derived from a similar embryonic origin; Variations on the basic structure allow different functions permitting exploitation of different ways of life /adaptive radiation; the suggests divergence from a common ancestor; Examples of a homologous structure (e.g. pentadactyl limb, flower, birds' beaks)

(c).

Long periods where there was no (apparent) change/stasis; Short periods of rapid evolution occurs following periods of mass extinctions leading to opportunities/caused by environmental disruption (meteors, earthquakes, volcanoes, etc.)/ rapid environmental change in short periods
Punctuated equilibrium is based on fossil evidence with no gradual changes rather than biochemical evidence.

(d).

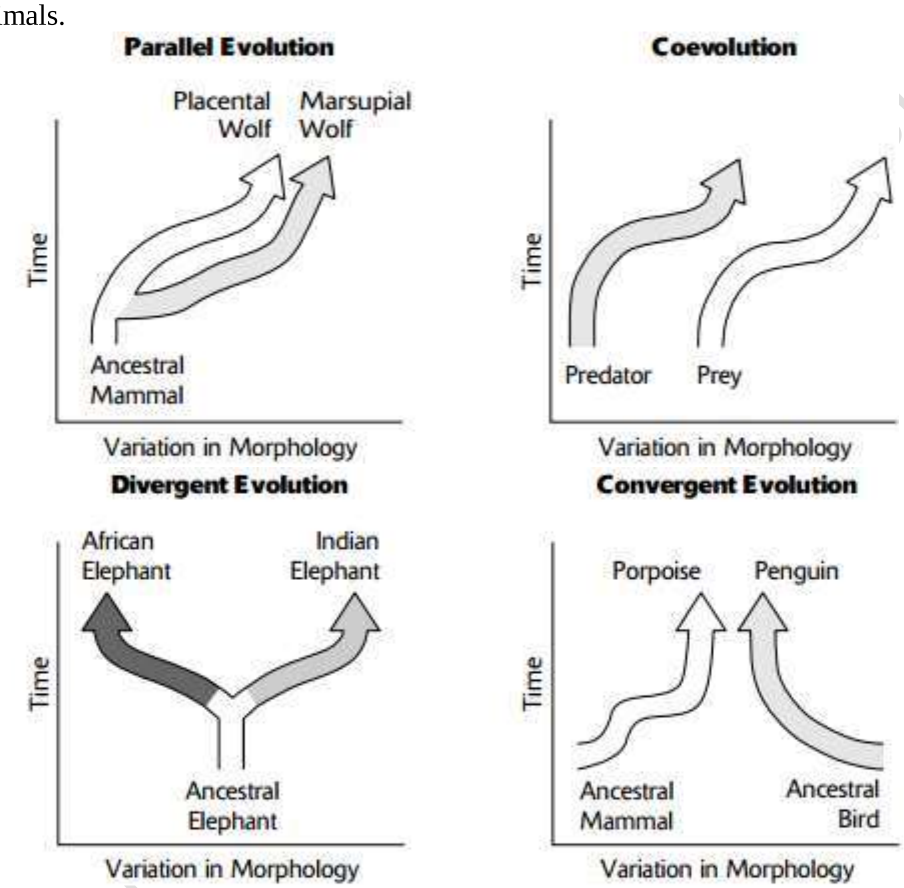
Punctuated equilibrium	gradualism
Involves faster mutation rates	Involves slower mutation rates
Involves more powerful natural selection	Involves less powerful natural selection
Environment undergoes sudden changes such as earth	Environment undergoes gradually progressive changes.
Involves discontinuous evolution	Involves continuous evolution
Involves faster evolution rates	Involves slower evolution rates

Question 19.

With examples, describe the various patterns of the evolution of species ***(20 marks)***

Divergent evolution describes two or more species that originate from a common ancestor and become increasingly different over time. This may happen as a result of allopatric or sympatric speciation or by adaptive radiation.
Convergent evolution describes two unrelated species that share similar traits. The similarities arise, not because the species share a common ancestor, but because each species has independently adapted to similar ecological conditions or lifestyles. The traits that resemble one another are called analogous traits. Sharks, porpoises & penguins have torpedo-shaped bodies with peripheral fins. These traits arise as a result of adaptations to aquatic life and not because these animals inherited the traits from a recent, common ancestor. Likewise eyes of squids and vertebrates are physically and functionally similar. However, these animals do not share a recent common ancestor. That the eyes in these two groups of animals originate from different tissues during embryological development confirms that they have evolved independently.

Parallel evolution describes two related species or two related lineages that have made similar evolutionary changes after their divergence from a common ancestor. Species from two groups of mammals, the marsupial mammals and the placental mammals, have independently evolved similar adaptations when ancestors encountered comparable environments.
Co-evolution is the tit-for-tat evolution of one species in response to new adaptations that appear in another species. Suppose a prey species gains an adaptation that allows it to escape its predator. Although most of the predators will fail to catch prey, some variants in the predator population will be successful. Selection favors these successful variants and subsequent evolution results in new adaptations in the predator species. Coevolution occurs between predator and prey, plants and plant-eating insects, pollinators and flowering plants, pathogens and the immune systems of animals.



Question 20.

Discuss each of the following as they relate to speciation. Give examples.

(a).Geographic barriers ***(08 marks)***
(b).Adaptive radiation ***(06 marks)***
(c).Polyploidy ***(06 marks)***

(a).

Allopatric speciation occurs when a geographic barrier, such as a river or mountain range, divides the existing population into two populations. Separated in this manner, the two populations are reproductively isolated and gene flow does not occur. As a result, changes in allele frequencies in one population may not occur in the other population. If the environmental conditions vary between the two populations, natural selection may favor different traits in the two populations. Genetic drift may also cause differences in allele frequencies, either because of the founder effect, or because either (or both) new populations are small. In these two cases, allele frequencies are strongly influenced by chance (genetic drift). Also, mutations in one population may introduce new alleles absent in the other population, thus providing new variation upon which natural selection can act.

(b).

Adaptive radiation occurs when a population is introduced to an area where many geographic or ecological conditions are available. When the introduced species enters the various new habitats, selection pressures will vary with habitat. For example, in colder habitats, larger animals may be favored (for insulation). In a habitat with many fruit producing plants, fruit-eating abilities among the animals may be favored. Adaptive radiation occurs among plants as well. For example, in a rain forest habitat, individual plants that have adaptations to wet conditions are favored, whereas in dry regions, plants with water conservation adaptations (thick cuticles, perhaps) are favored.

(c).

Polyploidy is the possession of one or more extra sets of chromosomes. As a result of nondisjunction during meiosis, gametes (sperm and eggs) have double the normal number of chromosomes. When a sperm produced in this manner fertilizes a similarly produced egg, the resulting diploid zygote also contains twice the normal number of chromosomes. The result is a polyploid individual. When this new individual undergoes a normal meiosis, gametes will contain twice the number of chromosomes (like its parent) and will be able to fertilize only similarly produced gametes. Thus, the polyploid individual and its progeny are reproductively isolated from the original population. The result is a speciation event occurring in a single generation. Polyploidy is common among plants and rare in animals.

Question 21.

(a).Explain what is meant by balanced polymorphism ***(03 marks)***

(b).With examples, describe the various ways in which polymorphisms are maintained in populations

(a).

Balanced polymorphism is the maintenance of different phenotypes in a population. Often, a single phenotype provides the best adaptation, while other phenotypes are less advantageous. In these cases, the alleles for the advantageous trait increase in frequency, while the remaining alleles decrease.

(b).

Heterozygote advantage; occurs when the heterozygous condition bears a greater selective advantage than either homozygous condition. As a result, both alleles and all three phenotypes are maintained in the population by selection. For example, the alleles for normal and sickle-cell hemoglobins (A and S, respectively) produce three phenotypes, AA, AS, and SS. AA individuals are normal, while SS individuals suffer from sickle-cell disease, because the sickle-cell allele produces hemoglobin with an impaired oxygen-carrying ability. Most SS individuals die before puberty due to sickle cell disease. AS individuals are generally healthy, but their oxygen-carrying ability may be significantly reduced during strenuous exercise or exposure to low oxygen concentrations (such as at high altitudes). However, AS individuals have a selective advantage (in Africa) because the AS trait also provides resistance to malaria. When AS phenotypes are selected, both A and S alleles are preserved in the gene pool and all three phenotypes are maintained.

Hybrid vigor (or heterosis); describes the superior quality of offspring resulting from crosses between two different inbred strains of plants. The superior hybrid quality results from a reduction of loci with deleterious homozygous recessive conditions and an increase in loci with heterozygote advantage. For example, a hybrid of corn, developed by crossing two different corn strains that were highly inbred, is more resistant to disease and produces larger corn ears that either of the inbred strains.

Frequency-dependent selection (or minority advantage) occurs when the least common phenotypes have a selective advantage. Common phenotypes are selected against. However, since rare phenotypes have a selective advantage, they soon increase in frequency and become common. Once they become common, they lose their selective advantage and are selected against. With this type of selection, then, phenotypes alternate between low and high frequencies thus maintaining multiple phenotypes (polymorphism). For example, some predators form a search image, or standard representation of their prey. By standardizing on the most common form of its prey, the predator optimizes its search effort. The prey that is rare, however, escapes predation.

Question 22.

(a).Explain what is meant by speciation ***(01 marks)***

(b)(i).Describe the various forms of speciation ***(04 marks)***

(c).Explain the various ways in which the above forms of speciation come about ***(15 marks)***

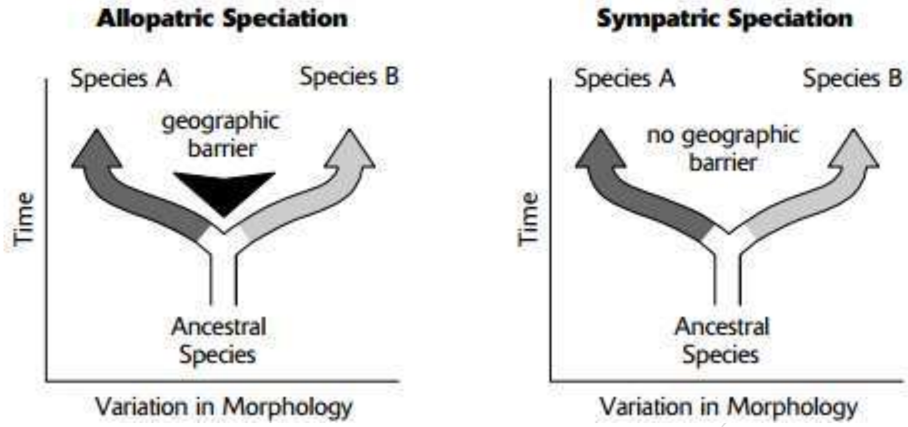
(a).

Speciation is the formation of one or more new species from an existing species.

(b).

Allopatric speciation; Formation of a new species when a population is divided by a geographic barrier so that interbreeding between the two resulting populations is prevented. The newly formed species thus occupy different geographical areas

Sympatric speciation; is the formation of new species without the presence of a geographic barrier. The newly formed species thus occupy the same geographical area.



(c).

Allopatric speciation;

Begins when a population is divided by a geographic barrier such as water body or mountain that prevents interbreeding. Once reproductively isolated by the barrier, gene frequencies in the two populations can diverge due to natural selection (the environments may be slightly different), mutation, or genetic drift. If the gene pools sufficiently diverge, then interbreeding between the populations will not occur if the barrier is removed. As a result, new species have formed.

Sympatric speciation;

Balanced polymorphism; among subpopulations may lead to speciation. Suppose a population of insects possesses a polymorphism for color. Each color provides a camouflage to a different substrate, and if not camouflaged, the insect is eaten. Under these circumstances, only insects with the same color can associate & mate. Thus, similarly colored insects are reproductively isolated from other subpopulations, and their gene pools diverge as in allopatric speciation.

Hybridization; occurs when two distinctly different forms of a species (or closely related species that are normally reproductively isolated) mate and produce progeny along a geographic boundary called a hybrid zone. In some cases, the genetic variation of the hybrids is greater than that of either parent and permits the population of hybrids to evolve adaptations to environmental conditions in the hybrid zone beyond the range of either parent. Exposed to different selection pressures, the hybrids eventually diverge from both parent populations.

Polyploidy; is the possession of more than the normal two sets of chromosomes found in diploid (2n) cells. Polyploidy often occurs in plants (and occasionally animals) where triploid (3n), tetraploid (4n), and higher ploidy chromosome numbers are found. Polyploidy occurs as a result of nondisjunction of all chromosomes during meiosis, producing two viable diploid gametes and two sterile gametes with no chromosomes. A tetraploid zygote can be established when a diploid sperm fertilizes a diploid egg. Since normal meiosis in the tetraploid individual will continue to produce diploid gametes, reproductive isolation with other individuals in the population (and thus speciation) occurs immediately in a single generation.

Question 23.

(a) Explain how each of the following may lead to speciation

(i). Geographical isolation ***(07 marks)***

(ii). Natural selection ***(05 marks)***

(b).How can organisms become extinct? ***(08 marks)***

(a)(i).

Large population splits into small sub-populations; sub-populations are prevented from interbreeding by physical barriers; such as large water bodies/mountains /forests; gene flow between populations is prevented; when each sub-population experiences differential gene mutations; variations and natural selection occur independently in each sub-population; these variations may prevent successful mating if members of the demes (sub-populations) come together again; and after many generations each population will develop into new and distinct species;

(a)(ii).

This can be disruptive selection; which occurs in response to environmental conditions fluctuating between two distinct extremes; this favours the presence of more than one phenotype within a population; the selection pressures acting within the population results in splitting of population into two sub-populations; if gene flow between the two populations is prevented; each population may arise into a new species;

OR

Directional selection; which occurs due to gradual change in environmental conditions; the selection pressures exerted within the population brings about emergence of variants (individuals showing variation); variants with better adaptations to the environmental conditions survive until they reproduce; their genes controlling the better adaptations continue to be transmitted to the next generations; and after many generations such better adapted individuals develop into new distinct species;

(b).

• Through intense competitions among organisms that occupy similar ecological niche; better competitors out compete the weak ones;
• Existence of unfavourable conditions to the organism; such as very low temperatures/ disease out breaks/ environmental pollutions; natural selection occurs; gradually eliminating the less adapted organisms;
• Lack of basic nutrients/ elimination of a link in the food chain; organisms occupying higher trophic levels will starve to death;
• In all cases the population size of the affected organisms rapidly decline due to death/ failure to reproduce offspring; their gene/ allele frequency rapidly decreases until when all the genes become non-existent everywhere;
• Introduction of alien species which out-competes the indigenous species

Question 24.

(a) What is meant by
(i). microevolution *(01 marks)*
(ii) macroevolution? *(01 marks)*
(b).Outline the factors that cause microevolution *(05 marks)*
(c)(i)Explain how microevolution of antibiotic resistant bacteria occurs. *(08 marks)*
(c)(ii)State other examples that justify the existence of microevolution *(05 marks)*

(a)(i).

Microevolution is a change in gene frequency within a population or species observed over short periods of time; for example, between one generation and the next, the frequency of a gene for pesticide resistance in a population of crop pests increases.

(a)(ii).

Macroevolution refers to evolution that occurs at or above the species level. It is therefore evolution on a scale of separated gene pools.

(b).

• Natural selection for the favored gene
• Immigration with the new immigrants carrying the gene,
• Mutation of the nonresistant genes to resistant ones
• Random genetic drift from one generation to the next.
• Gene flow

(c)(i).

The huge population size and short generation time of a given bacterial strain makes natural selection acts quickly. In each bacterial generation, new mutations and gene combinations are generated. If any of these confer resistance to a drug to which the bacteria are exposed, natural selection will favor those resistant gene versions. Over the course of many bacterial generations (a small fraction of a single human life-time), the bacteria adapt to our defenses, evolving to form resistant strains.

(c)(ii).

- Mosquitoes evolving resistance to DDT
- Resistance of pests to pesticides
- HIV strains evolving resistance to antiviral medicines
- Resistance of weeds to herbicides
- Variations in the size of the sparrows in the different locations

Question 25.

(a).Explain the following concepts of evolution
(i). transient polymorphism as a concept of evolution ***(02 marks)***
(ii).Theory of origin of species by panspermia ***(02 marks)***
(b).Describe how species are formed from pre-existing ones. ***(10 marks)***
(c).Describe the evidence for evolution provided by geographical distribution of placental marsupial mammals. ***(05 marks)***

(a)(i).

This is the existence of many different forms of an organism e.g. the ABO blood grouping system in the human population, colour and bonding patterns that arise in certain species of land snails, different colour patterns of grass hoppers and the peppered moth (Biston betularia).

(a)(ii).

Cosmozoan theory (panspermia theory): suggested that life reached the earth from other heavenly bodies, for example, meteorites in form of highly resistant spores of some organisms. This theory is however criticized for lack of evidence.

(b).

Speciation occurs along two main pathways: geographic separation (allopatric speciation) and through mechanisms that occur within a shared habitat (sympatric speciation). Both pathways isolate a population reproductively in some form. Mechanisms of reproductive isolation act as barriers between closely related species, enabling them to diverge and exist as genetically independent species. Prezygotic barriers block reproduction prior to formation of a zygote, whereas post-zygotic barriers block reproduction after fertilization occurs. For a new species to develop, something must cause a breach in the reproductive barriers. Sympatric speciation can occur through errors in meiosis that form gametes with extra chromosomes (polyploidy). Autopolyploidy occurs within a single species, whereas allopolyploidy occurs between closely related species.

(c).

The unique presence of the marsupials in Australia was due to continental drift and the subsequent land mass separation from the Pangea (plate tectonics or older land mass) before the appearance of placental mammals. Marsupials continued to survive in competition free areas. Elsewhere they were absent because of being outcompeted by placental mammals when they evolved. This discontinuity in the distribution of marsupials and placental mammals i.e similar organisms being found in different geographical areas suggests that they are fundamentally similar and have a common ancestral background but their minor differences are due to adaptive radiation in response to the varying selection pressures imposed on them by their environments. Their differences are attributed to divergent evolution.

Question 26.

(a)(i).State Darwin's law of natural selection ***(02 marks)***
(a)(ii).How did Darwin explain the development of the long necked giraffes ***(02 marks)***
(b).Explain the term industrial melanism in a peppered moth? ***(04 marks)***
(c)(i).Describe the different ways artificial selection had been practiced by humans ***(08 marks)***
(c)(ii).Outline the evidences for the modern theory of evolution(Neo-Darwinism) ***(04 marks)***

(a)(i).

It states that in a highly reproducing population, there is variation among individuals and some favourable characters are inherited such that those possessing them survive to reproduction stage, while those ones which are not favoured by their environment die before they reproduce i.e. favoured characters are selected for while the unfavoured ones are selected against.

(a)(ii).

Initially both short and long necked giraffe varieties existed. Due to exhaustion of food at the ground level the short ones could not reach the tree branches and hence starved and died of hunger. The long necked giraffes survived and produced the long necked giraffes.

(b).

It is a process that led to evolution of melanic form of moths which took place during industrial revolution or development through natural selection in a way that mutant forms never appeared before the light background thus eaten by the birds. Industrial revolution led to a dark/black back ground thus the black moths which were favoured were not eaten. Therefore, black moth became dominant and many

(c)(i).

Inbreeding; When by chance a variety of plants and animals arose which possessed some useful characters, it is bred with its close relatives in hope of retaining the characters for future generations.

Outbreeding; done to improve the existing varieties where two individuals of the same species each having the beneficial feature are combined during outbreeding to produce a better feature. Outbreeding produce stronger individuals with a better chance of survival.

Selective breeding; man conserves desirable characteristics which would otherwise be diluted by mating with unrelated individuals and out-breeding; eg polyploidy in crop and animal husbandry

Eugenics; The improvement of human race by the selective or elimination of specific characters through activities like genetic counselling.

(c)(ii).

- Evidence from geology e.g. fossils (paleontology) and stratigraphy.
- Evidence from genetic studies;
- Evidence form results of artificial selection and genetic engineering
- Evidence from molecular biology
- Evidence from ecology and ethology

Question 27.

(a).Discuss, with examples how sexual selection relates to speciation. ***(07 marks)***

(b).Explain how features of embryos in the early stages of development and possession of vestigial organs provide evidence for organic evolution ***(13 marks)***

(a).

Sexual selection is the differential mating of males within a species. Only males that win contests with other males or possess features that are attractive to females are able to mate. As a result, traits that improve a male's success in these two areas carry a selective advantage. Sexual selection results in attributes that improve success in contests (such as horns, antlers, large size, or increased musculature) or traits that are attractive to females (such as good nest-building ability, large territories, or long or colorful feathers as in peacocks and birds of paradise). Although sexual selection may change allele frequencies over time and result in new traits, speciation (the formation of a new species) does not necessarily occur.

(b).

Different vertebrates like fish, amphibians, birds, mammals have embryos with similar features; in the early stages of embryonic development; such common features include gill clefts/ single blood circulations/ undivided heart chambers/ internal pair of pouches / segmented myotomes; Cleavage/ gastrulation/ differentiations in the early embryonic development are also similar. The similarity in embryonic features supports the theory of recapitulation which states that ontogeny recapitulates phylogeny; that at various times in the early embryonic developmental stages an organism tends to show the evolutionary history of the ancestral group to which it belongs; and the different vertebrates must have had the same ancestry.

Vestigial organs are organs reduced in size; with no particular functions in certain individuals possessing it but quite prominent and functional in other different organisms such two different individuals possessing vestigial organs must have had a common ancestor.

Question 28.

(a)Describe how polyploidy and artificial selection lead to speciation *(10 marks)*

(b).Explain the effect of sickle cell genes on the susceptibility of human to named disease selection pressures

(a)

Polyploidy

Polyploids have higher hybrid vigor than normal diploids do exhibit greater resistance to pests and diseases, have greater hardness, greater drought resistance, early maturity, increased size and yield. Polyploids thus possess more selective advantage able to overcome several selection pressures than the normal diploids. Polyploids with an even chromosomal number are fertile breed to pass on their genes to the next generation; their numbers increase and over successive generations become the majority of population eventually forming a new species.

Artificial selection

Artificially selected organisms being with superior genes possess advantageous characteristics; outcompete those with inferior genes. They thus breed to pass on their genes to the next generation; their numbers increase and over successive generations; become the majority of population eventually forming a new species. Those with undesired characteristics, being denied chance to pass on their inferior genes get eliminated;

(b).

Homozygotes for normal hemoglobin (HbAHbA) are susceptible to malaria; thus selected against in a malaria endemic setting; but selected for in a sickle cell endemic area; constitute majority of the population in areas where sickle cell is the only selection pressures; Heterozygotes (HbAHbS); show heterozygous superiority/advantage; get selected for by both malaria and sickle cell selection pressures; make majority of the population where the two selection pressures co-exist; Homozygotes for sickle cell trait (HbSHbS); are protected against malaria; sicklers thus selected for in malaria endemic setting; but selected against in a sickle cell endemic area; and constitute majority of the population in malaria endemic areas;

Question 29.

(a).State the conditions under which changes in the allele frequency can be used to measure evolution by natural selection *(04 marks)*

(b).Describe how resistance to drugs arises in a named organism *(07 marks)*

(c).Explain how resistance supports the theory of evolution by natural selection *(09 marks)*

(a).

- When the population is large
- Random mating
- No mutation occurs
- No migrations

(b).

Resistance to penicillin by bacteria occurs by a chance/ mutation producing mutant strains that produce the enzyme penicillinase which de-activates penicillin; bacteria therefore becomes resistant to penicillins. The mutant allele is expressed immediately and not masked by dominant alleles. Exposure of the penicillins to the population containing mutant bacteria; will destroy all susceptible/ normal strains but not the mutant ones. These mutant forms therefore survive to reproduce their own kind & have the potential to further mutate into more resistant forms.

(c).

Application of drugs/ pesticides provides a selection pressure; that results in directional selection; non mutant/ susceptible strains are selected against/ destroyed by the drug/ pesticide; not allowed to transfer their genes to the next generation reducing their population; while the resistant strains survive/ selected for; grow to maturity; rep-roduce rapidly under ideal conditions; passing on their resistant genes to the next generation; Resistant strains form majority of the population and over successive generations; speciate to form new species.

Question 30.

(a).How do each of the following support organic evolution,

(i). Blood pigments *(04 marks)*

(ii).Homologous organs *(05 marks)*

(b).Discuss how each of the following factors can alter genetic equilibrium of a population.

(i).Genetic drift. *(05 marks)*

(ii).Isolation. *(06 marks)*

(a)(i).

Different vertebrates like humans, birds, snakes, fish contain the blood pigment haemoglobin in their blood; the blood pigment haemoglobin is also contained in blood of Annelids like the earth worms; this is proof that the different vertebrates and invertebrates had a common ancestral origin;

(a)(ii).

Different vertebrates like the human, whales, monkeys, rodents all possess homologous organs; such organs possess the same basic structures and features but perform different functions; for example the pentadactyl limbs/ears ossicles in mammals/bone jaw in fish; the same basic structures of the homologous organs is a proof of same common ancestral origin; the functional difference is to suit and adapt to different environmental conditions in different habitats.

(b)(i).

Genetic drift is sudden change in allele/gene frequency arising from sudden death of an individual; in a small sub-population; that occurs due to chance rather than natural selection; Loss of an/individual from a sub-population who was a sole carrier of certain genes: reduces allele/ gene frequency and the gene pool.

(b)(ii).

Isolation involves sub-population being prevented from interbreeding; by geographical barriers like mountains, lakes/environmental conditions/reproductive barriers/seasonal changes/genetic differences; gene flow is prevented such that each sub-population develops its own gene pool; when mutation occurs in separate sub-population independently; new mutant alleles emerge; gene/ allele frequency rises and the gene pool in each sub-population becomes large;

Question 31.

(a).Giving examples, explain the effect of;

(i). Increased selection pressure on a population. ***(07 marks)***

(ii).Stabilising selection pressure on a population. ***(07marks)***

(b).Explain how comparative anatomy supports the process of evolution. ***(06 marks)***

(a)(i).

Increased selection pressure occurs under harsh conditions; such as predation/competition/diseases/very hot temperatures/very cold temperatures etc; When the population is large resources become scarce leading to stiff intra-specific competition; causing a large number of poorly adapted individuals to die due to starvation/predation; Only the individuals well adapted/specialised at obtaining food/avoiding predation survive; leading to reduced variability and the population becomes uniform;

(a)(ii).

Stabilizing selection eliminates extremes of a phenotypic range; and selects for the intermediates; enhancing their reproductive success of the intermediates; By selecting phenotypes close to the mean; stabilizing selection reduces variation in the population; and therefore reduces the opportunity for evolutionary change;

(b).

Homologous structures have the same basic plan in the different organisms but modified to perform different functions/serve different niches; for example the pentadactyl limb in vertebrates; like in monkeys the digits are elongated for grasping tree branches and in man the same pentadactyl limb is modified for manipulation; Also the basic structure of all flowers consists of petals, sepals, carpels and stamens; yet number of petals and other aspects differ;Some homologous structures are reduced in size and these are called vestigial structures;

Homologous structures and vestigial structures show that organisms possessing them descended from a common origin; and this confirms divergent evolution;

Analogous structures have different basic structures but are modified to perform the same function; for example wings of insects and wings of birds/eyes of mammals and those of cephalopods etc; analogous structures confirm convergent evolution;

Question 32.

Briefly describe how the following can bring about speciation

(a).Geographical barriers ***(06 marks)***

(b).Adaptive radiation ***(06 marks)***

(c).Polyploidy ***(04 marks)***

(d).Sexual selection ***(04 marks)***

(a).

Allopatric speciation occurs when geographic barriers like mountains, oceans, lakes, rivers, deserts, etc physically separate individuals within a population into smaller subpopulations (demes); that become reproductively isolated to prevent gene flow; If environmental conditions vary between the two populations, natural selection may favour different traits in the two populations; Mutations in one population may introduce new alleles absent in the other population thus causing new variation upon which natural selection operates; Genetic drift may also cause differences in allele frequencies either because of founder effect or because the population(s) is/ are small;

(b).

Adaptive radiation is the emergence of divergent species from a common ancestor, dispersed to new habitats; Adaptive radiation occurs when a population is introduced to an area where many ecological conditions exist with varying selection pressures; Selection pressure causes changes in allele frequency and gradual structural modifications occur; causing varying adaptations to live in the new environment; Eventually the dispersed populations fail to successfully interbreed with the original parental population;

(c).

Polyploidy is the possession of gametes with an entire set of chromosomes duplicated once or several times as a result of failure of separation of homologous chromosomes during meiosis; Polyploid individuals can only fertilize other similarly produced polyploids; causing reproductive isolation from the original population thus enabling speciation to occur; Polyploidy is common in plants but very rare in animals;

(d).

Sexual selection is the differential mating of males within a species; Only males that possess attractive features to females or win contests with other males are able to mate; hence the features that improve a male's success are selected for. Although sexual selection may change allele frequencies over time & result in new traits, speciation does not necessarily occur;

Question 33.

(a).Explain what is meant by adaptive radiation ***(03 marks)***

(b).Describe how the different evolutionary advancements of mammals have helped them live successfully in their ecological niches ***(17 marks)***

(a).

Evolution/ emergence of a number of divergent species from a common ancestor; each species becoming adapted to occupy a different environment. Adaptive radiation occurs when a population is introduced to an area where many ecological conditions exist with varying selection pressures;

(b).

Evolutionary advancements that solved the challenge of support and locomotion

• Development of rigid and supportive locomotory structures/ Musculo-skeletal system/ bones, cartilages etc
• Some mammals adopted aquatic life; have overcome the challenges of locomotion in a terrestrial environment.
• Pendactyl limb plan; have made a variety of mammals suite in different ecological niches
• Wings eg in flying mammals like bats; have eased movement in form of flight
• Development of structures of balance like the semi-circular canals; have ensured balance and stability;

Evolutionary advancements that solved the challenge of food

• Well-developed alimentary canals/ digestive systems/ heterodont teeth; have eased digestion of food.
• Different feeding modalities like carnivory, herbivory etc; have reduced competition for food.
• Periodic episodes of dormancy; minimize energy expenditure/ food requirements in times of scarcity

Evolutionary advancements that solved the challenge of reproduction

• Long gestation periods; have allowed ample time for foetal development
• Internal fertilisation; have reduced chances of desiccation; increasing chances of reproductive success
• Embryonic development in the placenta; have ensured foetal protection during development
• Egg laying in some mammals like duck billed platypus;
• Seasonal breeding; has ensured breeding in only favourable conditions
• Secondary sex characteristics; successfully courtship hence successful reproduction.
• Well-developed courtship displays; successful reproduction

Defence against harmful situations like predation and diseases

- Large size; have scared off predators
- Camourflage/ mimicry/ warning colourations; have safe guarded mammals against predators
- Swift movements; have enabled mammals to escape from predators
- Nocturnal behavior of some mammals; have enabled escape from predators due to poor visibility
- Suckling/ mammary glands; have ensured adequate nourishment to new born mammals;
- Parental care; offered protection to young mammals
- Territorial behavior; has enabled mammals safe guard their territories from intruders
- Migratory behavior; has enabled mammals escape from disastrous events like quakes, fires, predators etc
- Pouches; in marsupials have protected young ones from predators
- Sickle cell trait; have allowed resistance to malaria.
- Polymorphism; have enabled organisms occupy a variety of ecological niches minus predatory interference

Evolutionary advancements that solved the challenge of transportation and gaseous exchange of materials

- Well-developed cardiovascular system /heart/ vessels; ensured efficient transportation of materials in the body
- Transport pigments like haemoglobin; have increased the efficiency of transportation of materials eg oxygen
- Well-developed gaseous exchange systems that are moist, of large surface area and highly vascularized.

Evolutionary advancements that solved the challenge of thermoregulation and dehydration

- Homeothermy; maintain an uninterrupted metabolic profile
- Insulation devices like fur, subcutaneous fat; have insulated the body against heat loss
- Water tight surface layer like keratinized epithelia; have protected body against dessication
- Heat tolerant tissues; have enabled mammals withstand dessication

Evolutionary advancements that solved osmotic challenges and dessication

- Metabolic water from stored fats e.g in camels; has enabled mammals achieve adequate hydration
- Elongated loop of Henle in mammals like the kangaroo cat;
- Hyper-secretion of ADH by mammals; for adequate retention of water
- Possess tissues tolerant to water stress;

Evolutionary advancements that solved the excretory challenges

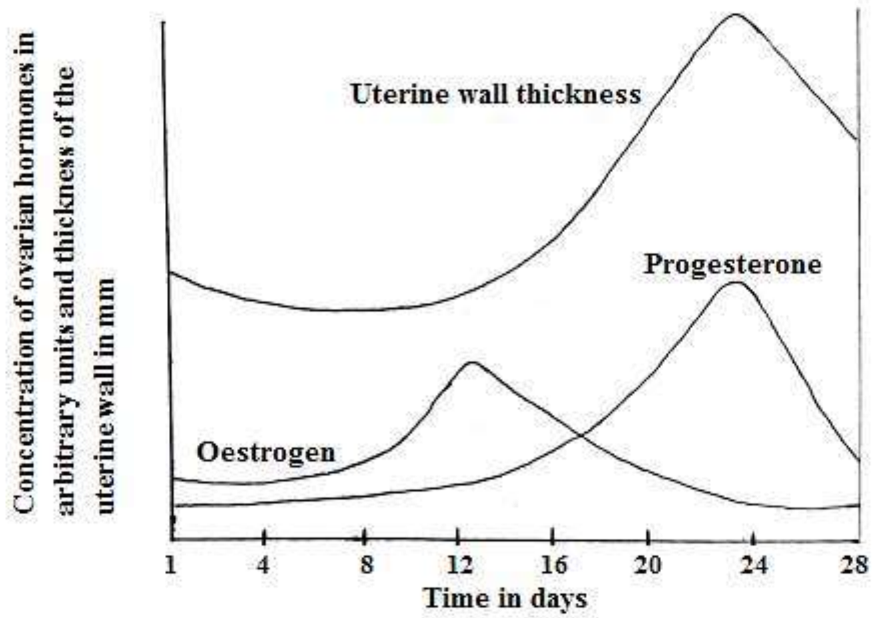
- Well-developed excretory system with efficient organs of excretion
- Water conserving excreta like urea and uric acid; have ensured water conservation

Evolutionary advancements that solved the challenge of small surface area to volume ratio

- Internal organs like the heart, lungs;

Chapter 11; Reproduction in living organisms

The graph below shows the changes in the sex hormones and thickness of the uterine wall obtained by close observations made using blood samples that were withdrawn from an adult human female at regular intervals of days and by scanning the uterus respectively. The investigation was done for over a period of one month (28 days) immediately after the previous menstruation period.



(a).Describe the changes in the concentration of:

(i) Oestrogen hormone. ***(05 marks)***

Oestrogen concentration is almost constant; from day 1 to 8; increased rapidly from day 8 to day 12 and attained peak concentration on the 12th day. Oestrogen concentration then decreased gradually from day 12 to day to day 24; remained constant up to day 28;

(ii).Progesterone hormone. ***(04 marks)***

Progesterone concentration is almost constant from day 1 to day 12; then increased gradually from day 16 to day 17; then progesterone concentration increased rapidly from day 17 to day 23; attaining peak concentration on day 23. Progesterone concentration then decreased rapidly up the 28th day.

(b) Compare changes in concentration of Oestrogen and thickness of the uterine wall. ***(05 marks)***

Similarities

- From the day 4 to day 6; both oestrogen concentration and uterine wall thickness were constant.
- Both attained peak values at particular times

Differences

Duration in days	Oestrogen concentration	Uterine wall thickness
Day 1 to day 4	Is almost constant	Decreases slowly
Day 6 to day 10	Increases slowly	Is constant
Day 10 to day 12	Increases rapidly	Increases slowly
	Attains peak concentration earlier/day 12	Attains peak concentration later (day 23)
Day 12 to day 23	Decreases gradually	Increases rapidly
Day 23 to day 28	Is constant	Decreases rapidly

(i) Thickness of uterine wall and progesterone concentration. ***(12 marks)***

Changes in uterine wall thickness directly/ closely follows the changes in progesterone concentration because progesterone increases uterine thickness(muscularisation) and vascularization of the uterus in preparation for implantation. From day 1 to day 6; as the concentration of progesterone remains constant, uterine wall thickness decreases slowly because of the on-going sloughing off of the endometrial walls; during menstruation. From day 6 to day 10; there is constancy of the uterine wall thickness as the progesterone concentration slowly increases due to the repair of the uterine lining following the previous menstrual flow. Besides, a rise in the FSH concentration; triggered new follicular growth; From day 10 to day 14; a slow rise in progesterone concentration causes a slow increase in uterine wall thickness because the increase in progesterone level increases muscularisation and vascularization of the uterine wall in preparation for implantation. Progesterone levels increased further rapidly from day 14 to day 23; peaking on the 23rd day because of ovulation that produced the corpus luteum; further increased uterine wall thickness rapidly. From the 23rd day to the 28th day; as there was a rapid reduction in progesterone concentration; uterine wall thickness reduced due to regression of the corpus luteum;

(ii) Oestrogen and progesterone concentration. ***(10 marks)***

Between day 1 and day 6; as the concentration of oestrogen remains constantly low, that of progesterone is also constantly lower; because of a regressed corpus luteum. Low levels of both hormones signals the pituitary gland to secrete FSH; that initiates follicular growth

(d) Explain what would happen if fertilization had occurred on the 21st day of the month (04 marks)

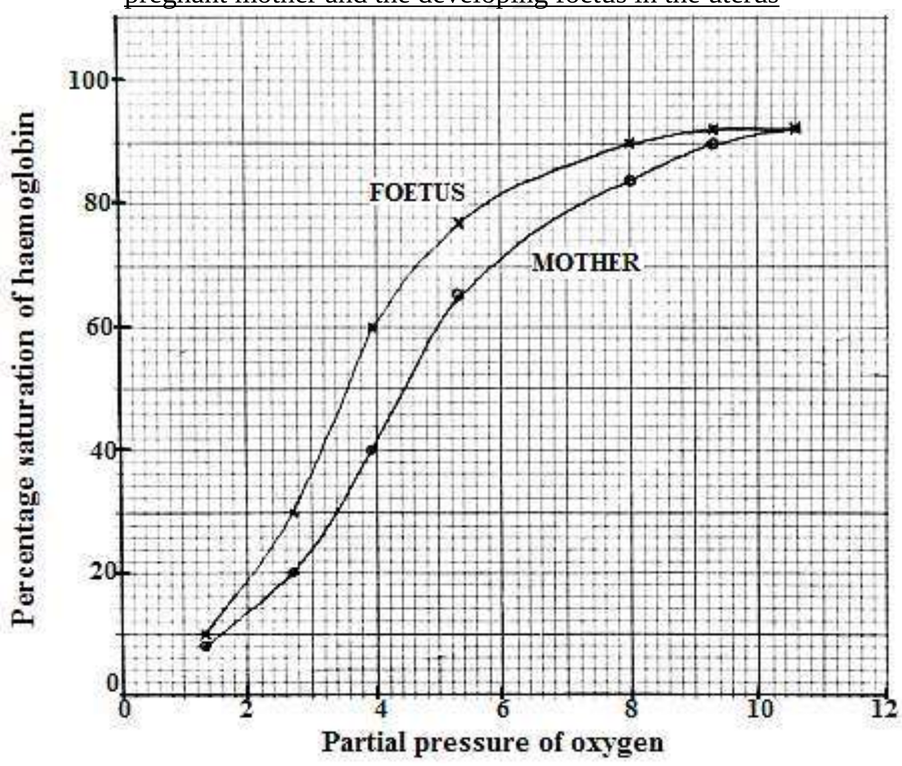
Question 2.

The table below shows the difference in percentage saturation of blood with oxygen at varying partial pressures of oxygen between a pregnant woman and that of a foetus developing in her uterus.

Partial pressure of oxygen in mmHg	Percentage saturation of blood with oxygen	
	Mother	Foetus
1.3	8	10
2.7	20	30
3.9	40	60
5.3	65	77
6.6	77	85
8.0	84	90
9.3	90	92
10.6	92	92

(a) Plot the results in a suitable graphical form. ***(04 marks)***

Graph showing the percentage saturation of blood with oxygen with partial pressure of oxygen (PPO_2) for a pregnant mother and the developing foetus in the uterus



(b)(i).Compare the percentage saturation of blood for the mother and that of the fetus. ***(04 marks)***

Similarities

Both percentage saturation of mother and the foetus;

• Generally display a sigmoid pattern with increasing PPO2

• Generally increase with increasing partial pressure of oxygen.

• Have equal maximum percentage saturation of haemoglobin with oxygen at 10.6 mmHg PPO2
• Have initially slow increase in percentage saturation at low partial pressures of oxygen.
• Have rapidly increasing partial pressure of oxygen for moderate ranges of oxygen partial pressures.
• Have slow and almost leveling off percentage saturation of haemoglobin at high ranges of PPO2

Differences

Foetal percentage saturation of blood	Maternal percentage saturation of blood
Oxygen dissociation curve lies to the left of the mother	Oxygen dissociation curve lies to the right of that of the foetus.
Generally higher except at 10.6 mmHg	Generally lower except at 10.6 mmHg
Increases gradually for 1.3-2.7 mmHg PPO_2	Increases slowly for 1.3-2.7 mmHg PPO_2
Remains constant for 9.3-10.6 mmHg PPO_2	Increases slowly for 9.3-10.6 mmHg PPO_2
Reaches maximum at lower PPO_2	Reaches maximum at higher PPO_2

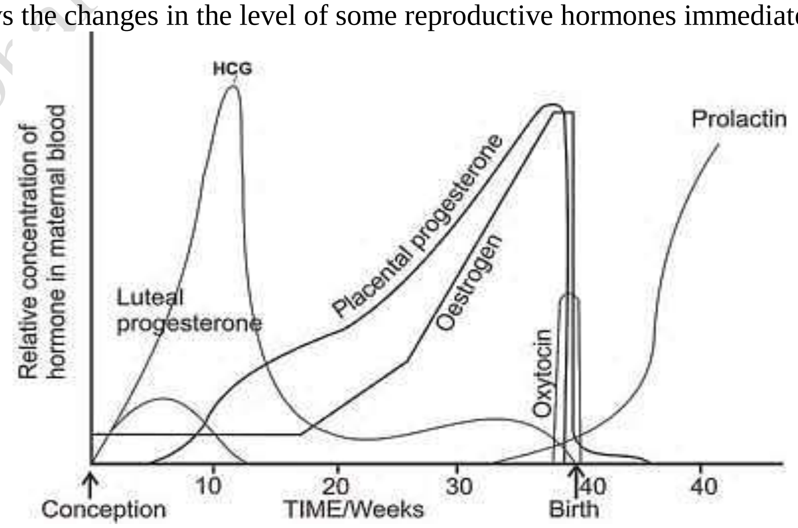
(b)(ii).Explain the differences if any that were identified in (b)(i) above ***(04 marks)***
Generally the percentage saturation of maternal haemoglobin with oxygen is lower than that of the foetus and is shifted to the right of the foetal curve; because the mother, being exposed to an environment of ambient/ higher PPO_2 renders her haemoglobin a lower affinity for oxygen but has higher dissociation to readily supply the actively metabolising tissues as well as to the foetus. Foetus on the other hand is only exposed to maternal oxygen whose partial pressure is very low compared to that present in the mother's vicinity/ environment. Therefore, the foetal haemoglobin develops a higher affinity for the little oxygen exposed to it; but compromises dissociation due to its relatively low metabolic profile.

(c).Account fully for the sigmoid shape of the maternal curve. ***(06 marks)***
The maternal curve is sigmoid because of the positive co-operative effect in which oxygenation of the first heme increases affinity for the 2nd,3rd and the 4th in turn. The percentage saturation of haemoglobin with oxygen between 1.3-2.7 PPO2 described by the lower left tail of the curve rises slowly as hemoglobin loads more oxygen at increasing (but still low) ambient tissue partial pressure of oxygen. But as each heme group binds an oxygen molecule, this changes the shape of globin in a way that facilitates the binding of the next oxygen, then that further facilitates the third, and that one the fourth. Thus, there is a positive feedback effect in which oxygen loading accelerates the loading of more O2, accounting for the rapidly rising mid portion of the curve between 2.7 to 9.3 PPO_2. Towards the upper right, at high ambient PO2, the curve plateaus as the haemoglobin approaches approximately full saturation/ most binding sites of haemoglobin are occupied by oxygen and can't load any more.

(d) Explain the physiological significance of the position of the fetal curve. ***(02 marks)***
Foetal oxygen dissociation curve shifted to the left of the maternal curve; implies increased affinity for oxygen; ensures that enough oxygen is obtained by diffusion via the placenta; permits fat ATP synthesis for rapid growth and development.

Part B

The figure below shows the changes in the level of some reproductive hormones immediately after conception.



(i) Compare the levels of luteal and placental progesterone. ***(04 marks)***

Similarities

• Both concentrations of luteal and placental progesterone increase up to the peak.
• Both concentrations of luteal and placental progesterone decrease rapidly after the peak
• Both concentrations of luteal and placental progesterone are equal at the 9th week.
• Both begin rising at a relative concentration of zero

Differences

Relative concentration of luteal progesterone	Relative concentration of placental progesterone
Gradual increase for the first 5 weeks.	Constantly at 0 for the first 5 weeks
Attains peak earlier after conception	Attains peak much later after conception
Reduce gradually from the 5th to 12th week	Increases gradually within the same time range
Lower peak	Higher peak
Zero for the period between 27th to 38th week	Gradual increase for the same time range
Zero up to the time of birth	Peaks at 38th week; then decreases rapidly up to birth

(ii).Explain the variation in the level of:

• HCG (Human Chorionic Gonadotrophin) hormone ***(06 marks)***

Initially zero concentration due to absence of corpus luteum or placenta. Rapid increase from 0 to 13th week attaining peak concentration on the 13th week; as the hormone is needed for maintenance/ persistence of the corpus luteum; for continued secretion of progesterone. The secreted progesterone ensures proliferation of glands in the uterine walls, embryonic nourishment and cessation of any ovulation. Rapid decrease the HCG level after the 13th week was due to the development of the placenta that prompted regression of the corpus luteum; HCG levels remained low and almost constant up to the 35th week due to gradual regression of the corpus luteum; a little HCG is also produced by the placenta. The HCG concentration lowers to zero due placental expulsion at birth; that ceased any more HCG production.

• Oestrogen hormone ***(07 marks)***

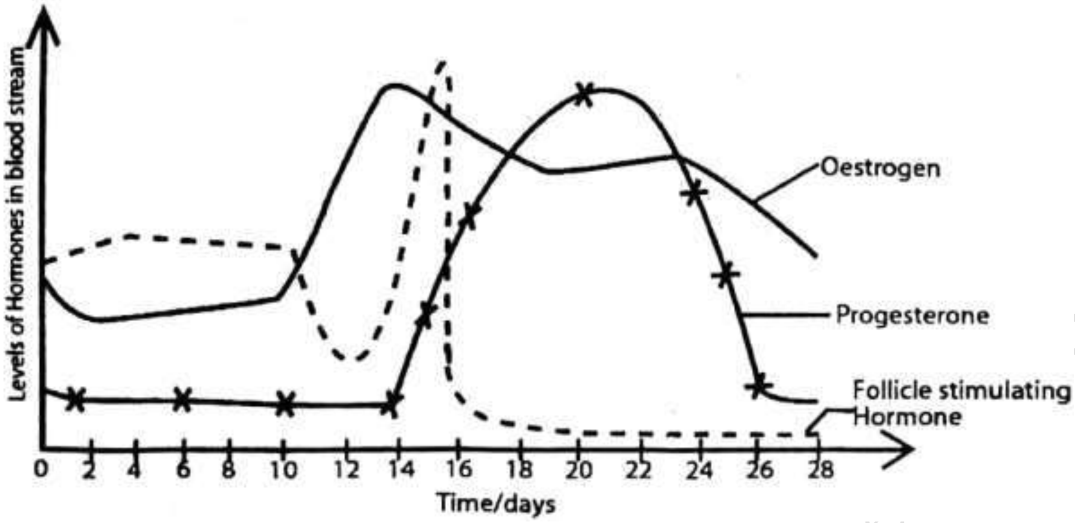
Initially low and constant from 0 to 18th week; because of production from the ovaries and some from the corpus luteum. There is negative feedback inhibition of FSH by the rising concentration of progesterone. Gradual increase from the 18th week to 27th week and the rapid increase from the 27th week to peak at 37th week; was due to the increased placental activity that releases oestrogen in plenty; Oestrogen stimulates hypertrophy of the endome-trial cells, formation of oxytocin receptors in uterus as well as promoting development of mammary glands in preparation for birth. From 37th week to birth, oestrogen concentration briefly remains constant; then falls rapidly because of placental expulsion as well a rise in prolactin levels; a hormone that inhibits secretion of oestrogen by negative feedback.

(iii) What are the effects of hormones oxytocin & prolactin towards the end of pregnancy ***(03 marks)***

Oxytocin; stimulates myometrial contractions, also stimulates milk ejection from glands and sinuses.
Prolactin; stimulates mammary glands to secrete milk.

Question 3.

A study was conducted on hormonal changes in the menstrual cycle of a fertile of reproductive age. Periodical changes in a level of gonadotrophin hormone, follicle stimulating hormone and two other steroid hormone oestrogen and progesterone were studied over 28 days of the menstrual cycle. The hormonal changes are shown in the figure below.



(a).Compare the variation in the level of oestrogen and progesterone hormones ***(06 marks)***

Similarities;

- In both, the hormonal levels decreased from 0 to 2 days; and from 23 days to 26 days
- In both, the levels of the hormones increased to reach a peak;
- In both the levels of hormones reached peak/ maximum.
- In both the levels of the hormones declined after the peak;
- The levels of the hormones is the same on 17th day and 23rd day.

Differences

Levels of oestrogen hormone	Level of progesterone hormone
Increases very slowly from 2 to 10 days and then increases rapidly up to 13 days:	Remained constant from 2 up to 13 days.
Decreased rapidly from day 14 up to 19 days	Increased rapidly from 14 up to about 19 days
Two peaks reached	One peak reached
Declined rapidly from day 26 up to 28 days	Remained constant from day 26 to day 28
Levels higher from 0 to 17 days and from 24 to 28 days.	Levels lower from 0 to 17 days and from 24 to 28 days
Levels lower from 17 up to 24 days	Levels higher from 17 up to 24 days
Attains peak earlier on day 13	Attains peak later on day 21.

(b).Explain the

(i). relationship between the follicle stimulating hormone and progesterone hormone ***(20 marks)***

From 0 to about 3 days; levels of follicle stimulating hormone(FSH) increased gradually while the levels of oestrogen decreased gradually; decrease in levels of oestrogen stimulates hypothalamus to produce gonadotropin releasing hormone (GnRH); Gonadotropin releasing hormone stimulates secretion of FSH; from the anterior lobe of pituitary gland. High levels of FSH inhibits secretion of the oestrogen from ovarian follicles by negative feedback From 3 up to10 days; oestrogen increases very slowly while FSH remain almost constant; but the levels of FSH remain relatively higher than oestrogen; because FSH stimulate development of few ovarian follicles which secrete little amounts of oestrogen and from 10 up to 13 days, levels of FSH decreased rapidly while the levels of oestrogen increased rapidly; because FSH stimulated development of very many ovarian follicles, which secrete larger amounts of oestrogen. Oestrogen causes repair and growth of endometrium; and inhibits further secretion of follicle stimulating hormones (FSH); so that only one graffian follicle develops within the ovary; From 13 up to15 days; the levels of FSH increased very rapidly to a peak while levels of oestrogen declined slowly; because levels of oestrogen had reached its peak and it stimulated hypothalamus to secrete more gonadotropin releasing hormone causing a temporary rapid increase in secretion of FSH; and luteinizing hormone (LH) from the anterior lobe of pituitary gland(ovulatory surge); LH stimulates ovulation; LH stimulates formation of corpus luteum; which secretes progesterone from15 up to16 days; levels of FSH declined rapidly while the levels of oestrogen continued to decline gradually up to day 20 where levels of FSH remained constant; high levels of oestrogen and increase in concentration of progesterone; inhibit secretion of FSH from anterior lobe of pituitary gland; FSH levels at its peak inhibit secretion of oestrogen from the ovaries; From19 up to 24 days; levels of oestrogen increased gradua-lly while levels of FSH remain very low and constant; this is because corpus luteum secretes smaller amounts of oestrogen and high levels of progesterone ; inhibiting secretion of FSH from anterior lobe of pituitary gland; From 24 up to28 days; levels of oestrogen declined rapidly while the levels of FSH remained constant; corpus luteum degenerates; secretion of oestrogen from it ceases and there continues to be no further secretion of FSH from anterior lobe of pituitary gland caused by the inhibitory effects of progesterone and oestrogen;

(ii).variation in the level of progesterone hormone throughout the menstrual cycle ***(05 marks)***

At 0 days; the levels of progesterone is very low and remained almost constant up to 2 days from 2 up to 14 days; the levels of progesterone remained constant within low levels; corpus luteum is not yet developed and no further secretion of progesterone into the blood stream. From 14 days up to about 17days, levels of progesterone increaeed rapidly because the corpus luteum formed is secreting large amounts of progesterone hormones; From 17 up to 21 days; the levels of progesterone increases gradually because the size of the corpus luteum begins to reduce ; and the levels of progesterone secreted reduces : From 21 up to 26 days; levels of progesterone declined rapidly; because corpus luteum is degenerating rapidly and further secretion of progesterone is inhibited/ reduced greatly complete degeneration of the corpus luteum; causes the levels of progesterone to remain constant up to 28 days

(c).Predict the changes in the level of the three hormones if fertilisation occurs on the 17th day of the cycle

- Level of progesterone will increase gradually and then rapidly above the levels of oestrogen
- Levels of oestrogen will increase very gradually but slightly below the levels of progesterone;
- Levels of follicle stimulating hormone will decreased gradually and remains constant at very low levels

(d).Suggest the reasons for your answer in (c) above ***(04 marks)***

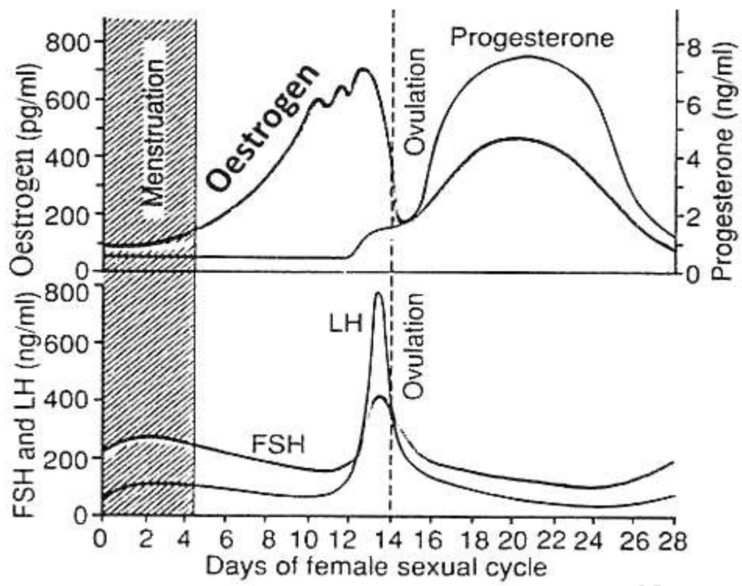
Diploid zygote formed will develop into a blastocyst, the cells of the outer layer of the blastocyst called trophoblasts secrete Human chorionic gonadotropin hormone which will maintain the corpus luteum for some time; secreting small amounts of oestrogen but larger amounts of progesterone; a role later played by the placenta when formed; Progesterone maintains the thickness of endometrium which sustains pregnancy; oestrogen stimulates formation of receptor molecules in endometrium; sensitive to oxytocin; that will later cause birth: FSH decrease to ensure no ovulation occurs during pregnancy/no development of graffian follicles take place during pregnancy;

(e).Explain the significance of the three types of hormones as fertility drugs ***(03 marks)***

They can be provided to mature female individuals as synthetic chemicals that can stimulate ovulation; they either provide gonadotropins such as FSH which stimulate the development of follicles or they provide a chemical which inhibit natural production of oestrogen; lack of oestrogen results in production of more FSH which stimulates follicular development

Question 4.

The graph below shows the changes in the sex hormones and thickness of the uterine wall obtained by close observations made using blood samples that were withdrawn from an adult human female at regular intervals of days and by scanning the uterus respectively. The investigation was done for over a period of one month (28 days) immediately after the previous menstruation period.



(a) Describe the changes in the concentration of:

(i) Oestrogen hormone. *(05 marks)*

(ii) Progesterone hormone. *(04 marks)*

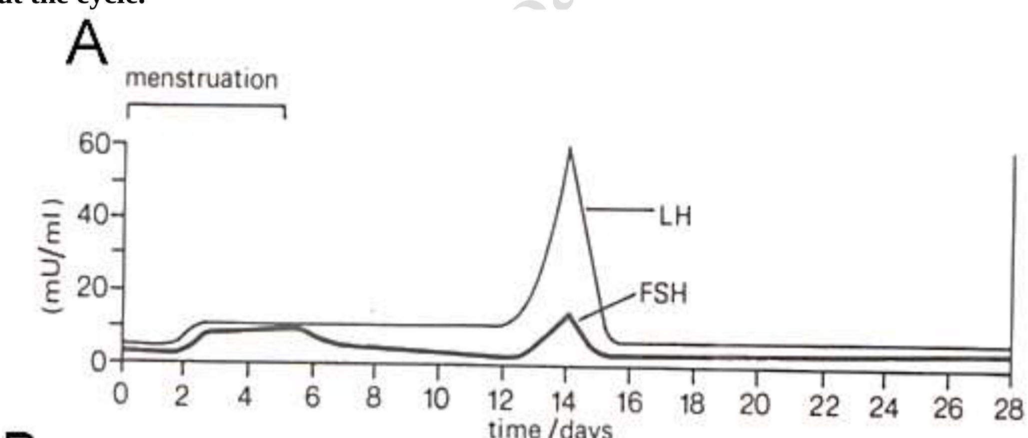
(b) Explain the different phases of the menstrual cycle *(10 marks)*

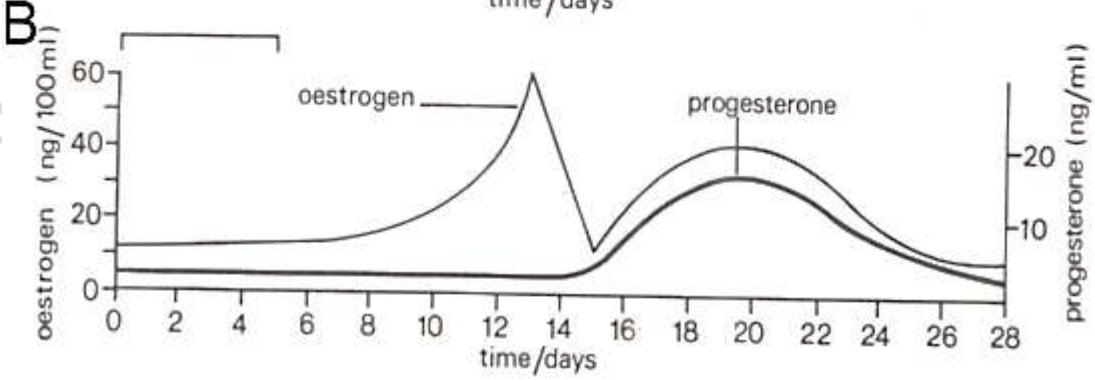
(c) Explain the relationship between oestrogen and progesterone concentration. *(10 marks)*

(d) Explain what would happen if fertilization had occurred on the 21st day of the month *(11 marks)*

Question 5.

Graph A and B deal with concentration changes, indicating the amounts of hormones present in the blood throughout the cycle.





(a)State three general features of animal hormones *(03 marks)*

• Secreted by endocrine glands also known as ductless glands.
• They are directly secreted into the blood stream,
• Glands of the endocrine system secrete hormones in very minute quantities
• Often the effect of these hormones is at a different site from the site of secretion.
• The action of the hormone is on specific tissue or organs known as target tissues or organs.
• They are known as chemical messengers; they modify and regulate the activity of the target tissues or organs.
• Most of the animal hormones are water-soluble and are derived from amino acids, peptides or proteins. These molecules are hydrophillic in nature and large so they cannot pass through the cell membrane. These hormones interact with receptor molecules seen on the surface of the membranes.
• Hormones like the steroid hormones eg thyroid hormone arc hydrophobic and they readily diffuse through the cell membranes and bind to receptor inside the cell.

(b).Using the two graphs in the figure above, explain the changes in the blood levels of the hormones with time during the cycle

From day 2 to day 3, concentration of both luteinizing hormone (LH) and follicle stimulating hormone(FSH) increase gradually. Gonadotrophin releasing hormone (GnRH) from the hypothalamus stimulates the anterior pituitary gland to secrete FSH and LH. FSH stimulates the growth and development of the graffian follicles in the ovaries wall of the ovaries or theca start secreting oestrogen thus its concentration increase gradually between day 6 and day 13 reaching maximum on day13. Increased oestrogen levels inhibits secretion of FSH. Decreasing FSH concentration rapidly between day 6 and day 7; then gradually between day 7 & day 12; but has little effect on the secretion of LH from the anterior pituitary gland it, thus its concentration remaining constant between day 3 and day 12. Peaking of oestrogen on day 13 triggers a sudden surge in the production of both FSH and LH; their concentrations increasing rapidly to the maximum between day 13 and day 14; LH stimulates resumption of meiosis in the primary oocyte to form Polar body and secondary oocyte which is released by rupturing of Graafian follicle (cause ovulation). Oestrogen concentration decreases rapidly between day 13 and day 15 to a rapid increase in concentration of LH; LH stimulates the remains of the graffian follicle to develop into corpus luteum (yellow body), which secretes progesterone and continues to secrete oestrogen: increasing the concentration of both hormones rapidly between day 15 and day 20; Progesterone causes the uterus to become highly muscular and vascular, and also inhibits the release of LH and FSH; decreasing their concentration rapidly between day 14 and day 15; The failure of oocyte fertilization also causes degeneration of the corpus luteum, which results in gradual decreased levels of oestrogen and progesterone.

(c).Basing on the effects of each of the hormones on the secretion of others, show how negative feedback operates in the human menstrual cycle

The hypothalamic Gonadotrophin-releasing hormone (GnRH) stimulates the anterior pituitary to secrete both FSH and L..H, FSH stimulates the secretion of oestrogen in the ovary. Increased levels of oestrogen inhibits FSH secretion and causes secretion of LH from the anterior pituitary. LH stimulates ovulation and development of corpus luteum, which secretes progesterone and also continues to secrete oestrogen, Progesterone inhibits the release of LH and FSH preventing development of any further follicles.

(d).Suggest what would be the effect on the blood level of the hormones if

(i). The ovary of the human is surgically removed

Level of oestrogen drastically reduce; Levels of gonadotrophins (FSH and LH) rise by negative feedback

(ii).Successful fertilisation occurred

Progesterone & oestrogen levels rise; levels of FSH and LH reduce; preventing further maturation of graffian follicles and ovulation respectively.

(e).Explain how use of each of the following may affect the blood levels of the hormones in the figure above

(i). Contraceptive pills

Adds more oestrogen and progesterone maintaining high levels of the hormones in blood which inhibits production of Gonadotrophin hormones from the pituitary glands

(ii).Fertility drugs

Inhibits negative feedback mechanisms of oestrogen (reduces oestrogen levels) in the hypothalamus & pituitary gland which stimulates the secretion of pituitary gonadotrophic hormones (increasing levels of FSH and LH).

(g).State the factors that affect breeding cycles of animals

- Temperature.
- Humidity
- Day length
- Life expectancy
- Genotype
- Food availability
- Testosterone concentration

(i). How is courtship of significance in reproduction of organisms?

- Attracts a male possibly from a considerable distance often by conspicuously noisy behaviors
- Drives away other mates competing for the female at oestrus
- Ensures mating occurs between members of the same species and between sexually fit and healthy individuals
- Synchronizes the activities of both partners for successful copulation.
- Induces a comparable level of sexual arousal in both partners making both equally ready and willing to copulate

Other questions

(a) Describe the trends of the curves in graph A ***(10 marks)***

(b)Give reasoned explanations for the changes expressed by the curves in graph A and graph B, relating them to each other where possible. ***(20 marks)***

(c)What would happen to the concentrations of the hormones if the ovary was surgically removed. Explain your answers. ***(05 marks)***

(e)What is the main role of progesterone ***(02 marks)***

Essay questions and answers

Question 1.

(a)Describe different mechanisms employed by mammals to increase chances of fertilization & survival.

(b).How does territorial behaviour contribute to evolutionary success of species ***(04 marks)***

(a).

- Development of secondary sexual characteristics; allows sexually mature individuals recognize and mate with each other;
- Seasonal breeding cycles; that restricts copulation to times that will ensure birth in seasons most favourable to the survival of offspring;
- Female receptiveness; to mate only when ovulation is taking place or even ovulation being stimulated by the act of copulation;
- Internal fertilisation; brings sperms and egg together within the relative safety and stability of the female genital tract;
- Internal development; of the embryo in a stable/ protected environment;
- The placenta acts as a barrier to harmful substances; and an exchange mechanism for beneficial ones;
- Suckling/ breast feeding; provides newly born with a fairly secure food source ideally suited for its early development; accept provides passive immunity.
- Parental care; allows development of young in a controlled and protected environment;
- Maximum use of learned behaviours e.g imprinting; which has the advantage of being adaptable to meet varying circumstances;

(b).

- Each mating pair is adequately spaced; to receive sufficient share of available resources; This increases chances of survival of members of the species;
- Promotes genes of most fit; due to the competition ensuring most adaptable individuals that have high chances of survival;
- Controls population size; due to competition ensuring sufficiency of resources for the individuals and increasing their chances of survival;

Question 2.

(a).With examples, distinguish between the following

(i).Diploid parthenogenesis and haploid parthenogenesis ***(05 marks)***

(ii)Apomixis and parthenocarpy *(03 marks)*
(b).Describe how parthenogenesis occurs in honey bees *(06 marks)*
(c)Explain the advantages and disadvantages of parthenogenesis *(06 marks)*

(a)(i).

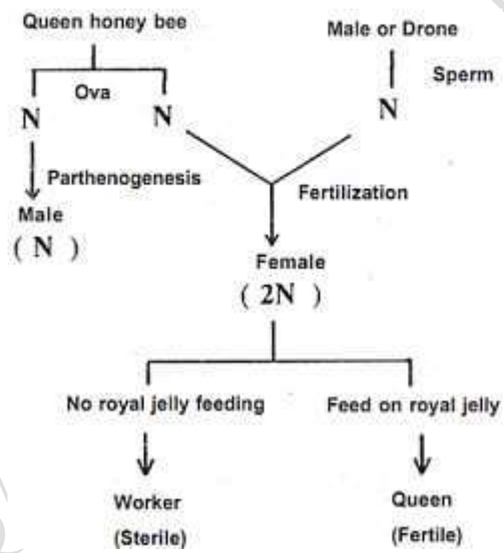
Diploid parthenogenesis/ ameoitic parthenogenesis: is the development of embryo from unfertilized diploid eggs that formed by mitosis instead of meiosis, resulting into diploid offspring, which are clones of the parent. It occurs in aphids, during which large numbers of wingless females are formed without necessitating the presence of males in flatworms, rotifers, crustaceans while haploid parthenogenesis/ meiotic parthenogenesis is the development of embryo from unfertilized haploid eggs that formed by meiosis and may develop directly into haploid offspring. It occurs in honeybees, wasps, ants, whiptail lizards.

(a)(ii).

Apomixis is the formation of plant embryo from an unfertilized haploid egg cell or from a diploid embryo sac mother cell or from a diploid cell in the ovule without fertilisation. It occurs in potatoes and citruses while parthenocarpy is fruit development without fertilisation, usually induced by auxins e.g in apples.

(b).

In honeybees, the queen bee can either fertilise the eggs as she lays them or allows them to pass unfertilized. Fertilised eggs become diploid females (fertile queens or sterile workers), and unfertilized eggs develop to become fertile haploid males (drones).



(c).

Advantages of parthenogenesis

• It avoids the problem in some animals of bringing together males and females at the right moment for successful fertilization.
• Produces a large number of organisms in a short time. E.g. in whiptail lizards all the parthenogenetic off spring are females, which all produce eggs, yet only half of bisexual population are egg-laying females.
• It eliminates in each generation all lethal genes that thrive in homozygous state

Disadvantages of parthenogenesis

• During sudden environmental changes, parthenogenetic species have limited capacity to shift gene combinations to adapt to the new conditions.

Question 3.

(a) Give an account of the role of the placenta as an
(i) Endocrine organ in mammals. *(08 marks)*
(ii).Non-endocrine role *(06 marks)*
(b).Outline the transport mechanisms involved in the exchange of substances between mother and developing foetus. *(06 marks)*

(a)(i).

It secretes various hormones which control development of the foetus: HCG (human chorionic gonadotrophin) causes the corpus luteum to continue secreting progesterone and oestrogen necessary for endometrial development for the first 3-4 months of pregnancy. Oestrogen prevents ovulation and menstruation, stimulates growth of mammary glands and increase in uterine muscle cells, and increases myometrium sensitivity to oxytocin Progesterone also stimulates growth of mammary glands, inhibits the contraction of uterine muscles and inhibits the release of prolactin (a hormone that stimulates milk production). Relaxin hormone relaxes the connective tissue in pelvic girdle to enlarge the cervix in preparation for birth.

(a)(ii).

Digested food and other nutrients are transported through umbilical vein to link up with the foetal blood Waste foetal products diffuse from umbilical artery to maternal blood. Oxygen diffuses from umbilical vein to the foetal blood while carbondioxide moves in opposite direction. Antibodies cross placenta from mother to foetus hence providing means by which passive immunity is acquired. It serves as a barrier to the transfer of solutes and blood components from maternal to foetal circulation. It prevents direct contact of maternal and foetal blood systems enabling them to operate at different pressures.

(b).

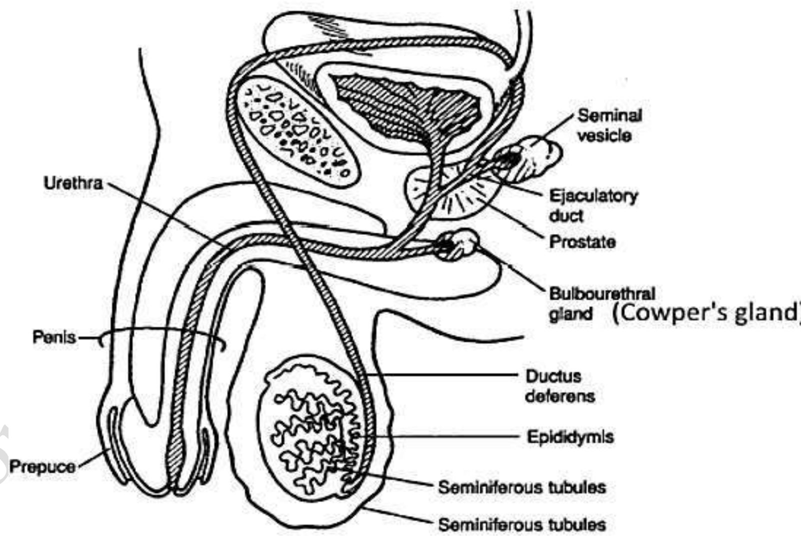
Water is exchanged by osmosis. Exchange of the respiratory gases (oxygen and carbondioxide), nitrogenous wastes (urea) from the foetus and to some extent ions (e.g sodium, potassium, calcium) is by simple diffusion. Glucose exchange is by facilitated diffusion. Ions (sodium, potassium, calcium) largely move by active transport. Amino acids iron and vitamins are exchanged by active transport.

Question 4.

(a).How the structures of the human reproductive systems are related to function *(18 marks)*
(b) Explain the significance of formation polar bodies during oogenesis. *(02 marks)*

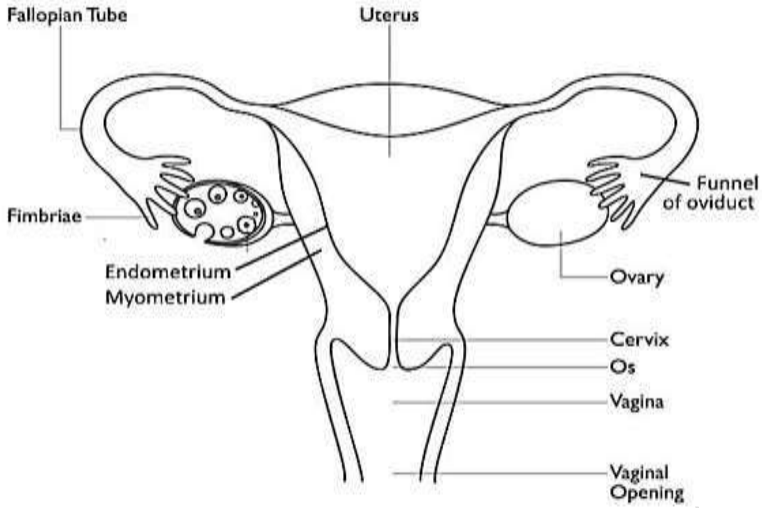
(a).

Male reproductive system



Penis; Delivers sperm to the neck of the cervix, as close to the ovulation site
Scrotum; Regulates testes' temperature at lower than body temperature for proper sperm formation; also protects the testes from mechanical damage
Testes; Contain seminiferous tubules that produce sperm; produce the male sex hormone
Prostate gland; Secretes an alkaline fluid that neutralizes the acidic vaginal secretions.
Seminal vesicles; Secrete some alkaline mucous fluid rich in fructose; the respiratory substrate for sperm motility.
Cowper's (bulbourethral) gland; Produces a mucous secretion for lubricating the penis during intercourse & neutralizing the acidity of any remaining urine.
Vas deferens; Stores sperm (up to many months) before ejaculation
Epididymis; Sperm maturation site (1-10 days) and stores spermatozoa (up to 4weeks)

Female reproductive system



Labia minora and Labia majora; Produce a lubricant mucus secretion during intercourse and protect the clitoris from abrasion.
Clitoris; tactile stimulation excites the female sexually during intercourse.
Vagina; passage for menstrual flow, receptacle for penis during coitus and lower part of birth canal.
Uterus; Site of implantation of fertilized egg, development of foetus during pregnancy and origin of muscular contractions that precede parturition.
Oviducts (Fallopian tubes); walls are muscular and lined with ciliated epithelium for moving egg from ovary towards uterus.
Funnel of oviduct; the finger-like projections sweep the egg into oviduct.
Ovaries; are sites for egg production, secrete the hormones oestrogen and progesterone.

(b).

• Polar bodies take the extra chromosomes resulting from meiosis in order for the ovum to carry haploid number of chromosomes.
• The unequal cytoplasmic division results into the formation of a large egg with the cytoplasm containing sufficient yolk for the development of the embryo.

Question 5.

(a).Describe how the structure of the placenta is adapted to function. ***(10 marks)***
(b).Describe the foetal circulation changes that immediately after birth ***(10 marks)***

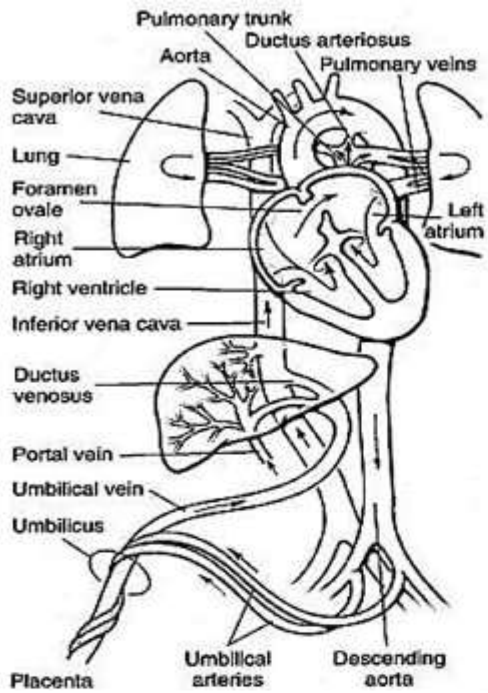
(a).

• Closeness of maternal and foetal blood vessels facilitates faster diffusion of substances.
• Chorionic villi cells contain numerous mitochondria to provide energy required for active transport
• Numerous chorionic villi, increase surface area for absorption of materials; exchange of gases.
• Two umbilical arteries; transport blood containing wastes from foetus to mother's blood for excretion.
• Umbilical vein; transport nutrient and oxygen rich blood from the mother to the foetus
• Numerous maternal arterioles; supply oxygen and nutrient rich blood to foetus
• Syncytiotrophoblast (syncytium); secretes HCG; important in barrier functions of the placenta.
• Numerous glandular tissues; secrete placental oestrogen, progesterone, HCG; important in maintaining the well-being of the conceptus
• Numerous maternal venules into which foetal blood containing wastes drains to be transported back to maternal blood for excretion.
• Decidualised arterioles and arteries i.e remodeled such that they are less convoluted and are of increased luminal diameter; increase maternal blood flow to the placenta; create steep concentration gradient;
allowing efficient material exchange.
• Endometrium breaks down in the region of the villi; so that placental villi may be bathed in maternal blood; making exchange more efficient but still keeping the fetal and maternal blood separate.

• Chorionic arteries; divide to cotyledon arteries; further divided to from a dense arterio-capillary venous ystem creates a steep concentration gradient allowing efficient material transport and exchange
• Selectively permeable placental barrier/membrane; allows selective diffusion of antibodies for passive immunity hormone diffusion; barrier also impedes microbes from accessing the foetus

(b).

Immediately after birth, gaseous exchange begins in baby's lungs; cutting the umbilical cord switches off placental circulation; Foetal heart shunts get closed; At birth, activation of breathing in the baby's lungs cause them to get distended; capillary network in the lungs get dilate allowing rich blood flow to the alveoli. Pressure in the rig-ht atrium sinks below that in the left atrium; foramen primum flaps over foramen secundum causing closure of foramen ovale; Cutting the umbilical cord; placental resistance cease; systemic peripheral resistance increase pressure in the aorta exceeds that in the pulmonary trunk; right left shunt becomes left-right shunt; increase in oxygen partial pressure within the aorta; causes contraction of the smooth musculature of walls of the ductus arteriosus causing its closure. Umbilical arteries and vein begin obliterating; more blood begins flowing to the kidney's and gut since they've become functional. Finally blood flows to the right atrium; then to the right ventricle to lungs and back to heart for systemic circulation.



Question 6.

(a).Distinguish between oestrus and menstrual cycles. ***(02 marks)***
(b).Outline the four main phases of the menstrual cycle ***(02 marks)***
(c).Describe the hormonal, physiological and structural changes that occur during the human menstrual

(a).

Oestrous cycle: series of hormone controlled changes in the non-primate reproductive cycle characterized by females experiencing a period of heightened sexual excitement just before ovulation while menstrual cycle: series of hormone controlled changes in the primate female reproductive system that result in monthly discharge of blood and uterine materials when fertilization fails.

(b).

• Follicular phase
• Ovulation
• Luteal phase
• Menstruation

(c).

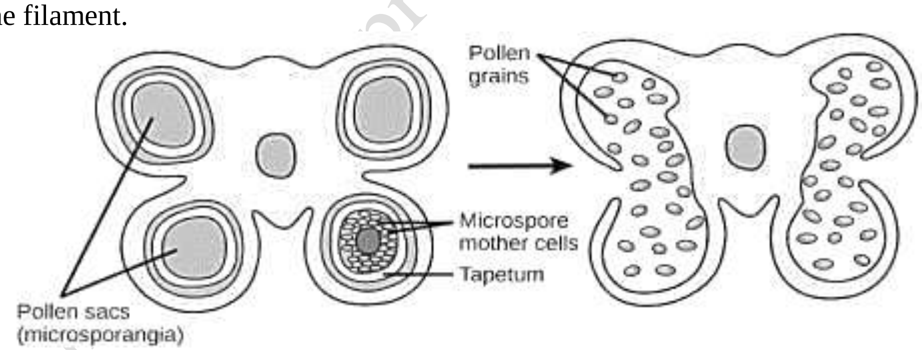
Gonadotrophin-releasing hormone (GnRH) from the hypothalamus; stimulates the anterior pituitary gland to secrete follicle stimulating hormone (FSH); FSH stimulates the development of primary follicles in the ovary and also stimulates the walls of the ovarian follicle to secrete oestrogen; oestrogen concentration in blood rises quickly; inhibits the production and release of FSH by the anterior pituitary gland; by a negative feedback mechanism; causing the repair and healing of the uterine wall following menstruation; peaking of oestrogen concentration triggers a sudden surge in production of both FSH and LH from the anterior pituitary; triggering ovulation; the remains of Graafian follicle to develop into corpus luteum (yellow body); the corpus luteum is stimulated to secrete progesterone and oestrogen; Progesterone together with oestrogen maintain the increase in thickness (muscularisation); and vascularization of the uterus; inhibits the release of LH and FSH; by negative feedback mechanism; decreased level of FSH prevents development of Graafian follicles; hence secretion of oestrogen stops; decreased level of LH prevents ovulation hence the corpus luteum degenerates; and progesterone decreases; the sudden decrease of progesterone level in blood completes menstrual cycle; as the hypothalamus resumes the secretion of GnRH; GnRH stimulates the anterior pituitary to secrete FSH as menstruation occurs; characterized by breakdown and shedding of endometrial materials;

Question 7.

(a).Describe the structure of the anther of a flowering plant ***(05 marks)***
(b).Describe the events leading to;
(i). Double fertilization in higher plants ***(07 marks)***
(ii).Ovulation ***(04 marks)***
(c).State the differences between stamens of insect and wind pollinated flowers. ***(04 marks)***

(a).

Anther is a bilobbed structure; borne at the end of a slender flexible filament. Its transverse section reveals a butterfly shaped structure having four pollen sacs, bilaterally arranged in pairs with respect to the main axis. Each pollen sac contains several pollen grains from pollen mother cells and is enclosed by a tapetum; that provides nourishment to the pollen mother cells Walls of the anther are made up of fibrous layers with thickened cell walls interrupted by lines of weakness called stomium along which dehiscence occurs. Epidermis forms the outermost layer of the anther walls. Along the midline axis lies a vascular bundle made up of xylem and phloem tissues; continuous with that of the filament.



(b)(i).

Pollen grains land on the stigma of a compatible species, germinates, a process facilitated by sucrose solution secreted by epidermal cells of the stigma. Pollen tube begins emerging. The tube nucleus occupies a position at the tip of the growing pollen tube meanwhile generative nucleus divides mitotically into a pair of male gamete nuclei. Pollen tube growth is positively chemotropic and negatively aerotropic thus grows down the style and grows towards the ovary. On reaching the ovary, the pollen tube enters the ovule through the chalaza or microphyle; reaches the centre of the ovule; penetrates wall of the embryo sac and bursts open. Tube nucleus then degenerates. One male nucleus fuses with a functional egg cell to form a diploid zygote, the other fuses with the two polar nuclei to form a triploid primary endosperm nucleus.

(b)(ii).

Anterior lobe of the pituitary gland secretes follicle stimulating hormone (FSH), causes the growth of the Graafian follicle. It begins with growth of the oogonium formed from the germinal epithelium. into the primary oocyte, get enclosed into the Graafian follicle. FSH also stimulates release of oestrogen from the ovary; which cause healing and repair of uterine wall following the previous menstruation. Increase in oestrogen level causes release of Luteinizing hormone (LH) from the anterior pituitary gland, its surge causes rupture of the Graafian follicle to release ovum into the oviduct.

(c).

Stamens of insect pollinated flowers	Stamens of wind pollinated flowers
Anthers enclosed in the petals	Anthers dangle outside the bracts
Short filaments	Long filaments and pendulous
Less pollen sacs in the anthers	Numerous pollen sacs in the anthers;
Fewer pollen grains produced	Large quantities of pollen grains produced.
Pollen grains are sticky	Pollen grains are not sticky.
Smooth, smooth and light pollen grains	Large or heavy pollen grains produced
Brightly coloured pollen grains	Dull coloured pollen grains
Anthers fixed at their bases or fused along their backs to the filaments so that they are immovable	Anthers attached only at the midpoints to the tip of the filament so that they swing freely in air

Question 8.

(a).Distinguish between;
(i).Accessory sex organ and accessory sex character *(02 marks)*
(ii)Primary sex organs and secondary sex organ *(03 marks)*
(b)Mechanisms leading to fertilization and subsequent development in mammals are of evolutionary advantage to their success. Describe some of the mechanisms you consider are of evolutionary advantage.
(c).Outline the main features of sexual reproduction in mammals *(08 marks)*

(a)(i).

Secondary sex organs (accessory organs) are organs associated with testes or ovaries which play some roles in reproduction but other than gamete production and hormone secretion e.g penis, prostate, seminal vesicles, sperm duct in males, and fallopian tubes, uterus, vagina, mammary glands in females while Accessory or external sex characters are external characters, which do not play any direct role in reproduction but are distinct and enable sexes to be distinguished as male and female. E.g. low pitch voice and facial hair (males) & high pitch voice (females).

(a)(ii).

Primary sex organs produce gametes, secrete sex hormones and development is under the control of FSH and LH while secondary sex organs do not produce gametes, do not secrete sex hormones and development is under the control of Oestrogen and progesterone in females and testosterone in males.

(b).

• Fertilisation and development are internal to limit wastage of gametes and provide protection to the young
• The breeding seasons coincide with the breeding cycle so that birth occurs at a time when environmental conditions are most favourable for growth of young.
• Feeding young ones on nutritious milk enables them to prepare for adult food as the digestive system develops.
• Secondary sexual characteristics enable easy identification of mating partners
• Parental care provides protection from predation and harsh environmental conditions to the young.
• Development of placenta enables gaseous exchange and the young to excrete wastes.
• Females are often more receptive to males during ovulation or the act of copulation stimulating ovulation.
• Fertilisation is internal

(c).

• Females go through a sexual cycle known as menstrual cycle
• Sexual cycle is restricted to the breeding season, except in humans and other primates, which are sexually receptive throughout the year
• Young ones are born at an advanced stage.
• There is display of courtship behaviour that leads to mating.
• Development of embryo is internal and completely dependent on the mother for food and protection.
• The young are fed on milk
• Parental care to the young is prolonged.

Question 9.

(a).Explain what is meant by perennating organs? ***(04 marks)***

(b).Explain the role played by perennating organs to the plants. ***(04 marks)***

(c).Briefly describe the artificial propagation methods in plants ***(09 marks)***

(d).Explain why root tubers are used as organs of vegetative propagation yet their roots lack buds.

(a).

These are parts of flowering plants specialised for vegetative propagation as well as food storage, enablinng plants bearing them to survive adverse environmental conditions e.g. cold or dry periods. The food manufactured by photosynthesis in aerial green leaves is translocated and subsequently stored as starch in rhizomes, corms, stem and root tubers, or as glucose in onion bulb.

(b).

During unfavourable conditions, the plant remains dormant but when conditions normalize, starch is hydrolysed to sugar and translocated to the young buds, enabling early growth, sprouting, and photosynthesis when there is little competition for nutrients from other species.

(c).

Cutting: A piece of root e.g. of lemon and tamarind, or stem e.g. sugarcane and cassava, or a complete leaf is dipped in rooting mixture composed of plant hormones, and allowed to grow in a rooting composite /soil.

Layering: Involves pegging down of stem of runners e.g. strawberry into the soil to induce development of adventitious roots, after which the new daughter plants are detached from the parent plants by cutting.

Grafting and budding: It is the insertion of a stem or bud of one plant, the scion onto another closely related plant, the stock, ensuring that vascular tissues are in contact. It propagates lemons, apples, roses, hibiscus & oranges.

(d).

Root tubers and swollen taproots must bear a small part of old stem if they are to act as organs of vegetative propagation. The swollen roots together with buds at the base of old stem form organs of vegetative propagation and perennation.

Question 10.

(a).Describe the mechanisms that promote out breeding in monoecious plants ***(07 marks)***

(b).Explain how sexual reproduction may cause variations ***(08 marks)***

(c).With the aid of a schematic diagram, show how alternation of generations occurs in a sexually reproducing organism ***(05 marks)***

(a).

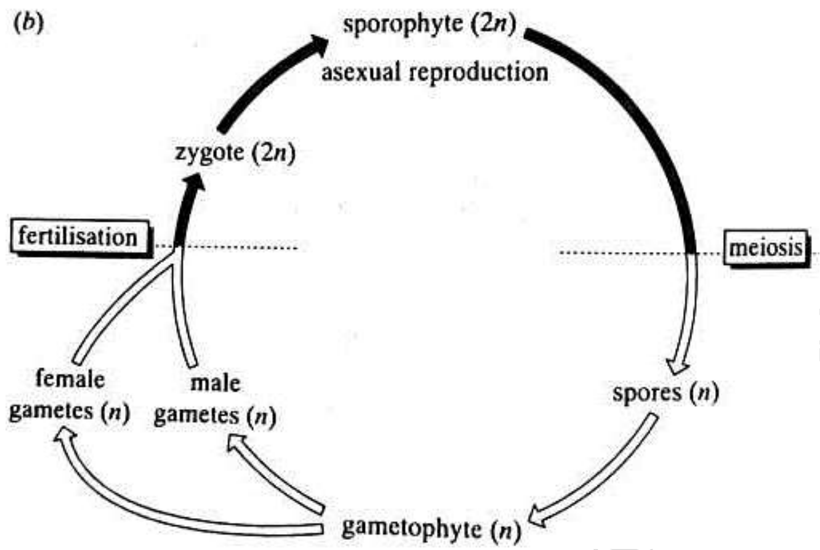
- Have separate male and female sexual organs borne on one flower or different flowers but of the same hermaphrodite plant
- Dichogamy; stamen and carpel ripen at different times. Stamens ripening before the carpel (protandry) or carpel ripening earlier (protogyny).
- Heterostyl; (differing style length), structure of the flower when the stigma is protected from coming into contact with its own pollen or stigma being taller than the surrounding stamens
- Self incompatibility; due to a genetically controlled production of chemicals that prevent pollen germination on the stigma of the same flower.
- Self sterility; in which the ovules can't be fertilized by pollen from the same plant thus calls for cross pollination
- In some flowers, stamens hang out of flowers ensuring that pollen is blown and scattered far away from the plant
- Flowers possess brightly coloured petals and sepals, produce nectar, have an attractive scent to attract insect pollinators which are agents of cross pollination.

(b).

- Crossing over; between chromatids of homologous chromosomes; occurs during prophase I. Linkage groups are formed at the chiasmata; new gene combinations created.
- Independent assortment and random distribution of chromosomes; orientation of chromosomes on the equatorial plane during metaphase is purely random; allows independent assortment and separation during anaphase I.
- Random fertilization; fusion of the male and female gametes is purely random allowing varied characteristics in off springs

• Mutations; chromosomal and gene aberrations; create new phenotypes in the population
• Artificial selection inform of polyploidy, artificial fertilization; have created variants of favoured characteristics.

(c).



Question 11.

(a).Distinguish between organs of vegetative propagation and organs of perennation in plants ***(07 marks)***
(b).State the advantages and disadvantages of natural vegetative propagation ***(09 marks)***
(c).Outline the ways through which variation can arise in a population ***(04 marks)***

(a).

Organs of vegetative propagation are the parts of the flowering plant other than the flower, such as root, stem, or leaf specialized for developing into new individuals when detached. Examples: rhizomes e.g. ginger, couch grass, canna lily and spear grass; corms e.g. coco-yam; stem tubers e.g. Irish potato, yams; root tubers e.g. sweet potato; bulbs e.g onion and garlic swollen tap roots e.g carrot; stolons e.g. blackberry; runners e.g straw berry while organs of perennation are plant parts specialised for storing the food used to develop into new individuals, enabling plants bearing them to survive adverse environmental conditions like drought. Examples: rhizomes, corms, stem and root tubers, bulbs, swollen tap roots.

(b).

Advantages of natural vegetative propagation
• It is a rapid means of reproduction and spread
• Offspring are genetically identical, preserving good strains.
• Perrenating organs enable survival in adverse conditions
• Their dispersal and spread is independent of external agents hence the process is faster.
• Plants are less affected by environmental factors
• Females pass all of their genes to the offspring.

Disadvantages of natural vegetative propagation
• Leads to overcrowding and competition for nutrients, unless separated artificially.
• New varieties cannot be produced, except by mutation resulting into reduced vigour & strength
• Diseases typical of a species are rapidly transmitted and can decimate a crop.

(c).

• During fertilization when male and female gametes with different genotypes fuse to form a zygote.
• Mutations during which there is alteration in gene structure and sequence.
• During meiosis by crossover during prophase I & also during random segregation of chromosomes on the metaphase plate.
• Effects of the environment may also prompt variation.

Question 12.

(a).Explain the following processes during fertilisation and state the significance of each.

(i).Sperm capacitation *(03 marks)*

(ii).Acrosome reaction *(03 marks)*

(iii).Fast block *(03 marks)*

(iv).Cortical reaction *(03 marks)*

(b). Briefly describe the hormonal control of spermatogenesis in humans. *(08 marks)*

(a)(i).

Sperm capacitation; involves activation of mammalian sperm to fertilise the egg, during which the acidity and enzymes in the female genital tract cause perforation of the sperm head by removal of cholesterol and glycoprotein to allow entry of Ca^{2+} and the release of acrosome enzymes. Entry of Ca^{2+} increases the beating activity of the sperm tail and also promotes acrosome reaction to enable sperm penetrate the egg.

(a)(ii).

Acrosome reaction; occurs in the sperm head on making contact with a secondary oocyte, during which the cell and acrosome membranes rupture to release hydrolytic enzymes e.g. hyaluronidase and proteases. Enables sperm head to penetrate the egg membranes.

(a)(iii).

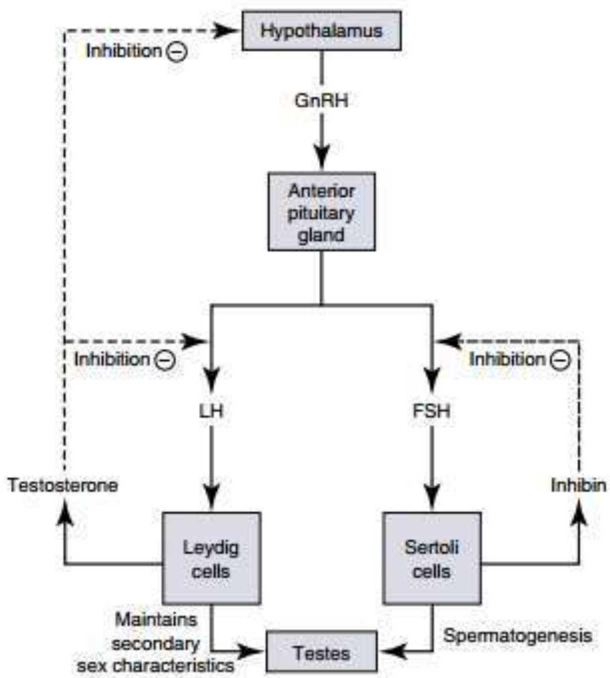
Fast block; A process during which contact of the first sperm with the egg membrane is instantly followed by an electrical potential change in the egg membrane to prevent entrance of more than one sperm. Fast block prevents entrance of more than one sperm into the egg (polyspermy) that would upset the diploid state of the embryo.

(a)(iv).

Cortical reaction; occurs following sperm penetration of the secondary oocyte during which lysosomes (cortical granules) fuse with the plasma membrane and release their contents, causing the vitelline mem- brane to harden and form the fertilization membrane to prevent polyspermy. Formation of fertilization membrane prevents multiple sperm entry into the egg (polyspermy) that would upset the diploid state to cause death of mammalian embryo.

(b).

Interaction of hormones from the hypothalamus and anterior pituitary gland working together controls spermatogenesis. From the hypothalamus, gonadotrophin-releasing hormone (GnRH) stimulates the anterior pituitary gland to secrete two gonadotrophins (gonad stimulating hormones), i.e. follicle stimulating hormone (FSH) and luteinising hormone (LH)/interstitial cell stimulating hormone (ICSH). FSH stimulates spermatogenesis by causing sertoli cells to complete the development of spermatozoa from spermatids. FSH also causes sertoli cells to release a peptide hormone inhibin that specifically inhibits FSH secretion. LH (ICSH) stimulates the leydig cells (interstitial cells) of the testes to secrete testosterone. Testosterone stimulates the growth and development of germinal epithelial cells (spermatogonia) to form sperm, and also works with FSH to stimulate the sertoli cells. However, increased testosterone level inhibits the secretion of GnRH and LH.



Question 13.

(a) Describe how the structure of the human gametes is related to function ***(14 marks)***

(b) Compare spermatogenesis and oogenesis in humans ***(06 marks)***

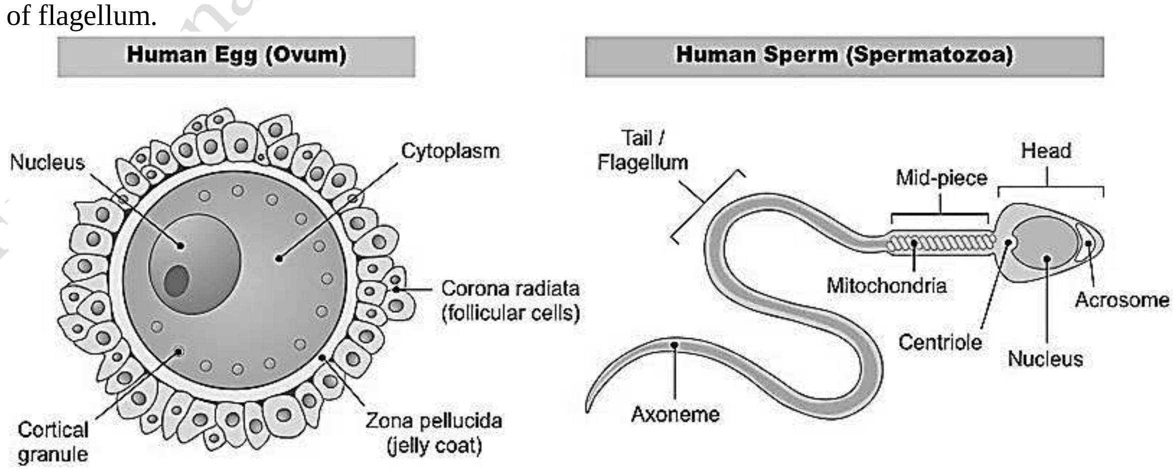
(a).

Ovum

Yolky cytoplasm; contains fat and protein which nourish the developing embryo
Cortical granules (lysosomes); contain enzymes that alter the structure of vitelline membrane to prevent polyspermy at fertilization, to avoid upsetting the diploid state of the zygote.
Vitelline membrane; undergoes structural changes that prevent polyspermy at fertilisation.
Nucleus; contains 23 chromosomes that complete meiosis II at fertilization to provide female haploid nucleus.
Polar body; contains 23 chromosomes, but is non-functional and degenerate

Sperm

Acrosome; contains hydrolytic enzymes which facilitate the penetration of the egg membranes prior to fertilization.
Nucleus; contain a haploid set of chromosomes, which on fusion with the egg restores the diploid state of organisms.
Mitochondria; complete aerobic to release ATP required for contraction of filaments during sperm's movement.
Tail piece (flagellum); enables motility of the sperm; one of the pair produces microtubules that form the axial filament of flagellum.



(b).

Similarities:

• Both begin with diploid germinal epithelial cells
• Mitosis and meiosis are involved in both
• Both yield haploid gametes
• Both occur in gonads.

Differences

Spermatogenesis	Oogenesis
Occurs in seminiferous tubules	Occurs in ovaries of females
Begins only at puberty.	Begins during embryonic development.
A continuous process and occurs all the time	It is a discontinuous process, only one egg matures in about 28 days.
During growth phase, primary spermatocyte shows only double the increase	Primary oocyte may show the increase of about four to eight times.
Four spermatids are formed from one primary spermatophyte	Only one ovum is formed from one primary oocyte.
Equal cytoplasmic divisions during meiosis I and meiosis II and no formation of polar bodies.	There is unequal cytoplasmic division during meiosis I and meiosis II and resulting into formation of polar bodies.
All stages are completed and sperms are formed in the testes only.	The secondary oocyte leaves the ovary and final second meiotic division at fertilization in the fallopian tube.
Male gamete or sperm is comparatively very small.	Female gamete is very large comparatively
Spermatid undergoes spermiogenesis to become sperm.	No such stage after the formation of ootid or ovum
Takes a longer time to complete	Takes a shorter time to complete

Question 14.

(a).Describe the hormonal control of the post-fertilization changes in the human female up to breast feeding
(b).Briefly describe the stages in the process of parturition (birth) ***(04 marks)***
(c).How is the viability of the sperms in humans maintained ***(05 marks)***

(a).

Human chorionic gonadotrophin (HCG); secreted from the placental trophoblastic cells; causes persistence of the corpus luteum; secretion of the progesterone from the luteal body continues; progesterone together with a small but steady secretion of oestrogen from the ovaries; maintains continual development of the uterine endometriurn; progesterone and oestrogen also inhibit further secretion of FSH and LH; by negative feedback as well as further follicular growth and ovulation respectively. After the first trimester (3 months) of pregnancy; corpus luteum regresses; role taken on by the placenta. During the entire course of pregnancy; the level of oestrogen keeps increasing as that of progesterone keeps reducing. Oestrogen promotes while progesterone inhibits uterine contractions; progesterone and oestrogen allows growth of mammary glands in preparation for lactation. The two hormones also inhibit the secretion of prolactin from the anterior pituitary gland. A sudden drop in the levels of the two hormones at the end of pregnancy permit secretion of prolactin; allowing onset of lactation. In the last moments of pregnancy, oxytocin levels from the posterior pituitary gland rise. Oestrogen increases uterine wall sensitivity to oxytocin. Oxytocin stimulatesrelease of prostaglandins that cause cervical ripening as well as initiating myometrial contraction, milk flow from the nipples and its letdown is stimulated by oxytocin; colustrum being the first milk produced during lactation.

(b).

The onset of birth is triggered by decreased progesterone and increased oestrogen levels during the last stages of pregnancy. The posterior pituitary produces Oxytocin, which causes contraction of the uterus that increase in force and frequency. Cervix dilates to allow passage of baby's head into the vagina while embryonic membranes rupture. Foetus is expelled in down face position, followed by afterbirth (umbilical cord and placenta) expulsion.

(c).

• Sperms are made at a temperature quite lower than the core body temperature
• Sperms are bathed in thick mucuous and milky fluid (seminal fluid); provides nourishment, optimum pH.
• Prostate gland secretes alkaline fluid; neutralizes acidity of urine & vaginal fluids aiding sperm motility
• Seminal fluid contains fructose; an energy yielding substrates for sperms, aiding spermatic viability
• Prostaglandins; suppress immunity by the female against foreign sperms.
• Proteolytic enzymes; contained in the milky alkaline fluid from the prostate gland; liquefy the coagulated ejaculate and the cervical mucus immediately after coitus; permitting motility.
• Mucus which forms a semi-viscous fluid in which sperms swim

Question 15.

(a).What is meant menstrual cycle? ***(06 marks)***
(b).What are the effects of uncontrolled births among humans ***(04 marks)***
(c).How is the growth of the Graafian follicle in the ovary initiated and controlled ***(10 marks)***

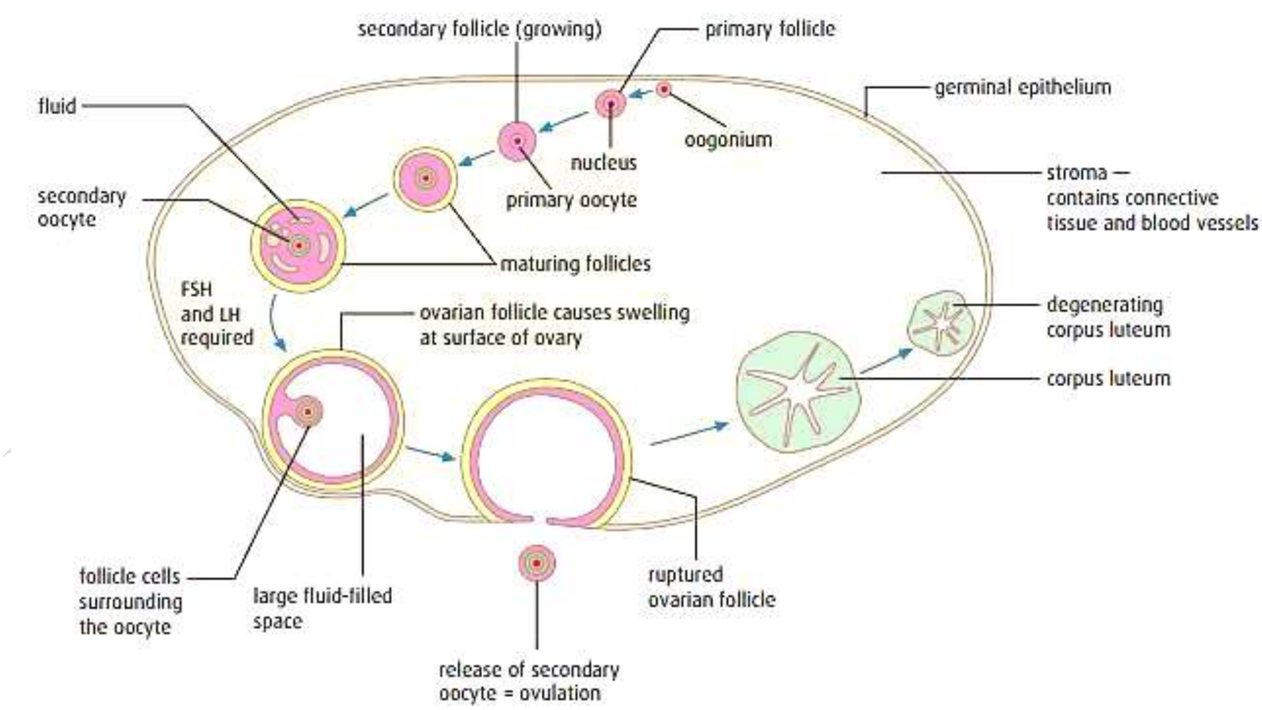
(a).

Menstrual cycle is a period of regularly occurring physiological changes in the endometrium of human females and some primates; which in absence of fertilization culminates in partial sloughing of the endometrium; manifests as a monthly blood shed (menstruation). Has the following phases;
Follicular phase; begins from the previous menstruation and ends with ovulation at day 14; during which the ovarian (Graafian) follicles develop.
Proliferative phase; oestrogen mediated increase in endometrial thickening occurs simultaneously with the follicular phase.
Luteal phase; begins from ovulation to menstruation; usually 14 days long.

(b).

• Environmental hazards; due to over consumption of natural resources
• Congestion; associated with higher risk of disease spread.
• Reproductive disease disposition; e.g vaginal fistulas, STDs.
• High risk of congenital anomalies, chromosomal aberrations/defects such as Down syndrome.
• Frequent/ unspaced births; adversely affects the health of the mother; reduces life expectancy.
• Population explosion; resulting in resource over exploitation.

(c).



Primordial follicle; one enveloping the primary oocyte arrested in diplotene (prophase I) undergoes; primary phase of growth in which follicular cells surrounding the primary oocyte change from squamous to cuboidal; proliferate to produce a stratified epithelium of granulosa cells; primary follicle is formed. Granulosa cells also secrete a glycoprotein coat on the primary oocyte; forming Zona pellucida. Many of the primary follicles become atretic; few viable ones enter the Secondary/ antral phase; many fluid-filled cavities emerge in the primary follicle; these coalesce to form one large cavity the Antrum. Connective tissue inside the ovary forms the protective sheath around the follicle; divided into highly vascular theca interna and less vascular more fibrous theca externa; secondary /Graafian follicle formed.

Control

Control is along the hypothalamo-pituitary-gonadal axis. Begins with the specialized hypothalamic neurons secreting Gonadotrophin Releasing Hormone (GnRH) stimulates gonadotropes of the anterior pituitary gland to secrete Follicle Stimulating Hormone (FSH) initiates growth of the Graafian follicle. Oestrogen from the ovaries inhibits FSH release by negative feedback while stimulating production of LH which causes pre-ovulatory changes in which there is resumption of meiosis I in the primary oocyte; secondary oocyte and polar body formed.

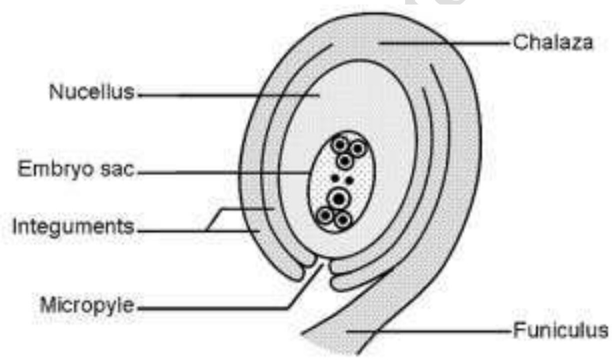
Question 16.

(a).Describe the structure of an ovule and pollen grain in plants ***(06 marks)***

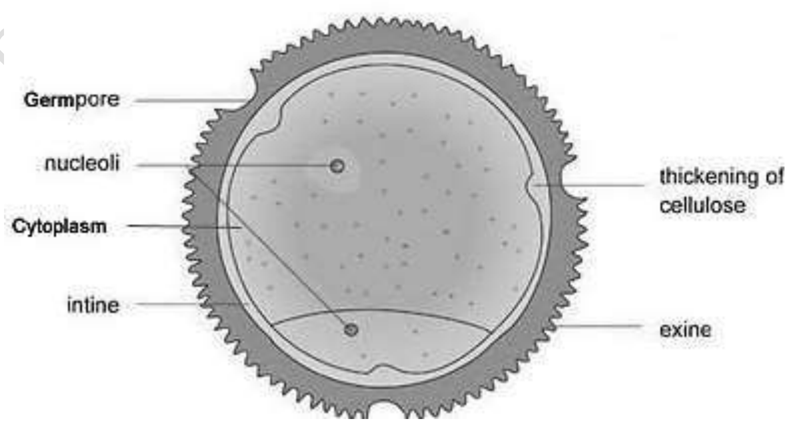
(b).How do the above mentioned gametes formed? ***(14 marks)***

(a).

Ovule; contains female reproductive cells. Has a supporting stalk, the funiculus; and the nucellus; a mass of cells containing the female gametophyte/megagametophyte called the embryo sac. In angiosperms, the nucellus is completely surrounded by a pair of integuments except at the small pore called the microphyle. Gymnosperms have a single integument.

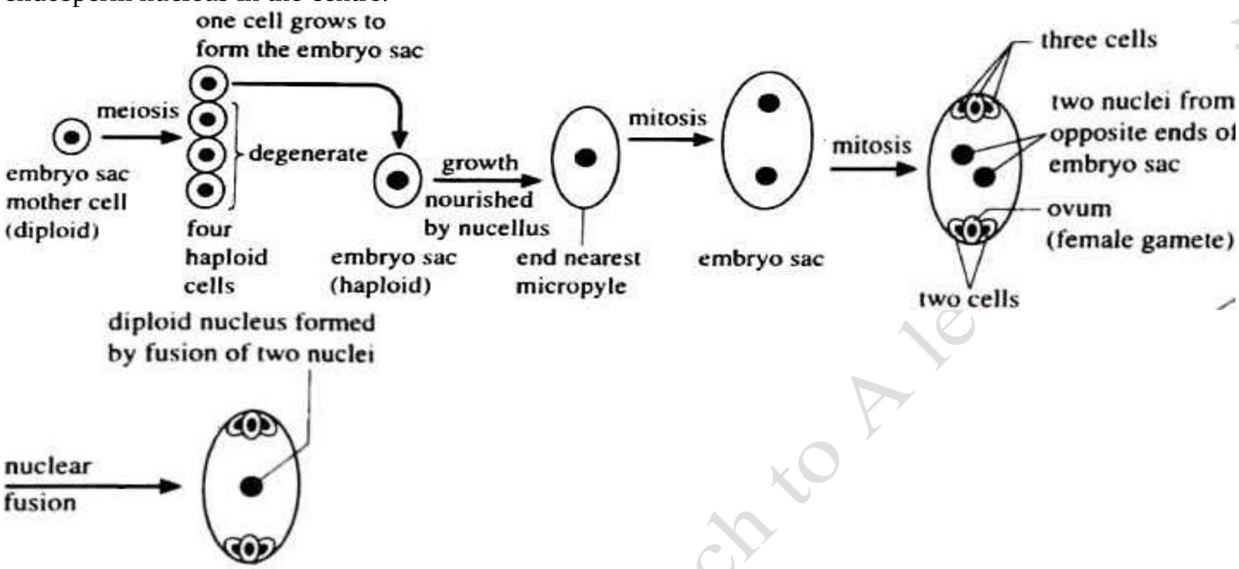


Pollen grain; contains male reproductive cell. It consists of a double wall i.e a delicate inner wall; called the intine; made up of cellulose; and a highly sculptured, hard and resistant outer wall called the exine. Inside the pollen grain is a tube nucleus and a generative nucleus.



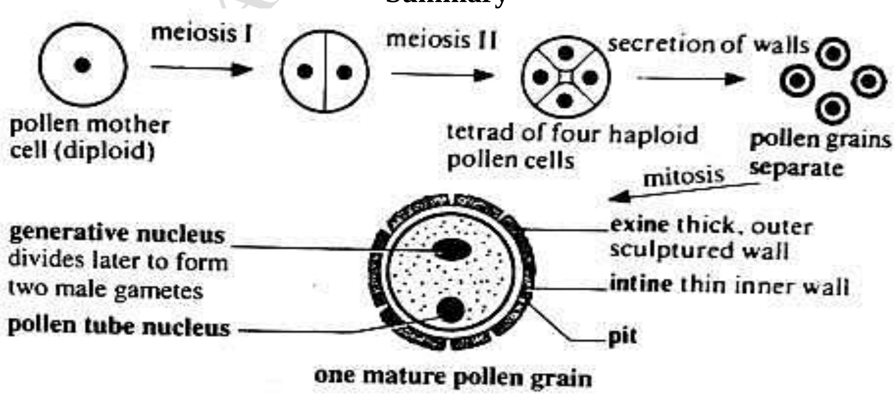
(b).

Formation of the female gametophyte/ embryo sac; one of the cells of the nucellus enlarge to form the embryo sac mother cell. The embryo sac mother cell divides meiotically to give four haploid megaspore cells; three of which degenerate and only one develops to form the embryo sac. The embryo sac nucleus divides mitotically to form 2 nuclei which migrate to the opposite poles. Each of the two at either end divides mitotically twice to form four haploid nuclei at each pole. One nucleus from either poles moves to the centre; fuse to form a diploid primary endosperm nucleus. The remaining six each, gets enclosed by the thin cell wall. One of the three nuclei near the microphyle forms the egg nucleus; the remaining two cells at the microphyle form the synergids which are nonfunctional ova and do degenerate while the other nuclei at the opposite pole to the microphyle become the antipodal cells. The mature embryo cell thus contains a total of 7 nuclei; two synergids; three antipodal cells and a diploid endosperm nucleus in the centre.



Formation of pollen grain; Repeated mitotic division occurs within the sporogenous tissue (centre of pollen sacs) producing a mass of swollen cells called microspore mother cells. Each microspore cell divides meiotically to form a tetrad of haploid microspores (pollen cells) which gives rise to pollen grains. These four cells later separate. A single haploid pollen grain nucleus divides mitotically; one of the daughter cells surrounded by a denser cytoplasm and forms a generative nucleus (male gamete) and the other forms the tube nucleus. Each pollen grain develops a hard resistant sculptured outer wall; the exine and a thin inner cellulose wall the intine.

Summary



Question 17.

(a).Describe the main events during gametogenesis in male and female humans ***(16 marks)***

(b).Outline the functions of sertoli cells ***(04 marks)***

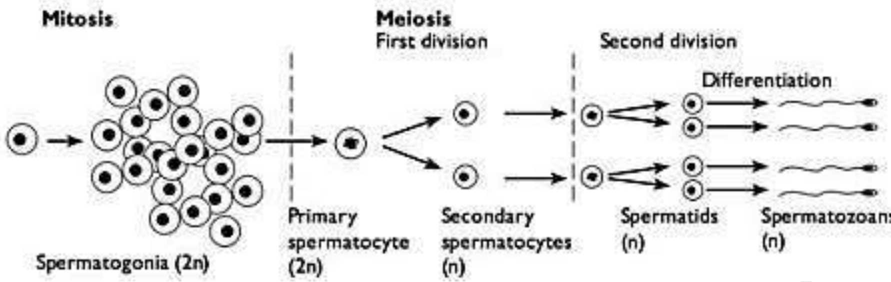
(a).

Spermatogenesis

Multiplication phase; At puberty, diploid germinal epithelial cells (primordial germ cells) of seminiferous tubules undergo repeated mitotic divisions to form a number of diploid spermatogonia.

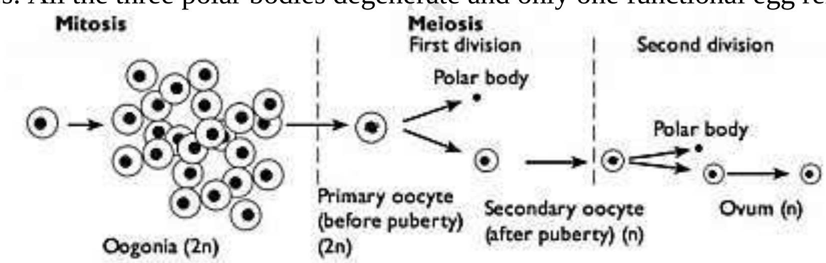
Growth phase; each spermatogonium increases in size and becomes a primary spermatocyte.

Maturation phase; Each primary spermatocyte undergoes the first meiotic division to form two haploid secondary spermatocytes which undergo second meiotic division to form four haploid spermatids, connected to each other by cytoplasm.
Spermiogenesis; in which the spermatids get embedded into sertoli cells to be transformed into sperm by losing part of cytoplasm, condensation of nucleus into head and formation of flagellated tail. The mature spermatozoa (sperms) finally detach from sertoli cells and are released into the lumen of seminiferous tubules.



Oogenesis

Multiplication phase; During embryonic development, diploid oogonia undergo repeated mitotic divisions to increase in number;
Growth phase; Some oogonia undergo mitosis to form primary oocytes, which remain at prophase I of meiosis, while the rest (now called follicle cells/granulosa cells) enclose the primary oocytes.
Maturation phase; At puberty, granulosa cells multiply to form primary follicle & other cell layers around the primary oocyte. The primary oocyte undergoes meiosis up to metaphase II only to form a secondary oocyte and 1st polar body. The primary follicle develops to form fluid filled secondary follicle and later Graafian follicle, which enclose secondary oocyte & 1st polar body. At fertilization, the secondary oocyte completes meiosis II to form a large ootid (ovum) and second polar body. The first polar body also undergoes meiosis at the same time to form two small polar bodies. All the three polar bodies degenerate and only one functional egg remains.



(b).

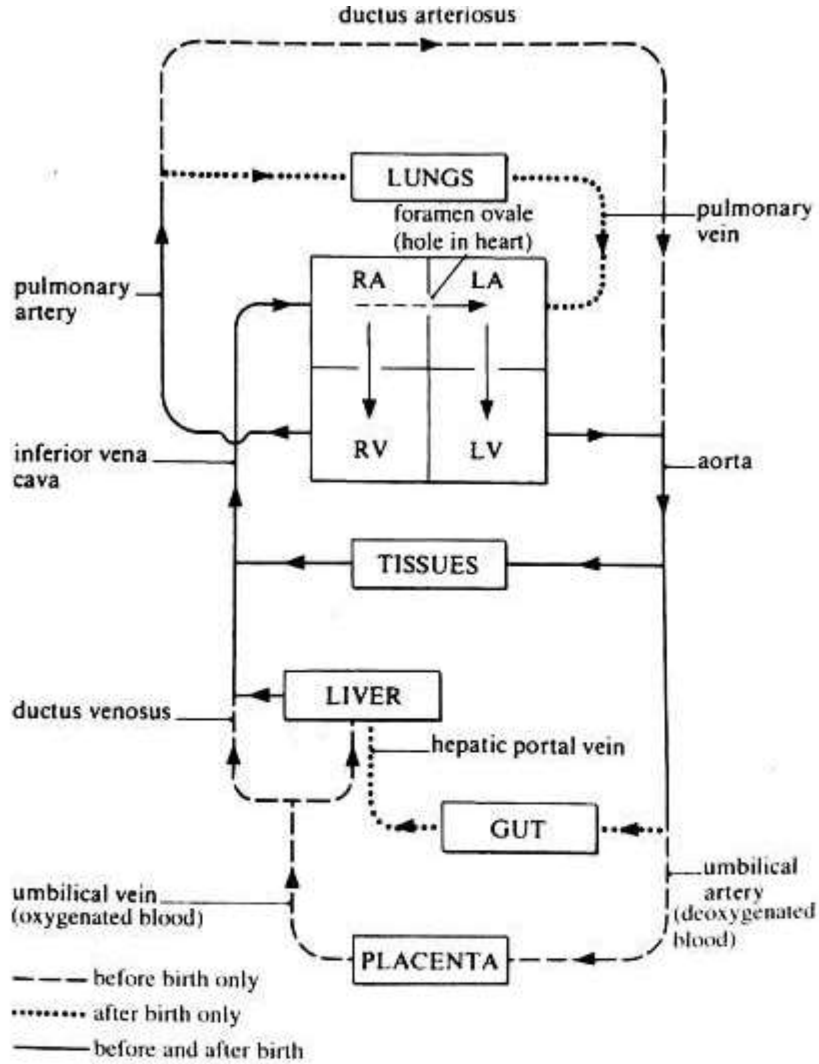
• Provide support and nourishment to germ cells and developing spermatids.
• Phagocytise (eat off) the cytoplasm of spermatids.
• Secrete a fluid that carries spermids through the tubules.
• Phagocytise foreign particles that invade the tubules.
• Secrete androgen-binding protein which is essential for testosterone activity particularly on spermatogenesis
• Secretes a fluid that release sperms into the lumen of seminiferous tubules (spermination).

Question 18.

(a).Describe foetal circulation before birth ***(10 marks)***
(b) Describe the developmental changes undergone by extra embryonic membranes of the human foetus

(a).

Oxygenated blood from placenta gets to the liver via the umbilical vein; a part flows through it and the rest bypasses it via the ductus venosus and gets to the right atrium via the inferior vena cava. Largest portion of blood in the right atrium flows through the foramen ovale to the left atrium and via then to the left ventricles via the mitral /bicuspid valves; from which it empties into the aorta that distributes it to the rest of the body. De-oxygenated blood flow through the superior vena cava into the right atrium where it partially mixes with the oxygenated blood from the placenta; and via the tricuspid valves gets to the right atria. Here it is pumped into the pulmonary trunk & the pulmonary arteries; a small portion passes through pulmonary circulation and via the pulmonary veins reaches the left atrium. Due to the high pressure in the lungs, a significantly large portion of blood bypasses pulmonary circulation; goes through the ductus arteriosus; from where it enters the descending aorta directly into systemic circulation. Deoxygenated blood then flows through the umbilical arteries back to the placenta for oxygenation and the cycle repeats.



(b).

The extra-embryonic membranes include the chorion, yolk sac, amnion and allantois. Outer cells of the blastocyst the trophoblasts grow and develop into an outer layer/membrane the chorion that nourishes and removes wastes from the developing embryo. Two cavities appear within the inner cell mass; cells surrounding them form two further membranes; the amnion and the yolk sac. The amnion is a thin membrane covering the embryo like an umbrella and offers protection. The yolk sac bears no significant function in humans. The cavity between the amnion and embryo has amniotic fluid secreted by the amniotic cells. The fluid supports the embryo and acts as a shock absorber. Cells between the early amnion and the yolk sac form the embryonic disc which later gives rise to the embryo. The embryonic disc undergoes gastrulation (differentiates into the outer ectoderm, middle mesoderm and inner endoderm layers). Exchange of materials between the embryo and the mother via the chorionic villi is adequate but soon the allantois develops from the embryonic hindgut. Allantois grows outwards until it gets in contact with the chorion forming the allanto-chorion; a structure; rich in blood vessels and contributes to the development of the placenta; a more effective and efficient material exchange structure.

Question 19.

(a).Under what circumstances may variations

(i).Occur in asexually produced individuals ***(03 marks)***
(ii).Not occur in sexually produced individuals ***(02 marks)***
(b).State the role of phytohormones in sex determination of flowering plants ***(02 marks)***
(c). Give an account of the various forms of asexual reproduction ***(13 marks)***

(a)(i).

• In some organisms that reproduce by sporulation, spores are formed by meiosis e.g in mosses and ferns.
• Random mutations may arise; cause variations among asexually reproduced individuals.
• Environmental factors; may make asexually reproduced individuals to vary phenotypically.

(a)(ii).

• Gametes may be formed mitotically; self-fertilization may occur e.g in mosses, ferns etc.

(b).

• Gibberellins modify sex of some flowers by promoting development of male flowers instead of female ones.
• Ethylene on the other hand promotes development of female flowers in the place of male flowers.

(c).

Fission; it is the division of the cell by mitosis into two or more equal sized genetically identical daughter cells. Binary fission (splitting into two) occurs in bacteria, amoeba and paramecium while multiple fission(schizogamy) i.e splitting into many occurs in plasmodium.
Sporulation/ spore formation; formation of small unicellular bodiesça1led spores by cell divisions which is dispersed from the parent plant and grow into new offsprings under favourable conditions. Occurs in fungi such as mucor, bacteria, mosses, ferns, liver worts and algae.
Fragmentation; here the parent organism breaks into two or more genetically identical pieces; each of which is capable of regenerating into anew individual. Occurs in sponges, spirogyra, cnidarians, flatworms etc.
Budding; here the parent cell forms an outgrowth (small bulge) which increases in size and finally detaches to grow into a new individual. It takes place in fungi such as yeast cell and in cnidarians such as hydra, obelia and flat worms like tapeworms.
Vegetative propagation; here a part of flowering plant with buds grow and develop into a new plant which at some stage, detaches from the parent plant and starts to live an independent life. Parts of the plant specialized to give rise to new individuals e.g root, stem or leaf are called propagues and act as organs of perennation. Organs of propagation include bulbs, corms, rhizomes/runners, stolons and tubes.

Question 20.

(a).How does development of the embryo sac in flowering plants differ from oogenesis in mammals such as humans? ***(04 marks)***
(b).Compare sexual and asexual reproduction ***(11 marks)***
(c) State the adaptations of flowering plants to self-pollination ***(05 marks)***

(a).

Similarities
• In both, mitosis is involved
• Both result in formation of offsprings

Differences

Development of the embryo sac	Oogenesis
Diploid nucleus formed by fusion of two male nuclei	No diploid nucleus.
Six haploid cells formed	Four haploid cells formed
Antipodal cells, synergids and egg cell formed	One egg cell and polar bodies are formed
Only nucleus divides and occurs before fertilization	Whole cell body divide and occurs during Fertilization

(b)

Similarity
• In both, there is transmission of genetic materials from parents to their offsprings.

Differences

Asexual reproduction	Sexual reproduction
Involves one parent	Usually involves one or two parents
No gametes are produced	Male and female gametes produced by gametogenesis.
Depends on mitosis only	Depends on both mitosis and meiosis being present at some stage of gamete formation
Offsprings are identical to the parent	Offsprings exhibit genetic variation
No zygote formation	Involves fertilization to form diploid zygote
Large number of offsprings produced	Fewer offsprings are produced
Commonly occurs in plants, simple animals and microorganisms	Commonly occurs in higher animals and some plants.
Offsprings mature faster	Offsprings mature slowly
Population numbers increase rapidly	Population numbers increase slowly

(c).

- Stamens and carpels mature at the same time
- Hermaphrodite plants my not open petals
- Hermaphrodite plants may remain under ground
- Pollen is released onto the stigma by matured anthers before the petals open
- Self compatibility; pollen is compatible only with tissues of the style
- Flowers are reduced and inconspicuous.
- Stamen are situated above the stigma or the anther is close to the stigma.
- Stigma often coiled to touch ripe anthers
- Style and filament coil on one another
- Flowers failing to open e.g in commelina.

Question 21.

(a).Outline the post fertilisation events that take place in a flowering ***(09 marks)***
(b).Give the advantages and disadvantages of vegetative propagation ***(11 marks)***

(a).

- Embryo sac divides repeatedly by mitosis to form zygote
- Endosperm nucleus forms the endosperm
- As embryo expands, the nucellus is crushed out of existence.
- Ovules develop into seeds.
- Interguments become seed coats.
- Outer interguments become the testa.
- Inner interguments become the tegmen.
- Ovary develops into fruit.
- Ovary wall becomes the pericarp/ fruit wall

(b).

Advantages

- It is a rapid means of reproduction and spread
- Offsprings are genetically identical, preserving good strains.
- Perrenating organs enable survival of plants in the adverse conditions
- Their dispersal is independent of the external agents hence the process is faster
- Females pass all their genes to the offsprings.
- Suitable for propagation of plants that produce little or no viable seeds.
- Easier, rapid and a more economical method of propagation
- Qualities of two plants can be successfully combined to form a more superior hybrid plant

Disadvantages

• New varieties cannot be produced except by mutation resulting in reduced vigour and strength.
• More susceptible to disease as the entire species since there is no genetic variation.
• Leads to overcrowding and competition for nutrients unless artificially separated.
• Vegetatively produced plants are short lived and small compared to seed propagated plants.

Question 22.

(a).State and describe the phases of the oestrus cycle *(10 marks)*
(b).How can a couple prevent unwanted pregnancies *(10 marks)*

(a).

An-oestrus; latent period with no visible sexual activity; corpus luteum regresses; uterine lining returns to its normal state and new follicular growth starts; oestrogen secretion diminishes while progesterone secretion stops;
Pro-oestrus; follicles develop in the ovary; involution of the corpora lutea occurs and gradual hormone secretion reduces; show increase in the secretion of FSH and oestrogen in preparation for the next oestrus cycle.
Oestrus; is the period of heat during which copulation occurs. In the ovary, Graafian follicles mature and oestrogen secretion increases; uterine lining proliferates; changes in the external and internal genitalia occurs; LH is secreted by the pituitary gland; cause ovulation (release of the oocyte).
Post-oestrus; is the period shortly after ovulation when mating is no longer permitted; corpus luteum develops in the ovary; uterine glands greatly develop; secretion of progesterone increases while oestrogen secretion diminishes.

(b).

• Use of contraceptive pills to suppress ovulation and conception.
• Use of male and female condoms; preventing ejaculated sperms from entering the uterus
• Diaphragm (cap) preventing sperms from entering the uterus
• Use of intra-uterine device (IUD) loop interfering with fertilisation and implantation
• Having sex during safe days.
• Use of diaphragm by female; prevents sperms from entering the uterus; preventing conception
• Vasectomy in males; prevent release of spermatozoa.
• Tubal-ligation in females; prevent of entry of ovum into the uterus;
• Insertion of foam/ spermicides inside the vagina before sexual intercourse; to destroy sperms.
• Coitus interruptus; prevent contact of sperms with the egg.

Question 23.

(a).Outline the causes of infertility and how they can be treated *(15 marks)*
(b).State the preventive measures against infertility *(05 marks)*

Causes of infertility

• Ovulatory disorders which can be hormonal, endocrine or by emotional stress.
• Anovulatory ovarian disorders like polycystic ovarian disorders.
• Anovulatory thyroid disorders like hyperthyroidic or hypothyroidic states.
• Chromosomal disorders
• Tubal dysfunction caused by pelvic inflammatory diseases
• Hormonal imbalances
• High vaginal acidity
• Thick cervical mucus impenetrable by sperms
• Cervical infections; cause recruitment of spermicide macrophages
• Uterine abnormalities like absent uterus, uterine fibroids and endometriosis
• Impaired spermatogenesis (malformed sperms, low sperm count)
• Impaired spermatic transport like Epididymal malformations in males.
• Ejaculatory dysfunctions inform of anejaculation, premature ejaculation
• Exposure to ionising radiations, mutagens and chemical agents like drugs.
• Autoimmune response; body mistakenly fights its ovarian tissues.
• Excessive overweight or underweight can disrupt the pattern of FSH and LH secretion.
• Too much prolactin secretion which reduces oestrogen production and may cause infertility.
• Implantation failure due to fibroids/tumors, inflammation, uterine congenital anomalies

Treatment of infertility

• Hormonal therapy for anovulatory disorders; by giving ovulatory agents like clomiphene, hCG analogue
• Salpingolysis, Salpingostomy and tubal anastomosis for tubal disorders
• Invitro fertilisation (IVF)
• Intracytoplasmic sperm injection
• Zygote Intrafallopian transfer
• Gamete Intrafallopian transfer
• Intra-uterine insermination
• Ovum/ ova donation
• Surrogacy
• Prevention of STDs

(b).

• Avoiding illicit drug use, tobacco use or excessive alcohol consumption.
• Avoiding exposure to industrial or environmental toxins
• Limit medications that can impact fertility
• Exercise regularly, eat balanced diet
• Limiting exposure to ionising radiations.

Question 24.

(a).What is meant by a spore? ***(01 marks)***
(b).What are the main features of sexual reproduction? ***(04 marks)***
(c).State advantages and disadvantages of sexual reproduction ***(10 marks)***

(a).

A spore is a haploid reproductive cell, usually unicellular, capable of developing into an adult without fusion with another cell.

(b).

It involves production of gametes by two separate parents, a process called gametogenesis. Isogametes are identical though dissimilar genetically. Anisogametes (heterogametes) differ slightly in size. Some species exhibit oogamy, the gametes greatly differ in size and activity. It involves fertilisation (syngamy), the union of male and female gametes Bacteria reproduce by conjugation.

(c).

Advantages of sexual reproduction

• Brings about genetic variability in a population by recombining parental characteristics, enabling a species to adapt to the changing environmental conditions
• During the life cycle of the organism, resistant stages develop enabling survival of adverse conditions.
• Formation of spores, seeds or larvae which may be used to disperse offspring and so reduce intra-specific competition.
• It leads to increased numbers of a population.

Disadvantages of sexual reproduction

• May result into lethal combination of genes
• In some animals, it is affected by seasonal breeding as organisms may sexually receptive at different moments.
• It relies so much on external agents hence reducing chances of occurrence
• It is a slower method of reproduction.
• There is wastage in production of males, many of which fail to reproduce & thus consume resources that could be applied in the production of females
• Females only pass half of the genes to the offspring because the genome is halved at meiosis.

Question 25.

(a).Briefly explain how negative feedback operates in the control of:
(i) Testicular hormone secretion ***(08 marks)***
(ii)The menstrual cycle ***(07 marks)***
(c) What hormonal changes occur in the endometrium during the menstrual cycle? ***(05 marks)***

(a)(i).

The hypothalamic hormone, gonadotrophin-releasing hormone (GnRH) stimulates the anterior pituitary gland to secrete both follicle stimulating hormone (FSH) and luteinising hormone (LH). FSH stimulates spermatogenesis by causing sertoli cells to complete the development of spermatozoa from spermatids. FSH also causes sertoli cells to release a peptide hormone inhibin that specifically inhibits FSH secretion. LH stimulates leydig cells of the testes to secrete testosterone. Testosterone stimulates the growth and development of spermatogonia to form sperm, also inhibits the secretion of LH by feeding back, both directly at the anterior pituitary gland and indirectly by reducing GnRH release.

(b)(ii).

The hypothalamic Gonadotrophin-releasing hormone (GnRH) stimulates the anterior pituitary to both FSH & LH. FSH stimulates the secretion of oestrogen in the ovary. Oestrogen in increased levels inhibits FSH secretion and causes secretion of LH from the anterior pituitary. LH stimulates ovulation and development of corpus luteum which secretes progesterone and also continues to secrete oestrogen. Progesterone inhibits the release of LH and FSH thus arresting development of any further follicles.

(c).

During the follicular phase, oestrogen (estradiol) from the ovary causes the uterine endometrium to repair and heal. During the luteal phase, progesterone secreted by the corpus luteum in the ovary causes the endometrium to become highly muscular and vascular. As the corpus luteum degenerates, the rapid fall in oestrogen and progesterone levels at the end of the cycle causes the endometrium to be sloughed off in menstruation.

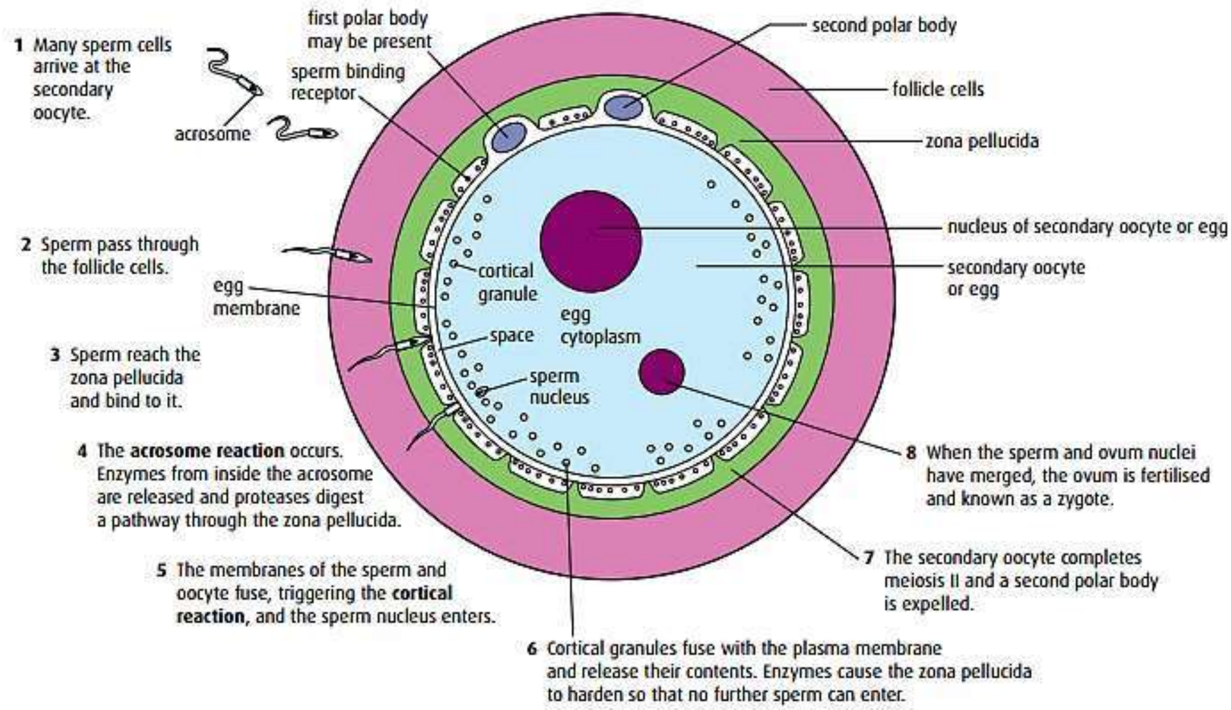
Question 26.

(a).Outline the events which lead to fertilization of an egg by a sperm. ***(12 marks)***

(b).Outline extra embryonic membranes associated with the human foetus ***(08 marks)***

(a).

On entering the vagina, sperm spend about 7 hours being capacitated, after which they move towards the oviduct-ts, aided by muscular contractions of the uterus and oviducts, and lashing of tail. A spermatozoon comes into con-tact with the oocyte by random movement. Acrosome enzymes hydrolyse a path in the granulosa layer of egg until the sperm head makes contact with zona pellucida. Sperm acrosome membrane ruptures to release hydrolytic enzymes (acrosome reaction) and the acrosomal filament pierces through the oocyte membranes up to the plasma membrane of the oocyte. An electrical potential change in the oocyte membrane occurs (fast block) followed by fusion of cortical granules with plasma membrane to discharge their contents (cortical reaction) which creates an osmotic gradient that draws water into the space between the plasma membrane and vitelline membrane. The two membranes are lifted away and the vitelline membrane hardens (fertilization membrane) to block polyspermy. While the sperm tail is lost and disintegrates, the nucleus expands and is now known as pronucleus. Entry of a sp-erm stimulates completion of second meiotic division of the secondary oocyte to form the second polar body, wh-ich disintegrates, and an egg. The haploid male and female pronuclei fuse to form a diploid zygote, which divides immediately by mitosis to form two diploid cells.



(b).

Chorion: It completely surrounds the foetus and is the foetal contribution to the placenta.
Amnion: Forms a fluid filled amniotic cavity that cushions the foetus from shock and mechanical damage.
Yolk sac: Contains little or no yolk, it is a temporary site for red blood cell formation.
Allantois: Derived from embryonic hind gut, it contributes blood vessels that form the umbilical cord.

Question 27.

(a).What are the main features of reproduction in birds? ***(05 marks)***
(b).How are birds suited for reproduction on land? ***(04 marks)***
(c).Compare embryo development in birds and mammals. ***(09 marks)***
(d).State the forms of parental care provided by mammals. ***(02 marks)***

(a).

• Fertilization is internal.
• Mating is preceded by elaborate courtship displays
• Hard shelled eggs (cleidoic/amniotic eggs) are laid in the external environment.
• Eggs are incubated usually by the mother as the embryo develops.
• Newly hatched young ones are fed and cared for by the parents

(b).

• Production of hard-shelled eggs for protection from mechanical damage.
• Fertilization is internal to avoid drying up of eggs and wastage of gametes
• Newly hatched young ones are fed and cared for by the parents e.g. nest building, brooding etc.
• Zygote develops within the amniote (cleidoic egg), which provides the embryo with a fluid-filled cavity in which it can develop on land.

(c).

Similarities

• Both contain yolk sac
• In both the embryo is surrounded by extra-embryonic membranes, which develop from tissues outside the embryo.
• In both the embryo is cushioned in the fluid-filled amniotic cavity.
• Embryo development is preceded by internal fertilization in both
• Allantois is involved in gaseous exchange.

• Protection from predators.

Differences

Embryo development in birds	Embryo development in mammals.
Yolk sac is well developed nourish the foetus	Yolk sac is poorly developed since the foetus derives nourishment from the mother.
Allantois is a depository organ for nitrogenous wastes e.g. uric acid.	Nitrogenous wastes e.g. urea diffuse into maternal blood.
Embryo is protected from damage by an outer shell.	Outer shell is lacking around the developing embryo.
Yolk sac transfers digested food to the embryo.	Digested food is transferred by placenta.
Allanto-chorion is lacking.	There is a developed allanto-chorion

(c).

• Feeding; feed the young ones on milk from mammary glands
• Provision of shelter
• Training of offspring.

Question 28.

(a) State physiological and morphological adaptations of flowers to pollination ***(15 marks)***
(b) Explain the mechanisms which limit inbreeding / promote outcrossing in plants ***(05 marks)***

(a).

Physiological adaptations for wind pollination
• Stamens and carpels mature at the same time
• Hermaphrodite flowers may not open petals
• Hermaphrodite flowers may remain under ground
• Pollen is released onto the stigma by matured anthers before the petal opens.
• Pollen is compatible with the tissues of style, thus allowing for their germination

Morphological adaptations for wind pollination
• Flowers are reduced and inconspicuous
• Stamens are situated above the stigma or the anther is close to the stigma
• Stigma often coiled to touch ripe anthers
• Style and filaments coil on one another
• Flowers failing to open e.g. in commelina.

Physiological adaptations for wind pollination
• Stamens ripen before carpel (protandry e.g. in salvia, deadnettle and dandelion) or carpel ripens earlier (protogyny)
• Self-incompatibility due to chemicals prevents germinating of pollen on the stigma of same flower (self-sterility)
• It is genetically controlled by self-incompatibility genes e.g. in pears pollen only becomes functional if the stigma surface on which it is has a different genetic composition

Physiological adaptations for wind pollination
• Dioecious flowers have either stamens or pistil
• Stamens situated below the stigma.
• Hermaphrodite (bisexual) flower containing both sex organs.
• Production of nectar to attract insects.
• Hanging of stamens or whole flower downwards so that falling pollen drops clear of that plant.

(b).

• Dioeciousness, all flowers on the plant being either male or female e.g. pawpaw
• Monoeciousness; having separate male and female flowers on the same hermaphrodite plant.
• Heterostyly (differing style length), structure of the flower e.g. when a stigma is protected from coming into co-ntact with its own pollen or stigma being taller than the anthers.
• Dichogamy; Stamens ripening before carpel (protandry) or carpel ripening earlier (protogyny).
• Self-incompatibility due to chemicals prevents germinating of pollen on the stigma of the same flower.

Question 29.

(a).Outline the differences between internal and external fertilisation *(03 marks)*
(b).Explain the evolutionary significance of internal fertilisation *(08 marks)*
(c).State the roles of sertoli cells in maintenance of sperm motility *(09 marks)*

(a).

Internal fertilisation	External fertilisation
Production of large numbers of gametes is unnecessary	Production of large numbers of gametes is very essential
Offsprings could be protected within the mother's body	Offsprings are usually not well protected
Offsprings can be allowed ample time to developed and get born at a later stage of development	Offsprings are often born when too young and helpless

(b).

• Internal fertilisation has led to production of offsprings at later stages of development capable of ably surviving and adhering to the variable environmental changes.
• Internal fertilisation has led to evolution of organisms that can reproduce in a variety of environments without the necessity of returning to water.
• Internal fertilisation has led to evolution of organisms that produce less gametes; since internal fertilisation is associated with greater chances of reproductive success.
• Internal fertilisation has led to evolution of reproductive strategy involving the embryo being retained in the mother's body; where it is provided with appropriate conditions for growth for example terrestrial invertebrates like insects have evolved oviparity (laying eggs with little development), ovoviparity (laying well developed eggs) & viviparity (extra-embryonic development).

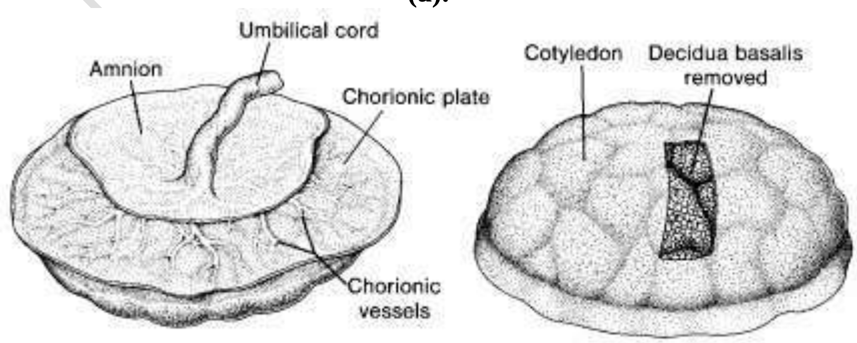
(c).

• Site for further development of spermatids into well-developed sperms
• Provide nourishment to the developing spermatids
• Secrete a fluid that fills the lumen of seminiferous tubules; that phagocytose foreign particles.
• Secrete inhibin that inhibits secretion of FSH and LH to reduce rate of spermatogenesis.
• Forms a barrier; prevents entrance of harmful substances into tubules that can interfere with spermatogenesis.
• Prevents sperms from passing out of tubule and into the blood where they could stimulate an immune response.
• Tight junctions between sertoli cells also form compartments that separate sperm cells in various stages of development.

Question 30

(a).Describe the structure of the mammalian placenta *(08 marks)*
(b).Explain the series of events that occur immediately after fertilisation till the formation of the placenta

(a).



Placenta is large/ thick long and discoid structure; it consists of cells derived from the fetus and the mother; the fetal part of the placenta consists of chorion; and finger like projections known as the chorionic villi; the maternal part of the placenta consists of endometrium (maternal uterine tissue); the chorionic villi grow inside the endometrium; spaces known as lacunae exist between chorionic villi and endometrium; which is supplied with network of arterial blood vessels of the mother; arterial and venous blood vessels run between the fetus and endometrium in a tough, long structure called umbilical cord. The umbilical cord is covered by cells derived from amnion & chorion

(b).

The zygote now begins a series of cleavage divisions which are rapid cell divisions without cell growth. As a result, each of the resulting cells, called blastomeres, contains substantially less cytoplasm than the original zygote. Successive cleavage divisions result in a solid ball of cells called a morula. As cell divisions continue, liquid fills the morula and pushes the cells out to form a circular cavity surrounded by a single layer of cells. This hollow sphere of cells is called the blastula, and the cavity is the blastocoel. Formation of gastrula or gastrulation, occurs when a group of cells invaginate (move inward) into the blastula, forming a two-layered embryo with an opening from the outside into a center cavity. A third cell layer forms between the outer and inner layers of the invaginated embryo. These three cell layers of the gastrula i.e the ectoderm, mesoderm, and endoderm (outside, middle and inside layers, respectively) are the primary germ layers from which all subsequent tissues develop. Extraembryonic membrane development begins with the chorion which is the outer membrane; implants into the endometrium. Later, the chorion, together with maternal tissue, forms the placenta which is a blend of maternal and embryonic tissues across which gases, nutrients, and wastes are exchanged.

Question 31.

(a).Discuss how negative and positive feedback mechanisms regulate the ovarian and menstrual cycles and explain how the cycles are affected if implantation of a fertilized egg occurs. ***(10 marks)***

(b).Describe the events which take place in reproduction beginning with production of gametes and ending with the successful implantation of the blastocyst ***(10 marks)***

(a).

The low levels of estrogen signal the beginning of the menstrual cycle by triggering a negative feedback response. The hypothalamus initiates the response by secreting gonadotropin releasing hormone (GnRH). GnRH, inturn, stimulates the anterior pituitary to release follicle stimulating hormone (FSH) and luteinizing hormone (LH). As part of the ovarian cycle, FSH stimulates the development of the egg within the follicle (completing meiosis I) and also stimulates the follicle to produce estrogen. In a positive feedback reaction to rising estrogen levels, the anterior pituitary secretes additional LH (after stimulation by the hypothalamus). This spike of LH in the middle of the cycle causes ovulation, the release of the egg (actually the secondary oocyte) from the follicle. After ovulation, the follicle, now called the corpus luteum, continues to produce estrogen and progesterone. These hormones regulate the menstrual cycle by stimulating the thickening of the endometrium (the inner lining of the uterus). In response to continued high levels of progesterone, a negative feedback response causes the anterior pituitary to stop production of LH and FSH. As a result, the follicle stops producing estrogen and progesterone, and the endometrium is sloughed off. If the egg becomes fertilized and implants into the endometrium, cells from the developing embryo secrete human chorionic gonadotropin (HCG), which induces the corpus luteum to continue production of progesterone which in turn maintains the endometrium.

(b).

Gametogenesis; diploid spermatogonia grow rapidly to form primary spermatocytes which undergo the first meiotic division to form secondary spermatocytes (2n) and then second meiotic division to form haploid spermatids, which then differentiate into sperms. In the female, the diploid oogonia grow into primary oocytes and then reach prophase of the first meiotic division prior to birth. The ovaries thus contain primary oocytes which are haploid and these only undergo second meiotic division after fertilisation by the sperm.

Mating; Appropriate courtship behaviour; synchronizes sexual activity between the female and male. Sperms are produced from the testes; travel through the epididymis; viability maintained by secretions from the prostate and Cowper's glands; released through the urethra into the female's vagina during ejaculation; travel by peristalsis up the female genital tract into the oviduct

Fertilisation; Acrosome of the sperm penetrates the vitelline membrane; leading to formation of fertilisation membrane and combination of the two haploid gametes to form diploid zygote.

Development of the zygote; ciliary movement of the zygote down into the uterus; Within one week, holoblastic cleavage to give blastomeres and blastocyst.

Implantation; in the uterine lining, development of the outer layer of the blastocyst into trophoblastic villi which project into the uterine lining. Formation of the amnion, chorion and allantois; the last two combining to form the placenta. The conceptus is maintained viable by the well balanced hormonal control.

Question 32.

(a).Describe the mechanisms in flowers which favour;

(i). In-breeding *(06 marks)*

(ii)Out-breeding *(06 marks)*

(b).State the genetic consequences of in-breeding and out-breeding in flowering plants *(08 marks)*

(a)(i).

• Movement of stamen or stigma when the flower gets older; so that the stigmatic surface touches the anthers or some part of the flower coated in pollen.
• Cleistogamy; flowers do not release pollen onto ripe stigmatic surface before the flower buds open thus favouring self-fertilization.
• Floral structure; some flowers are arranged that their corolla tube separates from the plant, the anthers rub against the stigma transferring pollen.

(a)(ii).

• Dichogamy; stamen ripen before stigma & ovule (protandry); or pistil ripens first before the stamens (protangyny).
• Unisexual flowers; dioecious plants; which limit in-breeding
• Floral shape; some highly specialised flowers, the stigma is exposed to allow insect entry.
• Incompatibility/ self-sterility.
• Conspicuous petals and sepals
• Nice smelling/ attractive scent production.

(b)(i).

In-breeding
• Reduces variation as a result of build-up of homozygotes.
• Less evolutionary potential due to stabilizing selection pressure and less adaptability to changing environment.
• Species are more vulnerable to disease due to homozygosity.
• Possible build-up of harmful recessive genes and their expression due to greater chances of recessive offsprings.

Out-breeding.
• Less vulnerability to disease for high colonization and survival chances.
• Greater evolutionary potential due to increased genetic variation.
• Greater adaptation to the ever changing environment; hence increasing chances of survival.
• Reduce chances of harmful recessive genes expressing themselves hence high hybrid vigour.

Question 33.

(a).Distinguish between genetic diversity and species richness *(02 marks)*

(b)(i).Outline various ways used in maintaining genetic diversity via breeding programs *(06 marks)*

(b)(ii)Explain how breeding programs and reintroduction schemes will help increase the population in the wild *(06 marks)*

(c).Outline how;

(i). the acrosome reaction is triggered in human reproduction *(04 marks)*

(ii) polyspermy is prevented after the acrosome reaction *(03 marks)*

(a).

Genetic diversity	Species richness
Considers one species	Considers different species
Considers alleles and genotype of a species	Considers various species within area

(b)(i).

• Captive breeding will increase population of species due to a small gene pool compared to wild
• Inter-zoo exchange of animals for breeding
• Zoos select mates of species; prevent inbreeding & avoid genetic drift
• Introduce alleles from other populations - encourage outbreeding
• Use of artificial insemination and IVF
• Measure the genetic diversity via DNA profiling.

(b)(ii).

• Advantageous alleles that are adapted to change are passed to offspring and the subsequent generations. This increases the number of species that are immune to disease etc.

• Use of invitro fertilisation or artificial insermination increase the number of offspring
• Reintroduction to the wild; increases allele frequency in the wild population

(c)(i).

• Stimulus - sperm makes contact with the zona pellucida
• The acrosome swells; and fuses w/ sperm cell membrane
• Digestive enzymes like hyaluronidase get released by exocytosis
• Enzymes digest zona pellucida; allow sperm cell to penetrate

(c)(ii).

• Sperm cell fuses with egg cell membrane; triggers cortical reaction
• Cortical granules fuse with egg cell membrane & released via exocytosis
• Contents of cortical granules released into jelly layer; thickens layer

Question 34.

(a).Describe the transport mechanisms involved in the exchange of substances between the mother and the foetus ***(08 marks)***
(b).Explain how smoking by a pregnant woman may damage the unborn baby ***(12 marks)***
(c).Describe the similarities and differences between the mammalian male and female gametes

(a).

Oxygen and nutrients diffuse from maternal blood to foetal blood; transported in umbilical vein; waste foetal products diffuse from fetal to maternal blood; from the umbilical artery; Capillaries of the allantois in the villi form huge surface area for exchange/ increased diffusion rate; microvilli of villi increase surface area further; some exchange by active transport eg ions and amino acids; facilitated diffusion eg glucose; pinocytosis in which the numerous mitochondria in the cells of chorionic villi provide energy for active transport and pinocytosis; cell surface membrane contain protein carriers molecules used in uptake of materials into the villi by active transport.

(b).

Carbonmonoxide and nicotine either enter the mother's blood, cross placenta into the foetal circulation increased likelihood of intrauterine growth restriction/ retardation; possibly due to reduction of blood flow through the placenta / vasoconstrictive effects of nicotine; carbonmonoxide may reduce the oxygen carrying capacity of haemoglobin. Other effects include; low birth weight, premature births, respiratory complications like the respiratory distress syndrome and birth asphyxia, congenital heart defects like patent foramen ovale and ductus arteriosus or ventricular septal defects, intrauterine fetal death and central nervous system defects like cerebral palsy.

(c).

Similarities

• Both gametes are produced by meiosis
• Process of gametogenesis occurs within gonads for both gametes
• Gametogenesis for both involves the multiplication, growth and maturation phase
• Both gametes are haploid

Differences

Male gametes (sperms)	**Female gametes (ova)**
Smaller about 2.5μm in diameter	Larger about 140μm in diameter
Cell differentiated into head, middle and tail	More uniform shape; mainly spherical
Motile	Non-motile
Only produced at puberty	Present though undeveloped at birth
No polar bodies	Has polar bodies
Produced and released in vast numbers	Fewer produced and many fewer released

Question 35.

(a).What is meant by double fertilisation in flowering plants ***(04 marks)***
(b).Explain how;
(i).asexual reproduction produces offsprings identical to the parent ***(04 marks)***
(ii).sexual reproduction causes variation among offsprings ***(05 marks)***
(c).Describe the formation of a seed following fertilization of the ovule ***(07 marks)***

(a).

This is where one of the male nuclei fuses with the egg nucleus; in the embryo sac to form a diploid zygote & the second male nucleus fuses with two haploid polar nuclei/ endosperm nuclei at the centre of the embryo sac to form a triploid endosperm.

(b)(i).

Production of offsprings doesnot involve gametes/ sex cells; offsprings thus produced by mitosis eg binary fission in amoeba, budding in hydra/ yeast, spore formation in mucor, fragmentation in spirogyra & parthogenesis in male bees.

(b)(ii).

Gametes or sex cells are involved and the gametes get fused; meiosis is involved in gamete formation i.e prophase I in which crossing over; and random segregation/ assortment of homologous pairs of chromosomes occurs in metaphase I.

(c).

The zygote divides rapidly by mitosis and develops into the embryo; which then differentiates into a young shoot, the plumule, a young root, the radicle and seed leaves, the cotyledons; the primary endosperm nucleus also divides mitotically to give a mass of cells, the endosperm; this remains in grains while in others it is quickly absorbed; nucellus becomes crushed out of existence to allow embryo and endosperm fill the area inside integuments; integuments become seed coat i.e the outer integuments become the testa, the inner integuments the tegmen; water content is reduced to about 15 percent;

Question 36.

(a).Explain the post-natal changes in the human embryo. *(08 marks)*
(b).What is the significance of the changes mentioned in (a) above? *(08 marks)*
(c).How is the mammalian placenta adapted for the transportation role? *(04 marks)*

(a).

Circulatory post-natal changes

- Systemic vascular resistance & aortic pressure increase; raising pressures in left atrium &ventricle too.
- Pulmonary vascular resistance greatly decreases as a result of expansion of the lungs.
- Closure of the foramen ovale; due to the low right atrial pressure and the high left atrial pressure.
- Functional closure of the ductus arteriosus; the increased systemic resistance elevates the aortic pressure while the decreased pulmonary resistance reduces the pulmonary arterial pressure.
- Closure of the ductus venosus; raising the portal venous pressure.

Pulmonary post-natal changes

- Initiation of breathing once placental connection is cut off; due to the initial hypoxic state during birth.
- Expansion of the initially collapsed alveoli; and hence expansion of the lungs
- Surfactant production in the lungs by the alveolar cells.

(b).

- The rise in systemic vascular resistance compensates for the tremendous blood loss through the placenta; preventing a sudden drop in the foetal blood pressure.
- The decrease in the pulmonary vascular resistance prevents compression of pulmonary blood vessels because of the small volume of the lungs maintaining pulmonary blood flow. It also reduces pulmonary arterial pressure, right atrial and right ventricular pressure.
- Closure of foramen ovale cuts off the right-left shunting of blood in the heart permitting channeling of dioxygenated blood to the lungs for oxygenation.
- Functional closure of the ductus arteriosus; permits initiation of pulmonary circulation
- The risen portal venous pressure after closure of the ductus forces portal venous blood flow through the liver sinuses.
- Initiation of breathing once placental connection is cut off; ensure gaseous exchange hence prevention tissue hypoxia
- Expansion of the initially collapsed alveoli; and hence expansion of the lungs; permit initiation of gaseous exchange via the lungs of the foetus.

• Surfactant production in the lungs by the alveolar cells; preventing alveolar collapse that can otherwise result in respiratory distress syndrome.

(c).

• Closeness of maternal and foetal blood vessels facilitates faster diffusion of substances.
• Chorionic villi cells contain numerous mitochondria to provide energy required for active transport
• Numerous chorionic villi, increase surface area for absorption and transportation of materials;
• Two umbilical arteries; transport blood containing wastes from foetus to mother's blood for excretion.
• Umbilical vein; transport nutrient and oxygen rich blood from the mother to the foetus
• Numerous maternal arterioles; supply oxygen and nutrient rich blood to foetus
• Numerous maternal venules; drain foetal blood containing wastes to be transported back to maternal blood for excretion.
• Chorionic arteries; divide to cotyledon arteries; further divided to from a dense arterio-capillary venous system; creates a steep concentration gradient allowing efficient material transport and exchange
• Selectively permeable placental barrier/membrane; allows selective diffusion of antibodies for passive.

Question 37.

(a).Compare the process of development of the pollen grain and the ovule ***(08 marks)***
(b).Describe the processes leading to the fertilization of an ovule after pollen has landed on the stigma

(a).

Similarities

• Both ovule and pollen grain arise from diploid mother cells
• In both mother cells divide meiotically
• In both a tetrad of haploid cells is formed from mother cells
• In both mitotic division of nucleus occurs

Differences

Pollen grain	Ovule
Arise from pollen mother cells	Arise from megaspore mother cell
Tetrad of cells formed from mother cell all develop into pollen grains	Only one of the tetrad of cells formed from mother cell develops into an ovule
Nuclei of resultant haploid cells divides once by mitosis	Nucleus of the remaining megaspore cell undergoes two successive mitotic division
Nuclei remain at the centre of the cell	Nuclei resulting from division of embryo sac nucleus migrate to opposite poles

(b)(i).

On landing upon the stigma the pollen grain adheres to the stigma by the sticky substance secreted by stigma cells absorbs water, sugars and germinate to give the pollen tube; the pollen tube grows into the stigma, down the style, to the ovary pushing its way between loosely packed cells and deriving nourishment from the surrounding tissues; the pollen tube nucleus is positioned at the tip of the growing pollen tube controlling growth while the 2 male nuclei (2 sperms) formed by mitosis from the generative nucleus follow closely behind chemical substances in the style and embryo sac enable the unidirectional rapid growth of the pollen tube towards the ovary after reaching the ovary, the pollen tube grows towards the ovule and usually enters through the microphyle, chalaza, or integuments; the pollen tube then reaches the centre of ovule penetrates the wall of the embryo sac bursts open and the tube nucleus disintegrates one sperm/ male nucleus fuses with the egg cell to form a diploid zygote while the other sperm/male nucleus fuses with the two polar nuclei to form a triploid primary endosperm nucleus; this is called double fertilization;

Question 38.

(a).Distinguish between fertilization in flowering plants and mammals. ***(05 marks)***
(b).Give an account of the events which occur in the oviduct leading to fertilization. ***(08 marks)***
(c).What are the advantages and disadvantages of internal fertilization in mammals ***(07 marks)***

(a).

Fertilisation in flowering plants	Fertilisation in mammals

Occurs in the embryo sac	Occurs within the ovum/ egg;
Double fertilization/two male nucleus are involved	Single fertilization/only one male nucleus involved
Haploid male nuclei fuses with both haploid nucleus and diploid nucleus	Haploid male nucleus fuses with only one haploid nucleus;
Zygote formed startsto develop into embryo sac	Zygote formed begins to develop in oviduct
Forms 3n-nuclei and 2n zygote	Only 2n zygote is formed

(b).

Sperms get into contact with the secondary oocyte/ the acrosome membrane of the sperm fuses with the egg next to it acrosome membrane ruptures releasing hydrolytic enzymes/ digestive proteases; sperm head binds to special receptors on the surface of the Zona pellucida; the hydrolytic enzymes digest the path through the zona pellucida; one sperm penetrates into the cytoplasm of the secondary oocyte; Cortical granules (lysosomes) in the cytoplasm of the secondary oocyte release enzymes which cause Zona pellucida to thicken and harden/fertilization membrane is formed/ the enzymes also destroy the sperm receptors on the surface membrane of secondary oocyte; the secondary oocyte undergoes second meiotic division to form haploid ovum and a polar body; the haploid nucleus of the sperm fuses with a haploid nucleus of the ovum; a diploid zygote is formed;

(c).

Advantages of internal fertilization
• Embryos are protected from hostile environment/ predators/mechanical damage;
• Embryos easily obtain nutrients;
• High chances for fertilization/ reliable/ efficient;
• Reduces wastage of gametes;
• Rapid growth due to optimum temperature;
• Promotes parental care;

Disadvantages of internal fertilisation.
• Embryos are vulnerable to toxic chemicals produced by mother;
• Foetus is entirely dependent on mother; when the mother dies, the foetus also dies too;
• The foetus may contract infections from the mother
• Mothers are deprived of nutrients which the foetus obtain from them;
• Delays fertilization since it relies on courtship;
• Long gestation period causes few offsprings to be produced;
• Mothers may be exposed to predation during periods of pregnancy

Question 39.

(a). Explain the functions of the mammalian placenta as a barrier. ***(05 marks)***
(b). Explain the series of events that will take place immediately after fertilization which leads to formation of placenta. ***(11 marks)***
(c). Describe how negative feedback mechanism controls the menstrual cycle ***(04 marks)***

(a).

Prevents maternal & fetal blood from mixing & stopping cases of agglutination occurs if blood is not compatible.
It prevents some pathogens and their toxins from crossing the placenta; protects fetus against certain infections;
It stops some maternal hormones and chemicals which are capable of causing damage to the fetus to pass from maternal blood into fetal blood';
It keeps apart maternal and fetal blood which operates at different pressures and no harm is caused to the fetus;

(b).

Immediately after fertilization, the diploid zygote undergoes cleavage; many small daughter cells form a solid mass of cells called morula' morula reach the uterus in 3-4 days mitotic cell division continues to form many smaller daughter cells known as blastomeres; the blastomeres arrange themselves into a fluid filled ball of cells called blastocyst; the outer layer of the blastocyst consists of blastomeres called trophoblast while in the uterus zona pellucida gradually disappears and the trophoblast make contact with the cells of the endometrium of the uterus; trophoblast obtain nutrients from the endometrium of the uterus; cells of the trophoblast further divide mitotically and multiplies ; between 6-9 days; trophoblast is embedded within the endometrium in a process called implantation;

Cells of the trophoblast differentiate into outer most membrane called the chorion and the inner most membranes known as the amnion; a sac like out growth develops from the embryonic gut and forms the third membrane called the allantois; allontois grows outwards until it gets into contact with a chorion to form allonto-chorion which develops into a placenta.

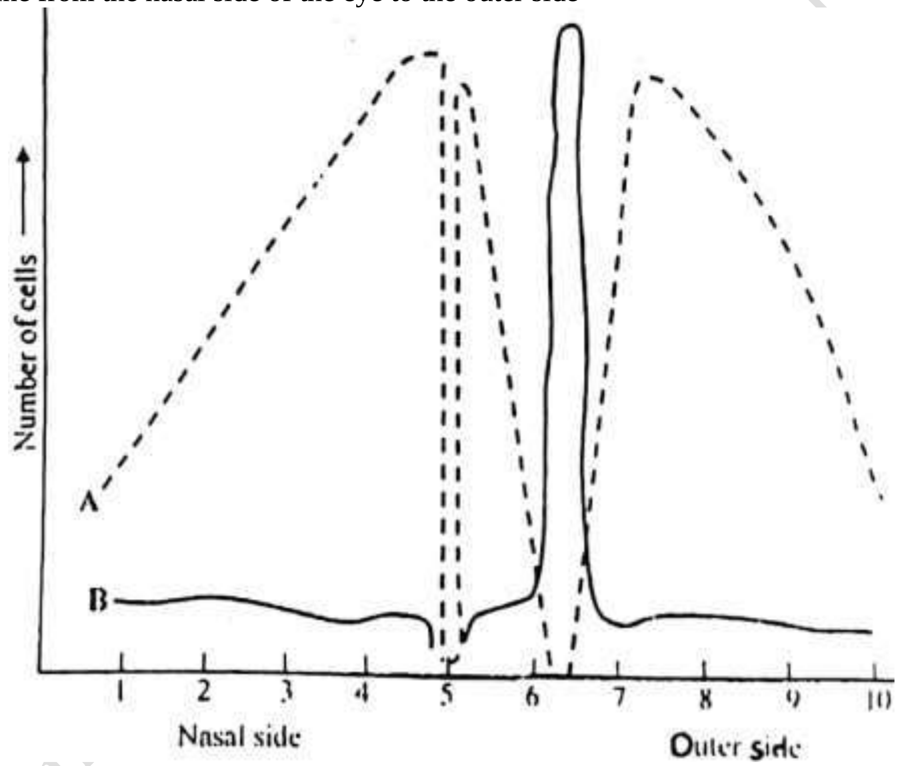
(c).

High concentrations of oestrogen inhibit the secretion of FSH & LH by the anterior pituitary gland. This happens during the first half of the menstrual cycle, causing the levels of FSH and LH to fall. However, when oestrogen levels are very high, a surge of LH secretion occurs, which brings about ovulation. Towards the end of the cycle, as oestrogen and progesterone levels fall, the inhibition of FSH and LH secretion is lifted, so the concentration of these two hormones begins to increase, leading to the start of a new cycle.

Chapter 12; Co-ordination and control

Part A

The graph below shows the number of receptor cells (type A and B) in arbitrary units in the human retina along a long a horizontal line from the nasal side of the eye to the outer side



(a)(i). Giving reasons, identify the types of receptor cells represented by A and B. ***(02 marks)***

Receptor cells A represent rods; no concentration at 6.3;/ no concentration of fovea. Receptor cell represent cones; highest concentration at 6.3;/ highest concentration of fovea.

(ii). Explain why there are no receptor cells at position 5. ***(04 marks)***

Position 5 where there are no receptor cells is called the blind spot; neurons from the rods and cones pass in front of the retina where they converge to form the optic nerve; they are so densely packed that no receptor cells occur.

(iii)What is the name of the region of the retina at position 6.3. Give a reason for your answer ***(01 marks)***

Fovea/ fovea centralis/ yellow spot;

Has highest concentration of cones/ lacks receptor cells A (rods);

(b). Explain why;

(i) the greatest concentration of receptor cells type B occurs at position 6.3 ***(03 marks)***

For the large concentration of receptor cells of type B (cones) at position 6.3 is that it lies on the optical axis directly opposite the center of the lens; it is here that the greatest refraction of light waves occurs; when a person is looking directly at an object; Type B receptor cells (cones) are sensitive to high light intensities hence their high concentration where the light intensity is greater (i.e at the force);

(ii).On entering a dimly-lit mom, objects in the room at first are invisible but gradually become visible.

In bright surrounding circular muscles are contracted and the pupil is constricted; this reduces the amount of light entering the eye; and reduces over stimulation of the cone cells; on entering a dimly lit room the radial muscles of the iris contract and the pupil slowly dilates to allow the maximum amount of light to enter the eye; the process takes a little time during which so little light enters the eye that the threshold value for stimulating the rod (which are sensitive to light of low intensity) is not reached and so nothing can be seen as the pupil dilates fully such that the threshold value for rods is reached and objects become visible;

(iii).In a dimly-lit room, objects are only visible in black and white colours ***(02 marks)***

The rods however do not respond to light of various wavelengths in the same way that three types of cone cell do; for this reason objects in the dimly-lit room are visible only in black and white;

(c)(i) From the graph, identify and describe the features of the receptor cells which allow colour vision.

• Highly concentrated at 6.3
• Low concentration at 5
• Evenly distributed between l to 4.8 and 7 to 10
• Increase rapidly between 6 to 6.3 and decrease rapidly between 6.3 to 7

(ii) The flowers of three species of a plant are similar in form and appear to have yellow colours of petals. When photographed in ultraviolet light, each species shows a different pattern on its petals. Using this information, explain how bees are able to distinguish between the flowers of the three species, but not humans.

Ultraviolet light comprises a range of wavelengths; in much the same way that visible light does; The cone cells of humans cannot distinguish different ultra violet wavelengths and the light from the petals stimulates the red & the green cones, uniformly giving the appearance of yellow; In bees, the rhabdom of their compound eyes can distinguish different wavelengths of ultraviolet light; The petals must have pattern of pigment that reflects the different ultraviolet light differently. The different wavelengths reflected produce a pattern when perceived by bees. In each species this pattern must vary, allowing the bees to distinguish the wavelengths;

Part B

A theory of colour vision suggests that a photoreceptor has pigment that exists in three forms namely- red, blue & green according to the colour of wavelength absorbed by each. The absorption of different wavelengths by the three forms of photoreceptor pigments is given in the table below. Study the information given and answer the questions that follow:

Wavelength (nm)	Amount of light absorbed as a percentage of maximum		
	Red cones	Green cones	Blue cones
660	5	0	0
600	75	15	0
570	100	45	0
550	85	85	0
530	60	100	10
500	35	75	30
460	0	20	75
430	0	0	100
400	0	0	30

(a) From the data, explain why light of wave length;

(i) 430nm appears blue. ***(02 marks)***

In 430nm, shows no light absorbed by the red and green cones; whereas the blue cones absorb the maximum amount of light (100%); Consequently, only the blue cones are stimulated by light of 430nm which gives the sensation of blue light.

(ii) 550nm appears yellow ***(02 marks)***

In the 550nm there is no stimulation of the blue cones but red and green cones; are equally stimulated which the brain interprets as yellow.

(iii)570nm appears orange ***(02 marks)***

The red cones have their maximum absorption 100% and green cones at 45% at this wavelength. The blue cones again absorb no light. The brain therefore interprets the impulses received as predominantly red with some green included such a mixture is as orange;

(b).Explain why two closely placed small objects can be easily distinguished by cones than rods.

Each cone cell has its own separate neurone; connecting to the brain; whereas groups of rod cells share a neurone; The light from such objects will enter the eye as two parallel beams very close together (Show retinal convergence) ;if these stimulate adjacent cone cells two separate objects are interpreted(visual acuity); If however, two adjacent rod cells are stimulated the chances are that they will be connected to the same neuron; The simultaneous stimulation of these two rod cells therefore results in a single neurone sending impulses to the brain which will be interpreted it as a single object; i.e. it cannot distinguish the two objects;

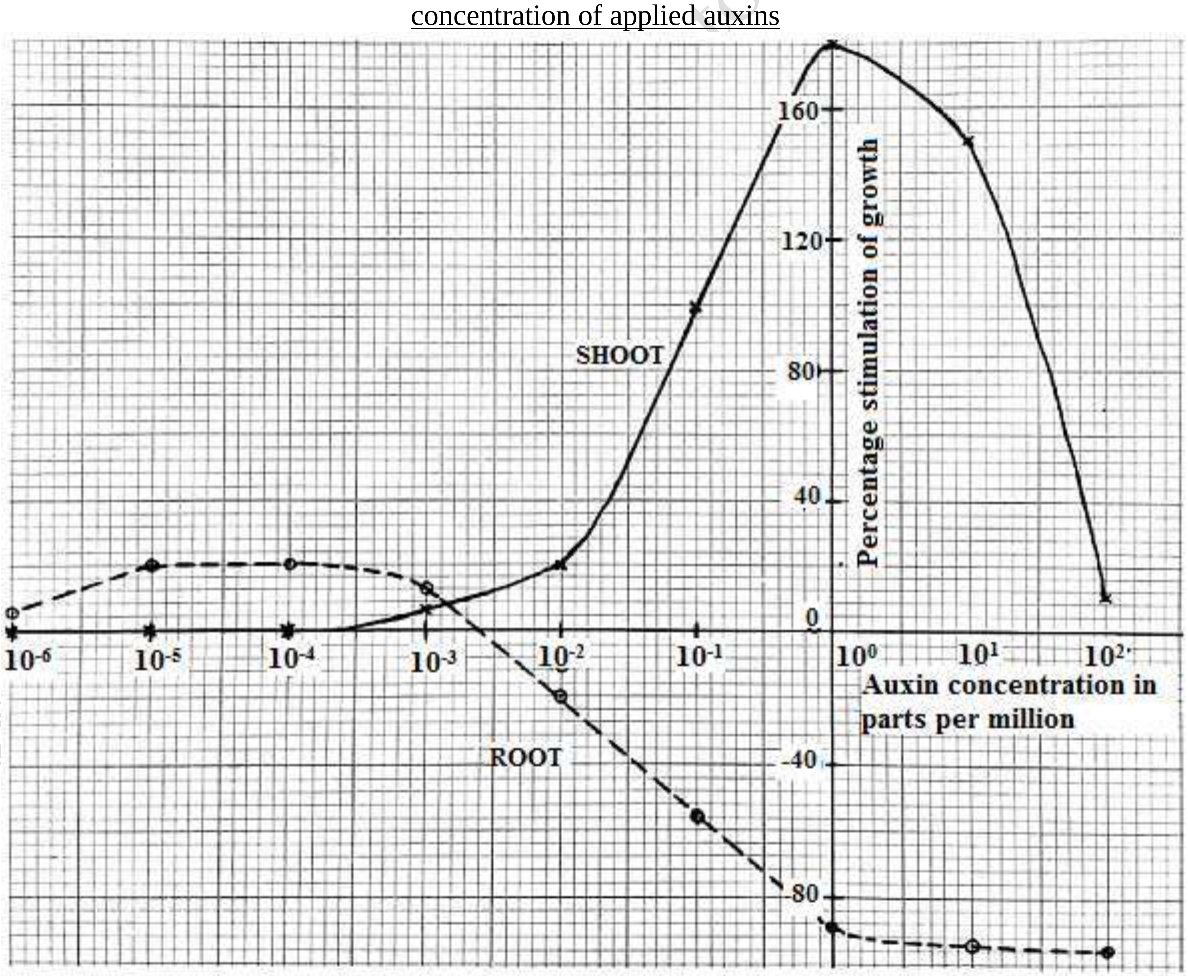
Question 2.

An investigation was carried out on the effect of applying different concentrations of auxin on roots and shoots of oat seedlings. The results in table 1 were obtained were expressed as percentage stimulation (+) or inhibition (-) of growth compared with untreated controls. Use the information to answer the questions that follow.

		Concentration of applied auxins (parts per million)								
		10^{-6}	10^{-5}	10^{-4}	10^{-3}	10^{-2}	10^{-1}	10^{0}	10^{1}	10^{2}
% stimulation of growth	Root	+5	+20	+20	+10	-18	-55	-90	-95	-98
	Shoot	0	0	0	+5	+20	+100	+180	+150	+10

(a)(i). Present the results in a suitable graphical form ***(07 marks)***

<u>Graph showing variation of percentage stimulation of growth in the root and shoots of oat seedlings with the concentration of applied auxins</u>



(a)(ii). Using your graph, describe the effect of different concentrations of auxin on root and shoot growth

Shoot

The concentration between 10^{-6} to 10^{-4} has no effect on growth; between 10^{-4} to 10^{-2} growth increases slowly and rapid increase to a peak at 100 after which it drops (to a concentration 10^{2};)

Roots

There is slow increase in growth rate between 10^{-6} to 10^{-5} a constant rate between 10^{-5} to 10^{-4}, the rate declines fast to 10^{0} and slowly rapidly to 10^{2};

(a)(iii) From your graph and table 1, point out the differences between the responses of the roots & shoots to different concentration of auxin ***(04 marks)***

Very low concentration of auxin (10^{-6} to 10^{-4} ppm) stimulate root growth while there is no effect on the shoot; Higher concentration of auxin (above 10^{-4} to 10^{3} ppm) decreases inhibits root growth while (10^{-4} to 10^{0}ppm) increases/ stimulates shoot growth between (10^{0} to 10^{2}) increase of auxin concentration rapidly inhibits shoot growth while its slowly inhibits root growth;

(b).In another experiment, groups of pea seedlings were treated as shown in table 2.

Table 2.

Group of seedlings	Treatment done
A	Apical buds removed
B	Apical buds removed and auxins placed on the cut stump
C	Apical buds removed and gibberellic acid placed on the cut stump
D	Apical buds removed and cytokinins placed on the cut stump
E	Seedlings left intact

At intervals after treatment, the length of the axillary shoots were determined and the results obtained were recorded as shown in table 3

Time after start of treatment (days)	Mean total axillary shoot length per group of seedling (nm)				
	A	B	C	D	E
2	3	3	3	3	3
4	10	4	12	9	3
6	30	4	45	32	3
8	50	5	90	47	3
10	78	6	116	80	3
13	118	30	150	119	3

(i).What was the effect of the treatment done, on each group of seedlings at the end of the experiment

Removal of the apical buds from seedling A and removal of the apical buds then applying cytokinin on the cut stumps of seedling D, produced moderate growth of the axillary shoots; The removal of the apical buds and applying auxin on cut stumps of seedling B caused slight /short growth of the axillary shoots. Removal of the apical buds and applying gibberellic acid on cut stumps of seedling C produced the greatest growth of the axillary shoots; Shoots left intact in seedlings E produced no more growth of the axillary shoots up to the end of the experiment;

(ii)Explain the results in table 3 ***(15 marks)***

Auxin stimulate growth mainly in the shoots; by stimulating cell expansion / elongation but inhibits growth of axillary buds/ promotes apical dominance in B. Auxin is synthesised at tips of shoots/ in young leaves and transported further back; so removal of the apical buds removes its inhibitory effect on the growth of axillary buds. The Gibberellic acids stimulate cells division, and elongation and growth of side branches from axillary buds; Cytokinins promote cell division / and differentiation in stems also promotes growth of buds but does not influence growth in length; so its application on the stumps of seedling D did not cause any significant increase in axillary shoot length because the apical buds/ source of auxin had been removed; seedling in E were left intact the hormones responsible for apical dominance are present throughout;

(iii).Outline ways in which auxins have been used in improving agriculture ***(04 marks)***

- They are used as selective weed killers
- Induction of fruiting in the absence of pollination (parthenocarpy);
- Used in storage of potatoes or other crops since they inhibit sprouting / prolong seed dormancy

• Synthetic auxins utilized as rooting agents on stem cuttings and for development of adventitious roots.
• Auxins are utilized as anti-abscission agents; preventing premature leaf and fruit fall
• Auxins have been used to delay flowering until an appropriate time.
• Auxins have been used increase fruit size.
• Auxins are utilized as anti-sprouting agents in potatoes; prolonging their storage time

Question 3.

Figure 1 below shows the changes in the membrane potential showing the electrical events associated with the nerve impulse in the axon while figure 2 shows changes in the permeability of the membrane of the axon to sodium and potassium ions during transmission of an impulse which occurs very fast and rapidly.

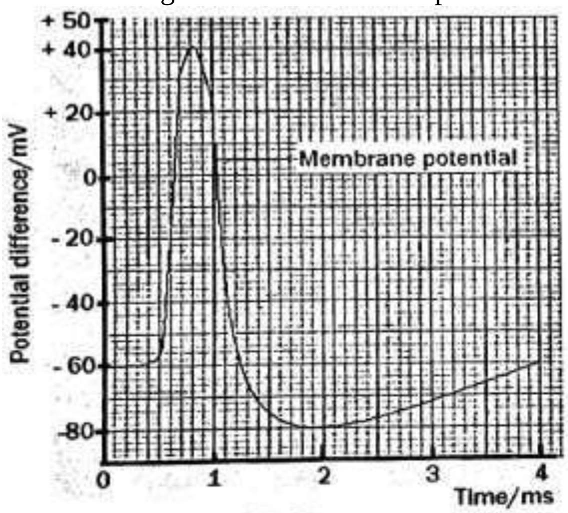


Fig. 1

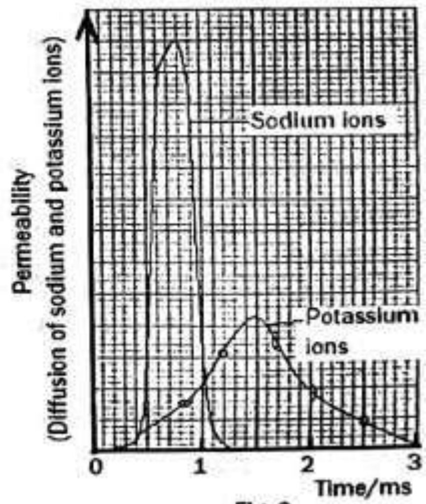


Fig. 2

(a).Compare the trend of diffusion of sodium and potassium ions across the membrane of an axon over a 3 milliseconds (ms) period. ***(08 marks)***

Similarities

• In both, diffusion of sodium and potassium ions increase rapidly to the maximum
• In both diffusion of sodium ions and potassium ions reach the maximum /peak;
• In both sodium ions and potassium ions diffusion decline rapidly after the peak;
• In both diffusion of sodium and potassium ions begin to increase from0.2ms;
• In both diffusion of sodium ions and potassium ions is the same at 10ms

Differences

• Diffusion of sodium ions are higher while that of potassium ions are lower between 0.4ms and 1ms.
• Diffusion of sodium ions is lower while the diffusion of potassium ions is higher between 1and 1.2 ms;
• Diffusion of sodium ions decrease rapidly while diffusion of K^+ increase rapidly between 0.8 and 1.4ms
• Diffusion of sodium ions increase more rapidly than diffusion of potassium ions from 0.4ms to 0.8ms.
• Maximum diffusion of sodium ions was reached at an earlier time; while maximum diffusion of K^+ reached at later time of 1.5ms;
• Diffusion of K^+ increase between 1.3 to 1.5ms & decline rapidly up to 3.0ms while diffusion of Na^+ cease

(b). Using both figures 1 and 2, Explain the trend of each of the following during the propagation of the impulse in the axon,

(i).Membrane potential. ***(10 marks)***

Between 0 and 0 4ms, the negative membrane potential is kept constant at -60mV; this is a resting potential, the outside of the membrane of an axon is more positive while the inside is more negative/ membrane is polarized. Between 0.4ms and 0.6ms the negative potential difference decreased rapidly to zero/ potential difference rapidly becoming less negative; this is because the outside of the membrane is building a slightly negative charges while the inside is building a slightly positive charges; Between 0.6ms and 0.85ms, positive potential difference increased rapidly to reach a peak at +40mV; this is because the outside of a membrane has attained a more negative charges while the inside attained a more positive charges/ membrane is more depolarized; a threshold value is attained at the peak, resulting into action potential/transmission of impulses. Between 0.85ms and 1.0ms, positive potential difference declined rapidly because the outside of the membrane is once again becoming slightly positive while the inside is becoming slightly negative/membrane is slightly repolarized. Between 1ms and 1.2ms the negative potential difference increased rapidly to 60mV/ resting potential/ potential rapidly becomes more negative; the outside of the membrane is more positive while the inside is more negative/ the membrane is repolarized; Between 1.2ms and 1.8ms; the negative potential difference increases beyond the negative resting potential/ potential difference is more negative than the resting potential; this is because the membrane is hyperpolarized; Between 2ms and 4ms the negative potential difference decreased gradually/ potential difference becomes gradually less negative to attain a resting potential; membrane of the axon is fully repolarized;

(ii).Sodium ions. ***(06 marks)***

Between 0and 0.3ms, diffusion of sodium ions remained constant; this is because there is net diffusion of sodium ions; sodium gates are closed/protein channels specific to sodium ions are closed; Between 0.3ms and 0.8ms diffusion of sodium ions increase more rapidly, there is stimulus; sodium gates/ protein channels specific to Na^+ ions open, sodium ions diffuse rapidly inside the membrane. Between 0.8ms & 1.2 ms; sodium ions diffusion decline rapidly; because an impulse has already been transmitted and sodium gates close.

(iii).Potassium ions. ***(06 marks)***

Between 0.4ms and 1.5ms the potassium ions diffusion increase rapidly; action potential has already been achieved and. many protein channels specific to potassium ions open; potassium ions diffuse rapidly outside the membrane. Between 1.5ms and 3ms the potassium ions diffusion decline rapidly, the membrane is becomes impermeable to outward diffusion of potassium ions/ protein channels specific to potassium ions close and potassium ions do not diffuse rapidly outside.

(c).In each case, state two factors which can cause rapid & slow propagation of impulses ***(06 marks)***

Rapid propagation of impulses caused by;

- Myelination of membrane of an axon.
- Larger diameter of the axon.
- High body temperatures/ endotherm;
- Adequate/ high concentrations of sodium/ potassium ions in the body

Slow propagation of impulses caused by;

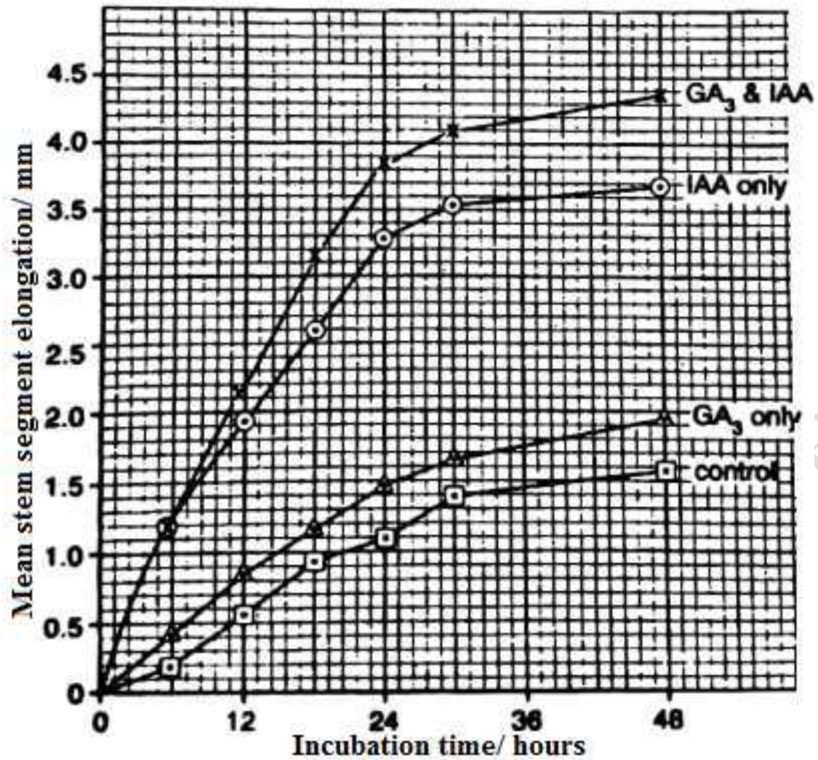
- Non-myelination of membrane of an axon.
- Smaller diameter of the axon;
- Low body temperatures;
- Low concentration of mineral ions

(d).Give the significance of fast conduction of impulses to organisms ***(04 marks)***

- Quick/ fast detection and escape responses from predators and danger;
- Fast detection of sudden changes in external and internal environments
- Homeostatic control mechanisms are achieved fast and easily;
- Fast stimulation of glands to secrete digestive enzymes resulting into fast digestion
- Fast responses due to fast secretion of hormones;

Question 4.

An experiment was carried out to investigate the effect of an auxin indole-acetic acid (IAA) and gibberellic acid (GA_3) on the elongation of segments of pea stem. A control group of pea segments received on added IAA or GA_3. Other groups of pea segments were treated with equivalent quantities of IAA only, GA_3 only or both IAA and GA_3. The results are shown on the graph below.



(a).Describe the effect of each of the following plant hormones on mean stem segment elongation

(i). Gibberellic acid GA_3 ***(03 marks)***

Increases mean segment elongation slightly rapidly increasing mean stem elongation in 24 hours & later gradually

(ii). Indoleacetic acid (IAA) ***(03 marks)***

Increases mean stern segment elongation greatly/ rapidly increasing within 24 hours and later gradually increasing

(b)(i).With reason, state the biological relationship exhibited by gibberellins and IAA ***(03 marks)***

Synergism; their combined effect is much greater than the sum of their separate effect

(ii).Explain the difference in the effect on the mean stem segment elongation when the pea plants were treated with IAA only and when treated with a mixture of IAA and GA_3 ***(03 marks)***

Mixture of IAA and GA_3 has a greater effect on mean stem segment elongation than when IAA was used only. In the mixture GA_3 initiates the formation of IAA; more IAA is secreted on addition to already added weakening the cell walls faster allowing greater elongation of the stem together.

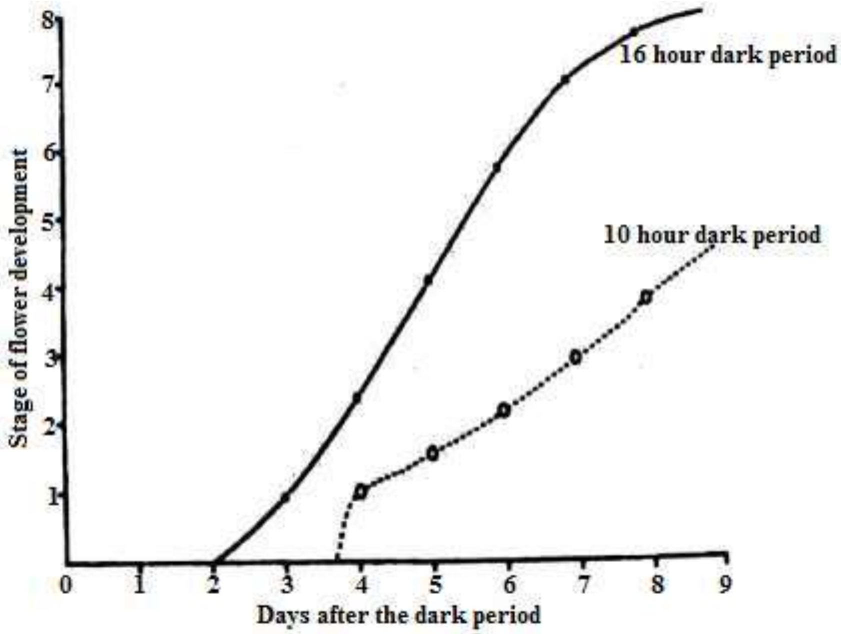
(c).Describe the role of GA_3 in seed germination ***(08 marks)***

Once released by the hydrated embryo following imbibition and in consequent translocation to the aleurone layer of the seed, gibberellic acid hydrolytic enzymes like carbohydrases like amylase, protease, ,lipase which on being transported to the food reserves catalyzes hydrolysis of stored food substance .to suitable food substances which are translocated to the embryo for respiration to provide energy for germination amino acids from protein hydrolysis used to synthesize enzymes and tissue, lipids for formation of other growth substances in the embryo which brings about seed germination

(d).How have farmers used IAA to their benefits ***(04 marks)***

- They have been used as selective weed killers
- Induction of fruiting in the absence of pollination (parthenocarpy);
- Used in storage of potatoes or other crops since they inhibit sprouting / prolong seed dormancy
- Synthetic auxins utilized as rooting agents on stem cuttings and for development of adventitious roots.
- Auxins are utilized as anti-abscission agents; preventing premature leaf and fruit fall
- Auxins have been used to delay flowering until an appropriate time.
- Auxins have been used increase fruit size.
- Auxins are utilized as anti-sprouting agents in potatoes; prolonging their storage time

(e). Flowering in the cocklebur plant occurs as a result of exposure to a period of darkness. The development of fl-ower has been divided into eight stages (0- no flower, up to 8 fully developed flowers). The graph below shows the average stage of flower development for two batches, each of 10 plants, one of which was kept in the dark for 16 hours and the other for 10 hours.



(i).Compare the effect of length of dark period on flowering of the cocklebur plants ***(04 marks)***

Similarities

• In both batches, stages of flower development increase with days after dark period.
• In both less than 2 day of dark period causes no flower development.

Differences

• Batch at 10 hours dark period doesnot reach full flower development after 8 days whereas that at 16 hours dark period reaches full flower development.
• Flower development increase faster/ rapidly for batch of 16 hours dark period whereas the one at 20 hour period increases gradually.
• Batch at 10 hours dark period requires more days (31 days) to start flower development while that at 15 hours requires 2days to start flowering.

(ii).Explain the difference between the two batches of plants after 8 days ***(02 marks)***

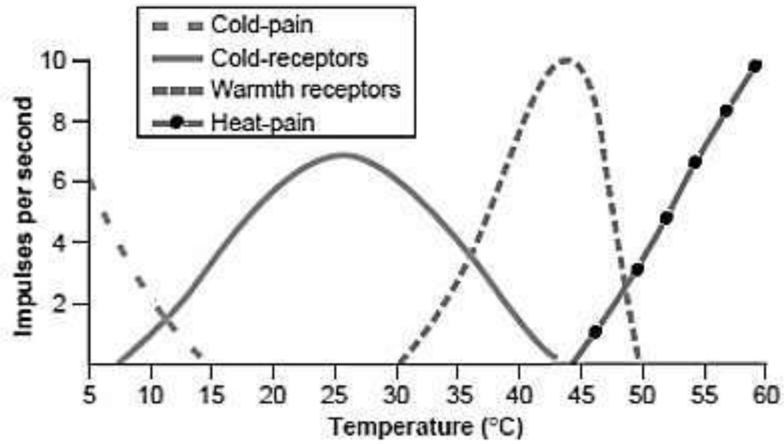
Cocklebur is in short day plant. 16 hours dark period was longer than critical length allowing accumulation of more phytochrome red (PR)/ sufficient phytochrome far red is converted to inactive phytochrome red; flowering to occur.

(iii)Suggest reason(s) why there was a delay between exposure to darkness & start of flower development

Accumulated growth promoter (phytochrome) requires some time to synthesize/ stimulate movement of florigen hormone from the leaves where they are synthesized to the flower bulb where they exert their effects

Question 5.

Figure I below shows the discharge frequencies at different skin temperatures of a pain fiber stimulated by cold, a cold fiber, a warmth fiber, and a heat-pain fiber.



(a) From the graph, describe the relationship between temperature and the responses of the four types of nerve fibers. (15 marks)

(b) Explain:

(i) Why when the temperature of the skin is actively changing, a person feels much stimulation than when the temperature remains constant. ***(05 marks)***

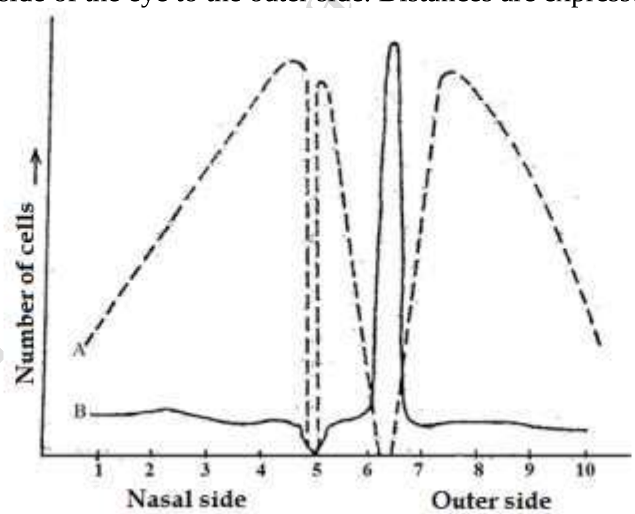
(ii) The significance of the phenomenon in (b) (i) above to an animal. ***(02 marks)***

(c) From the graph above, explain:

(i) How a person determines different temperatures of the environment. ***(02 marks)***

(ii) Why freezing cold and burning hot sensations can be painful ***(01 marks)***

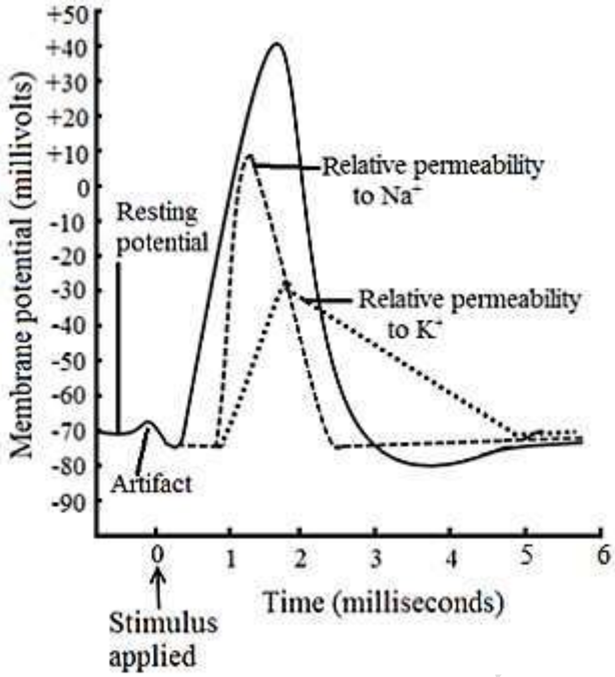
Figure II below shows the number of receptor cells (type A–Rods, Type B - Cones) in the human retina along a horizontal line from the nasal side of the eye to the outer side. Distances are expressed in arbitrary units.



(d) From the graph, describe the distribution of both types of receptor cells in the retina. ***(07 marks)***

(e) Explain the significance of the distribution of the two types of receptor cells in the retina as shown in the graph. ***(08 marks)***

The figure below shows changes in potential difference and permeability of the neurone membrane sodium ions & potassium ions during propagation of a nerve impulse in an axon.



(a).How is the potential difference of -70mV maintained across the axon membrane? ***(04 marks)***
(b).Account fully for the changes in potential difference & number of ion channels open from 0 ms to 2 ms.
(c).Explain the mechanism of propagation of the nerve impulse along the length of the axon.
(d) Describe the functional properties of neurones
(e) Explain the role played by synapses in animal responses.

Essay question and answers

Question 1.

(a).Distinguish between resting potential and action potential ***(02 marks)***
(b).Explain how the following processes are involved in the formation of nerve impulses
(i). Formation of a resting potential. ***(08 marks)***
(ii).Formation of an action potential and how the impulse is transmitted ***(10 marks)***

(a).

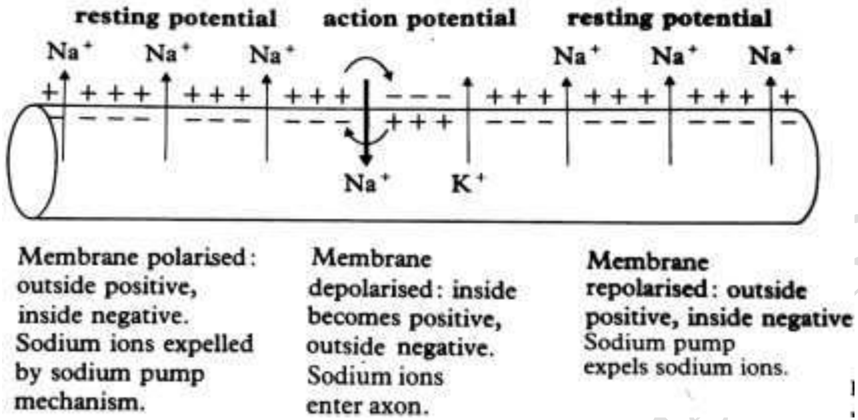
Resting potential is a change in membrane voltage (potential) that occurs in a nerve muscle or any other excitable tissue in absence of an excitation i.e no impulse in transit ***while*** an action potential is change in membrane voltage that occurs in a nerve, muscle or any other excitable tissue in presence of an excitation or impulse in transit.

(b)(i).

Resting potential is maintained by sodium-potassium pump mechanism and differential permeability of the axon membrane to sodium and potassium ions. At rest, axon membrane is more permeable to K^+ that is highly abundant in the axoplasm but almost impermeable to Na^+; abundant in the extracellular fluid (ECF). Therefore, at rest, potassium protein gated channels are open while sodium protein gated channels are closed; thus K^+ freely diffuse out of the axoplasm to the ECF without reciprocal entrance of Na^+. In addition, sodium- potassium pump operates pumping out three Na^+ in exchange for two K^+ ions. The net effect is a high cationic concentration on the outer axonal membrane relative to the inner making the membrane positively charged on the outside relative to the inside; This potential difference across the membrane measures up to approximately -80mV and the membrane is said to be polarized.

(b)(ii).

Upon stimulation, Na-K pumps break down; axonal membrane reverses its permeability to Na^+ and K^+ in which it becomes more permeable to Na^+ but less permeable to K^+. Na^+ channels open; K^+ channels close; causing a rapid influx of Na^+ along the steep electrochemical gradient and this proceeds by positive feedback. Net effect is a progressively increasing cationic concentration on the inner axonal membrane relative to the outer; Inner membrane potential progressively becomes more positive relative to the outside; an action potential builds up; At maximum influx of Na+, when all Na channels are open; maximum action potential of approximately +60mV; A nerve impulse is transmitted as a wave of depolarisations and repolarisations along the entire axonal lengths. Areas ahead of the action potential are depolarized; those behind are repolarized; and the impulse moves inform of a local circuit; from the depolarized zone to a repolarized one;



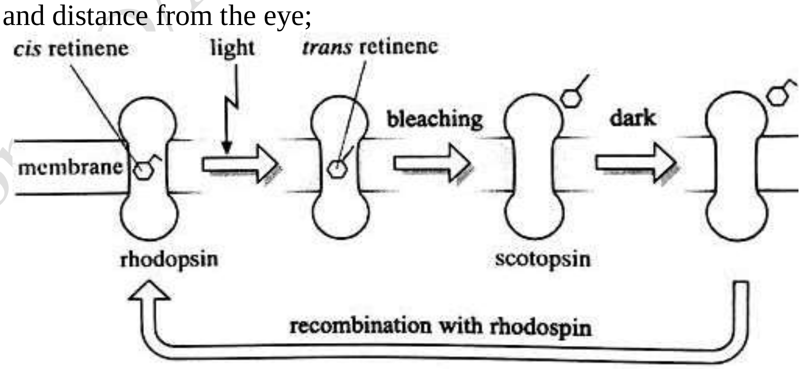
Question 2.

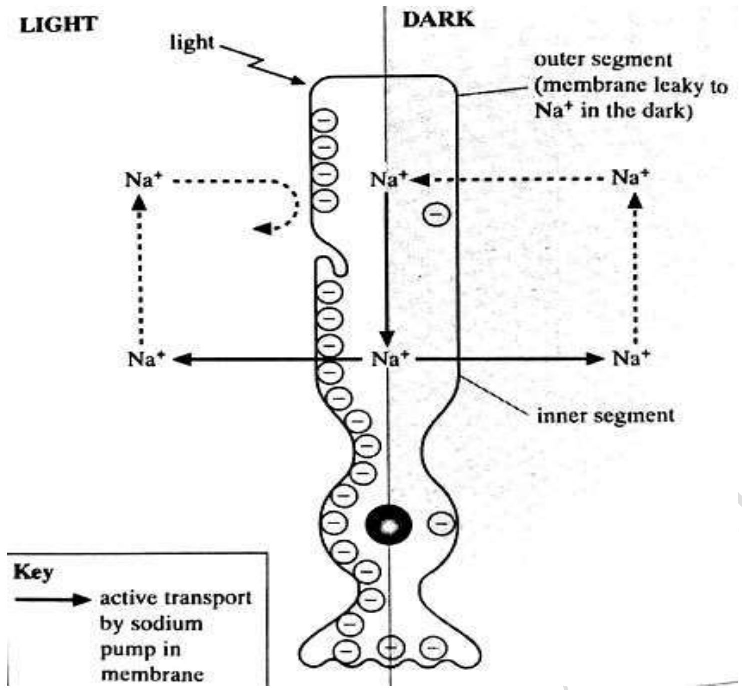
(a).Describe the events that lead to perception of a clear image from the a far object by humans during the bright day ***(10 marks)***

(b).Discuss the significance of coordinating systems of animals ***(10 marks)***

(a).

Parallel light rays from the distant object enter the eye through the cornea; refracts through the pupil. Circular muscles of the iris contract; radial muscles relax; limited light permitted through the constricted pupil; With the ciliary muscles relaxed; suspensory ligaments tauten, edges of the lens are pulled; lens becomes thin and less convex; reducing its refractive power; permitting focus of the parallel rays onto the retina; Light gets incident onto the photopsins/ cone opsins/ iodopsin; in the outer segment of the cones causes isomerization of 11-cis retinal to all trans-retinal; coupled with a conformational change in the proteins; Bleaching results; This closes Na^+ channels; reducing Na^+ conductance in the outer segment; membrane of the outer segment gets hyperpolarized; no neurotransmitter release at the inhibitory synapse; Adjoining bipolar neurone gets depolarized; release an excitatory neurotransmitter at the excitatory synapse with the bipolar neurone; generator potential established; builds to threshold; creates an action potential; that fires an impulse through the optic nerve fibres; to the occipital lobe; interprets the image in terms of shape, colour and distance from the eye;





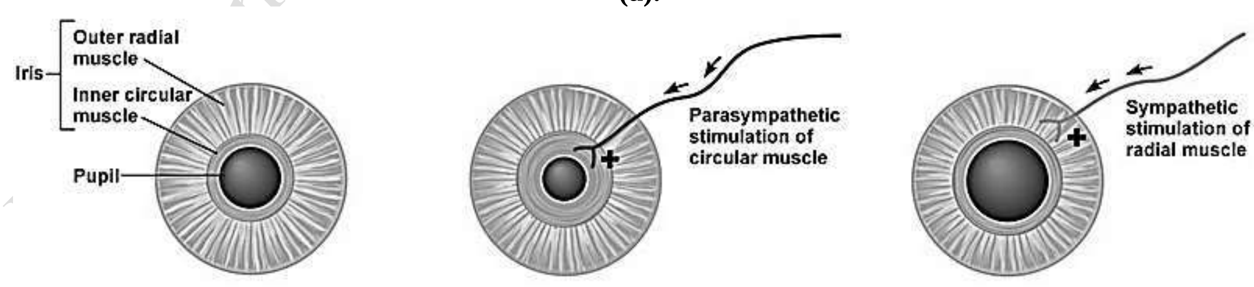
(b).

• Ensures effective cellular communication in multicellular organisms through cell signaling mechanisms such as hormonal and neuronal communication
• Ensures optimum cellular conditions since cellular activities are predominantly enzyme controlled;
• Enables the organisms overcome stressful changes in the external environment; through modifying their physiology/behaviour to maintain activity and survival of organisms;
• Ensures detection of toxicity within the cell's internal milieu (environment) prompts immediate removal to maintain effective cellular activity
• Effective homeostatic regulation of several physiological processes; such as temperature regulation, blood sugar regulation, electrolyte balance, hormonal regulation etc
• Effective reception to stimuli, interaction and appropriate response of the organism to the ever changing environmental stimuli.

Question 3.

(a).Describe the mechanism of control of light entering the mammalian eye ***(12 marks)***
(b).How do photoreceptor cells in the retina of mammals differ both functionally and structurally?
(c).How is co-ordination carried out by the mammalian nervous system

(a).



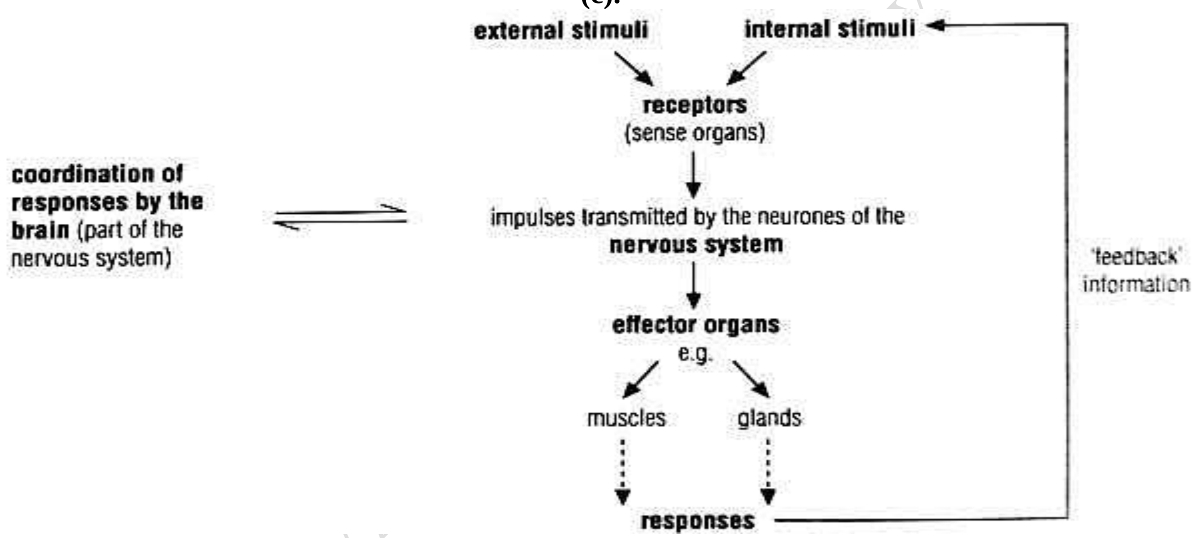
(a) Anatomy of iris and pupil **(b) Pupillary constriction** **(c) Pupillary dilation**

Much light entering the eye evokes parasympathetic efferent discharge cause contraction of circular (constrictor pupillae) muscles; and relaxation of the radial(dilator pupillae) muscles of the iris; pupillary constriction results; limited light permitted into the eye; Limited light entering the eye; evokes a sympathetic efferent discharge; cause contraction of the dilator pupillae (radial) muscles of the iris; and relaxation of the circular (constrictor pupillae) muscles; pupillary dilation occurs; permitting more light to enter into the eye;

(b).

Rods	Cones
Out segment is cylindrical/ rod shaped	Outer segment is flask/cone shaped
More in number on the retina (around 10^9 million)	Fewer on the retina (around 10^6 million)
Contain rhodopsin as the photosensitive pigment	Contain iodopsin as the photosensitive pigment
Demonstrates retinal convergence	No retinal convergence
Incapable of colour perception	Capable of colour perception
Sensitive to low light intensity	Sensitive to high light intensity
Distributed mainly on the periphery of the retina apart from the fovea.	Dispersed throughout retina but most concentrated on the fovea centralis
Lower threshold value	Higher threshold value
Increase sensitivity to low light intensity	Increase visual acuity of the eye
One type	Three subtypes.

(c).



Question 4.

(a).Describe the functioning of hormones in animals. ***(16 marks)***

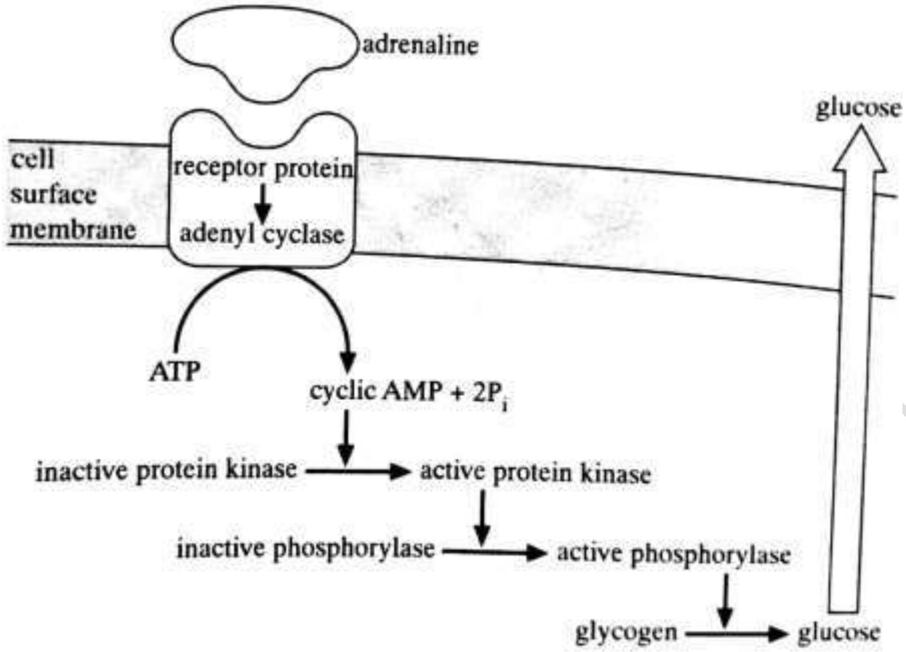
(b).How is the secretion of aldosterone controlled ***(04 marks)***

(a).

Hormones function by activating signal transduction pathways thereby influencing physiological, biochemical & metabolic reactions within cells. At molecular level, hormones do so in four ways; affecting transcription of genetic information e.g oestrogen, protein synthesis e.g growth hormone, altering enzyme activity eg adrenaline and changing the permeability of cell membrane e.g insulin.

Hormones functioning at the level of the plasma membrane/ functioning of peptide hormones

Amino acid derived hormones (amines, peptides and polypeptide hormones); being water soluble bind to specific receptors on plasma membrane transduce intracellular signals by the cyclic Adenosine monophosphate (cAMP) second messenger system. It begins with hormone-receptor complex being formed, activating adenylyl cyclase which mobilizes ATP molecules; converts them to cAMP which converts inactive protein kinases to active ones. Active protein kinases then phosphorylate several proteins whose effects may be alteration of protein synthesis machinery e.g growth hormone, alteration of plasma membrane permeability to water and electrolytes e.g insulin and ADH, affect enzyme activity e.g adrenaline or activate gene transcription resulting in increased expression of target proteins e.g thyroxine.

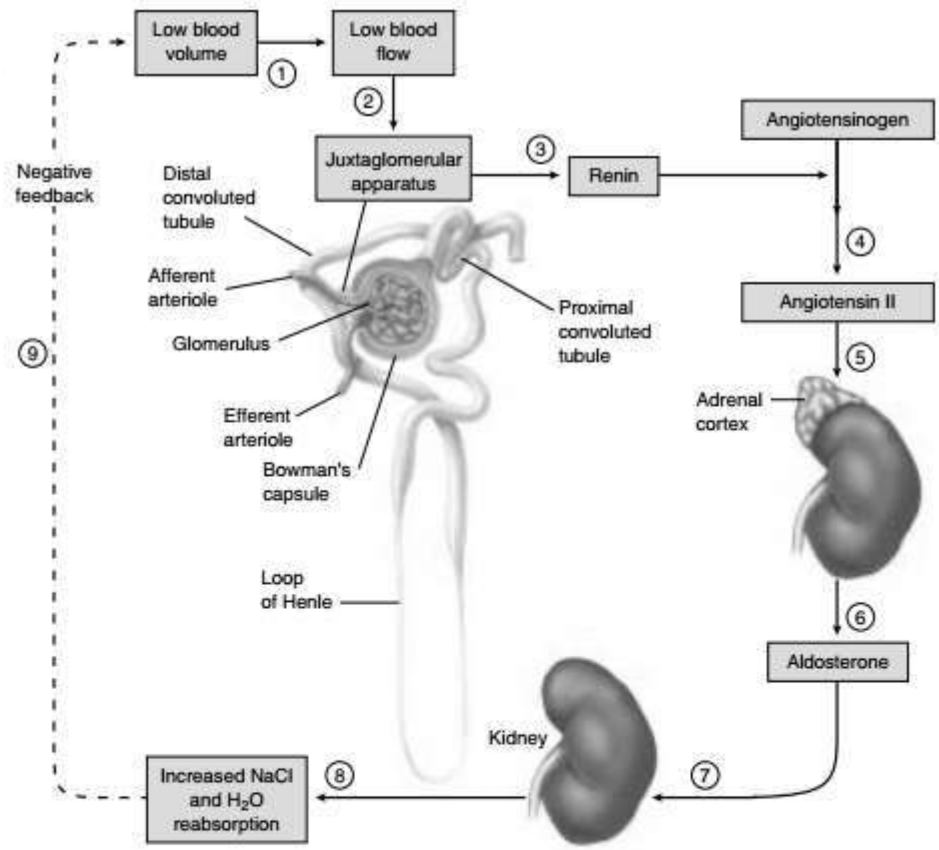


Hormones functioning at the level of the gene/ functioning of steroid hormones

Steroid hormones such as androgens, progesterone, oestrogen etc are lipid-soluble and thus readily diffuse through the plasma membrane of cells. They bind to specific receptor proteins in either the cytoplasm or nucleus. If the steroid binds to a receptor in the cytoplasm, the hormone-receptor complex moves into the nucleus. The hormone-receptor complex influences the protein synthesis machinery by binding to specific regions of the DNA, stimulating the production of messenger RNA (mRNA); that is then translated into specific proteins.

(b)(i).

Aldosterone secretion is controlled by the Renin-Angiotensin System (RAS); via negative feedback. Decrease in plasma sodium ion concentration or decreased blood pressure; triggers the release of renin from the juxtaglomerular complex cells in the nephrons; renin converts inactive angiotensinogen to angiotensin I which is also converted to angiotensin II by angiotensin converting enzyme in the lungs. Angiotensin II stimulates aldosterone release; from the Zona glomerulosa of adrenal cortex. The hormone causes Na^+ retention; and simultaneous loss of K^+. Sodium ions are followed by water. If blood pressure exceeds normal, or too much Na are retained; renin release ceases and RAAS is inactivated; Na^+ are lost in renal tubular fluid; followed by diuresis. K^+ are then retained.



Question 5.

(a).Describe the structure of the rod cell of the mammalian eye *(15 marks)*

(b).How are the rod cells modified to perform their function? *(05 marks)*

(a).

Rod cells are cylindrical structures. Outer segment of rod cell is long, slender and rod shaped and is in close contact with the pigmented epithelial cells. Outer segment has membranous disks that contain rhodopsin. Inner segment is connected to outer segment by means of modified cilium. Inner segment contains many types of organelles with large number of mitochondria. A slender fiber called rod fiber arises from inner segment of the rod cell and passes to outer nuclear layer through external limiting membrane. In outer nuclear layer, the enlarged portion of this fiber forms the cell body or rod granule that contains the nucleus. Synaptic terminal; thick fiber arising from the cell body passes to outer plexiform layer and ends in a small and enlarged synaptic terminal or body. Synaptic terminal of the rods synapses with dendrites of bipolar cells and horizontal cells. Synaptic vesicles present in the synaptic terminal contain neurotransmitter, glutamate.

(b).

Rod cells do retinal convergence in which several rod cells synapse with a single bipolar neuron. This arrangement increases the eye's sensitivity to light. On exposure to low intense light, each rod cell generates its own receptor/ generator potential; sub-threshold, in magnitude; these spatially summate form one large receptor potential whose magnitude is either equal or beyond threshold establishes an action potential that fires an impulse across the adjoining bipolar neuron; information sent to the brain via the optic nerve.

Question 6.

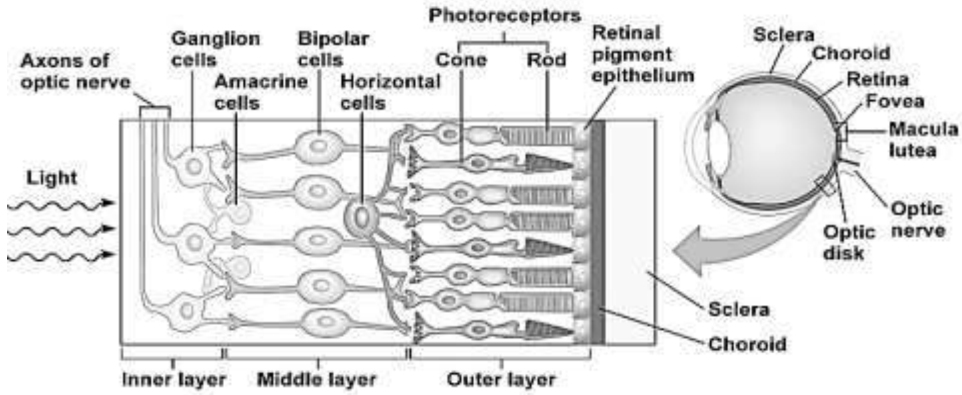
(a).Describe the structure of a mammalian retina *(05 marks)*

(b).Explain how fast speed of impulse transmission is ensured in nerve cells *(06 marks)*

(c).Describe post-synaptic changes occurring in excitatory and inhibitory synapse *(09marks)*

(a).

The retina consists of a photoreceptive/ outer layer; having cones; and rods; partly embedded in in a pigmented epithelium of the choroid; Next is the intermediate/ middle layer; containing bipolar neurones synapsing with the photoreceptor cells; This layer also contains horizontal cells; and amacrine cells; The inner most layer is the ganglion layer; containing ganglion cells; with dendrites in contact with bipolar neurones; and with axons of the optic nerve fibres;



(b).

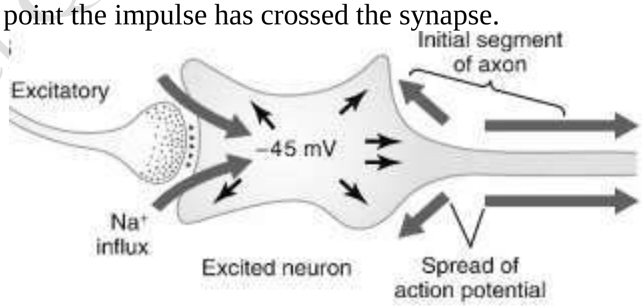
Myelination; myelin sheath covers the axons of nerve fibres and is only absent at nodes of Ranvier; Myelin sheath insulates the axon; ionic exchanges, depolarisations and repolarizations occur only at the nodes of Ranvier; Action potentials therefore just leap from one node of Ranvier to another and the speed of impulse transmission increase tremendously because of this saltatory transmission;

Increasing axonal diameter; The larger the axon, the faster the speed of impulse transmission; Giant axons offer minimal longitudinal resistance to flowing impulse within the axoplasm; the length of the membrane affected by local circuits increases; thereby increasing distance between adjacent depolarisations;

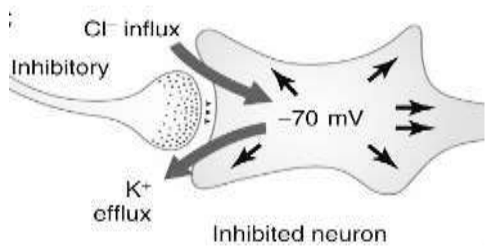
Increasing temperature; increase in temperature increases the diffusion rate of ions across the axon membrane and the rate of enzyme controlled reactions; This speeds up depolarisations and repolarisations establish local circuits fast enough thereby increasing the speed of impulse transmission;

(c).

At **excitatory synapse;** the reception of neurotransmitter substance (acetyl choline) on the receptor sites changes their configuration such that the membrane channels in them are opened up thus allowing sodium ions to diffuse; through the postsynaptic membrane into the post synaptic knob hence making it more positive. If a threshold value is reached, potential difference of the membrane therefore changes and an excitatory postsynaptic potential (EPSP) results; This fills up until the threshold is reached which results into an action potential being fired in the post synaptic neuron; At that point the impulse has crossed the synapse.



At an **inhibitory synapse;** release of transmitter substances (noradrenaline) or glycine or GABA into the synaptic cleft leads to the opening up of chloride ion channels; in the post synaptic membrane resulting into chloride ions entering and potassium ions leaving. As a result, the interior of the post synaptic membrane becomes more negative; this increases the threshold making the post synaptic membrane harder to be excited; an inhibitory postsynaptic potential (IPSP) is established.

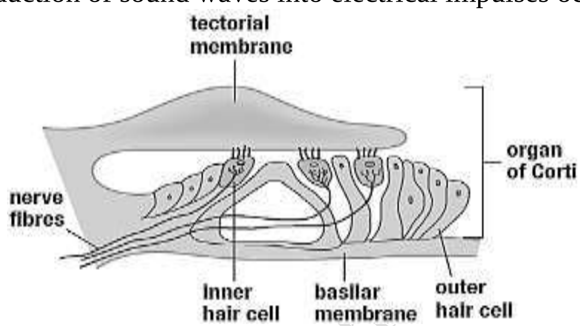


Question 7.

(a) What is meant by an organ of Corti? ***(02 marks)***
(b) Describe how low pitched loud sound is perceived by a human ear ***(14 marks)***
(c) Explain why someone who has been constantly rotating feels dizzy when he suddenly stops ***(04 marks)***

(a).

Organ of Corti is a unit in the cochlea of the inner ear consisting of the basilar membrane, sensory hair cells & the tectorial membrane where transduction of sound waves into electrical impulses occurs.



(b).

Sound waves get collected and concentrated by the pinnae; forwarded to the external auditory meatus, cause vibration of the tympanic membrane which also transmits the vibrations to the ossicles for impedance matching (amplification by 22 times). Amplified sound waves are then forwarded to the oval window; produce vibrations in the in the perilymph of the vestibular canal; transfers pressure waves via the Reissner's membrane to the endolymph of the middle canal, then to the perilymph of tympanic canal. Vibrations are then finally forwarded to the basilar membrane. Vibrations of the basilar membrane induced by the pressure waves, push many sensory hair cells near the apex of the cochlear (helicotrema) and cause them to shear against the tectorial membrane. Sensory hairs get depolarized; generator potentials are created; build up to threshold; initiate action potentials that fire impulses across the axonal membranes of cochlear nerves (vestibulo-cochlear nerve) to the brain. A loud high pitched sound is interpreted by the brain.

N.B; Basilar membrane becomes broader & more flexible as it passes from the base of the cochlea to its apex (helicotrema) and the sensitivity to vibrations of different frequencies change along its length. High frequency (pitched) sounds are interpreted if hair cells at the base of the cochlea are stimulated. Low pitched sounds are interpretted if hair cells at the apex of the cochlea are stimulated; Mid frequency sounds are interpreted if hair cells between the apex and the base are stimulated. Intensity/loudness depends on the number of hair cells stimulated. Fewer hair cells stimulated; low intense sound is interpreted; many hair cells stimulated; generate several receptor potentials; spatially summate and a loud (high intense sound) is detected.

(c).

When the head is constantly rotated, the endolymph in the semi-circular canals moves with constant velocity similar to that of the head. The fluid thus moves with zero acceleration & the brain interprets static equilibrium. When the rotation stops suddenly, the inertia exerted on the endolymph makes it continue with motion; and the patterns of the impulses are taken to the brain; which interprets dynamic equilibrium; when someone is resting. This accounts for the temporary dizziness.

Question 8.

(a).Describe the characteristics of receptor cells ***(06 marks)***
(b).Describe the role played by each of the following in maintenance of balance in a human body

(i). Semi-circular canals *(07 marks)*
(ii).Utriculus and sacculus *(07 marks)*

(a).

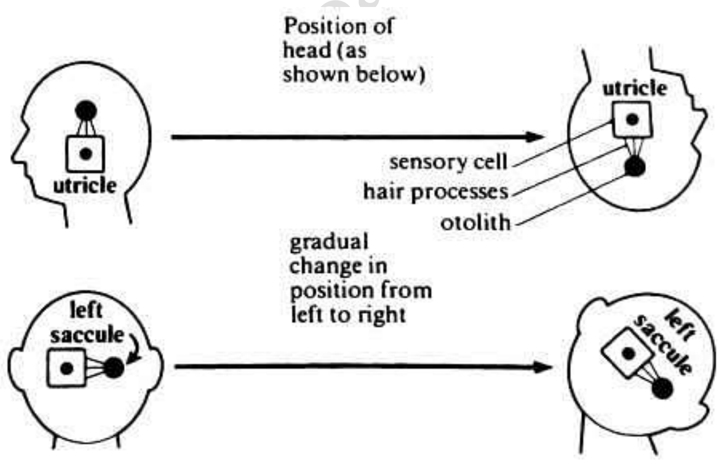
- They are specialised in structure and function
- Possess a resting potential when not stimulated.
- Transform energy in the stimulus into an action potential; when the receptor is stimulated.
- Each receptor produces a generator potential when stimulated.
- Each receptor has a threshold value of stimulation.
- Undergo adaptation; fails to respond to repeated stimulation.
- Obey the All or Nothing law‖
- Sensitive to low intensity stimulation
- Has general structural features but one end is frequently extended (axon)

(b)(i).

The end of each semi-circular canal has sensory cells embedded in the cupula. Movement of the head in a particular direction activates one of the canals. The cupula gets deflected in the direction opposite to one of the head movement due to inertia of the endolymph in the canals. Consequently, sensory hairs are stretched; create receptor potentials which on building up to threshold, creates an action potential that fires impulses in the vestibular nerve fibres of the vestibulocochlear nerve to the brain which interprets the movement of the head.

(b)(ii).

Utriculus & sacculus detect the position of the head & consist of sensory hair cells embedded in otolith ($CaCO_3$) which responds to the pull of gravity. When the head is stationary/static in an upright position, the otoliths set balance over the sensory hairs under the influence of gravity. Utricle responds to vertical movements of the head such that when the body is upside down; the otoliths produce stimulation when its receptor hairs are pulled downwards. The saccule responds to lateral or sideways movements of the head; tilting of the head distorts sensory hairs; impulses are produced which pass through the auditory nerve to the brain where orientation/ position of the head is perceived.



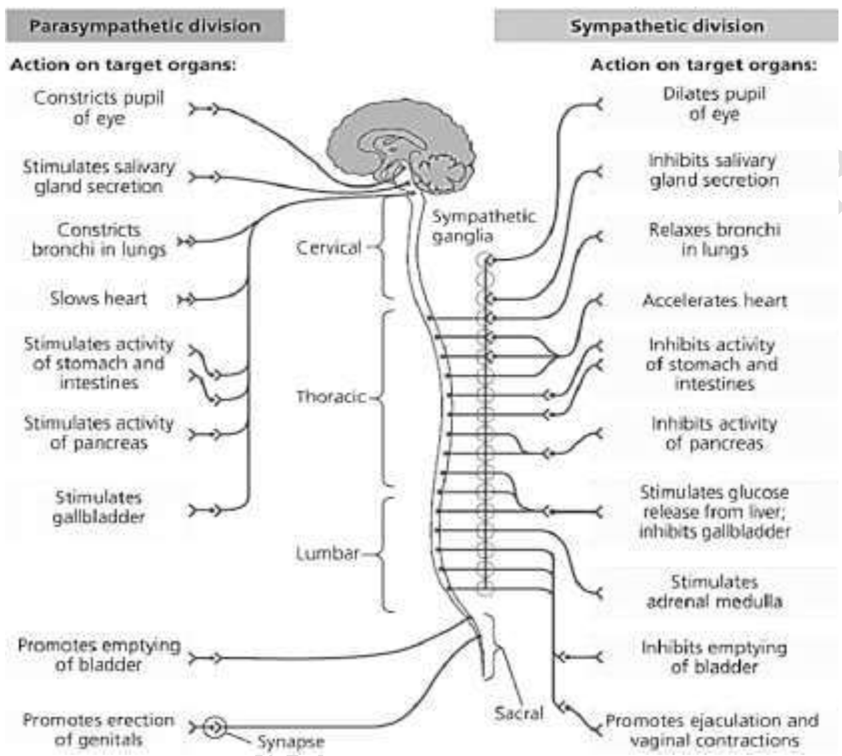
Question 9.

(a).Explain the functioning of the autonomic nervous system. *(12 marks)*
(b).What are the nervous system changes that occur when an individual suddenly touches on a sharp object?
(c).Outline the differences between grey and white matter *(03 marks)*

(a).

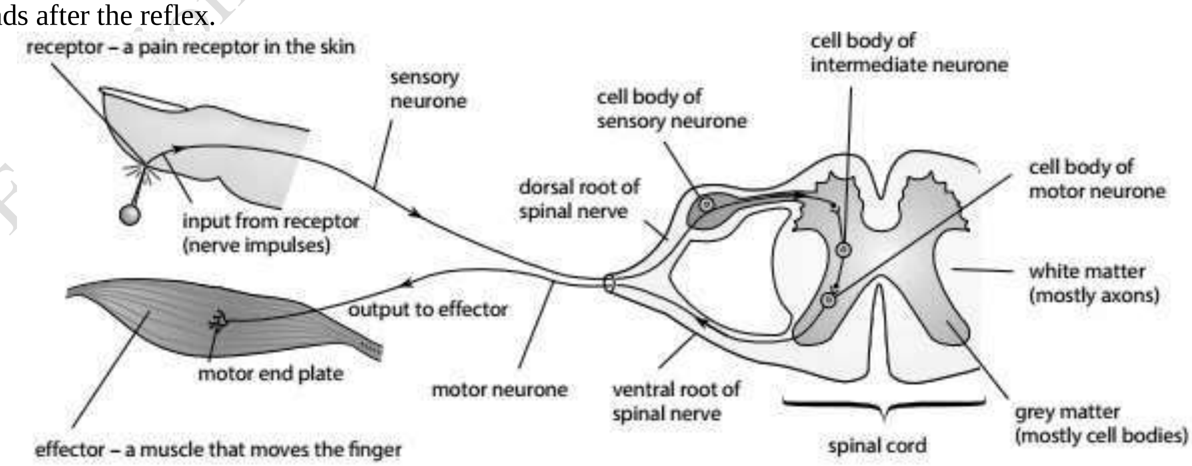
Autonomic nervous system (ANS) forms part of the peripheral nervous system that controls involuntary activities of internal organs and smooth muscles. No involvement of higher brain centres (cerebral cortex) except for smooth muscles of the anal and urinary sphincters which are partly under voluntary control. The ANS is made up of the sympathetic nervous system (SNS) and the parasympathetic nervous system (PNS) and each visceral organ receives nerve fibres from both. Pre-ganglionic fibres of both are cholinergic (release acetylcholine).

SNS; fibres arise from thoracic and lumbar sections of spinal cord; noradrenergic (release noradrenaline) at the effector organs; generally stimulatory/acceleratory e.g increase heart rate, blood pressure and ventilation rate, cause pupillary dilations and ejaculation etc. However, in gastro-intestinal tract (GIT), SNS decreases GIT secretions & motility/movement. SNS dominates during activity.
PNS; constituted by cranial nerves (those from the brain); cholinergic post-ganglionically at the effector organs; generally inhibitory; except in the GIT where it increases GI secretions and motility. PNS decreases heart rate, blood pressure, ventilation, causes pupillary constriction and erection. PNS dominates at rest.



(b).

Spinal reflex occurs. Pain receptors in hand get stimulated; send impulses to the sensory nerve fibre running through the dorsal horn of the spinal cord; impulses get relayed to the motor nerve fibre by the interneuron/ intermediate neuron that traverses the spinal gray matter. Motor fibre running in the ventral horn of the spinal cord; stimulate skeletal muscles of the effector organ/ foot; initiating rapid sudden withdrawal of the foot. Ascending fibres from the spinal white matter carry sensory information to the higher centre in the brain, interpreted then carried back by motor descending nerve fibres, to the spinal cord and finally to the region of pain. Pain is thus felt a few seconds after the reflex.



(c).

Grey matter	White matter
It's grey in colour due to high concentration of neurons.	It's white in colour due to concentration of axon.
Consists of cell body, dendrites and synapses of the brain.	Consists of nerve fibres arising from or to the nerve cells present in grey matter.
Contains numerous intermediate neurons.	Mainly consists of neurons connecting various parts of the body with the brain and links the brain to the spinal cord.

Question 10.

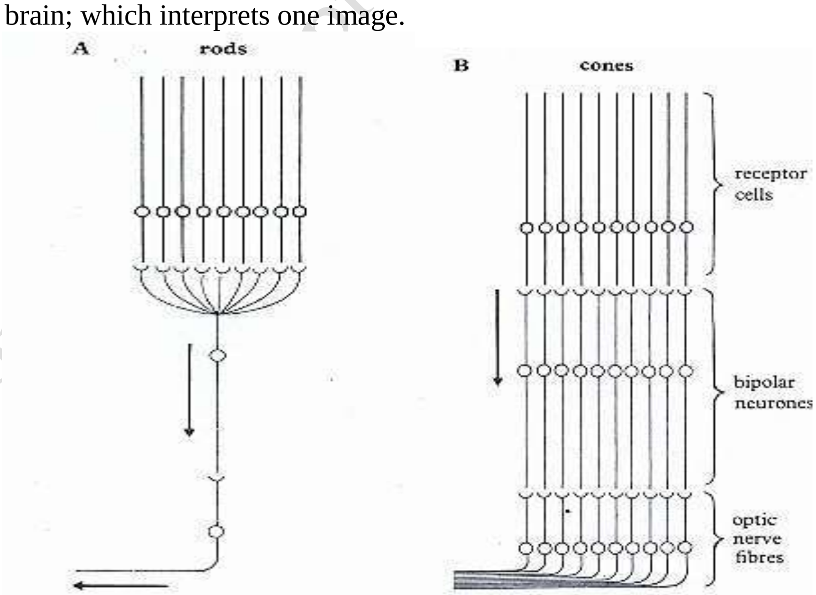
(a) Explain what is meant by the following;
(i) Visual acuity *(04 marks)*
(ii).Retinal convergence *(04 marks)*
(b).Explain how the mammalian eye achieves each of the following
(i) Visua1 perception under dim light *(06 marks)*
(i). Colour perception *(06 marks)*

(a)(i).

Visual acuity is the sharpness or clearness of vision. It depends on the sharpness of retinal focus. Visual acuity is done by the cones; maximally at the fovea; and it involves ability of the eye to distinguish between objects that are close together as well accurate distance judgment. Each cone synapses with a single bipolar neuron; each generates its own receptor potential above threshold; send separate impulses to the brain which interprets two or more images spatially separated.

(a)(ii).

Retinal convergence involves several rod cells establishing one synapse with a single bipolar neuron; which also connects to a single nerve fibre within the optic nerve. Sensitivity to low light intensity is achieved this way. Each rod cell on stimulation, establishes its own receptor potential. Several receptor potentials from different rods; spatially summate; form one large receptor potential whose magnitude is beyond threshold creates an action potential; fires an impulse to the brain; which interprets one image.



(b)(i).

Low light intensity evokes a parasympathetic discharge; causes relaxation of the pupillary sphincter muscles (circular) and contraction of the dilator papillae (radial); pupillary constriction (miosis) results. Amount of light entering the eye increases; Light gets refracted, by the cornea and lens through the vitreous humor, then strikes the rods of the retina. Rhodopsin converts to opsin and all trans retinal; closes the sodium mediated protein channels;

influx of sodium ions reduces in the outer segment while the sodium pump in the inner segment continues to pump out sodium ions; the rod cell gets hyperpolarized and the rate of release of the excitatory neurotransmitter is released at the inhibitory synapse. The adjoining bipolar neurone also gets hyperpolarized; but the ganglion cells of the optic nerve supplied by the bipolar neurone respond by producing an receptor potential. These spatially summate; establish a receptor potential beyond threshold; that creates an action potential; that fires an impulse to the brain.

(b)(ii).

Colour perception is achieved by the three isotypes of cones; red, green and blue cones. Iodopsin, the photosensitive pigment in the outer segment, occurs in three isoforms, each occurring in one of the three cones and is sensitive to either red, green or blue light. Light of a particular wavelength, on stimulating a responding cone; bleaches the corresponding isoform of iodopsin; establishes an action potential. Information is relayed to the brain which interprets colour corresponding to the wavelength of the stimulant light 100% sole stimulation of the green, red and blue cone leads to perception of the green, red and blue colours respectively. Equal stimulation of the red and green cones; yellow perceived, red and blue cones, magenta perceived, and green and blue cones, cyan perceived If all the three cones are equally stimulated, white is perceived whereas black is perceived when none of the cones is stimulated. Other colours are perceived basing on the relative stimulation of the three cones.

Question 11.

(a).Distinguish between photoperiodism and a photoperiod ***(02 marks)***
(b).State the effect of the photoperiod on dormancy of plants ***(04 marks)***
(c).Describe the role of phytochrome system in the control of flowering in plants ***(14 marks)***

(a).

Photoperiodism is the biological response of an organism to the relative changes in the length of the day while a photoperiod is the relative length of the day.

(b)(i).

Photoperiod greater than the critical period (12 hours) promotes flowering in long day plants, day neutral plants but not short day plants. Photoperiod less than the critical period promotes flowering in short day plants, day neutral plants but not long day plants.

(b)(ii).

Seed dormancy

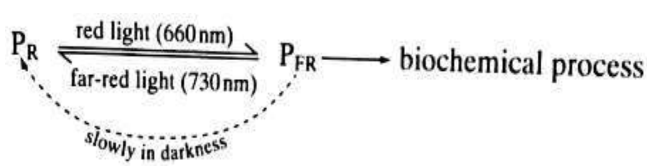
Photoperiod greater than critical period promotes breakage of seed dormancy while photoperiod less than critical period promotes seed dormancy

Bud dormancy

The photoperiod greater critical period breaks bud dormancy; photoperiod less than critical period promotes bud dormancy.

(c).

The phytochrome system consists of two interconvertible proteinaceous molecules; phytochrome red & phytochrome far red. Phytochrome red is more stable in far red light thus its concentration is more abundant at night while phytochrome far red is stable in red light its concentrations is more during the day. Phytochrome red favours flowering in SDPs but inhibits it in LDPs. Phytochrome far red favours flowering in LDPs; inhibits it in SDPs. During the day, presence of plenty of red light causes rapid conversion of phytochrome red to phytochrome farred. Phytochrome far red induces release of florigen stimulating the dormant buds of LDPs to develop into flowers. In SDPS, subjecting the plant to longer hours of the night (short day), enables the slow conversion of phytochrome far red to phytochrome red. Phytochrome red stimulates the release of florigen that activates dormant buds to bloom into flowers.



Question 12.

(a) Explain what is meant by vernalisation? ***(03 marks)***

(b).Explain the effect of light or darkness interruptions on flowering in angiosperms ***(10 marks)***
(c).Explain geotropism in plants ***(07 marks)***

(a).

Vernalisation refers to the exposure of the plant to low temperature requirements at allow initiation of flowering. The buds would stay dormant until exposed to temperatures as low as 4°C These temperatures stimulate the release of the hormone vernalin from the shoot apex; travels to dormant buds causing them to develop into flowers. The hormone also stimulates secretion of growth promoters like gibberellins which potentiate development of buds into flowers.

(b).

For short night/long day plants

Interruption of the short night with brief periods of white light; has no effect on flowering (flowering occurs) because the interruption causes shorter nights; that maintain a higher concentration of stimulatory phytochrome far red (P_{fr}); compared to inhibitory phytochrome red(P_r) since P_{fr} to P_r conversion is slow and requires exposure of the plant to longer nights.
Interruption of the long day with brief periods of darkness; does not affect flowering; because of still a higher concentration of stimulatory P_{fr} compared to inhibitory P_r. Interruptions of long days with long periods of darkness; flowering fails; due to conversion of stimulatory Pfr to inhibitory P_r such that P_r concentration greatly exceeds that of P_{fr}

For short day/long night plants

Interruptions of the long nights with brief periods of white light; no flowering occurs because the interruption causes rapid conversion of stimulatory P_r to inhibitory Pf_r . Besides, the interruption splits the long night into two short nights. The Inhibitory effect of flashing white light in the middle of the night; is reversed by providing longer interruptions with far red light.

Day neutral plants

Flowering is not affected by any form of light/darkness interruptions, because flowering of these plants is independent of the photoperiod.

(c).

Geotropism is the plant's movement to unidirectional gravitational force. The plant's shoot is negatively geotropic while roots are positively geotropic. Geotropism is controlled by auxins growth substance that mediates differential growth. During germination, when a horizontally lying seedling is subjected freely to gravity, auxins are made to accumulate on the lower sides of both the radicle and the plumule. A high concentration of auxins on the underside of the plumule causes differential growth in which there is more growth on underside; causing upward curvature of the shoot. On the other side, growth is inhibited on the underside of the radicle; causing downward curvature of the root. Geotropism is also attributed to statoliths, special starchy granules whose free fall under gravity initiates geotropism, increase in temperature decreases time of fall of the statoliths.

Question 13.

(a)Compare positive and negative feedback mechanisms of homeostasis ***(05 marks)***
(b).Explain the role of positive feedback in;
(i).Nervous transmission;
(ii)Parturition ***(10 marks)***
(c).Explain how the deviation in oestrogen level in blood is reduced to norm ***(05 marks)***

(a).

Similarities

• Both feedback mechanisms are triggered by a deviation from the norm physiological set point.
• Both feedback mechanisms involve the joint activities of the detector, controller and effectors.

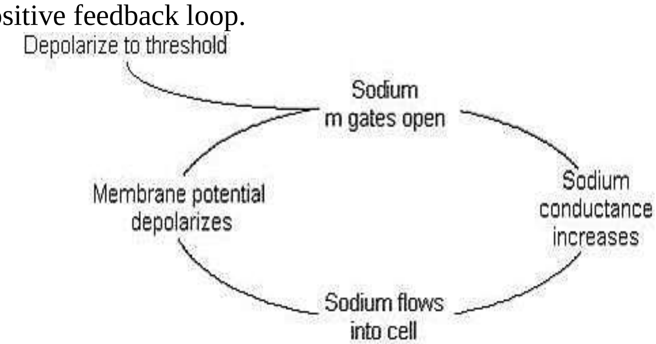
Differences

Positive feedback	Negative feedback
Corrective mechanisms continuously amplify the deviation from the physiological set point	Corrective mechanism nullifies/stops further deviation from the norm.
Aim is to potentiate further deviation from the Norm	Aim is to restore back the physiological set point (norm).

Detector always switched on; recognizes deviation the deviation; and continuously alert the controller	Detector gets switched off such that the controller is no longer alerted of the deviation.
Few in biological systems	Common in biological systems.
Examples include the clotting cascade, oxytocin release, nerve impulse transmission.	Examples include blood sugar regulation, regulation of hormones like anterior pituitary hormones, enzyme activity etc

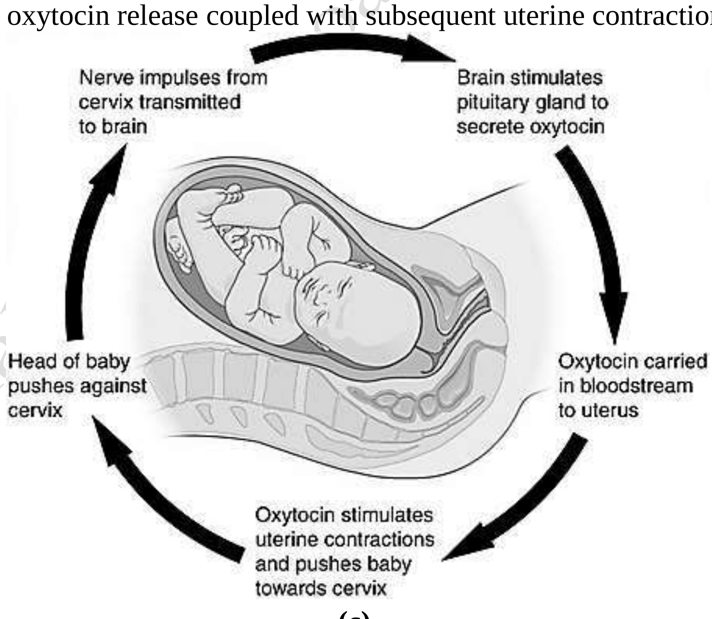
(b)(i).

Propagation of impulse causes cancellation of the negative resting potential; at a point that is completely depolarized; making the axonal membrane potential positive. Sodium gates, being sensitive to depolarization permit more sodium channels to open increasing sodium ion influx. As sodium ions pass into the axon through the membrane, they cause a further depolarisation. Depolarisation and sodium channel opening keep reinforcing and amplifying each other; constituting a positive feedback loop.



(b)(ii).

Head of the foetus pushes against the cervix; nerve impulses from the cervix are transmitted to the brain; posterior pituitary gland is stimulated to secrete oxytocin which is carried through the blood stream to the uterine walls; cause release of prostaglandins that initiate uterine contractions causing the foetus to push further toward the cervix; and this further amplifies more oxytocin release coupled with subsequent uterine contractions.



(c).

Oestrogen levels are regulated by negative feedback mechanisms by the hypothalamo-pituitary-gonadal axis. High levels of oestrogen suppress synthesis of kisspeptin a stimulatory protein that activates release of gonadotrophin releasing hormone (GnRH) from the hypothalamic neurons. Levels of GnRH thus reduce and this inhibits release of gonadotrophins (FSH and LH) from the pituitary gland; follicular growth of the ovaries and eventual ovulation ceases. Release of oestrogen from the theca and granulosa cells of the Graafian follicle is finally terminated till the physiological set point is re-established.

Question 14.

(a).Define the term generator potential *(01 marks)*
(b).Describe the behavior of a receptor cell in absence and presence of an appropriate stimulus *(15 marks)*
(c).State four structural differences between the two main branches of the autonomic system *(04 marks)*

(a).

Generator potential refers to the membrane potential established at the sensory cell after its local depolarisation in response to a graded strength of a stimulus applied to the associated receptors.

(b).

At rest, potassium channels open while sodium channels close; thus K^+ freely diffuses the axoplasm to the ECF without reciprocal entrance of Na^+. Sodium-potassium pumps pump out three sodium ions in exchange for two potassium ions. The net effect is a high cationic concentration on the outer axonal membrane relative to the inner making the membrane positively charged on the outside relative to the inside. Membrane gets polarized and resting potential is established; no impulse is transmitted to the sensory neurons. Upon stimulation of the sensitive parts of the receptor cell; there is reversed permeability of axon membrane to sodium and potassium ions; sodium channels open; potassium channels close; thus membrane becomes more permeable to sodium ions than potassium ions; causing an influx of sodium ions into the inner membrane along the electro-chemical gradient. Inner axonal membrane therefore becomes more positive relative to the outside; membrane gets depolarized. The established membrane potential difference constitutes the receptor or generator potential. A subliminal or subthreshold stimulus fails to evoke an action potential; while a threshold stimulus establishes an action potential; builds to the threshold creates an action potential; fires an impulse across the axonal membrane of the sensory neurons.

(c).

Sympathetic nervous system	Parasympathetic nervous system
Short pre-ganglionic fibres	Long pre-ganglionic fibres.
Long post-ganglionic fibres	Short post-ganglionic fibres.
Autonomic ganglion is close to the central nervous system(CNS);far away from the effectors	Autonomic ganglion is closer to the effector organ; far away from the CNS
Emerge from lumbar and thoracic segments of the spinal cord.	Emerge from the brain (cranial nerves) and a few from the sacral spinal segment.
Numerous post-ganglionic fibres	Fewer post-ganglionic fibres
Noradrenergic receptors at the effector organs.	Cholinergic receptors at the effector organs.

Question 15.

(a).State the comparisons between nervous and hormonal control in animals *(07 marks)*
(b).Explain the mechanisms controlling the release of hormones by glands *(08 marks)*
(c).Outline roles of the coordination and control systems in living organisms *(05 marks)*

(a).

Similarities

• Both release chemical substances as a means of communication between cells.
• In both, their principle role is co-ordination & control of the major physiological activities of the body thus maintain steady state in an organism.

Differences

Nervous control	Hormonal control
Electrical impulses and chemical transmission	Chemical transmission (hormones)
Rapid transmission and response	Slower transmission and relatively slow acting (adrenaline is an exception)
Offers short term changes/ effects	Offers long term changes
Response often very localized	Response may be very wide spread.
Pathway is specific (through nerve cells)	Pathway is not specific i.e hormones circulate in the blood stream to specific target sites
Origin of stimulus is sense receptor or organ.	Origin of stimulus is gland
Destination of stimulus is to specific point.	Destination is all over the body.

Site of action is the effector (muscle or gland)	Site of action is the target organ
Destination of stimulus is all over the body	Destination of the stimulus is to a specific part

(b).

Presence of specific metabolite in the blood; e.g excess glucose in blood causes release of insulin from the pancreas; lowering blood glucose levels.

Presence of another hormone in the blood stream; The release of trophic hormones depends on the presence of releasing hormones/ inhibiting factors secreted from the hypothalamus.

Stimulation by the autonomic nervous system (ANS); e.g adrenaline and noradrenaline are, released from the adrenal medulla in response to nervous stimulation arising from situations of fear, anxiety, stress and danger.

Influence of the internal biological control; release of hormone like gonadotrophins are under biorhythmic control of the internal biological clock.

(c).

• Effective cellular communication in multicellular organisms.
• Effective reception of stimuli by receptors.
• Effective transmission of sensory impulses to the central nervous system (CNS).
• Comprehensive and effective interpretation of stimuli by the CNS.
• Tailors an appropriate response to a given stimulus through the peripheral nervous system.
• Control body's physiological and metabolic processes; maintaining the body's steady state.
• Permits rapid escape of the organism from life threatening stimuli.

Question 16.

(a).Distinguish between

(i). Spatial summation and temporal summation ***(04 marks)***

(ii) Apposition eye and superposition eye ***(04 marks)***

(b).Compare the mammalian eye and an arthropod's compound eye ***(08 marks)***

(c).Explain the functions of auxins in plants ***(04 marks)***

(a)(i).

Spatial summation is when multiple post synaptic potentials (excitatory or inhibitory) from different pre-synaptic neurons add up to reach threshold and generate action potential that fires an impulse in the post-synaptic neuron while temporal summation is when a high frequency of action potentials in a single pre-synaptic neuron elicits post-synaptic potentials that overlap and add up with each other to reach threshold causing firing of an impulse in the post-synaptic neuron.

(a)(ii).

Apposition eye is a compound eye in which each ommatidium focuses only rays that are almost parallel to its long axis, so that each forms an image of only a very small part of the visual field. The image of the whole results from a combination of these part images e.g. in diurnal insects while Superposition eye is a compound eye in which the sensory cells of an ommatidium can pick up light from a large part of the visual field so that the image received may overlap those received by as many as 30 neighboring ommatidia. The superposition image has much brightness but low in sharpness compared with the apposition image e.g. in nocturnal insects.

(b).

Similarities

• Both have lenses
• Both have light sensitive cells

Differences

Mammalian eye	Arthropod's eye
Lens is elastic	Lens is inelastic
Eye has varied focus	Eye has a fixed focus
Lens is non-crystalline	Lens is crystalline
Movable eye due to muscle attachment	Eye is immovable because of no muscular attachment
High resolving power in bright light	Low resolving power

One visual unit	Several visual units/eyelets called ommatidia
Has both cones and rods	Has only cones
Capable of colour perception	Incapable of colour perception
Lower visual acuity due to fewer cones	Higher visual acuity due to numerous ommatidia
Lower sensitivity to light due to single eyelet	Higher sensitivity due to numerous eyelets
Forms a single non-overlapping image	Images overlapping with poor quality of vision
Narrow field of view	Wider field of view

(c).

Cell elongation; auxins cause elongation of cells just below the tip of the shoot/root resulting in growth.
Fruit growth; auxins promote enlargement of many fruits by causing cellwalls of fruit to stretch in all directions
Induce parthenocarpy; auxins do promote development of fruits without fertilization.
Root initiation; auxins are regarded; rooting hormone because they promote root development when applied to stem cuttings.
Apical dominance; allow growth of apical/terminal buds and inhibit growth of lateral buds.
Suppression of abscission; antagonize effects of Abscissic acid; thereby preventing pre-mature leaf and fruit fall

Question 17.

(a).Explain why the eyes of the cat glow at night when shone with a flash of light ***(07 marks)***
(b).Explain the trichromacy theory of colour perception ***(10 marks)***
(c).How does the human eye adjust itself in order to focus a near object ***(03 marks)***

(a).

Lying immediately behind the retina of a cat is a shiny layer called the tapetum lucidum that reflects visible light back through the retina, increasing the light available to the photoreceptors. The tapetum lucid- um contributes to the superior night vision of cats. The tapetum lucidum functions as a retroreflector which reflects light directly back along the light path maintaining the sharpness and contrast of the image on the retina. The reflection also occurs by constructive interference thus increasing the quantity of light passing through the retina hence the sensitivity of the cat's eye to light also increases.

(b).

According to the trichromacy theory of colour perception, iodopsin, the photosensitive pigment in the outer segment of cones, exists in three isoforms; each occurring in one of the three cones and is sensitive to either red, blue or green light. Differential stimulation of the red, green and blue cone by light of a particular wavelength leads to bleaching of corresponding isoform of iodopsin; establishing an action potential; information is relayed to the brain which interpretes colour corresponding to wavelength of the stimulant light e.g 100% green, red and blue cone stimulation leads to perception of green, red and blue colours respectively, secondary colours are perceived when there is equal stimulation of any two of the cones while equal stimulation of all the three cones yields white. Black is perceived when there is stimulation of none of the cones.

(c).

Ciliary circular muscle contract; radial muscles relax; tension in the suspensory ligaments is released; lens becomes more convex/thicker/ more curved; refract diverging light rays form a point object forming a sharp image of a near object on the retina.

Question 18.

(a).State four differences between electrical synapses and chemical synapses ***(04 marks)***
(b).Describe how an impulse is transmitted across a chemical synapse ***(16 marks)***
(c).Explain how acetylcholine; one that excites skeletal muscular activity will inhibit heart rate ***(07 marks)***

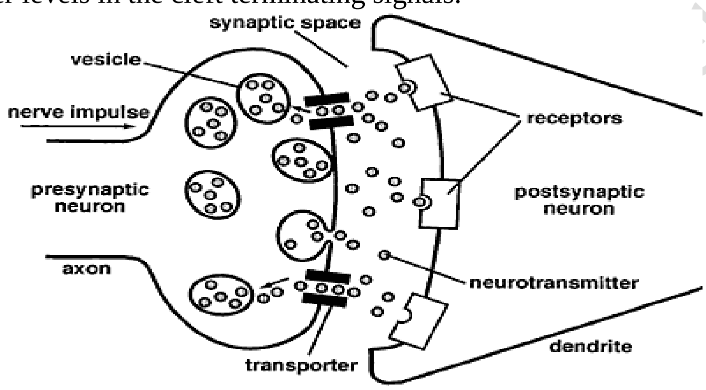
(a).

Electrical synapse	Chemical synapse
Shorter synaptic cleft	Longer synaptic cleft
Transmission mediated by an ion current that flows over the synaptic cleft.	Transmission mediated by chemical neurotransmitters over the synaptic cleft.
Faster transmission	Slower transmission
Bi-directional transmission	Uni-directional transmission

Longer refractory periods thus some delay in transmission.	Shorter refractory periods thus no delay in transmission

(b).

Action potential arrives at the axon terminal cause depolarization of the pre-synaptic membrane; calcium voltage gated channels open allowing calcium ion influx; calcium sensing proteins on the vesicles bind with the calcium ions; activating the vesicles which migrate to the pre-synaptic membrane, fuse with it release neurotransmitter by exocytosis; Calcium ions quickly diffuse back to the synaptic cleft; Neurotransmitter diffuses through the synaptic cleft; and then binds to specific receptors on the post- synaptic membrane which are ligand gated ion channels; These open causing differential ionic exchanges resulting in graded potentials; Excitatory neurotransmitters like acetylcholine make the post synaptic membrane for an excitatory synapse more permeable to Na^+ than K^+; depolarizing it hence forming an excitatory post synaptic potential (EPSP). Inhibitory neurotransmitters like GABA or glycine cause opening of the Cl^- channels of the post synaptic membrane; hyperpolarization occurs forming an inhibitory post synaptic potential (IPSP). Re-uptake by pre-synaptic neurons; enzymatic degradation and diffusion; reduces neurotransmitter levels in the cleft terminating signals.



(c).

The acetylcholine released at the vagal nerve endings greatly increases the permeability of the fiber membranes to potassium ions, which allows rapid leakage of potassium out of the conductive fibers. This causes increased negativity inside the fibers, an effect called hyperpolarization, which makes this excitable tissue much less excitable. This decreases the rate of rhythm of the sinus node, as well as decreasing the excitability of the A-V junctional fibers between the atrial musculature and the A-V node. This therefore slows the transmission of the cardiac impulse into the ventricles.

The same acetylcholine has excitatory effects on the skeletal muscles, when the acetylcholine bind onto a specific receptor molecules on the post synaptic membrane, it causes the sodium gates to open while chloride gates and potassium gates to close sodium ions diffuse rapidly inside the sarcoplasm; the inside of the membrane become more positive while the outside more negative; the membrane is depolarized; resulting into the excitatory post synaptic potential; which increases to reach a threshold value and action potential is generated;

Question 19.

(a).With examples, distinguish between synergism an antagonism ***(04 marks)***
(b).Outline the commercial uses of plant growth substances ***(14 marks)***
(c).Describe the role of oestrogen in the menstrual cycle ***(02 marks)***

(a).

Synergism is the interaction of two or more growth substances (hormones) to produce an effect that is greater the individual effect of each hormone e.g auxins and gibberellins interact synergistically to bring about internode elongation While antagonism is a condition in which interaction of two or more growth substances/ hormones produce opposing effects to each other e.g gibberellins break seed dormancy and thus allows germination but presence of Abscissic acid opposes stimulatory effects of gibberellins and thus promotes seed dormancy.

(b).

• Synthetic auxins utilized as rooting agents on stem cuttings and for development of adventitious roots.

• Controlled amounts of auxins utilized as selective weed killers in cereal crops.
• Auxins are utilized as anti-abscission agents; preventing premature leaf and fruit fall
• Auxins have been used to delay flowering until an appropriate time.
• Auxins have been used increase fruit size.
• Auxins are utilized as anti-sprouting agents in potatoes; prolonging their storage time
• Gibberellins and auxins utilized as fruiting (parthenocarpic) agents.
• Gibberellins utilized as germination promoters
• Gibberellins utilized as bolting agents in rosette plants like cabbages.
• Gibberellins utilized as internode elongating agents in genetically dwarf plants.
• Gibberellins utilized as modifier of sex of flowers as it promotes male flowers than female ones
• Ethylene utilized as a fruit ripening agent.
• Abscissic acid utilized as a germination inhibitor/ dormancy promoter
• Abscissic acid utilized as a sex modifier of plant flowers as it promotes female flowers.
• Cytokinins used on vegetables to preserve green colour/ anti-aging agent in plants; hence important in prolonging the life of flesh leafy crops such as cabbages, lettuces etc.

(c).

• Ensures re-epithelialization of endometrium, vascularization, repair & preparation of the uterus for implantation.
• Small amounts of oestrogens inhibit the production of FSH and LH by negative feedback

Question 20.

(a).Explain why cyclic AMP is referred to as a second messenger ***(04 marks)***
(b).Compare
(i).Tropisms and nastic responses ***(08 marks)***
(ii).Plant and animal hormones ***(08 marks)***

(a).

cAMP acts as an intracellular chemical messenger; activating specific enzyme catalysed reactions (cascade reactions) after it has been produced in response to a hormone (first messenger) that attaches onto receptor sites on the cell surface membrane.

(b)(i).

Similarities

• Both are plant responses to external stimuli
• Both are co-ordinated responses involving either hormones or electrochemical messengers
• Both may involve growth curvatures

Differences

Nastic response	Tropic response
Depends on external stimuli	Depends on the direction of the stimuli
Involves growth or turgor changes	Involves growth only
Are relatively fast	Are relatively slower
Dependent on electrochemical messengers	Dependent on hormones like auxins
Takes place in any part of the plant	Occurs in the growing parts of the plant

(b)(ii).

Similarities

• Both are organic substances
• Both act in low concentration.
• They exert their effect on other parts of the organisms other than where they are made.

Differences

Plant hormones	Animal hormones
Mainly exert growth effects	Affect a number of other physiological effects other than growth
Produced from unspecialized cells	Produced from specialised cells of the endocrine tissues

Exert effects quite close to their site of production	Exert effects at distant sites from the site of production
Lack Specifity; influence different tissues and organs sometimes in contrasting ways.	Affect specific target areas and have no effect on other organs
Tend to interact with each other in the control of growth.	Often act singly in bringing about a specific change.

Question 21.

(a).Outline the effect of light via phytochrome system on the different physiological process in plants
(b).Compare the effects of the various phytohormones ***(11 marks)***

(a).

Physiological processes	Effect of far red light and of darkness	Effect of red light and of white light
Germination of small seeds	Inhibits	Promotes
Growth of internodes	Promotes	Inhibits
Development of chlorophyll	Inhibits	Promotes
Chlorophyll synthesis	Inhibits	Promotes
Leaf expansion	Inhibits	Promotes
Lateral root growth	Promotes	Inhibits
Flowering in long day plants	Inhibits	Promotes
Flowering in short day plant	Promotes	Inhibits
Leaf fall (deciduous species)	Promotes	Inhibits

(b).

• Both auxins and gibberellins promote cell division in apical meristems; induce parthenocarpy; stimulate fruit growth; bring about cell enlargement in return growth; stimulate flowering in long day plants; cytokinins promote cell division in presence of auxins; both gibberellins and cytokinins promote lateral bud growth.
• Auxins promote apical dominance while gibberellins stimulate auxiliary root growth
• Auxins promote flowering in short day plants while gibberellins inhibit flowering in SDPs.
• Auxins promote femaleness in flowers while gibberellins promote maleness
• Auxins promote root initiation from stem/leaf cuttings while gibberellins inhibit development of adventitious roots.
• Phytochrome red inhibits stem elongation while phytochrome far red stimulates flowering in LDPs but inhibits it in SDPs
• Phytochrome red stimulates flowering in SDPs but inhibits it in LDPs.
• Ethylene/ ethene inhibits cell elongation while gibberellins promote cell elongation
• Abscissic acid stimulates bud dormancy while gibberellins break bud dormancy
• Lateral root growth is inhibited by phytochrome red but stimulated by phytochrome far red.

Question 22.

(a).Explain what is meant by the
(i).“All or nothing law” ***(02 marks)***
(ii).Refractory period ***(06 marks)***
(iii)Facilitation in relation to temporal summation ***(04 marks)***
(b).Explain the advantages and disadvantages of synaptic transmission ***(08 marks)***

(a)(i).

The law states that the magnitude of the action potential generated is always constant regardless of the amount of stimulus applied provided the stimulus is above threshold.

OR if the strength of the stimulus is below certain threshold intensity, no action potential is evoked. If, however the stimulus is above the threshold, a full sized potential is evoked and remain the same however much intensity the stimulus becomes.

(a)(ii).

It's the period of in-excitability that accompanies the recovery phase of the axon and it lasts for approximately 0.3 s. It is categorized into: **Absolute refractory period:** where the axon is completely incapable of transmitting an im-pulse regardless of the magnitude and duration of the stimulus. **Relative refractory period:** where it is possible to generate an impulse provided that the stimulus is longer than normal. Refractory period is important because it determines the maximum frequency at which an axon can transmit an impulse, ensures separation of action pote-ntial and specify the stimulus causing the excitation as well as preventing spreading of action potential and makes it flow in one direction.

(a)(iii).

Facilitation process involves the first impulse transmission being insufficient to trigger off an impulse in the post synaptic membrane but cause an effect therefore the second faster stimulation will add to the former and generate an impulse at the post synaptic membrane. The rapid repeated release of transmitter substance from several synaptic vesicles by the same synaptic knob as a result of an intense stimulus produces individual excitatory post synaptic potentials (EPSP) which are so close together that they summate and give rise to an action potential in the post synaptic membrane.

(b).

Advantages of synaptic transmission

- Transmits information within neurons.
- Directs impulse flow into one direction only
- Site for summation; both temporal and spatial.
- Site for integration of different sensory and motor information.
- Allow adaptation to a continous/ repetitive stimulus which may otherwise cause damage to effectors.
- They enable the body respond to weak stimuli as a result of facilitation.
- They are the physical basis of learning and memory.

Disadvantages of synaptic transmission

- Slows down the speed of transmission
- Are highly prone to drugs and fatigue which may inhibit impulse transmission.

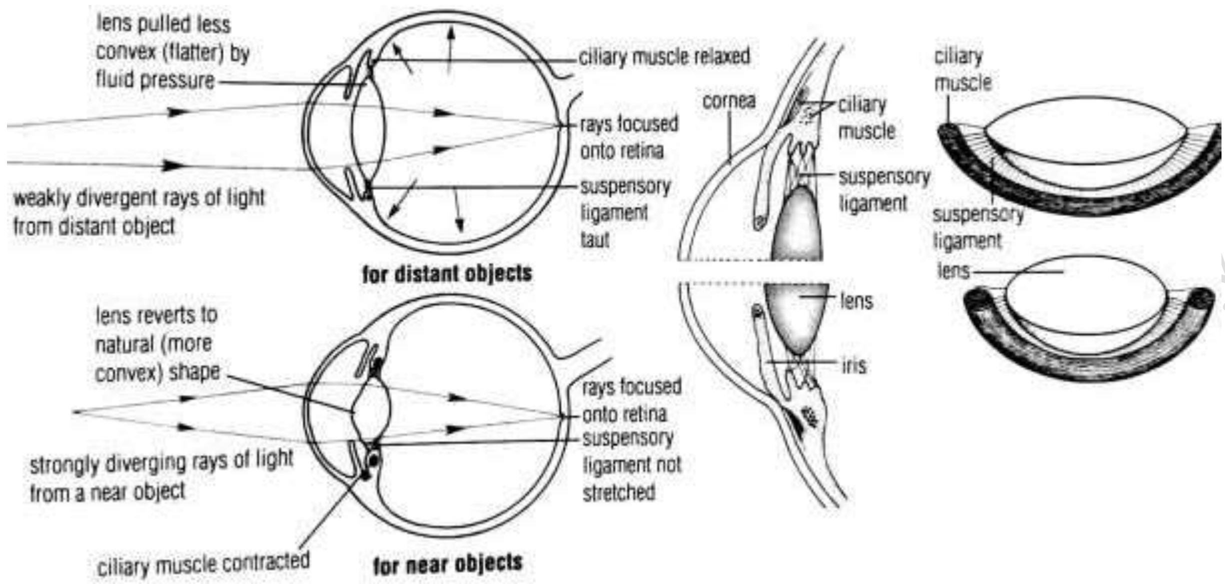
Question 23

(a).Outline the core principles behind which a human eye operates ***(04 marks)***
(b).Briefly describe the mechanisms of accommodation of the human eye ***(10 marks)***
(c)(i).Describe the structure an arthropod's compound eye ***(06 marks)***
(c)(ii)Outline reasons why having two eyes(binocular vision) is better than having one ***(03 marks)***

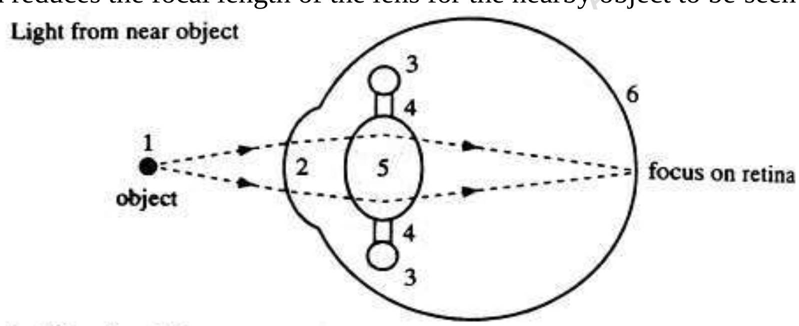
(a).

- Control of the amount of light entering the eye.
- Focus of the objects by the lens system
- Focussing images on a photosensitive surface
- Processing a captured image by the CNS to produce a sensible interpretable pattern which can be seen.

(b).

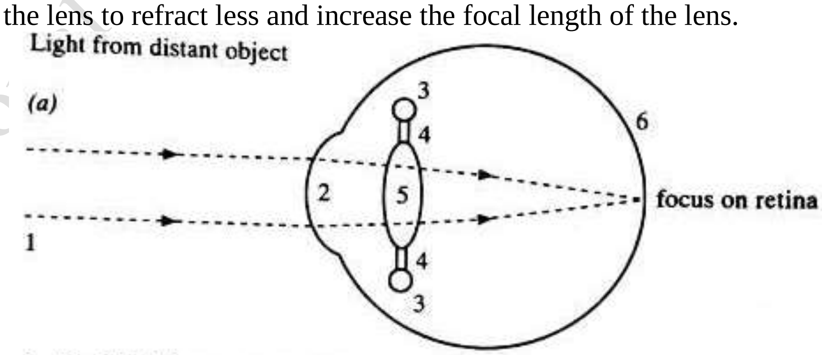


Accommodation for a nearby object: When looking at a nearby object, the ciliary muscles in the ciliary body contract, the suspensory ligaments slacken. This makes the lens short and thick. This increases the ability of the lens to refract light and reduces the focal length of the lens for the nearby object to be seen clearly.



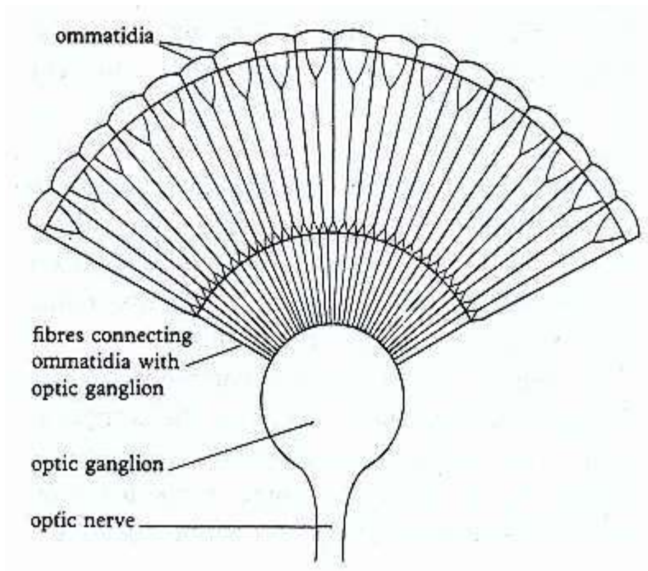
1 Diverging light rays reach eye
2 Cornea refracts (bends) light rays
3 Circular ciliary muscle contracted
4 Suspensory ligament slack
5 Elastic lens more convex
6 Light focused on retina

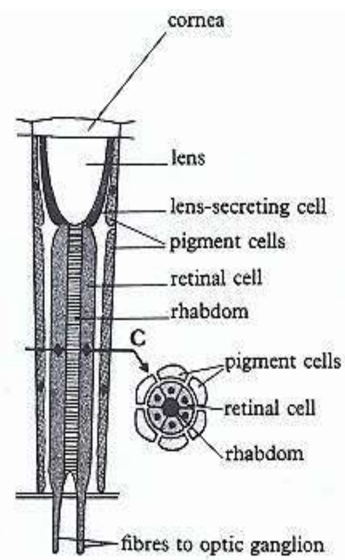
Accommodation for a distant object: When viewing a distant object, the ciliary muscles in ciliary body relax. This causes tension in the suspensory ligaments. The suspensory ligaments pull the lens apart making the lens thin and long. This makes the lens to refract less and increase the focal length of the lens.



1 Parallel light rays reach eye
2 Cornea refracts (bends) light rays
3 Circular ciliary muscle relaxed
4 Suspensory ligament taut
5 Lens pulled out thin
6 Light focused on retina

(c)(i).





An arthropods eye is a globular ovoid crystalline organ made up of numerous functional eyelets called ommatidia; Each ommatidium has elongated retinal cells surrounding the centrally placed light-sensitive rhabdom. The cone-shaped lens is capped by a flattened cornea while the lower part borders retinal cells and the sides are surrounded by the lens secreting cells. The rhabdom and retinal cells are connected to optical nerve cells. The rhabdom is formed from concentration of microvilli from retinal cells. The ommatidia are separated from each other by varying degrees of pigmentation. Photo-active reactions in the rhabdom cause depolarisation in retinal cells.

(c)(ii).

• Binocular vision gives a larger field of view
• A defect in one eye doesnot result in blindness i.e can be partly compensated by the other eye.
• Provides potential for stereoscopic vision for animals with two forward facing eyes.

Question 24

(a). With three examples, explain what is meant by lateral inhibition and give examples of its effects in these three sensory systems ***(10 marks)***
(b).Briefly describe the refraction errors of a human eye and how they can be corrected ***(10 marks)***

(a).

Lateral inhibition is a central nervous system phenomenon by which sensory information is sharpened by inhibition of incoming neighboring (lateral) field information from the periphery of that region which is maximally stimulated. The three sensory systems utilizing lateral inhibition are the senses of touch (cutaneous), hearing and vision.

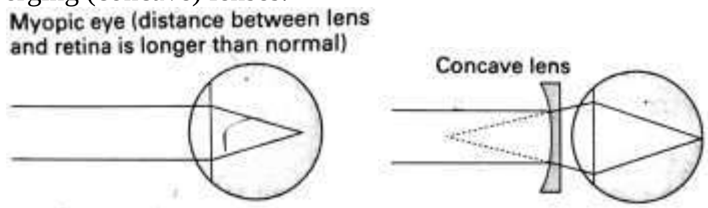
In the skin, a single touch is felt when a blunt object touches the skin because the surrounding fields have been laterally inhibited at the level of the central nervous system.

In the discrimination of different pitches of sounds with similar frequencies; neural activity is laterally inhibited so that the hair cells along the basilar membrane which are maximally displaced by sound waves are selected for interpretation by the auditory cortex of the brain while hair cells with neural activity from the surrounding regions are suppressed.

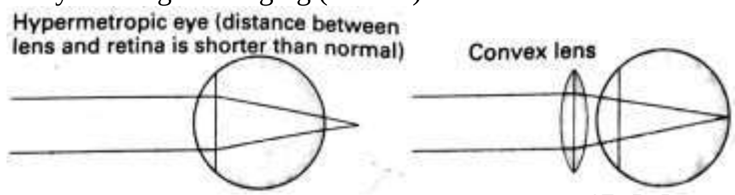
Lateral inhibition is also at work in the **processing of visual information** at the level of the ganglion cells in the retina. Here, the receptive fields of each ganglion cell resembles a bull's eye with a central core area and an outer surround area that oppose one another, that is, are antagonistic. Those ganglion cells that have on-center fields are excited by light at the center of their visual fields while the surround is suppersssed (or inhibited laterally). Those ganglion cells that have off center fields are inhibited by light in the center and stimulated by light in the surrounding Due to the distribution of these two types of ganglion cell fields along the retinal surface, incoming light excites some and inhibits some of these fields which translates later at the occipital (striate) cortex as sharper visual acuity.

(b).

Short sightedness (myopia): This is usually caused by a large eyeball or a very strong lens. Light from a distant object is focused in front of the retina. The individual can only see nearby object but not distant ones. This can be corrected by putting on diverging (concave) lenses.



Long sightedness (hypermetropia): This is caused by a small or short eyeball or a very weak lens such that a close object is focused far behind the retina. The individual can see distant objects but cannot see nearby objects. Long sightedness can be corrected by wearing converging (convex) lenses.



Astigmatism; This is caused by unequal refraction of the cornea and lens due to uneven curving in them. It results into some parts of the object being well focused on the retina and some not to be focused. It is normally due to old age. This can be solved by wearing cylindrical lenses.

Presbyopia; occurs when the lens hardens due to old age and does not focus. It can be corrected by wearing spectacles with convex lenses or often 2 pairs of spots may be necessary i.e. a pair with convex lenses for close vision and pair of concave lenses for distant vision or the two types of lenses can be combined into one pair known as bifocal spectacles.

Cataract; It is a condition which occurs when an individual is aging. It is caused by the eye lens becoming opaque due to a thin covering formed on it. It is corrected by surgical removal of the thin opaque layer of the lens.

Question 25

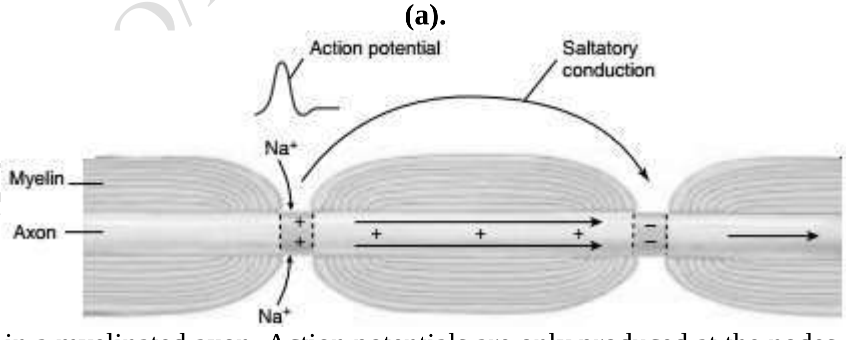
(a).Explain the events that occur during saltatory transmission/ conduction ***(06 marks)***

(b)(i).With aid of a schematic diagram, outline the basic organization of vertebrate nervous system

(b)(ii).Distinguish between somatic nervous system and peripheral nervous system ***(02 marks)***

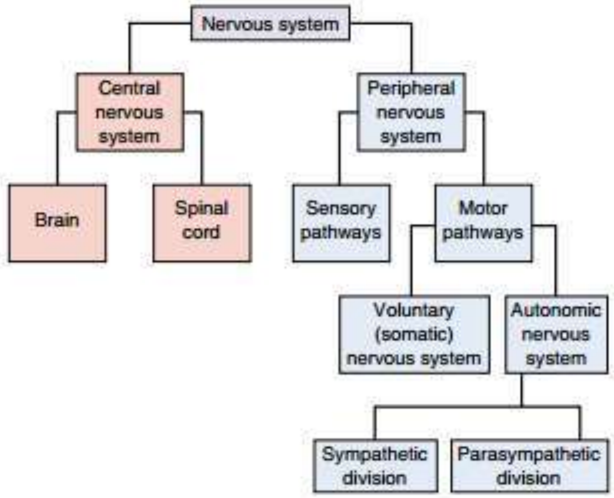
(c).Describe the physiology behind drug addiction in the people who overuse drugs such as cannabinoids like marijuana ***(08 marks)***

(a).



Saltatory conduction in a myelinated axon. Action potentials are only produced at the nodes of Ranvier in a myelinated axon. One node depolarizes the next node so that the action potentials can skip between nodes. As a result, saltatory (leaping) conduction in a myelinated axon is more rapid than conduction in an unmyelinated axon.

(b)(i).



(b)(ii).

The somatic nervous system is a component of the peripheral nervous system which controls activities where an individual has conscious control over. It includes sensory neurones that sense external stimuli and motor neurones which supply skeletal muscles. Autonomic nervous system on the other hand is that part of peripheral nervous system that controls activities where an organism has little or no conscious control

(c).

In a normal synapse, the neurotransmitter binds to a transporter molecule and is rapidly reabsorbed after it has acted. When a drug molecule binds to the transporters, reabsorption of the neurotransmitter is blocked and the post synaptic cell is overstimulated by the increased amount of neurotransmitter left in the synapse. The central nervous system adjusts to the increased firing by producing fewer receptors in the post- synaptic membrane. The result is addiction and when the drug is removed, normal absorption of the neurotransmitter resumes, and the decreased number of receptors creates a less-sensitive nerve pathway. Physiologically, the only way a person can then maintain normal functioning is to continue to take the drug. Only if the drug is removed permanently will the nervous system eventually adjust again and restore the original amount of receptors.

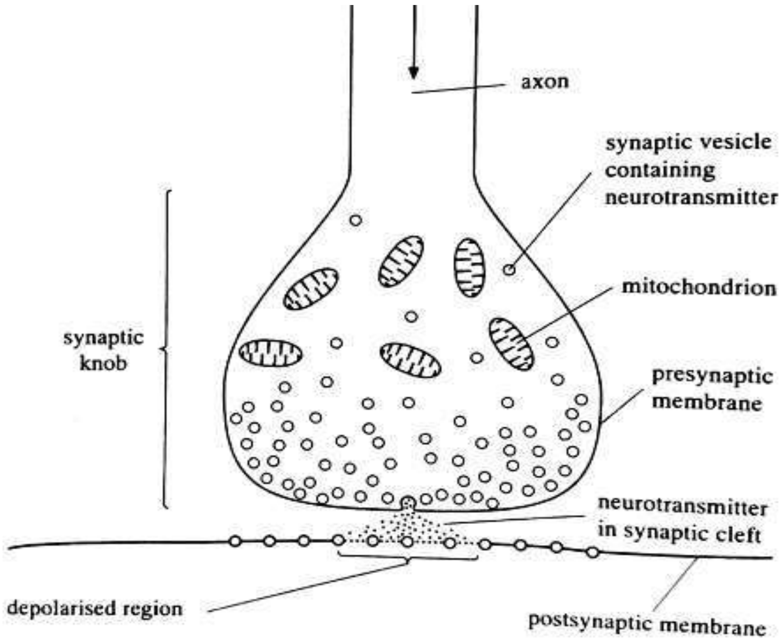
Question 26

(a).Describe the structure of a synapse *(05 marks)*

(b).With the aid of an appropriate graph, explain the membrane potential changes that occur in a neuron right from rest to transmission of successive impulses *(07 marks)*

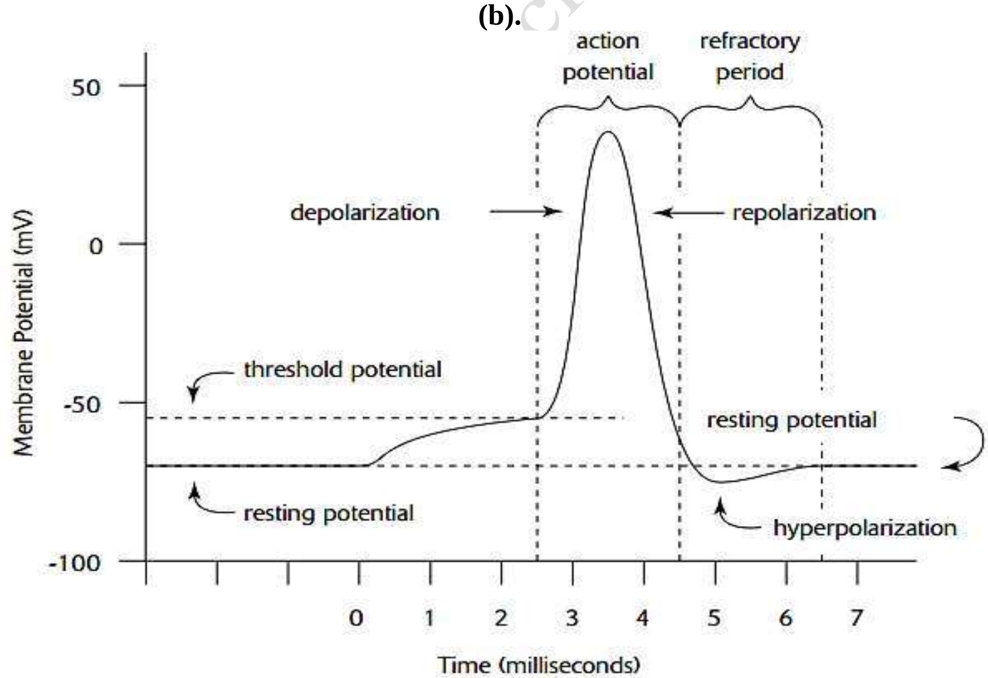
(c).Explain the physiology of acetylcholine as a neurotransmitter substance *(08 marks)*

(a).



The neuron whose axon transmits action potentials to the synapse is the presynaptic cell, while the cell on the other side of the synapse is the postsynaptic cell between which is a synaptic cleft that has a thin fluid film. The presynaptic membrane has calcium voltage gated channels. The end of the presynaptic axon is swollen and contains numerous synaptic vesicles, which are each packed with chemicals called neurotransmitters. The neurotransmitters diffuse rapidly to the other side of the cleft and bind to specific receptor proteins on the post-synaptic membrane.

(b).



At resting membrane potential, some K^+ channels are open and the Na/K pumps are active. In response to a stimulus, the cell begins to depolarize, and once the threshold level is reached, an action potential is produced. Rapid depolarization occurs (the rising portion of the spike) because sodium channels open, allowing Na^+ to diffuse into the axon. At the top of the spike, Na^+ channels close, and K^+ channels that were previously closed begin to open. With the K^+ channels open, repolarization occurs because of the diffusion of K^+ out of the axon. An undershoot occurs before the membrane returns to its original resting potential because of a K^+ efflux due to delayed closure of K^+ channels and influx of Cl^- through the open chloride channels.

(c).

Acetylcholine (ACh) crosses the neuromuscular junction or the post-synaptic junction. Acetylcholine binds to its receptor proteins in the postsynaptic membrane and thereby causes ion channels within these proteins to open. The opening of the chemically regulated channels permits Na^+ to diffuse into the postsynaptic cell at a faster rate than the K^+ that diffuse out. As a result, that site on the postsynaptic membrane produces a depolarization called an excitatory postsynaptic potential (EPSP). The EPSP then open the voltage-gated channels for Na^+ and K^+ that are responsible for action potentials. In skeletal muscle cell, the action potentials stimulate muscle contraction. For cholinergic synapses, the EPSPs produced must then travel through the dendrites and cell body to the initial segment of the axon of the adjoining neuron where the first action potentials will be produced, provided the EPSP depolarization is above threshold needed to trigger action potentials. The elimination of ACh is achieved by an enzyme in the postsynaptic membrane called acetylcholinesterase (AChE) which cleaves ACh into acetyl coA and choline which are its inactive fragments.

Question 27

(a).Discuss the functional characteristics of skeletal muscles ***(08 marks)***
(b).Explain the concept of echolocation in bats ***(06 marks)***
(c).State the structural adaptations of bats to enhance echolocation ***(06 marks)***

(a).

Excitability; the ability to respond to chemical and/or electrical signals and are neurogenic
Contractility; ability to shorten and cause movement of the structures to which the muscle is attached.
Extensibility; the capacity to stretch to normal resting length after contracting
Elasticity; the ability to return to the original resting length after the muscle has been stretched

(b)(ii).

Echolocation is the use of sounds made by the animal itself to avoid obstacles during flight and locate food in total darkness. Bats generate discrete pulses of ultrasound via the larynx and emit the sound through the open mouth or nose; then determine the time it takes for the sound to return, using the method of sonar to locate themselves and other objects in a totally dark environment. This is achieved by the characteristics of the echo. By using this information, the bat derives information on distance, direction, velocity and the nature of the reflecting object and thus makes decisions to avoid an obstacle, catch its preys or dip for water. The bat can as well access more than one target at a time perhaps perceives the 3D geometry of its surrounding.

(c).

• Unique larynx whose muscles are enlarged; cartilage fused and ossified to make a rigid framework
• Pinnae are large and enormous with a tragus.
• Cochlea is enormously enlarged with the basilar membrane narrow and tightly stretched.
• Constantly open nose; maintaining continuous and independent moving back and forth of sound.
• The nose has an epidermal modification like a horn and this directs the sound forward.
• Possess a nose leaf; an epidermal modification that amplifies and re-infuses sound

Question 28

(a).Distinguish between binocular vision and stereoscopic vision ***(04 marks)***
(b).Explain the following phenomena
(i) When a person moves from bright sunlight into a dimly-lit room; objects in the room cannot at first be seen but they gradually become visible. ***(04 marks)***
(ii) In the dimly-lit room, objects are only visible in black and white. ***(02 marks)***
(iii)Some nocturnal animals like cats close their pupils to a vertical slit and squint in bright light ***(04 marks)***
(iv).When trying to see a faint star in the sky, it is better to look slightly to one side of it rather than directly at it ***(04 marks)***
(v) If both your eyes are open and you press the side of one of your eyeballs, you see experience double vision.

(a).

Binocular vision; is vision in which both eyes aim simultaneously at the same visual target, equally and accurately as a coordinated team. Since the two eyes are placed close together, overlapping of visual angles allows more accurate judgment of distance of the object in front while **stereopsis or stereoscopic vision** is vision in which two separate images from two eyes are successfully fused/ overlapped into one image in the visual cortex of the brain.

First, both eyes must have binocular vision; then because the two eyes are located in different positions, each takes in a unique view from its own perspective sending two separate images to the brain simultaneously for processing, from where the images are fused into one three dimensional (3-D) image.

(b)(i).

In bright light, the circular muscles contract to narrow the pupil; and reduce on over-stimulation of the retinal cells by entry of light into the eye. In dim light, radial muscles contract to dilate the pupil slowly to allow entry of light; whose threshold at first is low to stimulate the rods for objects to be seen; but later improves to enable vision as the pupil dilates fully;

(b)(ii).

Rods which are sensitive to light of low intensity do not respond to light of various wavelengths causing images to appear black and white;

(b)(iii).

The retina of nocturnal animals is almost entirely composed of rods with rhodopsin which is particularly sensitive to low levels of light and breaks down so rapidly in bright light; The slit pupil and squinted eyes reduce the amount of light entering the eye to enable rhodopsin form faster than it breaks down for vision to occur;

(b)(iv).

When you look directly at an object, its image forms on the retina's Fovea centralis (yellow spot) which is packed with cone cells yet these are only activated by bright light, hence can't see in dim light. Looking slightly away from a faint star moves the image off the fovea and onto parts of the retina that have more rod cells, which are more light-sensitive than the cones.

(b)(v).

Pressing of eye ball distorts the eye position such that the two eyes are unable to look directly at an object in the same direction, hence the brain fails to blend together the images from the two eyes, causing double vision to be perceived.

Question 29.

(a).Distinguish between

(i). Exteroceptors and interoceptors *(02 marks)*

(ii).Primary receptors and secondary receptors *(02 marks)*

(b).Discuss Interoception using suitable examples highlighting the receptor, stimuli, location, structure and the process of transduction *(16 marks)*

(a)(i).

Exteroceptors are receptors that sense stimuli that arise in the external environment while Interoceptors are receptors that sense stimuli that arise from within the body.

(a)(ii).

Primary receptors consists of a single neurone which is sensitive to a particular stimulus and transmits nerve impulses to another neurone or effector; while a secondary receptor consists of a modified epithelial cell sensitive to a particular stimulus and a neurone.

(b).

Interoception

Stimuli	Introceptors	Location	Structure	Transduction
Temperature	(Thermoreceptors) Heat & cold receptors and cold receptors	Skin and hypothalamus	Free nerve ending	Temperature change opens/ closes ion channels in membrane
Touch	Meissner's corpuscles and Merkel cells	Surface of skin	Nerve ending within elastic Capsule	Rapid or extended change in pressure deforms the membrane
Vibration	Pacinian corpuscles	Deep within skin	Nerve ending within elastic Capsule	Severe change in pressure deforms membrane

Pain	Nociceptors	Throughout body	Free nerve ending	Chemicals or changes in pressure or temperature open/close ion channels in membrane
Muscle stretch	Stretch receptors	Within muscles	Spiral nerve endings wrapped around muscle spindle	Stretch of spindle deforms membrane
Blood pressure	Baroreceptors	Arterial branches	Nerve endings over thin part of arterial wall	Stretch of arterial wall deforms membrane

Question 30.

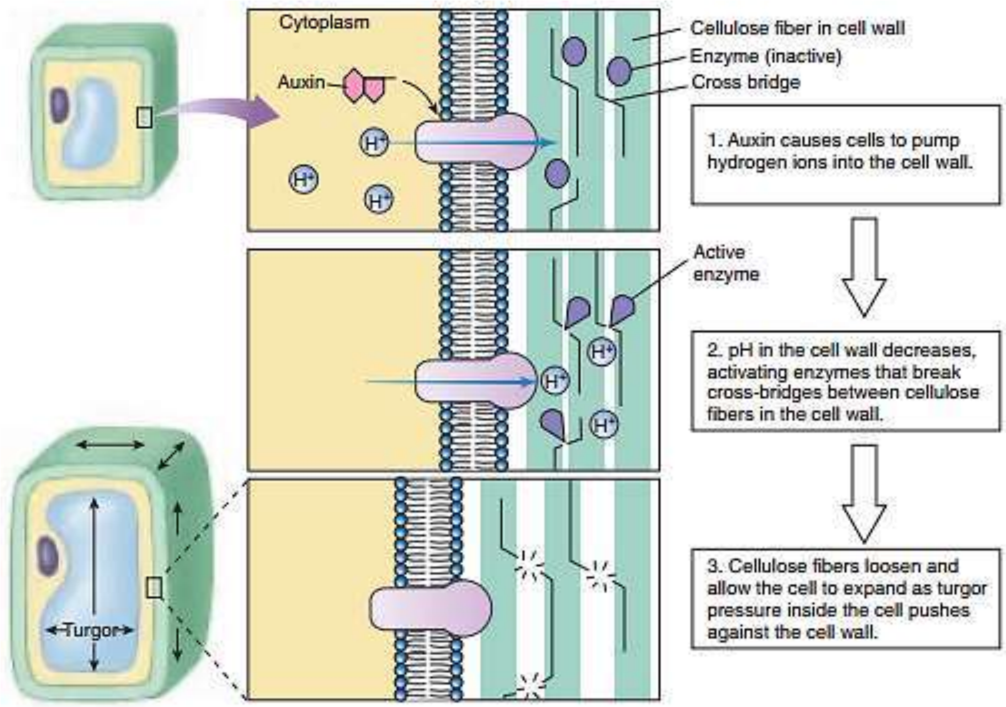
(a).State the functions of the major plant hormones and their sites of production ***(14 marks)***
(b).Describe the mechanism by which auxin bring about cell elongation in plants ***(06 marks)***
(c).Some buds remain dormant throughout the dry season. Why is this so? ***(05 marks)***

(a).

Auxin (IAA); produced from apical meristems and other immature parts of plants promote stem elongation and growth; formation of adventitious roots; inhibition of leaf abscission; promotion of cell division (with cytokinins); inducement of ethylene production and promotion of lateral bud dormancy
Cytokinins; produced from Root apical meristems and immature fruits stimulate cell division but only in the presence of auxin; promotion of chloroplast development; delay of leaf aging; and promotion of bud formation
Gibberellins; produced from root and shoot tips, young leaves and seeds. They Promote stem elongation of young and stimulate enzyme production leaves; in germinating seeds
Ethylene; produced from roots, shoot apical meristems, leaf nodes, aging flowers and ripening fruits. They participate in the control of leaf, fruit and flower abscission as well as promoting ripening of fruits
Abscissic acid; produced from leaves, fruits, root caps and seeds. ABA participates in inhibition of bud growth, control of stomatal closure; some control of seed dormancy; and inhibition of effects of other hormones
Brassinosteroids; produced from pollen, immature seeds, shoots and leaves. Have overlapping functions with auxins and gibberellins
Oligosaccharins; produced from cell walls. They participate in pathogen defense, and reproductive development.

(b).

Auxin stimulates the release of hydrogen ions from the target cells which alters the pH of the plant cell wall. This optimizes the activity of enzymes which break bonds in the cell wall, allowing them to expand.



(c).

Lateral bud inhibition or apical dominance; which is largely controlled by auxins. The gradient of auxins and gibberellins from the apical buds; attract food and cytokinins. Food substances eg sucrose from the leaf are translocated past the dormant lateral buds which have a higher concentration of growth inhibitors like ABA. Lateral buds are inhibited and they become dormant.

Question 31.

Each of the following events requires the recognition of a molecule. Explain how each of the following recognition processes occurs.

(a).Target cells recognize hormones. ***(07 marks)***

(b).B cells recognize antigens. ***(06 marks)***

(c).Postsynaptic membranes recognize neurotransmitters. ***(07 marks)***

(a).

There are two ways in which target cells recognize hormones. In cells that recognize steroid hormones, the hormone diffuses through the plasma membrane and nuclear envelope and binds with special receptor proteins in the nucleus. These receptors then activate transcription of specific genes. If the hormone is a peptide, the hormone binds to special receptor proteins on the plasma membrane surface. These receptors, in turn, trigger the conversion of ATP to cAMP, which, in turn, activates an enzyme that produces a particular cellular function.

(b).

B cells have special antigen receptors on their plasma membranes. In the production of B cells, millions of possible genetic combinations produce B cells with different kinds of receptors that will bind to different antigens. When an antigen enters the body, it will bind only to the B cell with the specific antigen receptor. When this occurs, B cells proliferate, producing plasma cells that have exactly the same antigen receptors. The antigen receptors are then released into the body fluids as antibodies, which bind and inactivate the antigens which stimulated their production.

(c).

When a neurotransmitter such as acetylcholine is secreted by the presynaptic membrane, diffuses across the synaptic cleft to the postsynaptic membrane. The neurotransmitter binds to one of many specific receptor proteins on the postsynaptic membrane. Depending on the neurotransmitter and the type of postsynaptic membrane, the binding of the neurotransmitter to the receptor will cause an influx of Na^+ or an efflux of K^+, resulting in an excitatory postsynaptic potential or an inhibitory postsynaptic potential, respectively.

Question 32.

(a).Briefly explain the effects of hypo and hyperthyroidism in humans ***(14 marks)***
(b)How are the secretions of the thyroid gland controlled ***(06 marks)***

(a).

Hypothyroidism

Primary hypothyroidism; characterized by cold intolerance, mental retardation, obesity, low heart rate, somnolence, low basal metabolic rate etc.

Cretinism; in infancy characterized by sluggishness, physical and mental retardation, dystrophy of bones and soft parts and lowered basal metabolic rate.

Myxedema; especially in adults characterized by generalised body swelling, mental and physical sluggishness, reduced metabolic rates, reduced heart beat rates, lowered body temperature and obesity (over weight).

Hypothyroidic Goitre; characterized by thyroid gland swelling due to compensatory rise in thyroid activity in response to the hypothyroidic state.

Hyperthyroidism

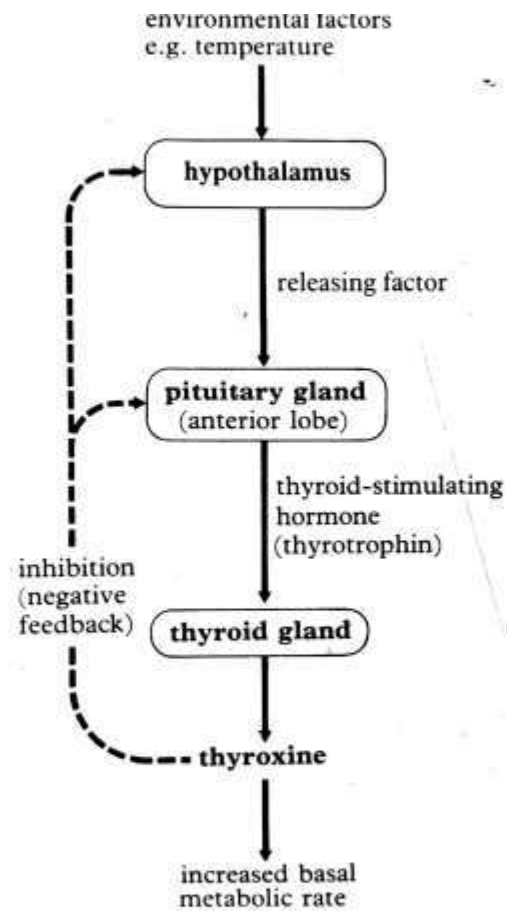
Primary hyperthyroidism; It leads to increased BMR, increased heart beat rate and ventilation rate, raised body temperature (heat intolerance), restlessness, muscle wasting, easy fatigability and other features of heart failure.

Thyrotoxicosis/ thyroid storm; fatal condition of hyperthyroidism due to excessive secretion of thyroid hormones characterized by sudden onset of palpitations, confusion, heart failure, raised blood pressures

Exophthalmic goitre; goitre accompanied by protrusion of eye balls

(b)(i).

Thyroxine levels are controlled by negative feedback mechanisms. Low Basal Metabolic Rate /BMR (low thyroxine levels in blood stream) triggers the release of Thyroid Releasing Hormone (TRH) from the hypothalamus; a hormone that sensitizes the thyrotropes of the anterior pituitary gland to release Thyrotropin (Thyroid Stimulating Hormone/ TSR); TSR then stimulates follicular cells in the thyroid gland to release Thyroxine (tetraiodothyronine); a hormone that raises BMR. Very high BMR (high thyroxine levels), switches off secretion of TRH; secretion of TSR also ceases; thyroid gland thus stops further secretion of thyroxine; till norm is re-established. Thyroxine also directly inhibits further release of TRH and consequently TSH.



Question 33.

(a).With an appropriate example, explain the concept of "correlation" in plant growth and state how it has been utilized in horticulture ***(05 marks)***

(b).How does the morphology of an etiolated plant suit it for growing through soil ***(03 marks)***

(c).How are the various tropic responses important to the plant ***(12 marks)***

(a).

Correlation is process by which one part of the plant controls the another via the influence of growth substances. Classical example is apical dominance which is a phenomenon whereby the presence of growing apical buds inhibits growth of the lateral buds. Apical dominance is under the influence of auxins. It also includes suppression of the later root growth by the growth of the main root. Removal of the shoot results in lateral bud growth (branching). This has been applied in pruning when bushy rather than tall plants are required eg in tea farms.

(b).

• The hooked plumule of dicots protects the delicate apical meristems form soil particles
• Elongated internodes ensure maximum chance of reaching light.
• Small leaves offer less resistance to passage through the soil (leaves of grasses remain inside the coleoptile).

(c).

• Positive phototropic and negative geotropic response of shoots and coleoptiles; allows exposure of leaves to sun-light; for effective photosynthesis.
• Roots negatively phototropic and positively geotropic; allows penetration of soil
• Rhizomes and runners are diageotropic; helps plants colonise new areas of soil.
• Hyphae are positively chemotropic; allow growth towards food.
• Tendrils are positively haptotropic; essential for support
• Sundew tentacles are positively haptotropic; enables capture of insect preys.
• Lateral roots are plagiogeotropic; allows exploitation of large volume of soil as well providing support.

• Branches are plagiogeotropic; maximize volume of space for effective capture of light.
• Pollen tubes are positively chemotropic; for growth towards the ovule; allowing successful fertilisation.
• Pollen tubes are negatively aerotropic; allows growth of pollen tube towards the style (away from air).
• Dicot leaves are diageotropic; maximize exposure of the leaves to maximize capture of light (at right angles to incident radiation)
• Roots and pollen tubes are positively hydrotropic; allows access to water vital for various living processes.

Question 34.

(a)Outline the physiological and biochemical effects of glucocorticoids like cortisol ***(07 marks)***
(b)How are the secretions of the glucocorticoids like cortisol controlled ***(06 marks)***

(a)(ii).

Carbohydrate metabolism
• Promote gluconeogenesis
• Promote liver glycogen formation.
• Raise blood glucose levels

Protein metabolism
• Promote breakdown of plasma proteins to yield energy
• Increase availability of amino acids for enzyme synthesis in the liver.

Other roles
• Prevent inflammatory and allergic reactions
• Decreases antibody production.

(b).

Cortisol is controlled by negative feedback. Low level of glucose in the blood stream trigger the release of corticotrophin releasing hormone from the hypothalamus; which also stimulates the corticotroph cells of the anterior pituitary gland to release adrenocorticotrophic hormone (ACTH); which causes the adrenal gland to release cortisone from the adrenal cortex; which accelerates gluconeogenesis and glycogenolysis. Excess of glucose in the blood stream inhibits further release of corticotrophic releasing hormone from the hypothalamus; which also inhibits release adrenocorticotrophic hormone (ACTH); suppressing further release of cortisol from the adrenal cortex;

Question 35.

(a).Describe the physiological events that lead to;
(i).Apical dominance ***(05 marks)***
(ii).Lateral bud growth and branching ***(06 marks)***
(b).Compare short day and long day plants ***(09 marks)***

(a)(i).

Apical dominance; is largely controlled by auxins. The gradient of auxins and gibberellins from the apical buds; attract food and cytokinins. Food substances eg sucrose from the leaf and cytokinins and mineral salts from the root apex; are translocated past the dormant lateral buds which have a higher concentration of growth inhibitors like ABA and a low concentration of cytokinins, auxin and gibberellins; to the shoot apex. Lateral buds are inhibited and they become dormant while apical nodes become dominant.

(a)(ii).

Lateral bud growth and branching is largely brought about by cessation of auxin production from the apical buds and raised cytokinin production in the lateral bud. Removal of apical buds ceases any more auxin production from the apical buds. The lateral bud becomes active and produces own cytokinin, auxins and gibberellins. The growth inhibitor like ABA at the lateral bud is inactivated. Food substances eg sucrose from the leaf and cytokinins and mineral salts from the root apex; are translocated to the dormant lateral buds. Growth is stimulated in the lateral buds allowing branching to occur.

(b).

Similarities
• Flowering in both plants is controlled by the photoperiod.
• Flowering in both plants is controlled by the phytochrome system
• Flowering in both plants follows activation of the dormant buds by florigen hormone.

Differences

Short day plants	Long day plants
Flowering is induced by dark periods longer than the critical length	Flowering is induced by the dark periods shorter than a critical length.
Examples include tobacco, soya bean, straw belly etc	Examples include cabbage, spring wheat, spring barley etc
Flower on exposure to far red light.	Flower on exposure to red light.
Phytochrome far red is slowly converted to phytochrome red by prolonged exposure to far red light.	Phytochrome red (660); rapidly converted to phytochrome far red on exposure to red light
Phytochrome red (660) induces flowering	Phytochrome far red (730) induces flowering
Phytochrome far red inhibits flowering	Phytochrome red stimulates flowering

Question 36.

(a).Explain what is meant by the following
(i). Dark adaptation ***(03 marks)***
(ii).Light adaptation ***(03 marks)***
(b).Describe the changes in the eyeball that result in each of the above adaptations ***(05 marks)***
(c).Outline mechanisms that enable humans to see over a wide range of light intensities ***(04 marks)***
(d). Radiologists, aircraft pilots and others, who need maximal visual sensitivity in dim light, wear red glass before entering dim-lighted area. Explain why this is so? ***(03 marks)***

(a)(i).

Dark adaption is process by which the person is able to see the objects in dim light. If a person enters a dim-lighted room (darkroom) from a bright-lighted area, he is blind for some time, i.e he cannot see any object. After sometime his eyes get adapted and he starts seeing the objects slowly. Maximum duration for dark adaptation is about 20 minutes.

(a)(ii).

Light adaptation is the process in which eyes get adapted to increased illumination. When person enters a bright-lighted area from a dim-lighted area, he feels discomfort due to the dazzling effect of bright light. After some time, when the eyes become adapted to light, he sees the objects around him without any discomfort. It is the mere disappearance of dark adaptation. Maximum period for light adaptation is about 5 minutes.

(b).

Causes of dark adaptations

Increased sensitivity of rods as a result of re-synthesis of rhodopsin; Time required for dark adaptation is partly determined by the time for re-synthesis of rhodopsin. In bright light, most of the pigment molecules are bleached. But in dim light, it requires some time for regeneration of certain amount of rhodopsin, which is necessary for optimal rod function.
Dilatation of pupil; Dilation of pupil during dark adaptation allows more and more light to enter the eye.

Causes of light adaptations

Reduced sensitivity of rods; During light adaptation, the sensitivity of rods decreases. It is due to the breakdown of rhodopsin.
Constriction of pupil; reduces the quantity of light rays entering the eye.

(c).

- Pupil changes
- Duplex retina i.e with both rods & cones as photoreceptor cells.
- Dark adaptation & pigment bleaching
- Light adaptation of the visual system and individual neurons

(d).

Because red light of spectrum stimulates the rods slightly while the cones are allowed to function well. Thus, the person wearing red goggles can see well in bright-lighted area and also can see the objects clearly as soon as he enters the dim-lighted area.

Question 37.

(a).How is the motor neurone suited for functioning? *(07 marks)*
(b).With appropriate examples, describe the various types of reflex arcs *(06 marks)*
(c).Compare neuronal cells with other cells found in a mammalian body *(07 marks)*

(a).

• The nucleus is relatively large to coordinate metabolic activities all over the large cytoplasm of the cell
• There are very many rows of Nissl's granules for massive synthesis of proteins.
• Axon is long to carry impulses over long distances to the target parts.
• The axon membrane is wrapped with a myelin sheath for fastening nerve impulse transmission.
• The axon membrane is wrapped with a thick myelin sheath for protection against damage.
• The myelination is interrupted at regular intervals by nodes of Ranvier increasing speed of impulse transmission through salutatory conduction.

(b).

Monosynaptic reflex arc: A reflex arc consisting of only a single chemical synapse between one sensory neuron, and one motor neuron e.g. patellar reflex, Achilles reflex, muscle spindle reflex
Polysynaptic reflex arc: reflex arc comprising of one or more interneurons connecting the afferent (sensory) and efferent (motor) neurones.

(c).

Similarities:
• All cells are surrounded by a cell membrane
• All have a nucleus that contains genes.
• All cells contain cytoplasm, mitochondria and other organelles.
• All cells carry out basic cellular processes such as protein synthesis and energy production.

Differences

Neurons	Other cells in the body
Specialised extensions called dendrites and axons	Lack dendrites and axons
Communicate with each other through an electroc-hemical process.	No such electrochemical communication
Contain some specialized structures (for example, synapses) and chemicals (eg neurotransmitters).	No neurotransmitters

Question 38.

(a).What is the main difference between a generator potential and an action potential *(02 marks)*
(b).Discuss exteroception using suitable examples highlighting the receptor, stimuli, location, structure and the process of transduction *(16 marks)*

(a).

The amplitude of a generator potential is proportional to the stimulus intensity whereas the amplitude of an action potential is always the same i.e it obeys the all or nothing law

(b)

Stimuli	Exteroceptors	Location	Structure	Transduction
Gravity	Statocysts	Outer chamber of the inner ear	Otoliths and hair cells	Otoliths deform hair cells
Motion	Cupula Lateral line organ	Semi-circular canals of the inner ear Within grooves of body surface of fish	Collection of hair cells Collection of hair cells	Fluid movement deforms hair cells
Taste	Taste bud cells	Mouth; skin of fish	Chemoreceptors: epithelial cells with microvilli	Chemicals bind to membrane receptors
Smell	Olfactory neurons	Nasal passages	Chemoreceptors: ciliated neuron	Chemicals bind to membrane receptors

Hearing	Organ of Corti	Cochlea of inner ear	Hair cells between basilar and tectorial membrane	Sound waves in fluid deform membranes
Vision	Rod and cone cells	Retina of eye	Array of photo-sensitive pigments	Light initiates process that closes ion channels
Heat	Pit organ	Face of snake	Temperature receptors in two chambers	Receptors compare temperatures of surface and interior chambers
Electricity	Ampullae of Lorenzini	Within skin of fishes	Closed vesicles with asymmetrical ion channel distribution	Electrical field alters ion distribution on membranes

Question 39.

(a).What is meant by the following terms as far as hormone functioning is concerned
(i). Target site *(02 marks)*
(ii) Cascade effect *(03 marks)*
(b).Outline the physiological effects of catecholamines such as adrenaline *(10 marks)*
(c).Distinguish between resting potential and generator potential *(05 marks)*

(a)(i).

Target site is an organ, tissue or organ bearing specific receptors for a particular hormone and responds specifically to that hormone eg the target organ for the action of glucagon is the liver

(a)(ii).

Cascade effect refers to a series of steps or stages in a physiological/ biochemical process that once initiated by a hormone continues to the final step by virtue of each step being triggered by the preceding one; sometimes with a cumulative effect.

(b).

- Dilates pupil of eye; permit adequate entry of light in the eye in the times of fear and flight.
- Cause the hair to stand on end
- Relax bronchioles thus increasing air flow to the lungs
- Inhibit peristalsis and digestion;
- Prevent bladder contraction;
- Increase force and the rate of heart beat
- Cause generalised vasoconstriction; increase blood pressure
- Stimulate conversion of liver glycogen to glucose
- Decrease sensory threshold
- Increase cerebral blood flow; raising mental awareness.

(b).

Resting potential	Generator potential
Attained when the outside of the membrane is more positive relative to the inside	Attained when the inside of the receptor membrane is more positive relative to the outside
Negative potential difference	Positive potential difference
Remains constant and never reaches threshold	Changes/ increases to threshold
Sodium ions actively pumped out	Sodium ions rapidly diffuse inside

Question 40.

(a).Explain what is meant by mutual inhibition as afar as a compound eye is concerned *(04 marks)*
(b).Compare the functionality of a compound eye and mammalian eye *(13 marks)*
(c).Explain the reason for the poor resolving ability of a compound eye *(03 marks)*

(a).

Mutual inhibition (latent inhibition) in compound eye is where if two ommatidia are stimulated simultaneously th-ey fire impulses at a lower frequency than when each is stimulated single because the ommatidia exert an inhibitory influence on each other i.e. mutual inhibition. The importance of mutual inhibition is that it improves contrast between light and dark boundaries.

(b).

Similarities

- Both are able to perceive colour (i.e have colour vision)
- Both function in bright and dim light
- In both light sensations is by light stimulating photosensitive cells
- In both the generated impulses are sent to the brain through the optic nerves.
- In both there is overlap of images.

Differences

Compound eye	Mammalian eye
has a fixed focus (no accommodation)	has adjustable focus (has accommodation)
Overlap of images is greater hence blurred images are produced	Overlap of images is smaller hence clearer images are produced
Detects light that is parallel to its long axis	Detects light reaching it at all angles.
Has lesser powers of colour vision	Has greater powers of colour vision
Has quicker detection of movement (pattern vision)	Has slower detection of movement
Has poor resolving ability and poor visual acuity .	Has good resolving ability and greater visual acuity
Has poor dark adaptation(poor vision at night)	Has better dark adaptation
Shows near sightedness	Can see both near and far

(b).

The poor resolving ability of the compound eye is due to the facts that, ommatidia are larger than rods and cones therefore few can be packed in the same area. There is greater overlap of images.

Question 41.

(a).Describe how light reception occurs in a compound eye of an insect ***(08 marks)***

(b).Outline some of the adaptations employed by vertebrates to improve vision ***(07 marks)***

(c).State the differences between hearing in bats and that in humans ***(05 marks)***

(a).

Only light entering the ommatidia parallel (or almost so) to their long axis reaches the microvilli extensions of the retinal cells forming the rhabdom. Any light entering at an angle to them is absorbed by pigmented cells which work like the iris. On reception of a light stimulus a photochemical reaction occurs as a result of which the membranes of the retinal cells are depolarized and impulses are fired into the nerves fibres which lead them to the optic ganglion and later into the optic nerve.

(b).

Diurnal animals

- Increase in the number of cones; to increase visual acuity in the prevailing increasing light intensity
- Enlargement of the eye to get a larger image by increasing the lens retinal distance
- Have colour filters which absorb light of various wavelength; thus decreasing chromatic

Nocturnal animals

- Have good number of both rods and cones giving sensitivity over a wide range of light intensity
- Adjustment of the eye aperture; regulates light entry into the eye.
- Migration of cells i.e pigment cells into light cells or light cells into pigment cells; to guard against high light intensities e.g in fish

Aquatic animals

- Possession of cornea and lens with refractive index close to that of water; minimizes refractive errors.

(c).

Hearing in bats	Hearing in humans
Depends on sound produced by themselves and reflected by some object in the environment	Depends on sounds produced from a vibrating object in the environment.

Have ability to eliminate noise in the environment from the echoes.	Have greater ability to discriminate between sounds due to well-developed brain.
Able to perceive sounds of very high frequency	Capable of only perceiving low frequency sounds.

Question 42.

(a).Explain how balance of the body is achieved ***(07 marks)***

(b).Describe the advantages organisms that perceive high frequency sounds have over those that perceive low frequency sounds ***(04 marks)***

(a).

Perception of gravity i.e position of the head (linear acceleration); it's a function of the utricule which responds to vertical movements and the saccule which responds to lateral or sideways movements of the head. When the head is upside down, the otoliths of the utricules fall way from the macula; pulling the sensory hair cells; generate a receptor potential; firing sensory impulses into the vestibular nerve to the brain. When the head is on one side, the sensory hair cells are stretched obliquely. The way the sensory projections are stretched determines the patterns of the impulses reaching the brain. These are interpreted accordingly and hence providing information about the position of the head.

Rotational movements (angular acceleration); it's a function of the semi-circular canals. When the head begins to rotate in any direction, the inertia of the endolymph causes it to lag behind and exerting pressure that deflects the cupula in the opposite direction; which bends the cilia at the top of the hair cells; The sensory cells create generator potentials leading to propagation of action potentials in the vestibular neurons.

(b).

• High frequency waves spread less and their echoes are so refined that they pinpoint the objects from which they are being reflected quite accurately as opposed to low frequency waves which spread widely and their reflections are too diffuse to pinpoint accurately the location of objects.

• High frequency sounds, being of short wavelength allow location of small objects since shorter wavelength sounds require minimal size of the object that will reflect it.

Question 43.

(a).With examples, state four ways hormones influence molecular reactions in cells ***(06 marks)***

(b).Describe the control of turgor changes in a sensitive plant like mimosa pudica ***(10 marks)***

(c).State the differences between accommodation of a near object and a distant object ***(04 marks)***

(a).

• Affecting transcription of genetic information eg oestrogen
• Affecting protein synthesis eg growth hormone
• Altering enzyme activity eg adrenaline
• Altering permeability of cell membranes eg insulin.

(b).

All the cells in the plant have active sodium pumps in their cell membrane whose activity keeps them in a state of resting potential. On being touched, the surface membranes of the area touched eg the leaflets become depolarised resulting in an action potential which is propagated through the surrounding phloem cells to a specialised group of parenchyma cells at the base of the leaflets in the pulvinus called motor cells. These cells respond to the depolarisation by actively pumping potassium ions from their cytoplasm into the extracellular spaces around themselves. As the concentration of potassium ions within the motor cells falls, their water potential becomes less negative & hence lose water by osmosis. They thus shrink and the leaflet is pulled upwards. Many such movements result in the leaflets closing up. If undisturbed again in close sequence, the leaflets return to their normal position by reversing the movement of potassium ions and hence the water potential.

(c).

	Objects near eye	**Object far from eye**
Light must be refracted	A lot	A little
Lens must be	Thick	Thin
Ciliary muscles	Contract	Relax
Suspensory ligaments	Slack	Tense

Question 44.

(a).Explain the various ways in which the efficiency of receptors is ensured *(07 marks)*

(b).Explain the differences in acuity and sensitivity to light by different parts of retina *(13 marks)*

(a).

Having various threshold; this extends the range of stimuli for receptor

Adaptation; provides an organism with precise information about changes in the environment.

Spontaneous activity; increases sensitivity of receptor by enabling it make a response to a stimulus that would normally be too small to produce a response. The direction of the change in the stimuli can be registered by this system as an increase or decrease in the frequency of the response in the sensory neurone.

Feedback control of receptor activity; reset the sensitivity of receptors to different ranges of stimulus intensity.

Summation; eg retinal convergence of rod cells; increase sensitivity to low light intensity.

Accessory structures;

Effect of hormones like adrenaline

(b).

The fovea is sensitive only at high light intensity; and sensitive to colour; due to presence of cones/ absence of rods. It has a high visual acuity; because of high concentration of cones. Each cone synapses with one bipolar neurone; synapsing with one ganglion cell. Each pair of the image is thus selected by a differrent cell eliminating blurring. The layer of nerve fibres is thin; and capillaries are absent; which minimizes interference. The outer edge is sensitive to low light intensity; insensitive to colour; and has a low visual acuity; because it has only rods which are not tightly packed; and has synaptic convergence which increase collective sensitivity but reduce detail. The blind spot is insensitive to light due to absence of photoreceptor cells

Question 45.

(a).Explain phototropism in plants. *(10 marks)*

(b).What is the significance of tropisms towards plant diversity? *(10 marks)*

(a).

Phototropism is the plant's response to unidirectional light; shoots being positively phototropic; roots being negatively phototropic. When a plant shoot is subjected to unidirectional source of light; the auxins on the illuminated side absorb more light energy than on the non-illuminated side. Therefore, more auxins are translocated to the shady side and less auxins are transported to the illuminated side. This results in differential growth in which the non-illuminated side experiences greater cell elongation than the illuminated side; a result of which is bending of the plant shoot towards the source of light (positive phototropism). Uniformly subjected light to the shoot results in no curvature of the shoot due to uniformly distributed auxins. For a plant root exposed to unidirectional light; auxins concentrate on the non-illuminated side inhibiting growth on that side such that the root grows away from light (negative phototropism).

(b).

Positive phototropic responses of the plant enable photosynthetic organs (leaves) access light so as to effect photosynthesis and this increases the gross productivity of primary producers.

Positive geo and hydrotropism of the roots; ensures access towards water; an important raw for photosynthesis; gross productivity of the primary producers is increased.

Tendrils are positively hapto/ thigmotropic; thus twine around other plants for support and access to light.

Pollen tubes are positively chemotropic and negatively aerotropic; grow towards the ovule to effect fertilisation; increasing the reproductive rate of plants; population rises.

Diageotropic response of plants parts like rhizomes and runners enable colonization of new areas; to avoid overcrowding.

Insectivorous plants being positively thigmotropic enables them catch the prey on contact.

Question 46.

Describe the significance of chemical composition, arrangement and distribution of photo receptors towards the normal functioning of the mammalian eyes *(20 marks)*

Significance of Chemical Composition of mammalian photo receptors

Rods; contain rhodopsin which is bleached; on being struck by the low light intensity light; Further bleaching of the trans-rhodopsin to opsin and retinine; result in depolarization of rods; and production of generator potentials;

which if raised to threshold evoke action potentials and fine impulses via bipolar neurons and optic nerves for vision in dim light; due to rapid decomposition and regeneration.
Cones on the other hand contain iodopsin; which is bleached to Trans iodopsin from cis iodopsin upon being struck by the high intensity light. The iodopsin is slowly decomposed and regenerated and the bleaching depolarizes the membrane of cones; there by producing the generator potentials; which build up to the threshold evoke action potentials; and fire impulses via the bipolar neuron; to the optic nerve fiber; enabling focus in bright light the slow decomposition and regeneration effect bright light vision. The cones are of basically three forms i.e blue, green & red whose differential stimulation results in the other different colors and shades perception.

Arrangement significance of mammalian eye photoreceptors

Rods: They show retinal convergence in which three rods synapse with a single bipolar neuron. This results in spatial summation and high sensitivity; of the rods since the individual generator potentials of all rods are summed up at the synaptic region to cause action potentials in the bipolar neuron; this increases sensitivity in the dim light; Three rods also associate via lateral neurons or horizontal cell which effect mutual inhibition on simultaneous stimulation of two receptor rods which are adjacent; This causes sharpens of what is focused cones;
Cones: Adjacent cells are connected by amacrine cells to coordinate their function. Cones do not show any retinal convergences i.e a single cone synapses will a single bipolar neuron which increases visual precision or acuity.

Distribution significance of mammalian photo receptors

Rods: All over the retina increasing chances of receiving light, stimulation and consequently increasing sensitivity.
Cones; They are parked at the favas which increases visual acuity and chances of light from close objects falling on 2 cones which are at least separated by a cone hence reducing mutual inhibition.

Question 47.

(a).How does the size of stimuli affect a nerve impulse? ***(05 marks)***
(b).How do the following muscle fibres work
(i).Fast Twitch Muscle Fibres ***(04 marks)***
(ii).Slow Twitch Muscle Fibres ***(04 marks)***
(c).Discuss the major properties of Synapses ***(07 marks)***

(a).

Does not affect size of the action potential. Action potential is all or nothing. When stimulus Intensity/size reaches or exceeds threshold: an action potential is evoked (ALL). When stimulus size does not reach threshold; no action potential is evoked (NOTHING). Larger stimuli increases the frequency (number) of action potential.

(b)(i).

Fast twitch: provide powerful but short lasting contractions; found in biceps and sprinters; adapted for anaerobic respiration: has thicker myosin for powerful contractions; contains more enzymes for anaerobic respiration. It contains a lot of phosphocreatine for providing phosphate to ADP to reform ATP (anaerobism).

(b)(ii).

Slow twitch: provides less powerful but long lasting contractions; found in thigh muscles and marathon runners; adapted for aerobic respiration has a rich blood supply; contains many mitochondria; contains glycogen and contain myoglobin (stores oxygen).

(c).

Unidirectionality; AP/nerve impulse travels in one direction from pre to post synaptic membranes pre-synaptic membranes has the neurotransmitter; post synaptic membranes has the receptors
Filters out low level stimuli; Low level stimuli do not release enough neurotransmitter therefore not enough Na^+ ion channels open; not enough Na^+ ions enter post synaptic neurone for threshold to be reached. Therefore no AP produced
Summation; low level stimuli add together to release enough neurotransmitter to produce an AP in the post synaptic neurone; can be temporal (low level stimuli present for extended period of time) or spatial (low level stimuli from a few presynaptic neurones add together).
Inhibitory; normal synapses are excitatory; some are inhibitory preventing action potential from occurring by making post synaptic neurones hyperpolarized

Fatigue/ adaptation; if synapse is bombarded with impulses at a high frequency; with time post-synaptic nerve cell ceases to respond (becomes adapted) and impulses are no longer generated in it; due to exhaustion of supply of transmitter substance; and its re-synthesis cannot keep pace with rate at which impulses reach the synapse; thus fatigued.

Question 48.

(a).Explain each of the following as applied to receptor cells;

(i).Flicker fusion ***(08 marks)***

(ii).Adaptation ***(05 marks)***

(b).Explain what causes vision using the fovea.

(i) to be in colour ***(02 marks)***

(ii) to have high visual acuity ***(05 marks)***

(a)(i).

Flicker is the shinning repetitive stimuli of light failing at receptor cell at a high frequency, thus nicker fusion refers to a phenomenon where a receptor cell fuses several stimuli into one continuous stimulus due to a higher frequency of its stimulation. For a receptor cell to detect several stimuli, they should be at a frequency sufficiently lower than the time taken for the cell to generate action potential and repolarize before the next stimulus is received. If the frequency of stimulation is increased, there comes a point when the generator potentials fuse resulting into a continuous stream of action potentials being discharged by the receptor; and now it cannot detect separate stimuli.

(a)(ii).

Adaptation is the failure of a receptor cell to respond to a stimulus as a result of its steady prolonged stimulation. If a steady stimulus is maintained; the generator potentials gradually decline and the frequency of action potential decreases. With time generator potentials fall below firing threshold and no further action potentials are discharged thus the receptor is adapted. It is as a result of the receptor membrane becoming less permeable to influx of sodium ions.

(b)(i).

Cone cells have photopigment iodopsin of three different types which are sensitive to blue light, green light & red light thus can detect different wavelength of light and their corresponding colours.

(b)(ii).

Visual acuity is ability of the eye to resolve two or more close stimuli and perceive them with precision. Cones have no retinal convergence. Each cone cell synapses with a single bipolar neuron which in turn connects to single optic nerve; thus able to send a separate signal to brain allowing precision/ high acuity. Cones are densely packed at fovea located at the centre of visual axis of the eye; which is the best position to receive focused light. Lateral inhibition of two adjacent cone cells sharpens the contrast between two close image.

Question 49.

Discuss the different reactions of plants to light. ***(20 marks)***

There are two main light sensing systems in plants, that is: **Phytochrome sensing system** (red light sensing system)**;** that affects plant flowering, seed germination, etiolation, senescence, abscission of leaves and circadium rhythm**; Blue light sensing system;** that regulates plant responses such as phototropism, stomatal opening and chlorophyll synthesis**;**

Phototropism; the plant response to light**;** is achieved by the action of the hormone **auxin** produced at apical meristems but actively transported to the zone of elongation**;** Unidirectional illumination causes auxins to move and accumulate on the shady side of the shoot**;** and promote faster cell elongation on the shady side to cause the shoot grow bending towards light**;** Uniform illumination causes auxins to move and distribute uniformly throughout the shoot**;** hence promoting equal and upright growth of the shoot**;**

Stomatal opening; is initiated when blue light activates the conversion of starch into malic acid and protons (H^+) In exchange for H^+ inside guard cells; guard cells actively take up K^+ ions using ATP from light reactions of photosynthesis and cytokinin (a plant hormone); As the concentration of K^+ ions increases in sap of guard cells, the concentration of H^+ ions decreases to increase pH above 7 (sap becomes alkaline);Guard cells increase uptake of Cl^- (anions) to maintain electrical and ionic balance inside and outside; Malate anions formed in the guard cells are neutralized by K^+ ions to form potassium malate, which enters the cell sap of guard cells to increase solute concentration; Water potential decreases to cause endosmosis into guard cells, which become turgid to open the stomata;

Photoperiodism, the plant response to changes in the photoperiod/ relative length of daylight and darkness in each 24-hour cycle**;** is brought about by the **phytochrome sensing system** (red light sensing system). During daylight, the **inactive** phytochrome red **(P_r/ P_{600})** which is manufactured by plants**;** absorbs red light and converts to phytochrome far red **(P_{fr}/ P_{730});** In **long day plants**/ plants that only flower when the length of darkness they have been exposed to is shorter than a certain critical length of darkness**;** high levels of P_{fr} stimulate the conversion of the inactive hormone precursor into florigen**;** which on transportation from leaves to buds induces flowering in long day plants**;** P_{fr} is converted back to P_r slowly in the dark or rapidly if exposed to far red light (730 nm)**;** In **short day plants**/ plants that only flower when the length of darkness they have been exposed to exceeds a certain critical length of darkness**;** high level of P_r and decreased level of P_{fr} stimulate the conversion of the inactive hormone precursor into florigen**;** which induces flowering in short day plants**;** In **day neutral plants** flowering occurs irrespective of photoperiod**;**
During **Germination** of some seeds like lettuce**; red light** stimulates germination**;** Red light promotes the production of P_{fr} in the seed**;** which in the presence of other factors like water stimulates the synthesis of gibberellin**;** which stimulates the **aleurone layer** in the seed to synthesise enzymes like **amylase;** that promote germination**;**

Question 50.

(a).Describe how a nerve impulse crosses a cholinergic synapse. ***(05 marks)***
(b).Explain the functions of a sensory neurone and a motor neurone in a reflex arc. ***(15 marks)***

(a).

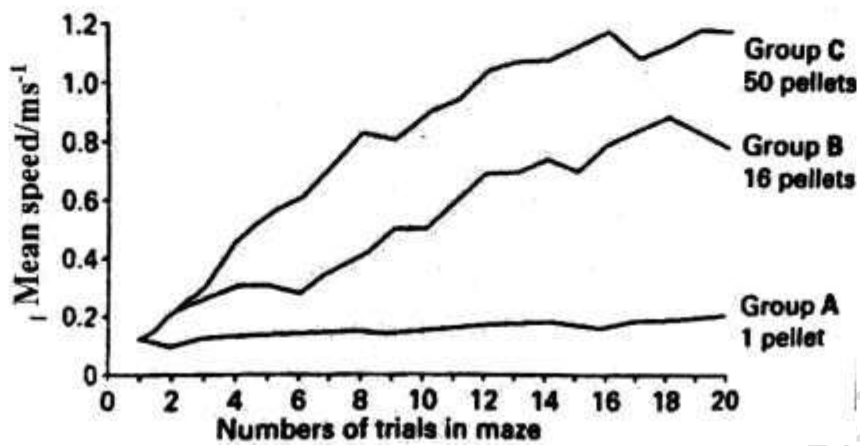
When the action potential arrives at the presynaptic knob; it causes calcium ion channels to open. Calcium ions flood into the neurone down their concentration gradient. The knob contains many tiny vesicles full of the neurotransmitter acetylcholine. The calcium ions make these vesicles move to the presynaptic membrane and fuse with it; releasing the acetylcholine into the synaptic cleft. This cleft is very small, so it takes only a millisecond or two for the acetylcholine to diffuse across it. On the other side of the cleft, there are receptor molecules in the postsynaptic membrane and the acetylcholine molecules fit perfectly into these. This makes sodium ion channels in the postsynaptic membrane open; so sodium ions flood in down their concentration gradient. This depolarizes the membrane; (gives it a positive charge inside) which sets up an action potential in the postsynaptic neurone.

(b).

A sensory neurone has its cell body in the ganglion in the dorsal root of a spinal nerve. It has a very long dendron that carries action potentials from a receptor towards its cell body and a shorter axon that carries the action potentials into the spinal cord (or brain). The ending of the dendron may be within a specialized receptor such as a Pacinian corpuscle in the skin. Pressure acting on the Pacinian corpuscle depolarizes the membrane of the dendron & generates an action potential.
The motor neurone has its cell body within the central nervous system (in the brain or the spinal cord). It has many short dendrites and a long axon. It will have many synapses, including several with sensory neurones. Thus the action potential from a sensory neurone can cross the synapse and set up an action potential in the motor neurone which will then transmit it to an effector such as a muscle or gland. The action potential then causes the effector to respond, for example by contracting (if it is a muscle).
In a reflex arc, the impulses travel directly from the sensory to the motor neurone (or sometimes via an intermediate neurone between them) without having to be processed in the brain. This means the pathway from receptor to effector is as short as possible, so the response can happen very quickly.

Chapter 13; Behaviour in living organisms

In an experiment, the ability of the rats to learn the route out a maze was investigated. Three groups of rats were used. Each rat in group A was put in the maze and when it found its way out, it was given one pellet of food. The time taken for each rat to get through the maze was measured and the mean speed for each group of rats calculated. Each rat in group A was put through the maze 20 times. The rats in the other two groups were treated in exactly the same way except that the rat in group B was rewarded with 16 pellets of food and each rat in group C with 50 pellets



(a).Giving evidences from the graph, state the type of learning behaviour shown by the rats in the experiments ***(04 marks)***

Operant conditioning/ instrumental conditioning/ trial and error learning/ associative learning;
Trial motor activities gave responses which were reinforced by a reward / association of the outcome of a response interms of reward increased future responses; associative learning efficiency was increased by repetition

(b).Explain how each of the following affected the behaviour of the rats;

(i).Number of trials made ***(06 marks)***

After 3 trials; The greater the amount of food given, the faster the maze was navigated; Rats are mammals with well-developed/ advanced brains; nervous system can quickly learn complex mazes/ larger reward increased/ reinforced rat's association of reward with movement through the maze/provided increased motivation/ large quantity of food provided increased reward rat's response was reinforced / higher motivation provided; making the rats to learn the maze faster.

(ii).Quantity of food ***(05 marks)***

After one trial, the more trials the rats made the faster the maze was navigated. Rats are mammals rats are mammals with well-developed /advanced brains/ nervous system; which can quickly learn complex mazes hence greater memory; the more trials made the rats to master the maze faster; requiring less time to find their way out.

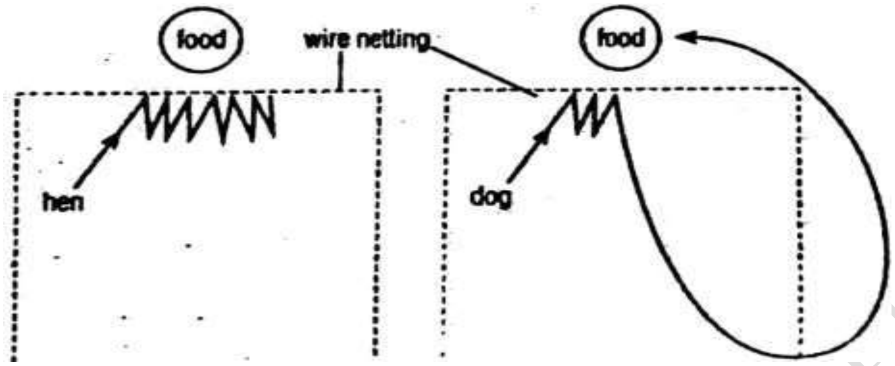
(c).Apart from the factors investigated, suggest two other factors that can increase the ability of the rats to learn by the form of learning under investigation ***(05 marks)***

Making the maze more complex
High level of brain development/ well developed nervous system

(d).How does the behaviour shown by rats in experiments differ from innate behaviour ***(05 marks)***

Instinctive (innate) behaviour	Learned behaviour
Inborn/ not acquired during an animal's life time.	Acquired during an animal's life time.
Genetically inherited	Not inherited but the ability to learn is Inherited
Intrinsic i.e also present in animals raised in isolation	Extrinsic i.e absent in animals raised in isolation from others
Inflexible i.e not modified by development or experience.	Adaptable; i.e capable of modification to suit the changing conditions.
Unintelligent and automatic	May be intelligent and intellectual
Stereotyped; i.e performed the same way	Permutable; i.e can change over time
Permanent despite minor modifications	Temporary and a short lived behaviour; although reinforcement can make it less or more permanent
Consummate i.e fully developed and expressed at first performance.	Progressive i.e subject to improvement or refinement through practice.
Only one stimulus is required	Involves more than one stimulus

(e). The figures below show the response shown by a hen and dog towards a visible food source when each was first starved and then placed separately in transparent wire netting left open at one end with food placed outside the netting on the opposite end which is closed.



(i).State the form of behaviour shown by each animal ***(01 marks)***

Insight learning/reasoning

(ii)Mention three characteristics of the type of behaviour identified in (e)(i) above ***(03 marks)***

- Uses information previously learnt from other behavioral activities (recall of past experiences) to solve problems never encountered before.
- It involves higher centers of the brain
- Uses intellectual abilities like reasoning, knowledge, cognition, thought
- It is perfected by training/rehearsal

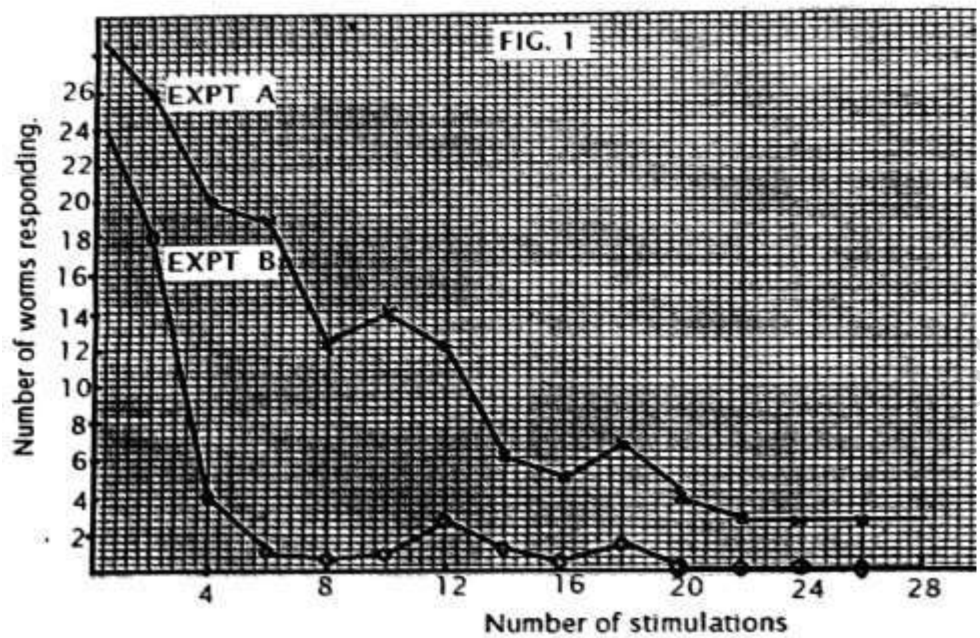
(iii)Explain the behavioural response shown by each animal ***(14 marks)***

Hen; makes several / seven attempts to reach food but; eventually fails; hen has poorly developed nervous system / less advanced brain/ low memory capacity, thus reduced ability to reason/ learn from past experience can only find its food accidently; upon escaping from the netting to reach the food;

Dog makes very few/ three attempts; and then eventually finds food; dog is a mammal with a well-developed nervous system/ brain / large cerebellum; with high memory capacity; hence capable of reasoning; offers a few attempts to size up the situation; reduces/ suppresses its natural drive towards food source; escapes from the netting so as to find the food source;

Question 2.

Figure 1 shows habituation to touch by a group of tube worms Branchioma. In this investigation, groups of worms were tested by brushing their protruding branchial crown. Two separate experiments were carried out. In experiment A, the worms were stimulated so gently that they only responded by withdrawing slowly in their tubes. In experiment B, the stimuli were sufficiently strong to excite a rapid response from the worms.



(i).What is the effect of frequency of stimulation on responses of the group of worms in experiment A and B.

• 0.4 number of stimulations cause high number of worms responding in both experiment A and B
• High number of stimulations of 28 causes a low number of worms responding for both experiment A&B
• Increasing number of stimulation from 0.4 to 6, decreases number of worms responding for both A &B;
• Increasing number of stimulations from 8 to 20/22, causes number of worms responding to rise and fall/ fluctuates for both experiment A and B;
• Increasing number of stimulations from 22 to 28 has no effect on the number of worms responding/ causes the number of worms responding to remain constant for both experiment A and B.

(b).Explain.

(i).the differences in the effects of intensity of stimulation on the number of worms responding in both experiment A and B. ***(10 marks)***

Gentle/weak stimulation causes a higher number of worms responding; this is because weak/gentle stimulations does not easily generate high frequency impulses; In receptors and synapses; resulting into few receptors in few worms to adapt/fatigue; allowing more worms to continue responding;

Strong stimulation lowers the number of worms responding; because strong stimulations are capable of generating high frequency impulses in the receptors and synapses which may result into many receptors and synapses to easily adapt in many worms preventing transmission of impulses and few worms show responses towards strong stimulations.

(ii).the responses of the group of worms in both experiments A and B beyond 22 number of stimulations.

In both experiment A and B, the number of worms responding remained low and constant between 22 and 28 number of stimulations. High number of stimulations/ repeated stimulations generate high frequency impulses; this causes few sodium ions to diffuse inside receptor cells; while high frequency stimulation prevents secretion of neurotransmitter from the pre-synaptic knob/ exhaustion of neurotransmitter at the synapse; threshold maynot be reached and no action potential generated and no further responses by the worms towards repeated stimulations.

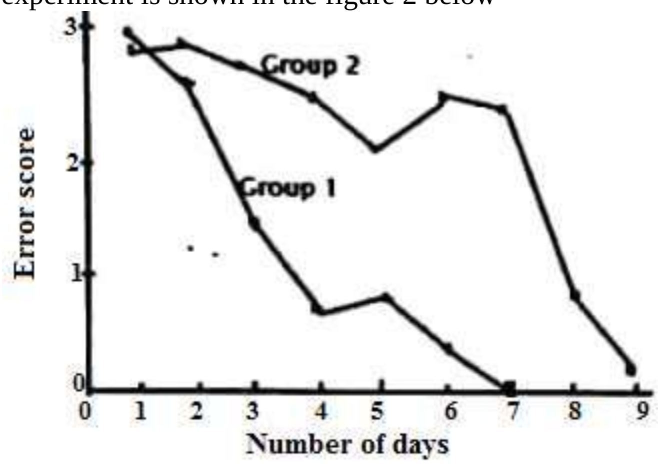
(c).What advantages does habituation provide to animals ***(04 marks)***

• Avoids wastage of energy on neither harmful nor beneficial stimuli;
• Enables quick escape from danger
• Repeated stimulation is ignored preventing fatigue
• Enables organisms survive in environments with disturbing stimuli like smelly places/ noisy areas etc.
• Helps animals identify neutral elements in their environment.
• Animal learns to disregard unimportant stimuli saving it from fatigue, energy and time wastage.
• Lowers animal's stress and anxiety to seemingly threatening but rather harmless or unimportant stimuli.

• Minimizes sensori-motor demands of the animal in responding to virtually neutral stimuli.
• Enables animals prioritize their responses; i.e attend to significant stimuli; ignore less significant ones.
• Helps animals recognise important clues or signals and hence adapt to the ever changing environment; by offering an appropriate response.

Part B

In another experiment, two groups of rats were previously led and placed to spend some time in the man before the experiment. When the experiment begun, each group of rats were separately introduced into a maze from the start and allowed to run about in the maze
Group 1 were given food whenever they succeeded to exit the maze every day.
Group 2 were not given food as they exit the maze until the seventh day of the experiment
The number of blind routes was made by the groups of the rats in the maze as they traverse was recorded as the error score. The result of the experiment is shown in the figure 2 below



(d).Account for the errors made by each of the groups while traversing the maze

(i).Group 1. ***(05 marks)***

Initially at day 1, the number of error scored by rats in group 1 was high because the rats had not stored enough information about the routes in the maze; Between 1and 4 days error scored by the rats in group 1 declined/ decreased more rapidly and between 5 and 7 days error scored by the rats in group I declined rapidly; because the rats had stored rapidly much information in the brain about the routes in the maze. Besides, they were motivated by the constant reward provided; making them learn faster and hence traversing the routes with reducing errors until no errors made by day 7. More gradual increase in errors score by the rats between 4 and 5 days; arises from the occasionally very few blind routes made by the rats during the experiment.

(ii).Group 2 ***(06 marks)***

From 1and 2 days, error score by the rats in group 2 remained constant; and then between 1 and 5 days the error score by the rats in group 2 declined gradually; the rats are slowly storing information in the brain about the routes because they were not motivated by any reward and they consequently learn slowly to successfully traverse the route. From 7 to 9days the error score by the rats in group 2 declined rapidly; because the rats are using much information stored in their brains about routes in the maze to traverse it/ due to exploratory learning; Between 5 and 6 days error scored increased gradually; by the rats in group 2 due to the few occasional blind routs made by the rats during the experiment.

(e).From the information in figure 2, state any three ways intelligence of an animal can be determined.

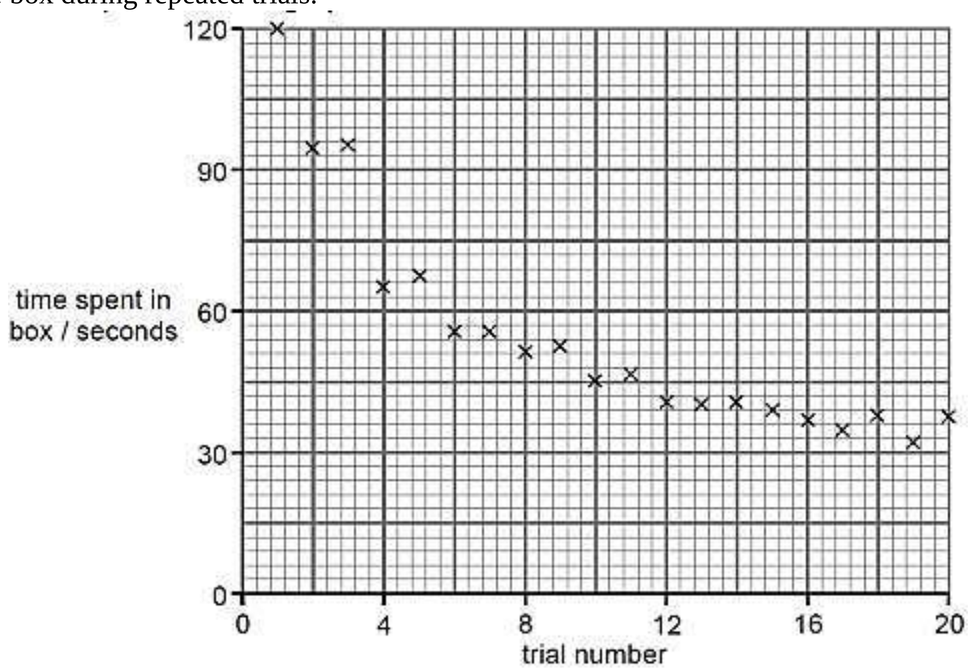
• The duration of time/days taken to cease/ stop error scores (with and without reward)
• The rate at which the errors scored decline with and without reward;
• The duration it takes to remember and accomplish the task without trials;
• The complexity of the routes in the maze it traverses.

Question 4.

(a) Define operant conditioning. ***(02 marks)***

Form of associative learning through trial and error learning where an animal learns to associate one of its own behaviors with a reward or punishment and then tends to repeat or avoid that behaviour.

(b). During an experimental trial, a cat was placed inside the puzzle box. If the cat pulled the loop with its mouth or a paw, the door opened and it could escape. The time taken for the cat to escape was recorded. The experiment was then repeated several times with the same cat. The figure shows a graph of the time taken for the cat to escape from the puzzle box during repeated trials.



(i) Account for the changes in time spent by cat in box at different trial numbers. ***(15 marks)***
Time spent by cat is highest at first trial; Cat spent a lot of time at first in cage since it had not learnt how to escape/ environment was new and still so complex. Cat investigated the puzzle box by exploration; pulled loop accidentally/ by chance/ by trial and error; a reward/ reinforcer; e.g food led to escape.
Time spent in the box decreased as number of trials increased due to learning; Rapid decrease in time spent by cat in the first 6/ few trials; greatest change in response occurs; cat highly motivated; food/ reward appears; thus positive reinforcement; improving performance; though error rate still high
From trials 6 to 20 there was gradual fall in response time; time spent in the puzzle box is very low; learned rapidly to associative escape with the reward; pulls loop sooner due to learning/ ease to remember; sufficient acclimatization period repetition enabled learning to occur
Time spent by cat in box fluctuates; rise in time is due to forgetting, fall in time is due to learning; need to make a choice, as learning is by choice.
(ii) What evidence shown by the figure shows that learning took place? ***(03 marks)***
Errors reduced with time; time spent in box reduced with increase to number of trials; Time spent in box fluctuated.
(iii) State three factors that could affect learning of a new situation like a maze in animals ***(04 marks)***
• The size of the reward or punishments
• The state of development of the brain
• The state of the development of sense organs
• The complexity of the mazes/ puzzle box
(iv) How could the time needed by the cat to escape out of the puzzle box be reduced? ***(03 marks)***
• Rewarding it at end of right attempt reduces time required for it to leave the cage giving it food
• When it makes wrong choice the cat is punished; increasing number of trials per day to enable learning;
• Reducing the complexity/ number of turns or the puzzle box
(c) Discuss the characteristics of reflexes ***(07 marks)***

• Heritable; encoded in DNA and passed from generation to generation
• Intrinsic; present in animals raised in isolation from others
• Stereotyped; performed in the same way each time by each individual of a particular species
• Inflexible; not modified by development or experience
• Consummate; fully developed or expressed at first performance
• Unintelligent and automatic; thus donot require learning/ conscious thought
• Conditioned (response); can be modified/ produced following exposure to new stimulus;

Essay questions and answers

Question 1.

(a).Outline the characteristics of innate behaviours *(05 marks)*
(b).Briefly describe the different forms of innate behaviours *(10 marks)*
(c).State the advantages and disadvantages of innate behaviour *(05 marks)*

(a).

• Heritable; encoded in DNA and passed from generation to generation
• Intrinsic; present in animals raised in isolation from others
• Stereotyped; performed in the same way each time by each individual
• Inflexible; not modified by development or experience
• Consummate; fully developed or expressed at first performance
• Unintelligent and automatic

(b).

Reflex behaviours: a simple, automatic response of a body to a stimulus that involves no conscious control e.g. Pull hand away from hot surface, baby feeding, horse tail swatting at flies. Reflexes enable bodies to respond quickly to a stimulus protecting them from harm. Escape reflex involve involuntary responses
which follow a specific pattern in response to a given stimulus e.g earthworms withdraw underground in response to vibrations on the ground

Orientation behaviors: are coordinated movements (walking, flying, swimming, etc.) that occur in response to an external stimulus. These behaviors have adaptive value for survival by helping the insect locate (or avoid) the source of a stimulus.

Kinesis: non-directional orientation behaviour where the rate of movement is directly proportional to the intensity of a stimulus e.g woodlice move around rapidly and randomly when exposed to light until they find better conditions then they stop moving or move slowly.

Taxis: A directional locomotory response to a given stimulus e.g fly maggots move away from light sources (negative phototaxis).

(c).

Advantages of innate behaviour

• Innate responses are generally rapid; organisms can react quickly to their environments e.g. the earth worm quickly / rapidly withdraws into its burrow, away from the danger.
• All animals of the same species will have the same set of behaviour patterns
• Innate behaviour suits species that have short lifespans; they don't have time to learn behaviours
• Suits species with no parental care
• Suits species with solitary lifestyles as they can't learn behaviours from other members of the species.
• Fixed action patterns can be adaptive; increase survival chances of organism limiting the number of neurones in invertebrates with less developed nervous system; required for a particular response

Disadvantages of innate behaviour

• Inflexible nature doesnot permit the organism adapt to ever changing environmental conditions
• Doesnot benefit animals with longer life spans since the behaviour is short lived

Question 2.

(a).Define learning *(01 marks)*
(b).Using relevant examples state and explain the various forms of learning *(19 marks)*

(a).

Learning refers the organism‘s ability to modify behavior based on past experience

(b).

Habituation; continuous repetition of the stimulus not associated with reward or punishment, extinguishes /causes cessation of any response to stimulus e.g birds learn to ignore scarecrows. It is important in development of behavior in young animals; helping to understand neutral elements in the environment like wind movement, cloud cover etc

Classical conditioning/conditioned reflexes; Here organism learns to associate a conditioned stimulus (e.g ringing of the bell) to an unconditioned one (e.g sight of food) to produce a response(e.g salivation).The organism therefore not only produces a response to the unconditioned stimulus but also to the conditioned one even in the presence of the latter alone e.g birds avoid eating black and orange cinnabar moth larvae because of the bad taste and also avoid all similarly coloured larvae even when they are nutritious.

Operant conditioning/trial and error learning; organism tries out experiments in its environment, responses ar-e enforced by other a reward (positive) or punishment (negative) Association of the outcome of the response in te-rms of reward or punishment increases or decreases future responses respectively. Associative learning efficiency increases with repetition.

N.B; Classical conditioning and Operant conditioning constitute Associative learning.

Latent /exploratory learning; Organism explores its environment; not for an immediate satisfaction of its needs or for an immediate reward (appetitive behavior); but rather acquire information that may be useful at a later stage hence latent. E.g in mice, knowledge of the immediate environment of its burrow may help it escape predators.

Insight learning; highest form of learning; uses information previously learnt from other behavioral activities (recall of past experiences) to solve problems never encountered before. It involves higher centers of the brain and intellectual abilities like reasoning, knowledge, cognition, thought are a pre-requisite. This form of learning is perfected by training/rehearsal.

Imprinting; simple, specialized genetically determined form of learning; occurs during receptive periods in an animal’s life. Young organisms begin associating and identifying themselves with other organisms, usually a parent or a large object; e.g goslings and ducklings deprived of their parents would follow man; one they would substitute as parent. Imprinting enables organisms to rapidly acquire skills possessed by parents e.g learning to fly in birds.

Question 3.

What is the importance of the following forms of behaviour to the survival of the organisms?

(a). Territorial behaviour. ***(08 marks)***

(b).Courtship behaviour ***(12 marks)***

(a).

• Territoriality reduces both intraspecific and interspecific competition for resources as an organism defends its te-rritory against invasion by other organisms

• Ensures adequate spacing of the mating pair of organisms and their off springs to receive the available resources e.g food, breeding space etc.

• Minimizes the spread of diseases and parasites since territory over population is avoided.

• Fighting is highly ritualized; minimizes injury and the weakened male usually retreats without sustaining a lot of injuries.

• Ensures freedom from interference during bond pair formation/ mating.

• Genes from the strong organism or the fittest are passed to the next generation; promote passage of superior genes to the next generation and elimination of inferior genes from the population.

• Territories are defended by using signals; reduces chances of fighting

• Controls population growth and promotes scattered population distribution.

(b).

• Appropriate courtship displays stimulate the organism to sexual activity

• Synchronizes gonadal development enabling gametes to mature at the same time ensuring successful fertilization at the time of mating.

• Brings about bonding between the mating pair.

• Allows rise in the levels of reproductive hormones and thus promote sexual maturation.

• Synchronizes organisms to produce off springs in the right seasons.

• Induces mating of individuals who accept each other.
• Courtship is also used as an isolating mechanism; preventing different off springs from interbreeding.
• Courtship enables organisms recognise each other as individuals and avoid aggression.
• Brings both mating partners to reproductive readiness simultaneously.
• Maintain distinct species.
• Suppresses negative tendencies like avoidance of body contact, escape behaviour or cannibalism.
• It minimizes breeding between different species
• It synchronizes the time of producing off springs with the availability of food.
• It leads to a rise in levels of reproductive hormone
• Important in preparation of nurseries
• Animals advertise their willingness to mate
• It ensures that members of the same species find each other and mate e.g. at dusk, different species of fireflies flash distinct light patterns. However, female fireflies of one species respond only to those males exhibiting the species-correct flashing pattern.

Question 4.

(a).Distinguish between each of the following;
(i).Tropism and reflex *(06 marks)*
(ii).Instinctive behaviour and learned behaviour *(09 marks)*
(b).State the advantages of a learned behaviour *(05 marks)*

(a)(i).

Tropism	Reflex
Plant response	Animal response
Movement is due to growth	Movement is due to muscular contraction
Response is slow	Response is rapid
Always involves movement of a plant part	Occasionally involves movement of the whole organism
Direction of response is related to the direction of stimulus	Direction of response can be unrelated to the direction of the stimulus
Influenced by growth substance	Influenced by impulse transmission

(a)(ii).

Instinctive (innate) behaviour	Learned behaviour
In born and not acquired during an animal's life time.	Acquired during an animal's life time.
Genetically inherited	Not inherited but the ability to learn is Inherited
Intrinsic i.e also present in animals raised in isolation	Extrinsic i.e absent in animals raised in isolation from others
Inflexible i.e not modified by development or experience.	Adaptable; i.e capable of modification to suit the changing conditions.
Unintelligent and automatic	May be intelligent and intellectual
Stereotyped; i.e performed the same way	Permutable; i.e can change over time
Permanent despite minor modifications	Temporary and a short lived behaviour; although reinforcement can make it less or more permanent
Consummate i.e fully developed and expressed at first performance.	Progressive i.e subject to improvement or refinement through practice.
Only one stimulus is required	Involves more than one stimulus

(b).

• Flexible
• Benefits animals with longer life spans and so there is time to learn.
• Permits modification to suit in a variety of changing conditions.
• Benefits animals with an element of parental care of the young; which involves learning from the parent

• Benefits animals that live with other members of the species for at least a time e.g. in herds & packs

Question 5.

(a) With examples explain what is meant by a Fixed Action Pattern (FAP) ***(05 marks)***

(b).Describe releasers as they relate to animal behavior ***(10 marks)***

(c).Distinguish between a reflex and a fixed action plan ***(05 marks)***

(a).

FAP is an inborn behavioural response triggered by a very specific stimulus, which once initiated, continues until completed. Each FAP is triggered by a unique stimulus known as a sign stimulus/ key stimulus, or, if it is a signal from one individual to another, it is called a releaser. Examples of FAPs include toad capturing a grasshopper/ prey (releaser is any movement by a small [prey-sized] nearby object) because a toad can starve even though it is surrounded by dead insects because it cannot recognise non-moving animals as prey.

(b).

A releaser is any sign stimuli that provokes a behavioral response {innate/stereotyped} e.g male stickle-backs attacking anything red including other male sticklebacks during mating season, when their own bellies were red, Chemical signals (e.g. pheromones) serve as important releasers for the social insects, the mammary glands of domestic rabbit mothers emit a pheromone that releases immediate nursing behavior by their babies (pups), male robin defending its territory will repeatedly attack a simple clump of red feathers instead of a stuffed robin that lacks the red breast of the males, Herring gull-red spot on beak triggering infant feeding response, urine in dogs serves as a sign for avoidance of territory, female digger wasp behavior must run course once triggered black gulls on identifying white egg shell pieces prompts egg shell removal.

(c).

Reflex	FAP
Simple motor action, stereotyped and repeatable	A complex motor act, involving a specific temporal sequence of component acts
Elicited by a sensory stimulus, the strength of the motor action being graded with the intensity of the stimulus.	Generated internally or elicited by a sensory stimulus. The stimulus acts as a trigger, causing release of the coordinated motor act. The action may be all-or nothing or graded in intensity, and it may be contingent on the type of sensory stimulus or internal state, but it maintains its basic pattern
Stimulus may not require brain activity, but instead may travel to the spinal cord, tracing a path called the	May be processed in the brain as well
Particular stimulus evokes the same response	Response to a particular stimulus can be modified by experience or precise conditions in which the

Question 6.

(a) What is meant by the term adaptation ***(03 marks)***

(b).Suggest the significance of the following forms of adaptations and give relevant examples in each case

(i).Camouflage ***(09 marks)***

(ii).mimicry. ***(04 marks)***

(iii)Warning colouration ***(04 marks)***

(a).

Adaptation refers to a set of structural, physiological or behavioural characteristics acquired by an organism so as to bring about its successful survival and reproduction in the habitat. It involves modification of the developmental pattern of the organism so as to raise its probability of surviving and reproducing. Adapted traits have evolved over several years; commonly caused by mutations that get genetically passed on to off springs.

(b).

Camouflage; the use of any combination of materials, coloration, or illumination for concealment, either by making animals difficult to see, or by disguising them as something else. It reduces predation chances, enabling the organism to reproduce and pass on advantages genes to offspring. Examples of camouflage adaptations in peppered moths during industrial revolution (industrial melanism) in which high levels of smog and soot led to disappearance of light coloured moths because they were easily spot by the predators (birds). Dark coloured ones however perfectly blended with the surrounding; harder to be spotted by the predators; evolved to new species. Predators due to food shortage die and have their numbers reduced. Other examples include; colour changes in chameleons, dull body colouration of arthropods like cockroaches etc.

(b)(ii).

Mimicry; species resembles surrounding or takes on properties of specific object or organism that makes it seem unpalatable or noxious to the predator. With this imitation, the mimicking organism escapes predation; thus its numbers increase and can give rise to a new species over successive generations. Meanwhile the predator population may reduce due to food scarcity or co-evolve accordingly. E.g animals like flower mantises, plant hoppers and geometer moth caterpillars resemble twigs, barks, leaves or flowers, sheep in a wolf clothing, palatable butterflies like Consul fabius mimics unpalatable ones e.g Heliconius ismenius, several palatable moths ultrasonic click calls to mimic unpalatable tiger moths, some octopuses alter their body shapes and coloration to resemble dangerous sea snakes etc.

(b)(ii).

Warning colouration includes aposematism in which warning signals take on forms of perceivable characteristics/ colours revealing the possible harm that may be associated with feeding on the prey. Both the prey and the predator are saved from the potential harm that can be associated with such a feeding interaction. E.g bright colours of the granular poison frog, aposematically coloured bettle (Hycleus lugen) signals a warning to the potential predators of their toxicity.

Question 7.

(a).Explain what is meant by a territory ***(02 marks)***

(b).Outline the;

(i) advantages and ***(09 marks)***

(ii).disadvantages of territoriality ***(09 marks)***

(a).

A territory is an area selected, demarcated and defended by an individual or groups of individuals of the same species from intruders of the same species or different species.

(b)(i).

- Exclusive access to food, particularly at times of shortage.
- Exclusive area for safe and undisturbed mating for successful breeding and raising young ones.
- Space for sexual display and courtship i.e pair formation.
- Spacing of animals avoids competition.
- Reduces aggression / conflicts.
- Improves local knowledge of predators and resources.
- Exclusive place to retreat and shelter.
- Dispersion of nests reduces predation.
- Higher survival rates.
- Males able to hold on to resources show their evolutionary fitness and are attractive to females.
- Minimizes the spread of disease and parasites
- Ensures the fittest individuals pass on their genes to the next generation
- Reduces intra-specific aggression since actual fighting is rare.
- It ensures protection of the vulnerable members of the species, the young, old and sick
- Species achieve maximum utilization of the habitat and available resources are shared among the population.

(b)(ii).

- Cost of defending territory includes risk of physical contact, and displays of strength.
- Need to be vigilant for intruders.
- Vocal or visual communication of territory ownership makes the individual vulnerable to predation.
- Difficult for smaller animals to hold territory; i.e. more likely to be attacked than larger animals
- Difficult to move if resources exhausted.
- Weak members fail to mate
- Members guarding the territory are at risk of predation
- It consumes time and energy

- Interferes with feeding, courtship and bearing of young ones
- Weak members are relegated to the edges of the habitat
- It is associated with aggression and conflict.
- Higher risk of predation if territory within predator's territory.
- Easy for predators to find.
- Ever present threat of take-over as surplus of animals without territory.
- Extra vigilance required at certain times of the year (e.g breeding season)
- Importance of territory size. If too large it's hard to maintain control. If too small, few resources for defence.

Question 8.

(a)With examples explain the following concepts in animal behaviour

(i).Agonistic behaviours ***(04 marks)***

(ii).Dominance hierarchy ***(05 marks)***

(b).Outline the importance of each of the above behaviours explained above ***(09 marks)***

(a)(i).

Agonistic behaviours are ritualized behaviours that substitute for physical contact and fighting e.g. yawn of babo-ons, dogs and baring their teeth, cats and raising their fur, birds raising their feathers, fighting and physical conta-ct in wolves, coyotes, seals, etc.

(a)(ii).

A dominance hierarchy: a form of social ranking within a group in which some individuals are more subordinate than others. The ability to form a dominance hierarchy is innate, but the position each animal assumes may be lea-rned. E.g the pecking order which is a dominance hierarchy formed by chickens. The top-ranking chicken can pe-ck any other chicken. The chicken lowest in the hierarchy is pecked at by all the other chickens in the group.

(b).

Importance of agonistic behaviours

- Aggressive behaviour is used to intimidate another animal of the same species.
- Animals fight or threaten one another in order to defend their young, their territory, or a resource such as food.
- Animals of the same species rarely fight to the death; fights are symbolic / highly ritualised.
- The fight is over when the defeated individual shows submission to the victor.
- In animals, usually the oldest or strongest wins the argument.

Importance of dominance hierarchy

- Reduces aggression, establishes order and stability
- Influences resources partitioning among organisms in a population (food, water, etc.)
- Influences the choice of mating
- Subordinate remains to obtain food, avoid predators, chance to mate
- Greater ability to detect and deter predators is achieved by groups of individuals working together.
- Knowledge and protection of food sources is shared with the group.
- Increased feeding efficiency
- Increased reproductive efficiency
- Increased offspring survival through communal feeding and protection
- The maternal care and group protection enhances the survival rate of the young.
- Young learn through observation and play

Question 9.

(a).With examples, what is meant by migration as part of animal behaviour? ***(04 marks)***

(b).Outline the advantages and disadvantages of migration of animals ***(16 marks)***

(a).

Migration is an inborn, seasonal, long-distance travel of animals to specific locations, usually with a return. Migr-ation is triggered by seasonal changes in weather, air temperature or day length, or changing food supply e.g wild-ebeest move towards rain in the dry season, Salmon return to native streams to breed after several years at sea, so-me animals move from one food source to another, while others migrate to particular breeding areas.

(b)(i).

Advantages of migration

• Offers breeding opportunities and good breeding grounds
• Organisms exploit suitable conditions for mating, breeding and rearing the young
• Animals that migrate have more off springs than resident species
• Ensures dispersal of plant propagules
• Reduce predator risk.
• Escape adverse conditions like bad weather and lower temperatures
• Flexible strategy-some members of the species can migrate and others not depending on where live.
• Stationary animals risk exhausting food supply using particularly if competition from other species.
• Opportunity for different members of the species to mate, and greater breeding variety
• Ideal when specialist food is required because the earth's resources are not evenly distributed.
• Birds migrating at night are usually safe from predators as few day-time birds of prey adapt to night- time hunting.

Disadvantages of migrations

• Large amount of energy required to travel long distances.
• Problems and risks of navigation.
• Risk of forgetting sites or not being able to find them again.
• Leave home territory empty allowing for invaders, and then fights on returning.
• Risk at temporary stopovers from lack of local knowledge about predators.
• Vulnerable to weather changes or poor conditions in one year.
• Many decisions required including optimal fuel load and optimal time of departure.
• Other risks like the change from salt to freshwater or vice versa for some fish.
• Evolutionary maladaptive behaviour in some cases; e.g. green turtles feed on eastern coast of South America but breed on Ascension Island (south Atlantic).
• Risks of night-time migration if animals normally active in day-time (e.g. bat predation of birds).

Question 10.

(a).Distinguish between disruptive colouration and cryptic colouration ***(03 marks)***
(b).Describe the different instinctive behaviours in plants ***(10 marks)***
(c).Describe the different forms of mimicry exhibited by animals ***(04 marks)***
(d).State the advantages and disadvantages of camourflage as an anti-predatory behavior ***(03 marks)***

(a).

Disruptive colouration (Disruptive camouflage or disruptive patterning) is form of camouflage that works by breaking up the outlines of an animal with a strongly contrasting pattern, thus decreasing detectability and predators who look at them may not be able to recognize them without their distinct shape being obvious while Cryptic coloration is one that allows an organism to match its background and hence become less vulnerable to predation or recognition by prey.

(b).

Tropisms: Growth movement towards (positive) or away (negative) from the stimulus e.g. phototropism, geotropism, hydrotropism, etc.
Nastism: Non-directional response to stimulus e.g. when touched, folding of Mimosa pudica leaves (thigmonasty), photonasty: response to light, nyctinasty; movements at night or in the dark; chemonasty; response to chemicals or nutrients, hydronasty; response to water, thermonasty; response to temperature geonasty/gravinasty; response to gravity and thigmonasty/seismonasty/haptonasty; response to contact.

(c).

Batesian mimicry; the palatable species mimics other distasteful species e.g. viceroy butterfly mimics the poisonous monarch butterfly, the harmless hoverfly mimics the painful stinging wasp
Mullerian mimicry; both the mimic and mimicked are unpalatable and dangerous e.g. the five spot Burnet moth and related moths.

(d).

Advantage of camouflage

• Reduces predation chances, enabling the organism to reproduce and pass on advantages genes to off-spring.

Disadvantages of camouflage

• Increases risks of being trampled upon while in the habitat.

• Makes it difficult to be noticed by potential reproductive mates

Question 11.

(a).Distinguish between altruism and kin selection *(02 marks)*

(b)What are some of the benefits and negative consequences of living in a group *(06 marks)*

(c).State the;

(i). significance of social behaviour in animals *(14 marks)*

(ii).factors affecting the size of a territory

(a).

Altruistic behavior is one in which an individual (the donor) performs an action that helps another animal (the recipient) with no apparent advantage to itself e.g alarm calling in squirrels, helpers at the nest in scrub jays, sterile worker castes in honey bees etc while kin selection is the evolutionary mechanism that selects for those behaviours that increase the inclusive fitness of the donor

(b).

• Group members can cooperate in finding food.
• Group hunters can catch larger prey than individual animals can
• Animals foraging might find spots where food is plentiful and all members of the group benefit rather than wasting time fighting over it.
• Groups can defend territories more efficiently than individuals
• Living in a group also provides better access to mates.
• There are also drawbacks to living in a group.
• Groups may attract predators or attacks by other animals because of scents or noises.
• Animals living in groups also spread disease more easily than animals living on their own

(c)(i).

• Females only give birth to one (or at least very few) infants at any one time, so the maternal care and extensive group protection towards these few young enhances the survival rate
• The young learn through observation of and play with other members of the group learned behaviour is vital to the survival of primates
• Knowledge and protection of food sources is shared with the group members
• Greater ability to detect and deter predators is achieved by groups individuals working together.

(c)(ii).

• Availability of environment resources.
• Feeding habits of animals e.g. large carnivores require several square miles.
• Number of individuals in a group.
• Use of the territory e.g. some use territory for breeding only and move out of the territory to feed.
• Levels of testosterone; high levels increase aggressiveness and thus increase the size of the territory

Question 12.

(a).Outline the pain withdrawal reflex in humans. *(06 marks)*

(b).Explain the role of natural selection in the development of behavior patterns. *(08 marks)*

(c).Explain how the following might improve an animal's chance of survival.

(i).Kinesis *(03 marks)*

(ii)Learning *(04 marks)*

(a).

• Pain sensed by receptor cells or nerve endings in the skin;
• Impulse passed along sensory neuron/ nerve to the spinal cord/ CNS.
• Passage through association neuron/ neurons in gray matter.
• Impulse passed along motor neuron/ nerve to muscles/ contraction of muscles pulls or moves limb away from source of pain.

(b).

Innate behavior patterns are inherited & develop independently of the environment with stereotyped responses to environmental stimuli; Animals show variation in their behavior; that are controlled by genes/ inherited from parents. Behavior patterns selected by the environment; make those animals with adaptive behavior more likely to survive; animals which survive leave more offspring (than those less adapted) cause a change in allele frequency. Population/ species starts to show more adaptive behavior and population has evolved.

(c)(i).

Kinesis is a non-directional response of organism in response to a stimulus e.g wood lice moves more in dry conditions and stands better chance of finding damp areas; favourable for its survival.

(c)(ii).

Through learning, the organisms acquire information from past experiences to adapt to new situations; can better obtain food, shelter and resources, increases mating chances and the organism learns to avoid dangerous situations. Co-operation between individuals may increase survival.

Question 13.

(a).Outline Pavlov's experiments on the classical conditioning of dogs. ***(03 marks)***
(b).Describe the roles of different members of a colony of honey bees. ***(06 marks)***
(c).Describe the social organization of honey bee colonies. ***(06 marks)***
(d).What is the importance of the following forms of animal behaviour
(i). Exploratory learning ***(03 marks)***
(ii).Insight learning ***(03 marks)***

(a).

• (Unconditioned) stimulus of food/ sight of food accompanied by bell ringing
• Salivation is the (unconditioned) response
• (Conditioned) stimulus of bell ringing given before/ without unconditioned stimulus / sight of food made salivation become the conditioned response (to the bell ringing)

(b).

Queen bee for reproduction; drone / male: fertilize queen. Workers (sterile females): perform wax making, nurse by feeding larvae and secrete royal jelly. Worker forages for food, nectar, pollen, clean or ventilates hive soldier worker bee protects hive while scout workers communicate location of food to rest of hive.

(c).

Honey bee colonies are organized on caste system/ division of labor; and cooperate to regulate internal temperature of hive. The colony contains one queen which lays eggs, produces pheromones to give instructions to the workers. The colony contains many workers. Swarming when there are more workers than the queen can control the hive. Workers feednurse the brood larvae, forage for food/ pollen/ nectar, communicate with each other by exchange of pheromones, communicate with each other by dances. The colony contains fewer drones than workers, drones mate with queens. Workers evict drones when they are not needed, protect queen from invaders and builds /maintain/ repair hive.

(d)(i).

• Animal explores its new surrounding and gets information which may be useful at later stages.
• Animal gets to identify its immediate escape routes
• Animal gets to identify its immediate food sources.

(d)(ii).

• Enables animals solve complex problems; based on intellectual abilities of reasoning, thought, memory
• Enables animals address new problems/ stimuli never encountered before.
• With adequate training and rehearsal, the animal learns to perfect its response; with little or no mistakes.

Question 14.

(a).Outline the characteristics of the following modes of learned behaviour
(i). Conditioning ***(05 marks)***
(ii).Trial and error learning ***(05 marks)***
(b).Describe how classical conditioning differs from operant conditioning ***(04 marks)***
(c).Explain the importances of each of the above in (a) above forms of learning ***(06 marks)***

(a)(i).

• Results from association of two stimuli presented simultaneously
• It is temporary in nature; if not reinforced, organisms stop responding (extinction) occurs.
• It involves involuntary response

• It is reinforced by repetition of stimuli
• Removal of the cerebral cortex results in loss of response.

(a)(ii).

• The associative stimulus follows the action i.e it doesnot need to be presented at the same time with it.
• Response is improved by repetition
• It is temporary in nature but lasts longer than conditioning
• It is an involuntary response
• Removal of cerebral cortex doesnot results in loss of response.

(b).

In classical conditioning, an animal learns to associate particular stimulus with a reinforcer (unconditioned response) while in operant conditioning; an animal learns to associate a particular behaviour with a reinforcer
In classical conditioning, the delivery of reward or punishment is controlled by the experimenter/ trainer while in operant conditioning, an animal own the behaviour; and determines whether a reward appears or not.

(c)(i).

Classical conditioning in the wild enables animals to modify their behaviours in such a way that they reap maximum reward from the environment and get into less trouble (punishment) as result, they get to learn their predators and predators learn their preys; palatable from unpalatable species etc.
Operant conditioning enables the organism continuously improve its behaviour; makes less and less errors with repetitive practice (trials); till the behaviour is perfected and the organism poses the correct responses eg a rat will make several attempts in a maze; to find food; keeps minimizing errors and finally becomes perfect.

Question 15.

(a).Outline two other causes of loss of responsiveness to stimuli apart from habituation ***(02 marks)***
(b).Communication in animals is commonly used in species recognition, mating behavior and organizing social behavior. With examples, discuss the various mechanisms through which organisms communicate and the significance of each ***(18 marks)***

(a).

• Fatigue or sensory adaptation
• Generalization

(b).

Chemically by means of pheromones; can be releaser pheromones (cause immediate and specific behavioral changes) or primer pheromones (cause physiological changes)
• Reproductively receptive female moths attract male moths by emitting releaser pheromones into the air.
•Ants secrete a releaser pheromone to mark trails that guide other ants to food.
• Queen bees, queen termites, and queen ants secrete primer pheromones that are eaten by workers. Pheromones prevents development of reproductive ability.
• Many male mammals spray urine throughout their territories (especially along their borders) to warn other animals of the same species to keep out.
Visual; observed in animals during displays of aggression (agonistic behavior) or during courtship preceding reproduction.
• Various visual displays like red bellies, head-up posture, zigzag motions, and swimming to the nest are all visual cues that serve as releasers for reproductive behavior in stickleback fish.
• Male sage grouse assemble into groups called leks in which the birds make courtship displays to solicit females. After observing the males, a female will choose one for a mate.
• Wolves make threatening gestures by staring and baring their teeth. Lowering their tails and lying on their backs are submissive behaviors.
Auditory. Sounds are commonly used to communicate over long distances, through water, and at night.
• Whales' songs produced at infrasound frequencies (below the audible range of humans) can be heard for hundreds of miles by other whales.
• Related female elephants form herds and use infrasound for greetings, communicating danger and singing songs that announce reproductive readiness to solitary males who may be miles away.

• Calls of male frogs and male crickets ward off male rivals, attract females, and function in species recognition.
• Songs of male birds provide for species recognition, a display to attract mates, and a warning to other males of territorial boundaries.
• Tactile. Touching is common in social bonding, infant care, grooming, and mating.
• Wolves greet the dominant male in the pack by licking his muzzle.
• Bees utilize tactile communication inform of circular & waggle dance to provide information about food location

Question 16.

What is the importance of each of the following forms of behaviour in animals
(a).Imprinting *(06 marks)*
(b).Habituation *(06 marks)*
(c).Associative learning *(08 marks)*

(a).

• Bond pairing with the parents guaranteeing parental protection
• Responsible for future bond pairing of the young ones. Pairing between members of the species or sex.
• Enables offsprings rapidly acquire survival skills possessed by parents eg learning to fly, capture preys.
• Imprinting behaviours like subconscious learning not to mate with relatives limits chances of inbreeding
• Eases training of circus animals; by imprinting them to their trainers.
• Establish an instant bond with the parent who will impart essential skills for survival, provide food, offer protection and warmth;

(b).

• Helps animals identify neutral elements in their environment.
• Animal learns to disregard unimportant stimuli saving it from fatigue, energy and time wastage.
• Lowers animal's stress and anxiety to seemingly threatening but rather harmless or unimportant stimuli.
• Minimizes sensori-motor demands of the animal in responding to virtually neutral stimuli.
• Enables animals prioritize their responses; i.e attend to significant stimuli; ignore less significant ones.
• Helps animals recognise important clues or signals and hence adapt to the ever changing environment; by offering an appropriate response.

(c).

Importance of operant conditioning (trial and error)

• Enables the animal continuously improve its behaviour; makes less and less errors with repetitive trials
• Animals learn to reinforce behaviour associated with reward and avoid that associated with punishment.
• It is the basis for training animals (positive and negative reinforcement).
• Motivates the animal to explore its environment; identifying areas associated with punishment or reward
• Several trials associated with punishment demotivate the animal as well being energy & time consuming

Importance of classical conditioning

• Enables animals modify their behaviours in such a way that they reap maximum reward from the environment and get into less trouble (punishment) as result, they get to learn their predators and predators learn their preys; palatable from unpalatable species.
• Programmes animals to associate conditioned response not only to natural unconditioned stimuli but also to newly acquired conditioned stimuli.
• Organism learns to associate unconditioned stimuli with conditioned stimuli; so produce a response
• Wasteful exaggeration of the conditioned response incase of presence of the conditioned stimulus but in the absence of an unconditioned stimulus.

Question 17.

(a).In what ways might normal imprinting of goslings be important for their survival *(02 marks)*
(b).Write short notes on each of the concepts of animal behaviour
(i). Biorythms *(04 marks)*
(ii).Vacuum activity *(04 marks)*
(iii).Displacement activity *(04 marks)*
(iv).Courtship *(04 marks)*

(a).

Imprinting influences social behaviour enabling a gosling to follow its mother in order to gain food, protection and shelter and when it matures, to mate and interact positively with other geese.

(b)(i).

Biorhythms are behavioural activities of organisms that occur at regular intervals and are controlled by external factors together with the biological clock e.g courtship displays, nesting behaviors of birds in spring and the migration of certain bird species in autumn. Rhythms involving the internal clock are called endogenous rhythms and those controlled by the external factors are termed exogenous rhythms.

(b)(ii).

Vacuum activity is a form of behaviour in which a stressed/annoyed/disappointed organism performs a normal response towards a wrong organism or object in a way of reducing frustration. The organism has high motivation but no releaser presents itself e.g showing irritation towards someone who is not the cause of the irritation but acts as a substitute.

(b)(iii).

Displacement activity is a form of behaviour in which a stressed organism performs an action that is trivial and irrelevant to the situation in order to relieve frustration. It occurs when motivation is high but two conflicting releasers present themselves e.g one of a pair of birds involved in territorial dispute may resort to nest building activities such as pulling up grass after being defeated.

Question 18.

(a).With suitable examples, describe the different types of stimuli ***(08 marks)***
(b).Outline the
(i).significance of releasers, ***(05 marks)***
(ii)role of hormones in determining behaviour of animals ***(03 marks)***
(c).State the factors that stimulate migratory behaviour in animals ***(04 marks)***

(a).

Motivational stimuli: These are the stimuli that determine the state of the animal responses. Motivators may be due to internal physiological state determined by the levels of hormones in the body, external stimuli e.g environmental factors such as light, temperature, chemicals etc. In birds, when the day length becomes longer, they are stimulated to reproduce and the ovaries and testis become mature.
Releasing stimuli: These elicit a behavioural response causing an organism to act in a certain way e.g attractiveness of food, colour, shape and posture can cause an organism to respond.
Terminating stimuli: Is that stimulus that brings behavioural response to an end e.g. satiety of food, finished nest, ejaculation etc.

(b)(i).

- They coordinate the activities of the organisms in the territory.
- Releasers act as a means of communication among members of the same species.
- They help to avoid open conflict
- They are used as signals for protection of territories
- Act as appeasers

(b)(ii).

- Hormones may affect the growth of nervous connections in the brain during developments
- They may suppress or enhance effectors
- May affect nerve cells & synapses in the brain by blocking inhibitory pathways or opening excitatory pathways

(c).

- Changes in water temperature for the case of migratory fishes like salmons
- Strength and direction of water current
- Changes in chemical composition of water
- Hormonal changes
- Seasonal changes in temperature in case of terrestrial animals
- Change in the photoperiod

Question 19.

(a).How can the transfer of short term memory to long term memory be enhanced? ***(03 marks)***

(b).With examples, state the relevance of the various pheromones in animal behaviour ***(17 marks)***

(a).

- Rehearsal
- Adopting a positive emotional state/ attitude.
- Linking new information to information already in the long term memory

(b).

Alarm pheromones; some organisms like ants, bees, termites release volatile substances that trigger flight, aggression or as an alert to the rest about an incoming threat/ predator.

Territorial pheromones; mark boundaries and identity of an organism's territory eg urine of dogs and cats contains territorial pheromones.

Trail pheromones; social insects use trail pheromones made up of volatile hydrocarbons to mark their paths towards the source of food and return to their nests eg in ants.

Signal pheromones; cause short term changes like the neurotransmitter release that activates/ triggers a response eg gonadotrophic releasing hormone in rats elicit lordosis behaviour important in copulation.

Releaser pheromones; these alter the behaviour of the recipient eg mother rabbits release mammary pheromones that trigger immediate nursing behaviour by their babies, others use powerful attractant molecules to attract mates from a long distance.

Primer pheromones; trigger a change in developmental events; eg queen bees, queen termites and queen ants secrete primer pheromones that are eaten by workers preventing development of reproductive ability.

Aggregation pheromones; important in mate selection, overcoming host resistance by mass attack and defence against predators common in some arthropods (diptera, hemiptera etc).

Sex pheromones; increase availability of the female for breeding; and promote sexual interractions eg reproductively receptive female moths attract male moths by emitting releaser pheromones into the air.

Epideictic pheromones; secure a safe breeding/ hatching ground for organism eg female insects who lay their eggs in a certain area release these pheromones in the vicinity of their clutch to signal other females of the same species to clutch elsewhere.

Question 20.

(a).Define the term behavior & describe the difference between instinctive and learned behaviour in animal

(b).With example(s), of instinctive behaviour, explain fully the way in which the response is brought about

(a).

Animal behaviour refers to the observable responses of an animal to the environment around it; responses usually involve movements of all or part of the body, but may include other changes like colour changes.

Instinctive behaviour implies that the animal has inherited responses to particular stimuli; triggered automatically; fixed action patterns; behaviours that have been modified over many generations by natural selection; culminating in complex behaviour patterns; essential in animals with short life span with no time for trial and error learning or solitary animals with little opportunity for learning from others of their species; includes taxes/ kinesis/ their instincts/ social behaviour etc.

Learned behaviour involves memory; is an adaptive behaviour as a result of previous experience/ environment includes habituation; classical conditioning eg Pavlov's dogs; operant conditioning/ trial and error learning; exploratory learning; insight learning; imprinting.

(b).

Deep tendon reflexes such as knee jerk reflex; when stretched receptors detect stretch in the tendon, impulses are sent via a predetermined pathway along the sensory neurone to spinal cord to motor neurone to muscle/ effectors which contracts; reflex actions are innate determined by inherited nervous pathways; food begging response of young birds is an example of stereotyped behaviour; involves fixed action patterns; colour displayed by open mouth of nestling/ tapping on red spot on parent's beak are specific stimuli called sign stimuli; parent bird responds by feeding chick; in many insects, sign stimuli activate genetically preprogrammed nervous pathways which make muscle perform appropriate movements; kinesis is a random movement in which rate of movement is related to intensity of stimulus eg wood lice move faster in dry environments than in damp ones; result is that woodlice stay longer in favourable environment; taxis occurs in response to direction of stimulus; woodlice show negative photaxis; move away from light; result is that they again are more likely to find favourable environment;

Question 21.

(a).State the factors that could affect learning of a new situation like a maze in animals ***(05 marks)***

(b).Outline the

(i). Similarities between trial and error learning and conditioning ***(04 marks)***

(ii).Salient features of imprinting behaviour in animals ***(08 marks)***

(a).

- The complexity of the situation/ maze
- The type of motivation/ reward/ organisms' state of readiness to learn
- The level of development of the nervous system
- Nature of the learning environment
- Age of the organisms.

(b)(i).

- Both involve the association of stimuli
- Both involve involuntary response
- Both are temporary in nature
- Both are reinforced by reception

(b)(ii).

- Imprinting is a simple specialised genetically determined form of learning
- Occurs mainly in birds and mammals
- Takes place during a brief genetically determined receptive period usually shortly after birth or hatching
- Young organisms begin associating and identifying themselves with other organisms, usually a parent
- Once parent is absent, they imprint on the first, larger moving object they see first
- Associated with establishment of bond between the parent and the offspring
- Imprinting enables organisms to rapidly acquire skills possessed by parents e.g learning to fly in birds.
- Behavior is irreversible

Question 22.

(a).Explain the factors affecting animal behaviour ***(06 marks)***

(b).What are some of the problems faced by migrating organisms ***(07 marks)***

(c).Write short notes on courtship as a form of animal behaviour ***(07 marks)***

(a).

Hormones; may modify behaviour patterns; eg testosterone increases the incidence of aggressive behaviour, and prolactin releases nest-building responses in birds

Time of the day or season; rhythmic changes in behavour may occur according to the time of the day or season eg seasonal migration of animals may depend on the photoperiod or season.

Characterstic behaviour patterns may be released when an animal meets another member of the same species eg a male bird meeting a female on his territory may spark off a cortship display; however should he meet another male, he will threaten him until the intruder withdraws

(b).

- Death by predation
- Prone to parasites and pathogens at stop-overs
- Face a problem of bad weather e.g. strong winds blow the bird off course
- Food shortage before reaching the breeding ground leads to fatigue and stress.
- Lack of stop-overs due to man's manipulation of the environment
- Reverse migrations that lead to organisms being out of range
- Collisions with buildings and high land marks in birds

(c).

Courtship Behaviour: is a set of display behaviours in which an animal attempts to attract a mate and exhibit their desire to copulate. Courtship behaviours include singing in male birds, peacocks display flamboyant plumage colors and prominent tail feathers, preening (sit with their bodies touching one another to show that they are not intending to harm their partner), dancing in birds and building nests in birds etc.

Chapter 14; Locomotion in living organisms

Question 1.

(a).Compare the structure and functioning of cardiac and skeletal muscles *(10 marks)*

(b).Explain how structural features of birds are related to flight *(10 marks)*

(a).

Similarities

• Both are striated with myofibrils (actin and myosin) that alternate with each other.

Differences

Cardiac muscles	Skeletal muscles
Shorter cells interconnected by intercalated discs	Elongated cells with myotendinous junctions
Only one or two nuclei	Multinucleated
Centrally located nuclei	Peripherally located nuclei
Poorly developed sarcoplasmic reticulum	Well-developed sarcoplasmic reticulum
Higher mitochondrial content	Relatively lower mitochondrial content
Involuntary action	Voluntary action
Myogenic	Neurogenic.
Autorhythmicity	Motor nerve ending stimulation
Not easily fatigue	Easy fatigability
Aerobic sources of energy	Both aerobic and anaerobic energy sources
Innervated by the autonomic nervous system	Innervated by somatic nervous system

(b).

Structural features	Significance
Fore limbs modified into wings	Instruments of flight.
Wings equipped with special flight muscles	Their action serves to propel the bird in air
Elongated flight feathers(remiges)	Provide wing shape; increase the wing's surface area
Thick leading edge with a convex upper surface and a concave lower surface	Ensures reduced air pressure above the wing and increased air pressure above the wing with minimum turbulence
Numerous down feathers	Adequate insulation during flight
Tail feathers	Serves as a rudder for turning and landing
Hollow/ pneumatic bones	Reduce weight of the bird
Coracoid, furcula and scapula form a sturdy tripod	Provide a large surface for attachment of large flight muscles
Large keel	Attachment of powerful flight muscles
Extremely light feathers	Provide light weight wing, tail and body contouring.
Possess a light keratin beak/ lacks a true jaw or teeth	Ensures light weight

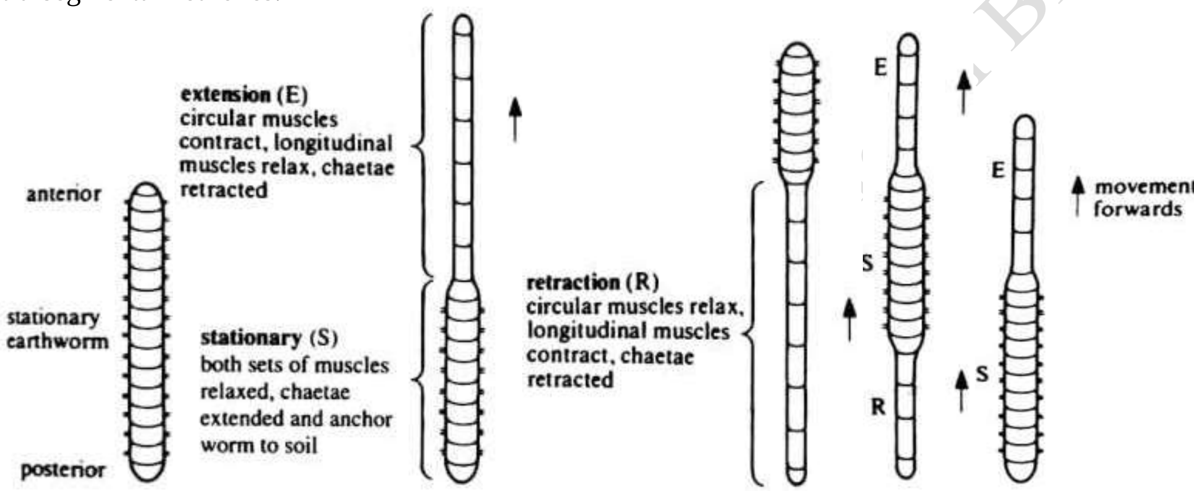
Question 2.

(a).Describe the mechanism of movement in any named annelid. *(12 marks)*

(b).How does a skeletal muscle contract upon stimulation? *(08 marks)*

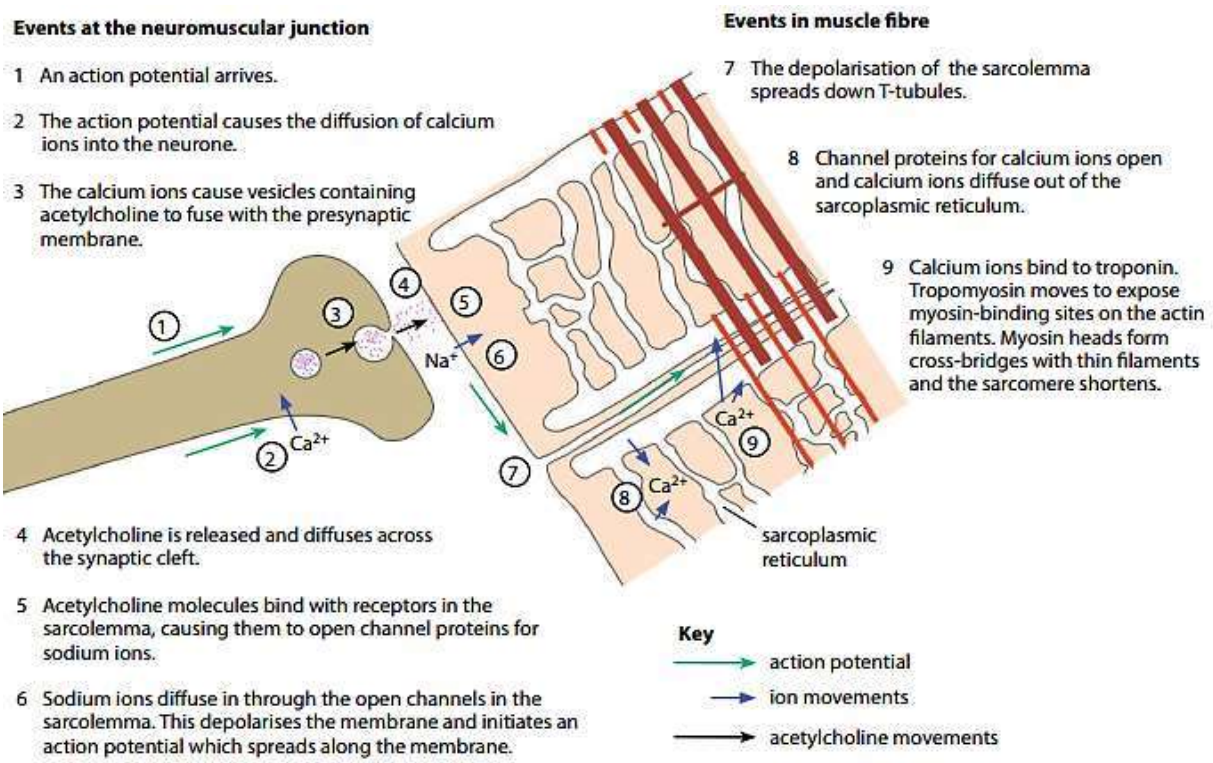
(a).

Movement in an earthworm is by peristaltic waves of muscular contractions against coelomic cavity hydrostatic skeleton; a process that alternately shortens (thickens) and lengthens the cylindrical body of the organism. Crawling is initiated when circular muscles at the anterior end contract while longitudinal muscles relax segment by segment backwards as a wave along the body, there by exerting pressure on the coelomic fluid, which is forced to move at right angles to the squeezing circular muscles, while at the same time the chaetae retract inwards in this region of contracted circular muscles. The net result is forward extension of the anterior end. The movement of the fluid stretches the set of longitudinal muscles, which then contract to stretch the circular muscles back to the relaxed position, causing segments to elongate and thin. Forward extension of the anterior end is coupled with contraction of longitudinal muscles and relaxation of circular muscles in the more posterior segments causing body swelling and protrusion of chaetae this region. As the successive peristaltic waves approach towards the rear end of the body, longitudinal muscles in the anterior region contract, circular muscles relax, the chaetae protrude to anchor at the ground and pull the rear end forward. Control of muscle contraction is brought about by a complex network of inter and intra-segmental neurones.



(b).

Arrival of the impulse at the neuromuscular junction/ motor endplate causes depolarization of pre-synaptic membrane; influx of Ca^{2+} via calcium voltage gated channels occurs; Ca^{2+} activate the synaptic vesicles; which move to the pre-synaptic membrane; fuse with it; release acetylcholine by exocytosis. Acetylcholine is received by specific receptors on the motor end plate membrane; depolarize it; creates an endplate potential; builds up to threshold; creates an action potential that fires an impulse; mitochondria produce ATP, Ca stores (T system and the sarcoplasmic reticulum) produce calcium ions; Calcium ions combine with troponin; calcium-troponin complex formed; complex displaces tropomyosin block from the attachment site on actin filaments; myosin cross bridges using their globular head to attach onto the actin filaments; pull such that the myosin filament slides past the actin filaments; a result of which is shortening of the sarcomere length, H zone almost disappears; A band remains unaltered; and I band shortens; classic of muscle contraction;



Question 3.

(a).Distinguish between

(i). Synchronous and asynchronous flight muscles in insects *(03 marks)*

(ii).Direct and indirect muscles *(05 marks)*

(b).Describe the mechanism of flight in insects *(12 marks)*

(a)(i).

Synchronous flight muscles	Asynchronous flight muscles
Contract once for each neural impulse	Contract more than once for each neural impulse
Occurs within insects that beat their wings less than 100 times per second	Active in insects that flap at very high frequencies
Are direct muscles	Are indirect muscles

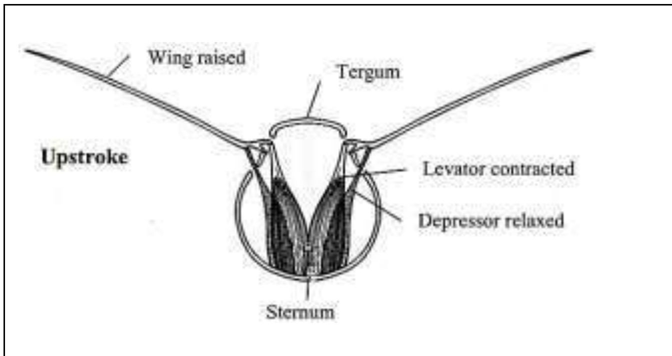
(a)(ii).

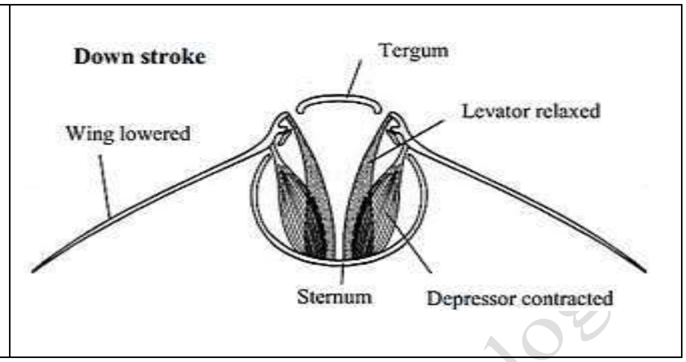
Direct flight muscles	Indirect flight muscles
Directly attach to wing bases e.g. dragonflies, may flies	Attach to interior of thorax (NOT directly to wings) e.g. houseflies, honey bees, midges, etc
Are Synchronous muscles	Are asynchronous muscles
Frequency of wing beat corresponds to the rate at which the nervous system can send impulses	Frequency of wing beat exceeds the rate at which the nervous system can send impulses.
Only respond to neural stimulation to establish a contraction.	The muscles exhibit stretch reflex i.e. automatic contraction in response to being stretched.
Wing beat is slower (about 5-50 times/second)	Faster wing beat

(b).

Using direct flight muscles

During the upstroke, the elevator muscles contract, the depressor muscles relax at the same time, the wings are elevated. During the downstroke, the depressor muscles contract and the elevator muscles relax at the same time, the wings are depressed down.

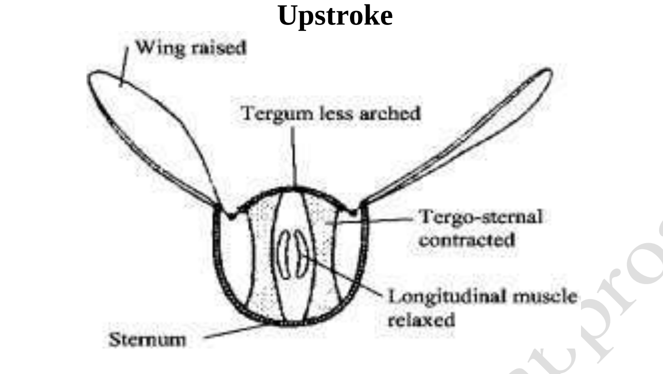




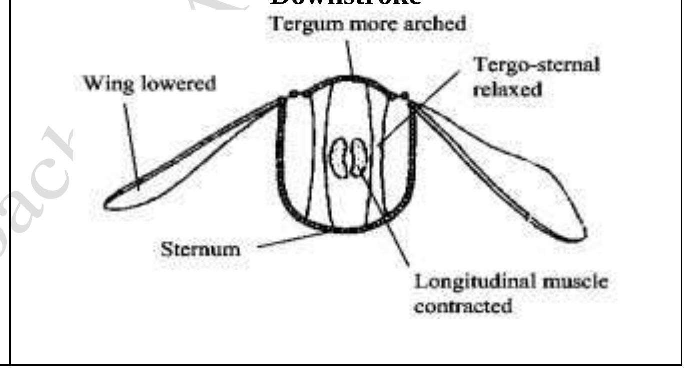
Using indirect flight muscles

Flight in insects is achieved by the antagonistic action of two indirect muscles (not directly attached to the wings) i.e longitudinal muscles and dorso-ventral muscles. During down stroke, longitudinal muscles contract, dorsoventral muscles get reciprocally innervated so they relax. Concavity of the roof of the thorax (tergum) is increased and the tergal attachment rises relative to the pleural attachment; wing goes down. During upstroke, dorso-ventral muscles contract; longitudinal muscles relax; tergal attachment is pulled downwards relative to the pleural attachment; wing goes up. Direct muscles (those attached to the base of the wing); fine tune the wing stroke and folds the wings at rest.

Upstroke



Downstroke



Question 4.

(a).Explain how ATP production is maintained during muscle contraction ***(06 marks)***

(b).Describe how support and buoyancy is achieved by;

(i). Elasmobranches ***(08 marks)***

(ii).Teleosts ***(06 marks)***

(a).

Phosphorylation of ADP by creatine phosphate provides a very rapid means of forming ATP at the onset of contractile activity.

Phosphocreatine + ADP ⇔ATP + creatine

In a resting muscle fiber, the concentration of ATP is always greater than ADP leading to the reformation of creatine phosphate.

Oxidative phosphorylation of ADP; in mitochondria during aerobic respiration (need myoglobin for oxygen transfer)

Substrate level phosphorylation of ADP in glycolysis; during anaerobic respiration to form lactic acid in the process. The accumulation of lactic acid is associated with muscle fatigue, which is broken down later in the liver using oxygen to constitute what is called oxygen debt.

(b)(i).

Support in elasmobranchs like dog fish sharks, skates and rays is provided by constant swimming using fins. These fish's density is slightly greater than that of water and must swim continuously to avoid sinking. Such are adapted by possession of large pectoral and pelvic fins which direct swimming upwards, possession of heterocercal tail i.e. a tail with smaller upper and larger lower lobes for generating much lift and forward motion. During forward motion the pectoral and pelvic fins are all held at a slight angle to the body, generating a force which can be resolved into upward and backward components. The upward component force lifts the anterior end up in the water while the backward component force called backward drag being small only slightly impedes motion and is easily suppressed.

(b)(ii).

Support in teleosts is provided by adjusting air in the swim bladder which may be a closed swim bladder filled with gaseous mixture of oxygen, nitrogen and carbondioxide; all secreted from blood vessels in its wall. The closed type is the most common in bony fish. An open swim bladder having a duct connection to the pharynx and operates as follows: Expulsion of air from the swim bladder increases the fish's relative density and it sinks. If it's to stay afloat, the fish first swims to the water surface then gulps air into the swim bladder to decrease the specific gravity so that the body weight equals the weight of water displaced.

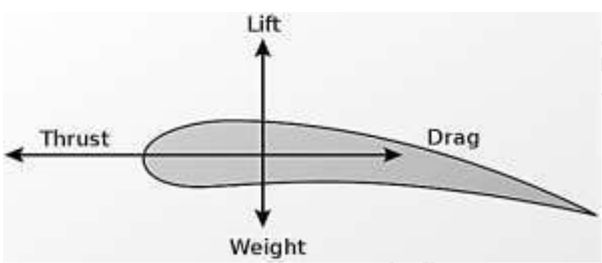
Question 5.

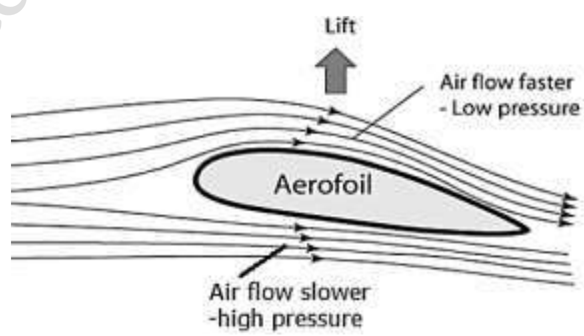
(a).Describe the bird's wing as an aerofoil. ***(12 marks)***

(b).Explain the effect of angle of attack on lift during flight of birds ***(08 marks)***

(a).

Bird's wing is an aerofoil due to its shape, leading edge is broader than the trailing edge and the upper surface is slightly convex while lower surface is slightly concave. During gliding, more curved stream lines of air moving at a faster speed pass over the upper surface of the wing and fewer curved streamlines at a slower velocity; pass under the lower surface of the wing. The air above the wing thus exerts lower pressure while that below the wing exerts higher pressure; creates a pressure gradient; that raises the trailing edge above the leading edge consequently increasing the angle of attack. As the angle of attack increases, more lift is created and once the critical angle of attack is reached, the wing stalls. Driving force of the bird is opposed by drag force while lift is opposed by the sinking force; a component of the bird's weight. Lift and drag when resolved establish aerodynamic force; one that moves the bird at an angle to the air stream Note; An aerofoil is any smooth surface/ appendage which when moved through air creates an aerodynamic force; which makes the appendage move at an angle to the air stream.





(b).

The angle of attack (AoA): is the angle at which the leading edge of wing cuts into the forward airflow. Increasing the angle of attack increases the volume of air diverted over the wing and leads to an increase in lift, but this is at the expense of drag which quickly increases. In a bird excessive AoA results in air turbulence / interruption of airflow (eddy) above the wing which causes a flight stall e.g. when taking off or landing. Air turbulence above the wing in birds is prevented by the alula (bastard wings) and the end- feathers, both of which serve as sloths to smoothen the airflow above the wings.

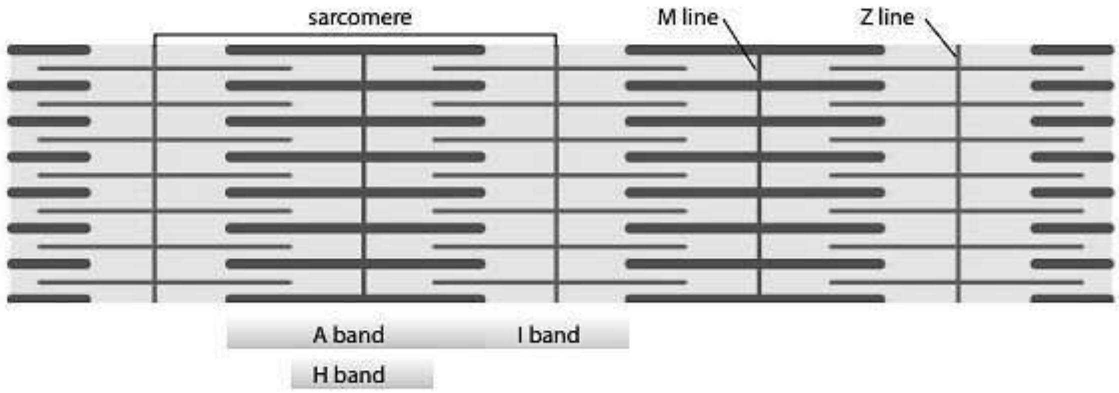
Note; angle of attack decreases with increasing speed.

Question 6.

(a).Describe the structure of a myofibril of a skeletal muscle ***(10 marks)***

(b).How are the skeletal muscle structures related to function ***(10 marks)***

(a).



One myofibril shows alternating cross striations; which are light (isotropic) and dark (anisotropic) bands and is made of filamentous proteins; myosin (thick) and actin (thin) overlapping to give the striated appearance. Actin filaments are anchored at their midpoints to a structure called the Z-line. The region from one z-line to the next is called a sarcomere, which is the functional unit of muscle contractions. Sarcomeres are sections of myofibril that are separated from each other by areas of dense material called "Z discs". "A band" is the relatively darker area within the sarcomere that extends along the total length of the thick filaments. "H zone" is the region in which there are only thick filaments, and no thin filaments at the centre of the A band of each sarcomere. The "I band" is the region between adjacent A bands, in which there are only thin filaments, and no thick filaments. (Each I band extends across two adjacent sarcomeres).

(b).

• Each muscle cell is long to allow considerable contractile effect.
• The fibres are parallel to each other so that contractile effect is transmitted along same axis.
• Muscle fibres taper at both ends for interweaving to improve muscle strength.
• Muscle fibres have very many mitochondria to provide much ATP needed in muscle contraction.
• Cross bridges enable actin and myosin to fit into each other to allow sliding during muscle contraction.
• There is a rich supply of blood vessels to supply nutrients to and drain wastes away from cells.
• There is much myoglobin for storage of oxygen needed very much in aerobic respiration during exercising.
• There are motor end plates to allow innervation that result in contraction.
• There is a dense network of internal membrane system (including transverse tubules) for Ca^{2+} storage which is very much needed in muscle contraction.
• Reciprocal innervation ensures antagonistic muscular contraction to bring about realistic movement.

Question 7.

(a).How are bony fishes adapted to their mode of locomotion? ***(05 marks)***
(b) State differences between flight in birds and that in insects ***(08 marks)***
(c).Describe the forms of instability arise in a teleost fish and how they are counteracted ***(07 marks)***

(a).

• Streamlined body; permits movement in water with minimal resistance/friction
• Powerful myotomes; generate strong propulsive forces that move the fish in water
• Large homocercal caudal fins; whose side to side lashing generative a propulsive force.
• Lateral lines; increase sensitivity of the fish to food identification & predators;
• Multi-filamentous gills; enable efficient gaseous exchange during movement in water
• Air filled swim bladder; permit change in overall density of the fish aiding depth control (buoyancy and sinking)
• Fan-like pectoral fins and pelvic fins; situated on either sides of the body; allow generation of lift (pectoral fins only); also counteract pitching and rolling.
• The scales overlap backwards; to minimize friction of water and other objects on the body.
• Presence of numerous mucus glands on the skin; secrete plenty of mucus on the skin minimize friction of water objects on the body.

(b).

Flight in birds	Flight in insects

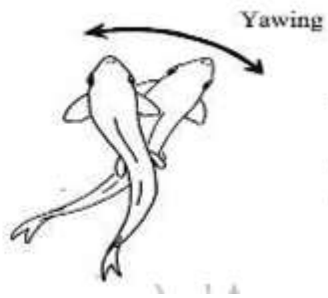
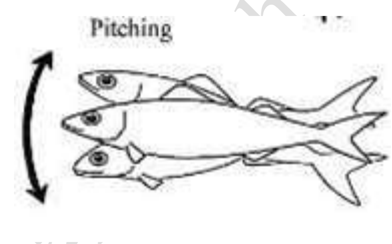
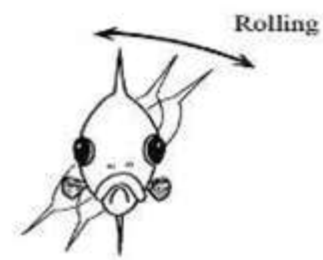
Use direct muscles	Use both direct and indirect muscles
Rate of wing beats per second is low	Rate of wing beat per second is very fast
Flight muscles have myoglobin	Flight muscles lack myoglobin
Muscles are attached on the endoskeleton	Muscles are attached to the exoskeleton
Wing is thick, made up of bones, muscles and covered by feathers	Wing is membranous; made up of chitin
Keel extension for muscle attachment	Muscles attached to the tergum and sternum
Supply of oxygen to active muscles is indirect i.e through blood stream	Supply of oxygen to active muscles is direct i.e through the tracheal system
Turbulence is prevented by the bastard wings	Some insect holders have haltares to prevent turbulence
Air penetrates the wing to reduce resistance	Air doesnot penetrate the wings.

(c).

Yawing; lateral deflection of the anterior part of the body resulting from propulsive action of the tail and contraction of the myotomes. It is counteracted by the general massiveness of the head and the pressure of the water against the side of the body and also by the median /unpaired fins vertical fins (anterior dorsal fins and posterior dorsal fins) and ventral fins.

Pitching; tendency for nose to plunge vertically downwards counteracted by the dorso-ventral flattening of the body; and the large flap like horizontal fins (pectoral fins and to a lesser extent pelvic fins).

Rolling; rotation of the body about the longitudinal axis; it is counteracted by both vertical fins (anterior & posterior dorsal fins) and horizontal fins (pectoral and pelvic fins).

Yawing	**Pitching**	**Rolling**
		

Question 8.

(a).Describe the process of locomotion in a bony fish ***(11 marks)***

(b).Explain the adaptations of bony fishes for effective locomotion in water ***(09 marks)***

(a).

Locomotion in a bony fish is achieved by the alternate contraction and relaxation of myotomes arranged on either side of the vertebral column beginning at the anterior end of fish travelling down the body. When swimming, the myotomes on one side of the body contract bending the vertebral column/ tail to one side. Successive contraction and relaxation of the myotomes result in a series of waves along the body; resulting in side to side movement of the caudal fin. The unduration of the body and the lateral movement of the caudal fins cause rapid backward flow of the surrounding water; producing a forward thrust; propels the fish in a forward direction. Caudal fish exerts a backward pressure against a large volume of water, resulting in a powerful forward thrust and lateral drag; counteracted by the inertia of the water against the anterior end of the body and the large surface area of the dorsal median fins. Three forms of instability are experienced during the locomotion include yawing which is due to lateral deflection of the anterior part of the body counteracted by the dead and the unpaired fins. Pitching; in which the nose plunges vertically downwards; counteracted by the dorso-ventral body flattening and the large flap-like horizontal fins. Rolling, this is rotation of body about the longitudinal axis counteracted by both vertical and horizontal fins.

(b).

• Streamlined body; enables the fish swim through water with less resistance.
• Large eyes; offer a wide field of view.
• Inner ears with well-built semi-circular canals; maintains balance.
• Powerful myotomes; whose contractions and relaxations generate the propulsive forces.
• Gills with numerous gill filaments; increase surface area for gaseous exchange
• Presence of body scales do overlap backwards offer protection and minimizing flow resistance.
• Highly sensitive olfactory organs; detect changes in smell; for easy detection of food and predators etc
• Rigid and flexible skeleton; permits stability; and efficient modulation of the locomotory process.
• Fish's body is fusiform-shaped (spindle shaped) & laterally compressed; reduce water resistance on swimming
• The slippery layer of mucus on the skin reduces water resistance during swimming
• The presence of many rayed-fins enables the fish to swim and also maintain its balance / stability in water
• Scales are arranged in a head to tail direction to reduce water resistance during swimming
• The swim bladder in bony fish maintains buoyancy
• Extensive blood vascular system supplies oxygen & nutrients to the muscle for contraction & drain away wastes
• Body is highly muscular to generate great propulsive force against water resistance
• The neuromuscular activity is highly coordinated resulting in reciprocal innervation.
• The lateral line enables sensitivity of fish and also functions as an echo location process for the fish to identify its surroundings while in water

Question 9.

(a).Outline the importance of support in terrestrial plants ***(04 marks)***
(b).Explain the mechanism of support in dicotyledonous plants ***(04 marks)***
(c).Describe the different mechanical tissues found in plants ***(12 marks)***

(a).

• Enables holding leaves to receive maximum sunlight for photosynthesis
• Enables exposing flowers in the most suitable position for pollination
• Allows holding fruits and seeds in the possible favourable position for dispersal
• Maintains plant shape.

(b).

Turgidity of cells; fully turgidity cause close packing of parenchyma cells in cortex and pith of the stem making them press against one another to keep herbaceous plants and young woody plants erect. Absence/ insufficient water reduces turgor pressure causing loss of support due to wilting.

(c).

Collenchyma cells have uneven thickened cellulose cell walls, and are alive. They are in young plants, herbaceous plants and some organs such as leaves. Collenchyma tissues provide flexible support (a mechanical function) to stems and leaves, enabling withstanding the lateral force of the wind. The walls of collenchyma cells can be deformed by pressure or tension and retain the new shape even if the pressure or tension ceases.
Sclerenchyma fibres and sclereids have lignified cell walls and are dead when mature. They are found in small groups in cortex, pith, phloem and shells of coconuts. The tough and elastic cell walls of elongated fibres allow the cell to be deformed but can snap back to their original size and shape when the pressure or tension is released. Provides great tensile or compressional strength in plants parts, such as in the vascular tissues of stems and roots and the bundle sheath of leaves while support the tree while the elasticity allows the trunk and the branches to sway in the wind without breaking.

Question 10.

(a).Describe how the distribution of vascular tissues is adaptive to function ***(12 marks)***
(b).Outline support in terrestrial plants and that in aquatic plants ***(08 marks)***

(a).

Vascular tissues in leaves are located at the upper side of midrib and lateral veins, and it extends throughout the leaf surface. This enables resisting tearing forces acting on the leaves blade by the wind.
The vascular tissues in young dicot stems are located at the root periphery (near edge); increases the resistance to the bending stresses produced by wind or the passing animals.

Vascular tissue in woody stems are made up of lignified secondary xylem tissues (known as wood) occupy most part of the woody stem, which makes the stem very hard and rigid to avoid support depending on cell turgidity. **Vascular tissues in dicot roots** are located at the centre of the root centre to increase the tensile strength to resist up-rooting force produced by the pulling effect of wind and also provide sufficient incompressibility against the longitudinal compression by the load from overhead and against the lateral pressure exerted by the surrounding soil.

(b).

Support in terrestrial Plants	Support in aquatic Plants
Require mechanical support because air will not hold up plant structures in the same way that water does.	Density of water is much higher than air, hence providing a larger up thrust force
The presence of collenchyma cells, sclerenchyma cells and the abundant highly lignified thick-walled xylem vessels in terrestrial plants implies that support depends on these specialized thick-walled cells.	No collenchyma and sclerenchyma cells are found in aquatic plants, and the poorly developed xylem vessels indicate that aquatic plants do not depend on these cells for mechanical support.
Small air spaces in stem since air with low density only provide limited support to plants.	There are numerous large air spaces in the stem and the leaf of aquatic plants suggest that aquatic plants depend on the buoyancy of water for support.

Question 11.

(a).State the importance of ciliary and flagellar movements in living organisms ***(08 marks)***

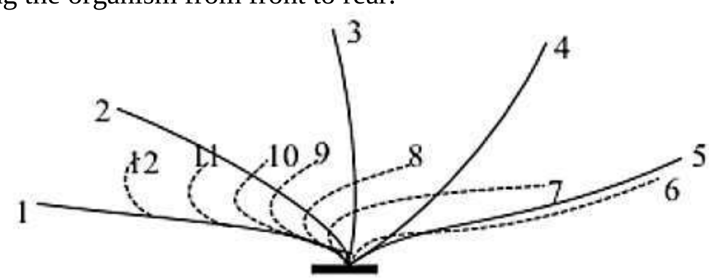
(b).Describe the mechanism of ciliary movement ***(12 marks)***

(a).

• Ciliary movement enables paramecium to avoid danger and drive water and food into their gullet.
• In certain molluscs, they facilitates gaseous exchange by passing water currents over the gills
• In echinoderms, they enables locomotion by driving water through the water vascular system.
• Ciliary movement in the oviduct or fallopian tubes of human female moves ova towards the uterus.
• Ciliary movement in nephridia of annelids e.g. earthworms moves wastes
• Flagellum of sperms enables their swimming movement.
• Flagellum enables the movement in certain protozoans like euglena.
• Ciliary movement of the cells lining the respiratory tract of humans drives away microbes and dust particles towards the nose or mouth.

(b).

A ciliary beat cycle consists of an effective (power) stroke phase and a passive recovery stroke phase. During the effective stroke phase the fully extended cilium makes an oar-like movement towards one side exerting maximum force on the surrounding fluid. The cilia beat in reverse when the power stroke is directed toward the anterior end of the organism so as to propel it backwards while beating towards the posterior end causes the cell or organism to swim forward. In the passive recovery stroke phase which follows the effective stroke, the cilium moves back by propagating a bend from base to tip in an unrolling motion to reduce drag. The cycles of adjacent cilia are slightly out of phase so that they do not bend at exactly the same moment, resulting in metachronal rhythm in which waves of ciliary activity pass along the organism from front to rear.



Question 12.

(a).Explain what is meant by amoeboid movement ***(01 marks)***

(b).Outline the relevance of amoeboid movement to living organisms *(02 marks)*
(c).Describe the mechanism of amoeboid movements in a named unicellular organism *(17 marks)*

(a).

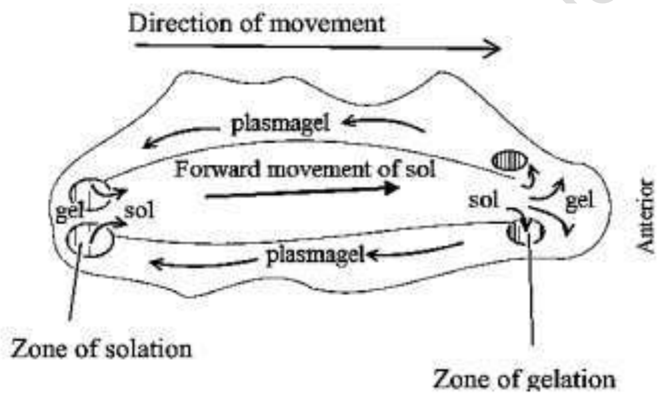
Amoeboid movement is a crawling-like type of movement characterized by protoplasmic protrusion to form temporary feet-like structures called pseudopodia.

(b).

• Enables amoeba to move about to obtain food and avoid dangers.
• Enables phagocytic breakdown of pathogens and effete RBCs by the macrophages.

(c).

Movement in the amoeba occurs by the sol-gel theory, the plasmalemma attaches to the substratum. Stimulation of the ectoplasm (plasmagel) at a certain point causes its conversion to plasmasol and flowing of the pressured plasmasol (endoplasm) into the weakened area, forming first a bulge and then a tube. The movement is sustained by contraction of the outer gel layer which squeezes inwards, causing cytoplasmic streaming towards the tip of the pseudopodium. Within the advancing tip at the fountain zone, plasmasol is converted to plasmagel which is then deposited on the sides of the pseudopodium. At the temporary posterior (rear/hind) end of the cell the plasma gel is converted to plasmasol, which then flows forwards into the newly formed pseudopodium so much so that the whole of body cytoplasm comes into it. Now the plasmagel tube contracts and the body moves forwards. Soon after this a new pseudopodium is again formed in this direction.



Question 13.

(a).Outline the unique properties of muscles that enable their functionality *(04 marks)*
(b).State the advantages and disadvantages of the of skeletons possessed by annelids and arthropods

(a).

• Excitability
• Contractibility
• Extensibility
• Elasticity

(b).

Hydrostatic skeleton eg in annelids like earth worms

<u>Advantages of a hydrostatic skeleton</u>

• Elastic and can bend accordingly when a muscle contracts enabling burrowing.

<u>Disadvantages of a hydrostatic skeleton</u>

• Regularly face a loss of pressure because their skeleton is also their gut.
• Due to lack of a strong supportive system, majority of the invertebrates are small
• The slow motion compromises the animals' escape response from predators.
• The organisms are limited to moist habitats because of the need to minimize water loss by evaporation

Exoskeleton eg in arthropods

<u>Advantages of exoskeleton</u>

• Exoskeletons contain rigid and resistant components that offer protection against predators, bacterial attack and desiccation while on land.

• Exoskeletons contain rigid components that offer support enabling maintaining body shape.
• Exoskeleton of arthropods contains rigid framework of ingrowths known as apodemes which serve as attachment sites for muscles.
• In arthropods the exoskeleton is modified into appendages which offer more rapid locomotion.
• The arthropod exoskeleton contains various folds, flaps & parts modified for feeding & structures for respiration
• Exoskeletons are often highly coloured for camouflage
• The arthropod exoskeleton is jointed enabling flexibility in locomotion

Disadvantages of exoskeleton

• Exoskeletons being rigid impedes the smooth and steady growth of arthropod and so must be periodically be shed to allow growth, which makes the animal temporarily vulnerable for predation and water loss by evaporation until hardening.
• An exoskeleton cannot support large sized animals because of their large volume and body mass necessitating an impossibly heavy and thick exoskeleton.

Question 14.

(a).With examples, distinguish between slow twitch and fast twitch muscle fibres ***(03 marks)***
(b).How are the above distinguished muscles adapted to function ***(07 marks)***
(c). Briefly describe the physiology of
(i) Muscle relaxation ***(06 marks)***
(ii) Rigor mortis ***(04 marks)***

(a).

Slow-twitch fibres e.g. calf muscle contract more slowly, less powerfully and over a longer period hence suited to endurance work e.g. marathon running while fast-twitch fibres e.g. biceps muscle contract more rapidly, more powerfully and only for a short period hence suited to intense exercise e.g. weight lifting.

(b).

Adaptations of slow twitch muscle fibres:

• Large reservoir of myoglobin for storage of oxygen; facilitate aerobic respiration to avoid lactic acidosis
• Much glycogen to provide a source of metabolic energy.
• A rich supply of blood vessels to deliver oxygen and glucose needed in aerobic respiration to provide ATP.
• Numerous mitochondria to produce ATP that maintains muscle contraction.

Adaptations of fast twitch muscle fibres:

• Thicker and more numerous myosin filaments.
• High concentration of enzymes involved in anaerobic respiration.
• Store of phosphocreatine; rapidly generate ATP from ADP in anaerobic conditions

(c)(i).

Ca^{2+} are pumped back into sarcoplasmic reticulum. ATP binds to myosin head, detaching it from actin as the myosin head recharges or cocks. Troponin-tropomyosin regulated inhibition of actin and myosin interaction is restored. Finally, active tension disappears and the rest length is restored. Sarcomere length increases/ Z lines get distant; I Band elongates; H zone lengthens and becomes evidently visible and A band remains unchanged in length. Such features signify a relaxed muscle.

(c)(ii).

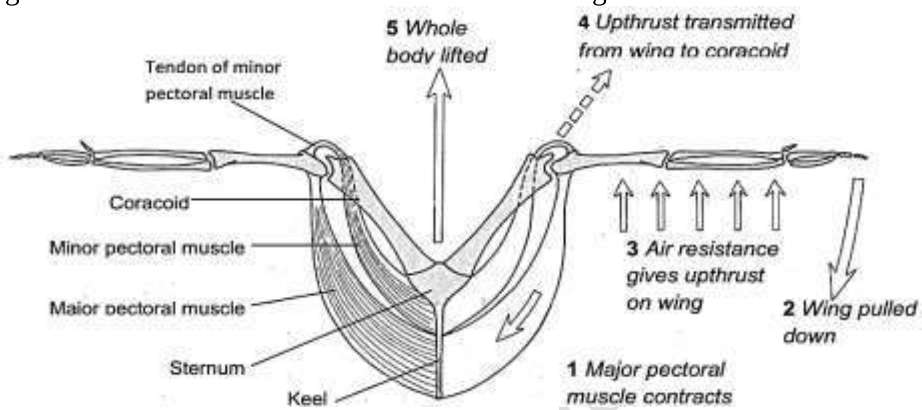
Upon death, there's increased permeability of sarcoplasmic membrane to Ca^{2+} allowing Ca^{2+} influx into the sarcoplasm hence promoting the cross-bridge formation between actin and myosin (muscle contraction). However, efflux of Ca^{2+} from the sarcoplasm into the sarcoplasmic reticulum fails because of lack of ATP since respiration would have ceased. The myosin globular head remains permanently cocked into the actin attachment site and causes the muscle to remain contracted, relaxing only when decomposition.
starts.

Question 15.

(a).Describe the mechanism of flapping flight in birds ***(08 marks)***
(b).How the birds adapted to flight in air ***(12 marks)***

(a).

Downstroke is marked by contraction of pectoralis major muscle and relaxation of pectoralis minor muscle (supr-acoracoideus) at the same time; abduction (elevation / raising) of humerus to a nearly vertical position and also retraction (pulling back) of wings to a horizontal position backwards; full extension of the elbow and wrist joints; pronation (dropping of leading edge relative to the trailing edge) and slight protraction (stretching out) slightly of humerus. This is followed by the downwards and forwards movement of wings until they lie parallel to and in front of the body. This is accomplished in part by protraction (stretching out) of the humerus. Flexed wrist reduces air resistance. The up-stroke of the wing is much more rapid than the downstroke. During upstroke the pectoralis minor muscles (supracoracoideus) contract; the pectoralis major muscles relax at same time; the wings are first adducted (elevated/raised); bent at the wrist; the arm is rotated slightly so that the leading edge is higher than the trailing edge; thus reducing the air resistance and the rush of air lifts the wing.



(b).

- Birds' bodies are streamlined (spindle shaped) during flight for overcoming air-resistance during flight.
- The endoskeleton is hollow (pneumatized) to reduce weight, and many unnecessary bones are fused into a single structure e.g. some vertebrae, pelvic girdle, finger and leg bones.
- Many unnecessary parts like urinary bladder and pinna are totally eliminated while reproductive organs (testes, ovaries and oviducts) are kept tiny during non-breeding seasons to reduce weight.
- The sternum bone is extended into a large keel, for the attachment of large powerful flight muscles.
- The vanes of the feathers have hook lets called barbules that zip them together, giving the feathers the strength needed to hold the airfoil.
- The major wing bones have internal strut-like reinforcements to prevent buckling during stress.
- The respiratory system is extensive and very efficient in supplying muscles with oxygen to facilitate much energy release needed in muscle contraction during respiration
- Their efficient circulatory system powered by a four-chambered heart enables fast supply of oxygen and food to the body tissues and carry away wastes.
- Large brains that are connected to eyes coupled with high-speed nerve transmission enable quick decision making especially when landing.
- The large size of eyes in relation to their body size, coupled with eye keenness enable high visual acuity without crashing into objects.
- The flight muscles of most birds contain oxygen-carrying compounds, (myoglobin and cytochrome) for storing much oxygen which facilitates the release of much energy needed in muscle contraction.
- The forelimbs have become modified into wings which act as aerofoil, generating lift when passed into air.
- They have high body temperature which maintains the high metabolic rate for generating much energy.

Question 16.

(a).Discuss the reasons why animals have to move from one place to another ***(10 marks)***

(b).Describe how support is achieved in;

(i).Herbaceous plants ***(04 marks)***

(ii)Woody plants ***(06 marks)***

(a).

To obtain food; the food requirements of most animals are unavailable in their immediate vicinity.

To capture food; eg carnivores running after preys
Escape from predators; essential for survival
To find mates; essential for the survival of species by allowing reproduction
Distribution of organisms; movement to new areas allow genetic variation to be exploited and its evolutionary potential to be realized.
Reduction in competition; prevents over-crowding and intraspecific competition
To find shelter; from both biotic and abiotic factors
To maintain position; paradoxically sharks must swim to stay still (this involves movement from place to place because the shark moves horizontally to maintain a vertical position)
Reduce vulnerability to diseases; a scattered population is less likely to suffer epidemics of diseases.
Escape from waste products; these are toxic and may carry disease.
For distribution of individuals; where individuals of different genotype move to new areas allowing realization of individual's evolutionary potential;
Prevents overcrowding; reducing intraspecific competition between organisms;
For support & maintaining position; such as in sharks that must swim continuously to maintain their position;

(b)(i).

Support in herbaceous plants is provided by the turgidity of parenchyma/ collenchyma tissues. Osmotic intake of water makes the cells turgid. The turgor pressure of the fluids in the vacuoles pushes the cell contents/ plasma membrane against the cell wall; creating support for its stem/ roots and leaves. The cell walls are thickened by cellulose; which gives additional support to herbaceous plants.

(b)(ii).

Support in woody plants is achieved by specialized tissues/ sclerenchyma, xylem vessels or tracheids. These tissues have cellulose cell walls which are lignified for additional support. Sclerenchyma cells are dead; with thick cell walls that are impermeable to water. The xylem vessels have thick walls of lignin which are deposited during the plant's secondary growth. The lignified xylem vessels form woody tissues of the stem; makes plant stronger and hence provides support. Tracheids are also dead cells with walls and very small diameters.

Question 17.

(a).Describe the mechanism of the bipedalism movement mode exhibited by organisms ***(12 marks)***
(b).Explain why;
(i). man stands on soles but generally sprints on toes ***(04 marks)***
(ii).sprinters crouch (bend down) before taking off for a race ***(02 marks)***
(c).Exoskeletons are an efficient means of supporting small animals. Explain briefly why an animal of the size of a dog would require a disproportionately large and unwieldy exoskeleton to support its body mass

(a).

Bipedal locomotion is walking, running, and standing on two rear limbs. During walking, the calf muscle of the right limb contracts to raise the right heel; causing the ball of foot to exert a contact force on the ground; generating the ground reaction force (GRF) which thrusts the body forward and slightly upwards. The weight of the body shifts to the left foot which is still in contact with the ground to provide support. Extension of the right limb results in its heel touching the ground first to bear the body weight transferred to it from the left side. Further forward movement of the body exerts backward pressure against the ground through the right big toe. As the right leg bears the body weight, the left heel is raised and the whole sequence repeats. This sequence in which the right leg alternates with the left, heel-and-toe action continues until walking ceases. The GRF is composed of the lift force which thrusts the body off the ground and the forward force that propels the body forward; the magnitude of which depends on the angle bet- ween the ground and the main axis of the limb. A large angle between the ground and the main axis of the limb (e.g. 90^o) results in large lift force which thrusts the body vertically upwards with no forward force, a small angle causes a relatively bigger forward force and small upward lift.

(b)(i).

Standing on soles increases the surface area for supporting the body weight in a balanced posture. Sprinting on toes increases the effective length of limbs; enabling taking longer strides that propel the body forward over a greater distance and at a faster pace even if the speed of limb movement remains the same.

(b)(ii).

Crouching creates a small angle between the ground and the main axis of the limb; resulting in maximum forward thrust rather than upward lift; hence propelling the body a greater distance forward.

(c).

Compared with a small animal. A dog has a small surface area to mass ratio; exoskeletons are surface features therefore dog would require a very thick exoskeleton to support its relatively high body mass.

Question 18.

(a).Distinguish between;

(i). Plantigrade, digitigrade locomotion and unguligrade locomotion ***(06 marks)***

(ii).quadrupeds and tetrapods ***(03 marks)***

(b).Describe the mechanism of movement in organisms that exhibit quadrupedalism ***(11 marks)***

(c).Explain why in terrestrial tetrapods it is advantageous to have limbs below and parallel to the sides of the body e.g in mammals rather than lateral to the body e.g in amphibians

(a)(i).

Plantigrade locomotion involves walking with the podials and metatarsals flat on the ground e.g. humans, bears, rabbits, kangaroo, rats and hedgehogs while digitigrade locomotion involves walking on the toes with the heel and wrist permanently raised e.g. birds, wolf, dog, cat, lion etc. Unguligrade locomotion on the other hand involves walking on the nail or nails of the toes (the hoof) with the heel/wrist and the digits permanently raised. Ungulates include horse, zebra, donkey, cattle, camel, hippopotamus, goat, pig, sheep, giraffe, antelope, and gazelle etc.

(b).

Quadruped; an animal especially a mammal having four limbs all specialized for walking while a tetrapod is a vertebrate animal having four limbs e.g. amphibians, reptiles, birds and mammal. A tetrapod may use only two limbs for walking.

(c).

Contraction of extensor muscle causes each limb to act as a lever by extending and exerting a backward force that presses the foot against the ground thus thrusting the animal forward and slightly upwards; because an equal and opposite force called reaction force is transmitted along the length of the limb against the body while contraction of flexor muscle pulls the limb forward and lifts it off the ground. During walking, only one limb is raised at a time; the other three remain anchored to the ground to provide tripod support / stability in a sequence of leg movement as follows: left forelimb; right hind limb; right forelimb; left hind limb. During slow running, tripod support is lost because the two fore limbs are moved together followed by the two hind limbs in the sequence of left forelimb; right forelimb; right hind limb; left hind limb. During maximum speed running, the organism uses its back to attain speed. All the four legs may be lifted off the ground at the same time, with alternate upward arching of the back coupled with rear feet extension in front of the front feet and the front feet extension behind the rear feet, and full extension of the vertebral column coupled with full extension of front legs forward and rear legs rearward to increase stride length.

Question 19.

(a).What is a sarcomere? ***(01 marks)***

(b)(i).Explain the roles of calcium, tropomyosin, acetylcholine & ATP in the sliding filament theory of muscle contraction ***(12 marks)***

(b)(ii)Distinguish between temporal summation and muscle fibre recruitment ***(02 marks)***

(a).

Sarcomere is a region between two Z lines of a muscle fibre, acting as a contractile unit of a muscle

(b)(i).

Calcium; enable myosin heads to bind onto actin. Calcium ions bind to troponin causing it and the tropomyosin to which it is attached, to move away from the binding from the binding site on actin so myosin heads can attach/ switch actin into the one position so that actin and myosin can bind/ activates ATPase; release acetylcholine/ neurotransmitter from presynaptic membrane so neurotransmitter diffuses across to muscle cell post synaptic membrane/ sarcolemma.

Tropomyosin; blocks the myosin head binding sites on the actin filament; serving as regulatory protein of muscular activity. Tropomyosin prevents the muscle from being subjected to excessive contractions which would otherwise result in fatigue.

Acetylcholine; acts as a neurotransmitter depolarizing the post-synaptic membrane; whose effect results in an endplate potential; that is propagated to the muscle fibre; firing an action potential causing calcium ion release.
ATP; provides energy to break cross-bridges/ rotate myosin heads/ drives the ratchet mechanism; provide energy to pump calcium ions back into the sarcoplasmic reticulum; formation of phosphocreatine

(b)(ii).

Temporal summation is the adding together of muscle tensions produced in a single motor unit at different times, whereas fibre recruitment results from the addition of muscle tensions produced in different motor units at the same time.

Question 20.

(a).What are the support functions of water in living organisms ***(07 marks)***
(b).Explain the electrical properties of skeletal muscles in animals ***(13 marks)***

(a).

Water is not easily compressible, making it a useful structural agent. Its support functions include;
• Forms the hydrostatic skeleton in earthworms
• Forms the coelom of many invertebrates
• Constitutes turgor pressure; keeps herbaceous plants and herbaceous parts of woody ones erect.
• Constitutes the aqueous and vitreous humour of the eye
• Erection of the penis
• The amniotic fluid around the mammalian foetus
• As a medium in which many organisms live permanently it provides support for the whole body.

(b).

Single twitch; smooth muscle contraction and relaxation which occurs when a single muscle fibre is provided with a single electric shock of sufficient intensity.
Summation; occurs when two shocks of sufficient intensity are subjected to the muscle fibre in quick succession. If the second shock is provided when the muscle fibre has started relaxing, two distinguishable twitches are given. However, if the second shock is provided before the muscle fibre begins to relax, a smooth muscular response is given.
Tetany; occurs when a single muscle fibre is subjected to a train of shocks of sufficient intensity. The muscle fibre is maintained in a state of contraction called tetany. Relaxation only occurs when the stimulus is removed.
Fatigue; occurs when a muscle fibre is continuously stimulated. Muscular response gradually decline & eventually disappears; muscle is said to be fatigued and is caused by exhaustion of oxygen and ATP supply.

Question 21.

(a).Explain the challenges of locomotion and support faced by animals in a
(i). Terrestrial habitat ***(06 marks)***
(ii).Aquatic habitat ***(06 marks)***
(b).State the advantages and disadvantages of the skeleton possessed by mammals ***(08 marks)***

(a)(i).

• Gravitational pull/ weight; opposes upward movement of the terrestrial organism
• Resistance forces like friction; creates drag forces that counteract effective movement of the organism.
• Instability on land; such as poor limb control, being blown up by wind etc.

(a)(ii).

• Buoyancy in water; counteract sinking; call for greater energy requirements.
• Resistance forces in water; such as viscosity creates drag forces that increase with velocity
• Instabilities in water; like yawing, rolling and pitching.

(b).

Advantages of an endoskeleton
• It's jointed for flexibility to allow diverse range of locomotory patterns
• Endoskeleton does not limit space available for internal organs and can support greater weight.
• Bone are hard for protecting delicate parts like the brain, lungs, heart, spinal cord, etc.
• Bone tissue is mineralized and hence acts body's physiological mineral reserves like Ca^{2+}
• Mammalian bones manufacture the defensive leucocytes.

• Vertebrates have a versatile support system & as a result, they develop faster & bigger bodies than invertebrates.

Disadvantages of an endoskeleton

• Endoskeleton are enclosed in other tissues do not offer much protection from predators in some animals

• Endoskeletons do not contribute to minimizing water loss from the body by evaporation.

Question 22.

(a). Describe the different ways in ways in which continuous exercise promotes muscle performance in humans ***(07 marks)***

(b).Explain how flight is achieved in insects ***(13 marks)***

(a).

• Increases number of mitochondria within muscle cells resulting in large & rapid production of ATP.

• Increases the diameter and the number of individual muscle fibers.

• The number of motor limits to be activated increase, increasing strength of muscle contraction

• Amount of myoglobin increases; increasing amount of oxygen stored, avoiding anaerobic respiration.

• Tolerance to high levels lactic acid increase, prolonging the period within which muscle can fatigue.

• Fats in muscle fibers are rapidly converted to fatty acids and glycerol; then oxidized to generate energy

• Muscle strength and speed of muscle contraction and relaxation' is increased

• Number of blood vessels supplying the muscle fibers; maintaining a constant concentration gradient

• Nervous coordination between pairs of antagonistic muscles improves for rapid and efficient activity

• More phosphocreatine, glycogen and fats are stored to provide more energy

(b).

Flight in large winged insects such as locusts, butterflies etc is brought about by direct flight muscles, nerve impulses stimulate contraction of these flight muscles (synchronous flight muscles) these are elevator and depressor muscles. When the elevator muscle contracts, the depressor muscles relax, wings are raised upwards (upward stroke occurs), when the depressor muscle contracts the elevator muscle relaxes the wings are pulled downwards/ down stroke occurs, rapid upstrokes and down strokes produce flapping movements and as the wings move forward and backwards during flapping, they act as an aerofoil in this case the air currents are driven downwards causing the air pressure below the wings to become greater than the air currents above, the pressure gradient exists providing a lift force.

In other insects/ small winged insects the flapping movements is brought about by two sets of antagonistic indirect muscles. These are a pair of dorso-ventral muscles and longitudinal flight muscles (asynchronous flight muscles). When dorso-ventral muscles contact/ longitudinal. muscles relax; resulting into upstroke and when longitudinal muscles contract the dorso-ventral muscles relax resulting into down stroke. The rapid flapping movements of the wings generate a lift force

Question 23.

(a).How do the following contribute to flight in large winged insects

(i). Flight muscles ***(05 marks)***

(ii).Aerofoil nature of the insect's wings ***(05 marks)***

(b).Explain how modifications of the plant organs provide support ***(10 marks)***

(a)(i).

Nerve impulses stimulate alternate contractions and relaxations of two types of antagonistic flight muscles; the direct and indirect muscles. Indirect muscles have two sets of muscles and dorso-ventral muscles. When dorso-ventral muscles contract, longitudinal muscles relax; the tergal attachment of the wing is pulled downwards relative to the pleural attachment resulting in the wings going upwards. When longitudinal muscles contract, dorso-ventral muscles relax; concavity of the roof is increased and the tergal attachment rises relative to the pleural attachment resulting in the wing going downwards. Continous movement of the wing in an up and downward fashion results in flight.

(a)(ii).

The upper leading edge of the wing of an insect, being broader, convex, with smooth surfaces moves in air at an angle (angle of attack) to the air stream; compared to the lower and trailing surface which is concave/ giving the aerofoil appearance of the wing. During flapping, air flows faster over the upper surface than at the lower surface;

creating a higher air pressure below the wings and lower air pressure above the wings. The pressure gradient is resolved into a lift force;

(b).

• Xylem vessels/ tracheids/ sclerenchyma are found at the central regions of the roots; and in the mid-ribs/ net veins of leaves; they are arranged in ring forms or scattered In the stems of plants; they are highly lignified adding extra mechanical strength.

• Stems of herbaceous plants contain numerous thin walled parenchyma cells; when these cells are fully filled with water they become turgid providing extra support.

• Collenchyma located at the periphery in the cortex (cortical regions) of the roots/ stems/ leave cells have extra cellulose deposited at their corners for extra strength.

• Roots of some plants develop into prop roots like maize plant/buttress roots/deep roots; for firm anchorage and support.

Chapter 15; Growth and development

Figure 1 and 2 show growth patterns of organs in humans and the mean growth rate in the different sexes respectively. Figure 1 represents the size attained by the human body organs from birth, expressed as a percentage of the post-natal growth. Figure 2 represents the mean growth rate changes in centimeters per year, in boys and girls, from birth to maturity. Study the figures and answer the questions that follow.

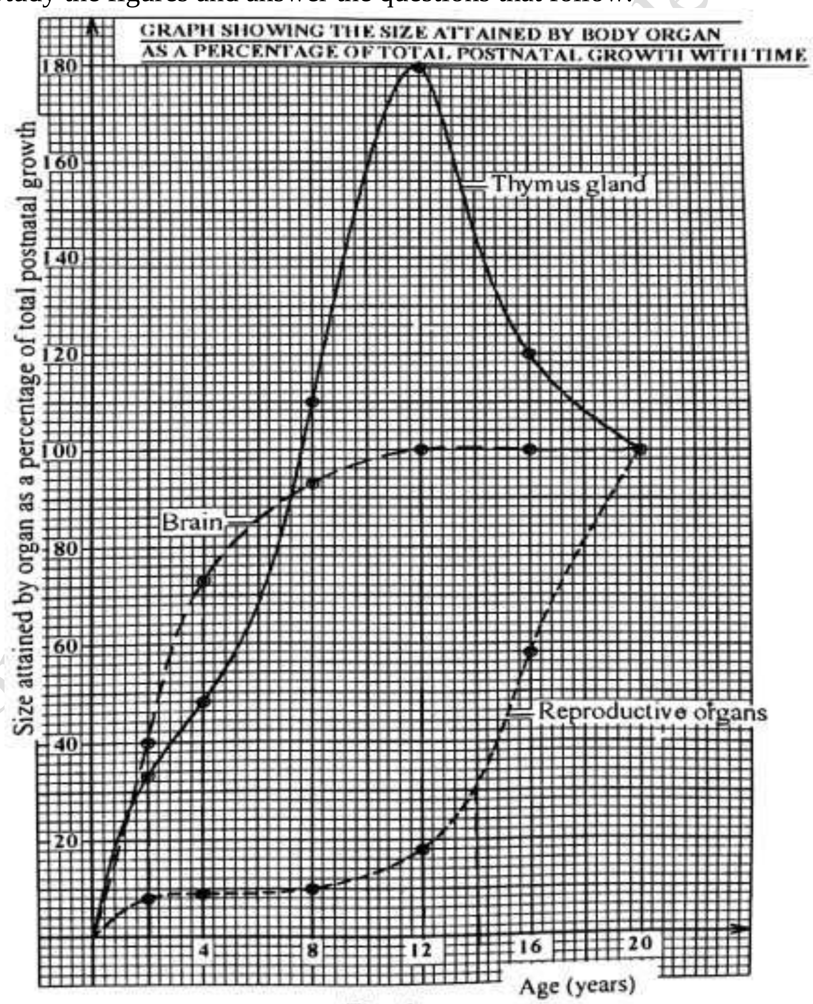


Fig. 1

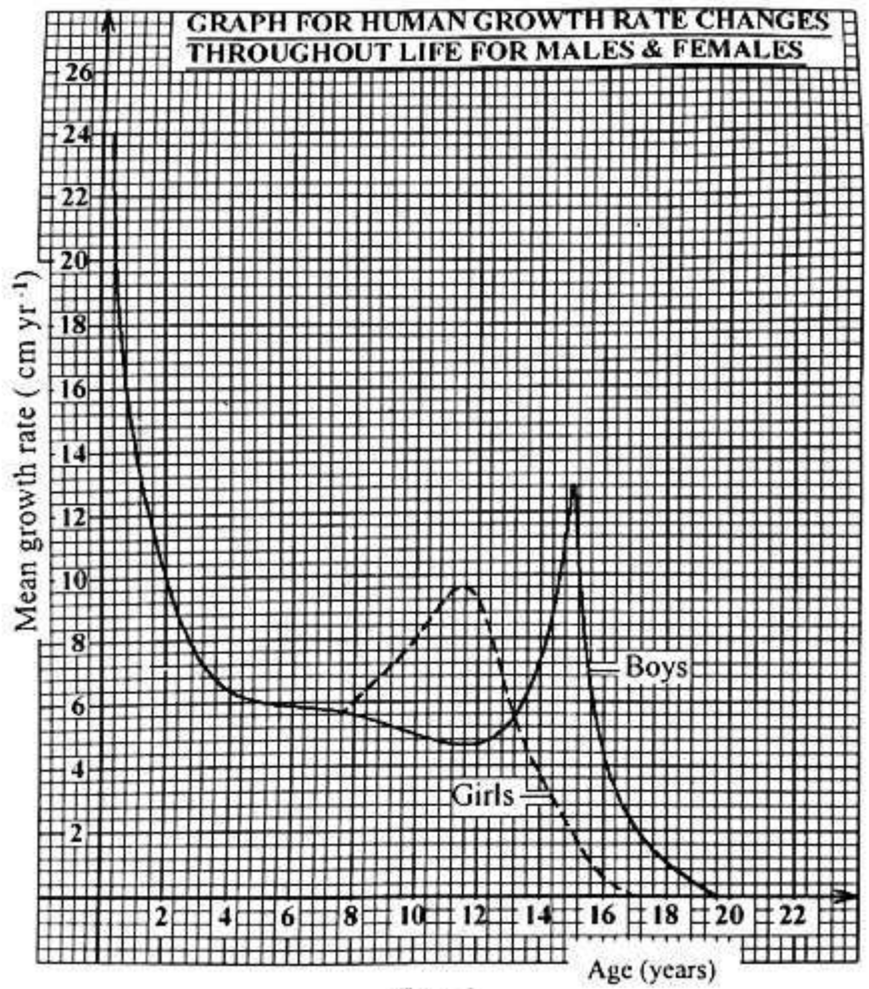


Fig. 2

(a).Describe the growth pattern shown by the

(i). Thymus gland ***(04 marks)***

From 0 to 2 years, growth increases rapidly; from 2 to 4 years gradually; rapidly from 4 to 12 years to a peak/ maximum; then decreases rapidly/sharply; from 12 to 16 years and gradually; up to the 20th year;

(ii) Brain ***(04 marks)***

Growth increased rapidly from 0 to 2 years; gradually from 2 to 4 years; more gradually from 4 to 12 years; remained constant; after 12 years;

(iii)Reproductive organs ***(04 marks)***

From 0 to 2years; growth increased gradually; and from 2 to 8 years; growth remained almost constant; increased gradually; from 8 to 12years; and then rapidly; from 12 to 20 years;

(b).Explain the growth pattern shown by;

(i). Thymus gland ***(06 marks)***

Growth of thymus gland like others is allometric/ uneven growth; it increases rapidly from birth to a peak at 12 years to produce white blood cells; to fight infections; as immunity has not yet been acquired; the mass of the gland reduces from 12 to 20 years to almost half as more of the thymic tissue is replaced by adipose tissue; also bone marrow of the long bones is fully developing to produce white blood cells for body defence;

(ii) Brain ***(04 marks)***

The brain grows rapidly before 5 years to coordinate; growth; development; of different parts of the body and learning;

(iii)Reproductive organs ***(02 marks)***

Reproductive organs grow very little in early life up to 12 years as a urogenital organ for excretion; they increase rapidly after 12years due to the onset of sexual maturity at puberty;

(c).Compare the mean growth rate in boys and girls ***(08 marks)***

Similarities

• Similar trends in growth from 1- 7.6 years;
• Both have a spurt of growth rate or attain peak/maximum
• In both growth rate reduces with age to zero;
• In both mean growth rate is the same at 13.2; and 7.6 years;
• From 4 to 7.6years growth rate is constant;

Differences

Growth in boys	Growth in girls
• High peak/growth spurt	• Low peak/growth spurt;
• Rapid increase in mean growth rate to peak	• Gradual increase in mean growth rate to peak;
• Steep decline from peak	• Gradual decline from peak;
• Mean growth stops later	• Mean growth stops earlier;
• Boys spurt to peak later	• Girl spurt to peak earlier;
• 7.6 to 11.6 growth rate decreases gradually	• 7.6 to 11.6years growth rate increases gradually;
• 12 to 15years mean growth rate increases rapidly	• 12 to 15years mean growth rate decreases rapidly

(d).Explain the relationship between the size attained by reproductive organs and the mean growth rate between 11-20 years ***(08 marks)***

11 to 20 years represents the onset of puberty/adolescence; the size of the reproductive organs increase rapidly; In girls puberty occurs earlier than in boys; due to early secretion of oestrogen hormone; that promotes development of reproductive organs and female sexual characteristics; In boys, the rapid increase is due to testosterone hormone; that maintains and enlarges the testes/ secondary sexual characteristics) and growth of the male spurt at puberty; The mean growth rate finally decrease later because the reproductive organs have attained their maximum size therefore the level of hormones decrease;

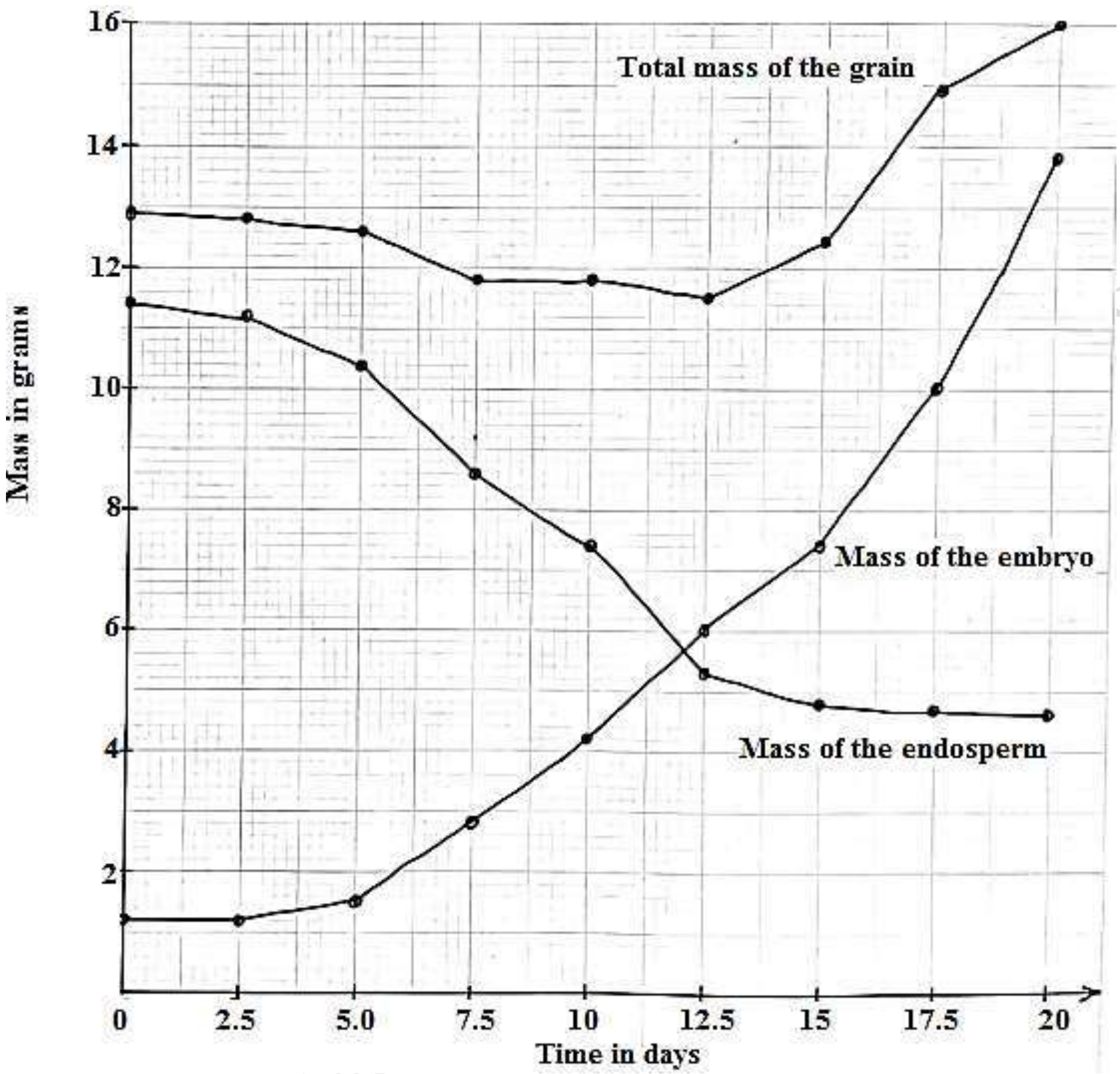
Question 2.

The data in the table below was obtained from an experiment on the germination of barley grains. The average weights of the seedlings were obtained at different stages of germination and recorded for 20 days

Seedlings	Time in days								
	0.0	2.5	5.0	7.5	10.0	12.5	15.0	17.5	20.0
Mass of embryo (g)	1.2	1.2	1.5	2.8	4.2	6.0	7.4	10.0	13.8
Mass of endosperm (g)	11.4	11.2	10.4	8.6	7.4	5.3	4.8	4.7	4.6
Total mass of grain (g)	12.9	12.8	12.6	11.8	11.8	11.5	12.4	14.9	16

(a) Using the same axes, plot suitable graphs to show the information provided in the table ***(04 marks)***

<u>A graph showing the relationship between the mass of the embryo, the endosperm and the total mass of the grain with time.</u>



(b) Explain the variation in the graphs of the embryo and endosperm ***(14 marks)***

At time of 0 days; the mass of endosperm is higher while the mass of embryo is lower; this is because food reserves in the endosperm are not yet hydrolysed; no growth of the embryo occurs; From time of 0 to 2.5 days; the mass of endosperm remains almost constant while the mass of the embryo is constant; imbibition occurs; activation of embryo begins to secrete gibberellins; resulting into synthesis of very little hydrolase enzymes; hydrolysis of food reserves begins in the endosperm but no soluble food substances translocated away from endosperm; no growth occurs at the embryo; From time of 2.5 to 7.5 days; the mass of the endosperm decreases gradually while the mass of the embryo increases gradually; this is because gibberellins stimulated synthesis of various hydrolytic enzymes such as α-amylase; which catalyzed break down of starch to glucose; lipase catalyses hydrolysis of lipids to fatty acids and glycerol; protease catalyses breakdown of proteins to amino acids; small amounts of soluble products, glucose/ fatty acids /glycerol/ amino acids are translocated away from the endosperm; to the embryo; where in the embryo they are used for cell division/cell differentiation / formation of new tissues; little growth of the embryo occurs; From time of 7.5 to 12.5 days; mass of the endosperm decreases rapidly while the mass of the embryo increases rapidly; more hydrolytic enzymes synthesized which catalyzed the hydrolysis of more food reserves in the endosperm; a lot of soluble products translocated away from the endosperm; to the embryo; in the embryo rapid growth of plumule and radicals occurred; From time of 12.5 to 20 days; mass of endosperm decreases more gradually while the mass of the embryo increased rapidly; because food reserves in the endosperm is almost depleted/most soluble products translocated away from the endosperm to the embryo; and green foliage leaves have grown in the embryo; which now photosynthesize organic food;

(c)(i). Give an advantage and disadvantage of using dry weight in the experiment above
Advantages
• It gives accurate measurements as variations in water content are eliminated
Disadvantages
• Leads to destruction of tissues
• It's energy and time consuming
• Requires more skills in conducting
• Tedious
(ii).Why do the total masses of the embryo and endosperm not equal to the total mass of the grain?
• Extra structures such as the testa adds more weight
• Breakdown of food reserves to soluble and simpler substances in the endosperm;
• Respiration of respiratory substances in the embryo leads to loss of weight due to loss of carbon dioxide and water;
(d) Explain the sequence of events that lead to formation of the final products that are used in germination and state the use of each of these final products in the growth of the seedling. ***(08 marks)***
Imbibition of water that activates the embryo to secrete hormone gibberellins; gibberellins diffuse to the aleurone layer; stimulating synthesis of hydrolytic enzymes which catalyse the hydrolysis of insoluble food reserves to soluble products; for example amylase catalyses the breakdown of starch to glucose/ lipase hydrolysis of lipids to fatty acids and glycerol/ protease hydrolysis of proteins to amino acids; Glucose /fatty acids/ glycerol/ amino acids are actively transported to the embryo; glucose respired to generate energy; amino acids used for synthesis of functional proteins; soluble products are used for formation of new tissues/cell membranes/plant structures;
(e)(i).Some grains may not germinate even when all other conditions have been satisfied. What are the advantages and disadvantages of such a phenomenon? ***(07 marks)***
Advantages
• Full maturity of the embryo occurs;
• Increases concentration of gibberellins, a germination promoter;
• Reduces rapidly the concentration of germination inhibitor abscissic acid;
• Seeds escape harsh environmental conditions;
• Soluble food products are reserved;
• Competition for nutrients reduced due to low metabolism;
• Seed coat becomes softened; Disadvantages
• Seeds may be destroyed by pests;
• Seeds rot when kept for long;
• Net productivity reduced;
• Resources underutilized;
(ii).Why do seeds fail to germinate properly when they are still fresh? ***(04 marks)***
• Hard seed coat;
• Immature embryo;
• High level of Abscissic acid in the seeds/ ascorbic acid present in the fruit juices;
• Lack of adequate light;
• Unfavourable temperature;
• Damaged embryo;

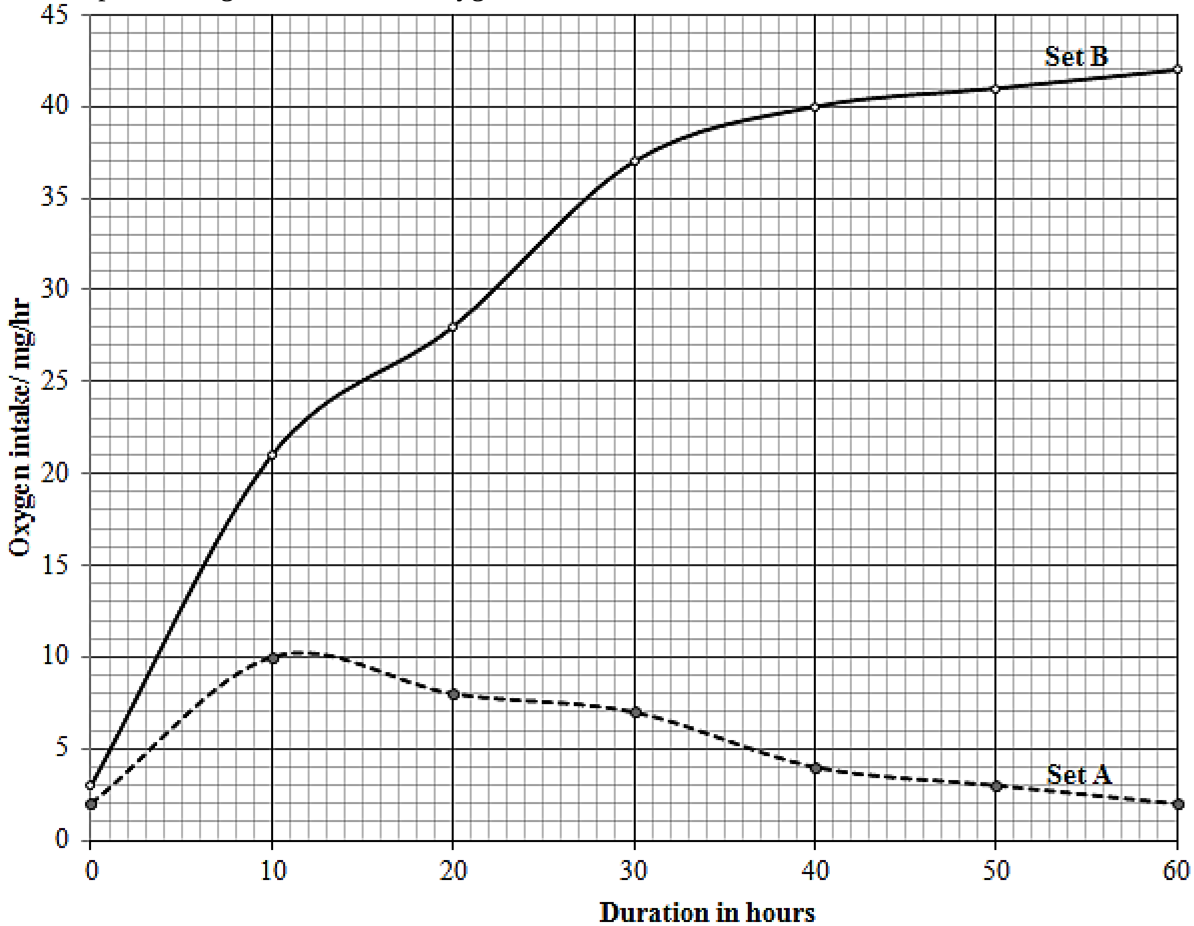
Question 3.

Two sets of seeds(A) dormant seeds and B which are non-dormant seeds were soaked for 24 hours. After this period, investigations were conducted to determine oxygen intake by the seeds. The table below shows the results obtained.

Oxygen intake Mg/hr	Duration in hours						
	0	10	20	30	40	50	60
Seeds in set A	2	10	8	7	4	3	2
Seeds in set B	3	21	28	37	40	41	42

(a).Plot a graph to represent the information in the table above ***(08 marks)***

Graph showing the variation in oxygen intake of seeds in sets A and B with duration of time



(b)(i).Describe the trend of oxygen intake by seeds in set B ***(05 marks)***

From 0 to 10 hours, there is a rapid increase in oxygen intake. From 10 to 30 hours, there is a gradual increase in oxygen intake and from 30 to 60 hours; there is a slow increase in oxygen intake; attaining maximum intake of 42 mg /hr at the 60th hour.

(b)(ii). Compare oxygen intake in the two sets of seeds ***(05 marks)***

Similarities

From 0 to 10 hours; oxygen intake increases in both A and B Initially oxygen intake is slow

Differences

Time duration	Oxygen intake for B	Oxygen intake for (A)
Generally	Oxygen intake is higher	Oxygen intake is lower
From 0 to 10 hours	Rapidly increases	Gradually increases
From 10 to 60	Continues to increase gradually up to 30	Slowly decreases all through
	Highest intake was 42mg/hr at 60 hours	Highest intake was 10mg/hr at 10 hours

(c)(i).Suggest reasons for the initial increase in oxygen intake by both sets of seeds up to the 10th hour

- Soaking makes seed coat permeable to oxygen
- Soaking increases elasticity of the seed coat, thus creating space for oxygen absorption
- Possible slow rate of respiration in the embryo plant to keep it alive
- Soaking increases the dissolution of oxygen in aqueous state making it readily diffusible.

(c)(ii)Explain the difference in the trend of oxygen intake in the two sets of seeds after 10 hours of soaking

Set A (dormant seeds); there is minimal metabolic activity/ little or no enzyme activity in the tissues; so decreasing oxygen intake. Since there is little or no breakdown of stored carbohydrate reserves; there is a reduction in aerobic respiration; with little or no embryological development.

Set B (non-dormant seeds); embryo is beginning to germinate; involving formation of new cells of tissues; which is an active metabolic process requiring energy. Therefore, the stored food reserves get hydrolysed and then oxidized to produce energy; for growth i.e the increase in aerobic respiration results in continous increase in oxygen intake.

(d)(i)Give four ways viable seeds utilize absorbed water ***(04 marks)***

- Hydrolysis of stored foods
- Enzyme activation
- Medium for physiological processes like photosynthesis
- Transport medium for nutrients
- Temperature regulation
- Regulation of the stomatal rhythm

(d)(ii)State the advantages and disadvantages of seeds dormancy ***(05 marks)***

<u>Advantages of seed dormancy</u>

- Enables the plant survive adverse conditions; only germinate under favourable environmental conditions
- Allows ample time for dispersal; and over longer distances.
- Prevents germination of all seeds at the same time which may otherwise predispose them to intense competition
- Improves species survival of seed propagated plants.
- Permits rapid reduction in the concentration of the germination inhibitors like ABA
- Allows increase in the concentration of germination promoters like gibberellins
- Reserves soluble food products;
- Permits full maturity of the embryo.
- Prevents seeds from germinating in pods.

<u>Disadvantages of seed dormancy</u>

- Natural hazards may destroy the seed
- Increased susceptibility to pest attack
- Increased susceptibility to diseases due to humid warm conditions
- Food reserves decrease with time
- Reduced viability

Question 4.

Figure 1 shows the relative changes in the dry mass of the endosperm and embryo during germination of maize in a well illuminated environment. Figure 2 shows changes in content of lipids and sugar in castor oil seeds during germination in the dark.

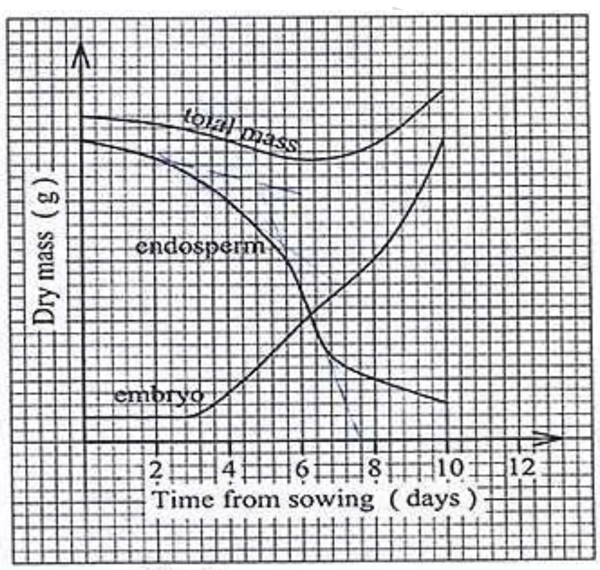


Fig. 1

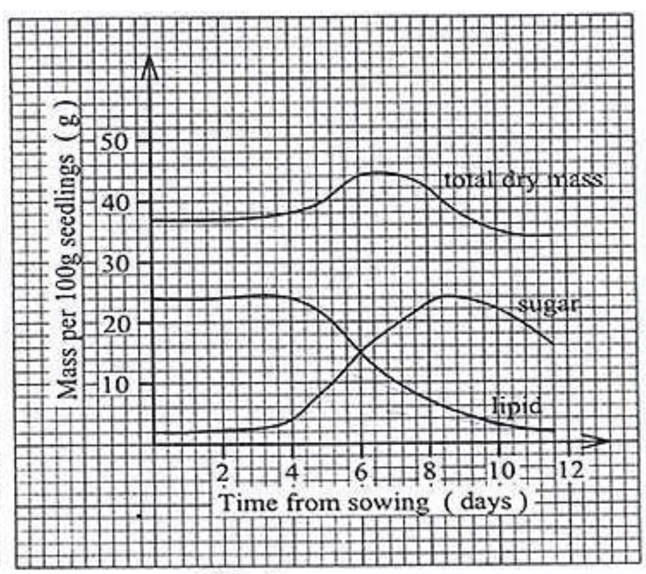


Fig. 2

(a). Explain the changes in each of the following, during germination of maize.

(i) Dry mass of endosperm ***(07 marks)***

Between 0 to 2 days; there was a gradual decrease in dry mass because of imbibition; little hydrolysis of stored food substances like starch to simple sugars; proteins to amino acids; lipids to fatty acids and glycerols; which are translocated to the embryo for growth respiration. Between 2 to 6.8 days; there was a rapid decrease due to much hydrolysis of stored food; synthesis and activation of more enzymes. Between 6.8 and 10 days, there was a gradual decrease; due to oxidation of the little food remaining in the endosperm / food is almost depleted.

(ii) Dry mass of embryo ***(06 marks)***

Between 0 to 3.2 days; the dry mass was constant; because of little or no translocation of soluble food substances into it. Between 3.2 to 8 days, there was a gradual increase because soluble food materials are translocated & growth of tissues/ cell division begins. Between 8 to 10 days; there is a rapid increase due to growth of foliage leaves which photosynthesize food.

(iii).Total dry mass ***(05 marks)***

Between 0 to 6 days; dry mass decreases gradually; due to aerobic respiration/ oxidation of food in the endosperm and embryo. Between 6 to 7 days; total dry mass was almost constant/ minimum; because the rate of respiration balances rate of growth/ anabolism balances catabolism. Between 7 & 10 days, there is a rapid increase in dry mass due to formation of the first foliage leaves; which photosynthesize food.

(b).Explain the changes in each of the following during germination of castor oil seeds.

(i) Lipid content ***(06 marks)***

Between 0 to 4 days; lipid content was constant; because castor oil stores lipids which had not been converted to sugars; and translocated to the embryo. Between 4 to 8 days; lipid content reduces rapidly because lipids are converted to sugars then translocated for growth of the embryo.

(ii).Sugar content ***(04 marks)***

Between 0 and 3.2; sugar content was constant; because lipids had not yet been converted to sugars and translocated to the embryo. Between 3.2 to 8 days; there is a rapid decrease in sugar content because lipids are converted to sugars and translocated for growth of the embryo. Between 8 to 11.6 days; there was a gradual decrease in the sugar content because lipids are exhausted/ depleted/ sugars being utilized in respiration.

(iii).Total dry mass ***(02 marks)***

Between 0 to 2.4 days; total dry mass was constant; because lipids had not yet been converted to sugars. Between 2.4 to 6 days; total dry mass increased gradually because lipids were being converted to sugars and translocated to the growing parts of the seedlings. Between 6 to 11.6; there was gradual decrease because lipid reserves were low/ depleted/ high utilization/respiration of sugars.

(c).When the respiratory quotient (RQ) of the castor oil seedling was measured on the fifth day, the embryo was found to have an RQ of about 1.0, while the cotyledons had an RQ of about 0.4 to 0.5. Suggest an explanation for these results. ***(04 marks)***

Respiratory quotient (RQ) OF 1.0 in the embryo indicates aerobic respiration of sugars/ carbohydrates; derived from lipids; since castor oil has little sugar reserves. RQ of 0.4 to 0.5 in cotyledons implies conversion of lipids to sugars; and oxidation of a mixture of fatty acids and sugars.

(d).Suggest differences in changes of lipids, sugar and total dry mass of castor oil seedlings if they were introduced to a well illuminated environment on the sixth day. Explain each difference suggested. ***(06 marks)***

Sugar content would increase; because photosynthesis would commence to produce more sugars.

The lipids would decrease gradually because of the utilization of sugars from photosynthesis.

The total dry mass of the seed would show continued increase; because of growth of the embryo.

Question 5.

A study was conducted on the germination and early growth of sorghum. The grains were soaked in cotton wool in a green-house and at two; day intervals, samples were taken and separated into two components, of endosperm and embryo (seedling), which were then oven dried and weighed. Figure 1 shows the variation of total dry mass, dry mass of endosperm and embryo. Use the information to answer the questions that follow.

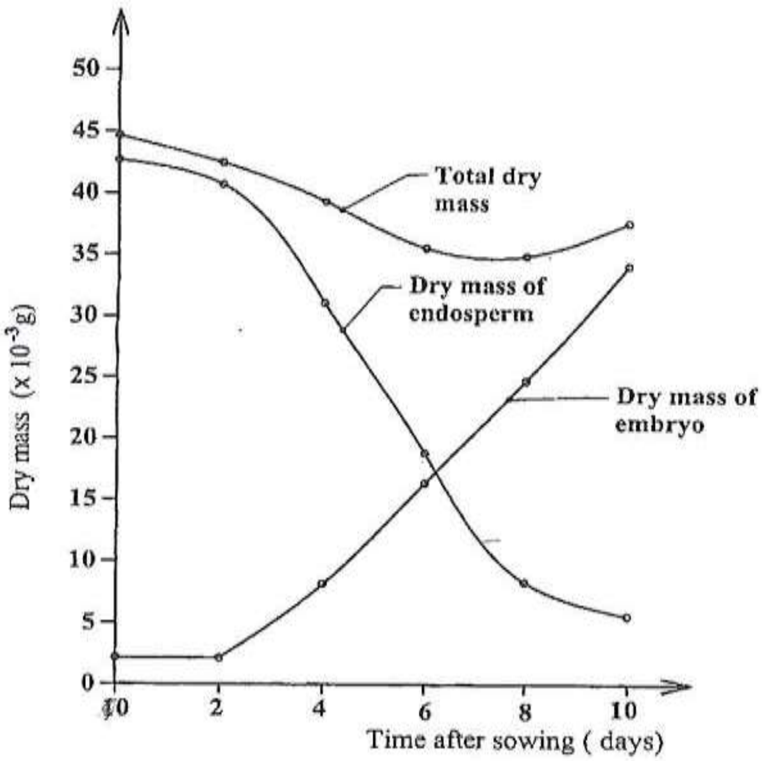


Fig. 1

(a) Explaining the variation with time of;

(i) dry mass of endosperm ***(10 marks)***

Between 0-2 days the endosperm decreases gradually, due to imbibition to activate enzymes for hydrolysis of stored food. Between 2-8 days the dry mass of the endosperm decreases rapidly / drastically as stored food principally stored starch is hydrolysed to sugars/ maltose; proteins to amino acids and lipids to fatty acids and glycerol which are translocated to the growing region/ embryo for growth or respiration. Between 8-10 days, there is gradual decrease in mass of dry endosperm because all the stored food is almost depleted /embryo has started photosynthesis.

(ii) dry mass of embryo ***(07 marks)***

Between 0-2 days, dry mass remained constant due to little / no soluble products from the endosperm. Between 2-10 days, the dry mass of the embryo increased rapidly, as sugars, amino acids, fatty acids and glycerol resulting from hydrolysis were made available for anabolism/ cell division and cell differentiation for growth of the plumule and radicle.

(iii) Total dry mass ***(08 marks)***

Between 0-6 days, the total dry mass decreases gradually due to aerobic respiration which consumed sugars in both endosperm and embryo. Between 6-8 days, total dry mass almost remains constant as the mass of endosperm balances the rate of growth. Between 8-10 days there is a gradual increase because the first foliage leaves emerge and start photosynthesis, the increase in the dry mass compensates for respiration loss.

(b).Outline the reasons for

(i).over drying the seeds during the experiment. ***(01 marks)***

To get accurate results / get constant results.

(ii).

Separating the seed constant to compare dry weight of the endosperm and embryo,

(iii).Sowing seeds in a greenhouse ***(01 marks)***

Provide suitable temperature for germination/ growth/ controlled temperature;

(c).State the method that was used to measure growth and its limitations ***(04 marks)***

Dry mass method

Limitations

• It necessitates killing of organisms
• It takes a lot of time/tedious
• Embryo is to be damaged during removal of moisture
• Obtaining organisms of the same age/ size/ viability/ genetic make-up is difficult.

(d)(i).Outline two internal factors in the seeds that would affect the results above ***(02 marks)***

• Genetic factors
• Germination/growth inhibitors
• Premature embryo
• Hard seed coat

(d)(ii).What precautions could have been taken to ensure reliable results ***(02 marks)***

• Inhibition; soaking the seeds before sowing/ growth promoters like gibberellins/ flashing with light
• Premature embryo; providing an after ripening period/ harvesting period.
• Hard seed coat; Chipping/ microbial attack/ abrasion of the seed

(e).State the conclusion that can be drawn from the graph after 8 hours ***(01 marks)***

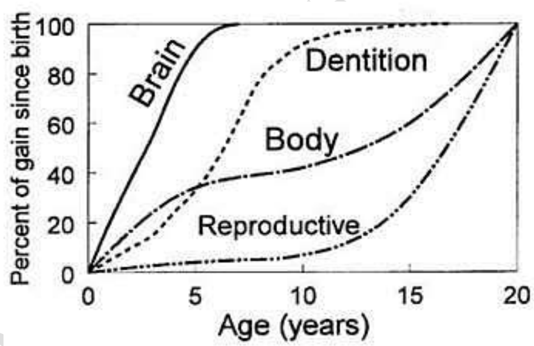
The total dry mass increases with onset of photosynthesis

(f).Explain what would happen if the experiment continued for another 10 days ***(04 marks)***

Dry mass of the endosperm would decrease to zero; due to exhaustion of food reserves; and the total dry mass would increase rapidly due to increase n the number of photosynthetic tissues;

Question 6.

The figure below shows the relative growth rates of the brain, teeth (dentition), whole body & reproductive organs of humans.



(a) Describe the pattern of growth of all the organs shown in the graph above. ***(10 marks)***

(b) Explain the rate of growth of the:

(i) Teeth. ***(06 marks)***

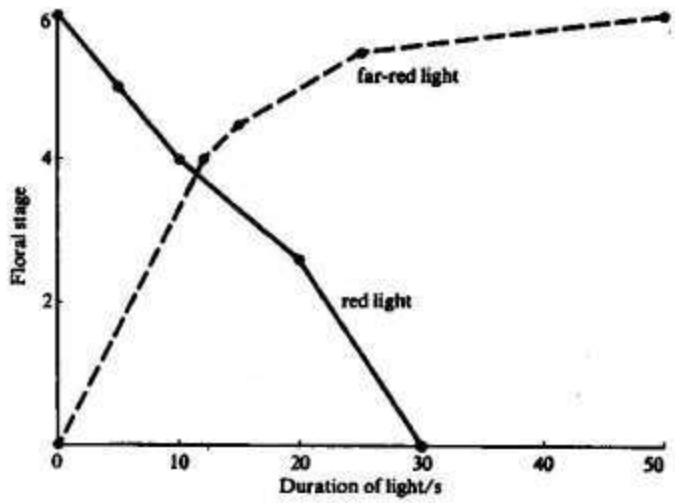
(ii) Brain. ***(06 marks)***

(iii) Whole body. ***(05 marks)***

(c) Identify and explain the growth pattern exhibited in the figure. ***(02 marks)***

Question 7.

A study was carried out to determine the effect of red and far–red light interruptions of long night on the intensity of flowering of a short-day plant. The figure below shows the results obtained from the study.



In another experiment, three species of the genus of a plant and a hybrid between two of them were tested for their vernalisation requirements. The sample plants of each strain were subjected to different periods of time at 40°C before being returned to their original conditions. The number of days which elapsed between the end of cold treatment and the onset of flowering were recorded. The results obtained are shown in the table below.

Weeks at 4°C	Number of days between end of cold treatment and the onset of flowering			
	A	B	C	AXB (Hybrid)
0	*	40	25	75
1	160	38	25	65
2	110	36	25	50
4	90	34	25	40
8	35	32	25	32
16	24	28	25	24

KEY: *= did not flower

Use the above information in the table and figure to answer the questions that follow.

(a) Describe the effect of interruption of the night period on the intensity of flowering of each of the following types of light:

(i) Red light ***(04 marks)***

(ii) Far-light ***(04 marks)***

(b) Give the explanation for the effects described in (a) above. ***(10 marks)***

(c) Explain how red and far–red light interruptions would have affected the intensity of flowering if they had used a long day plant ***(03 marks)***

(d) (i) What was the effect of subjecting the sample plants of each strain to different periods of time at 40°C.

(ii) Explain the results shown in the table ***(08 marks)***

(e) Predict and explain what would happen if the experiment in the table had been carried out at 10°C.

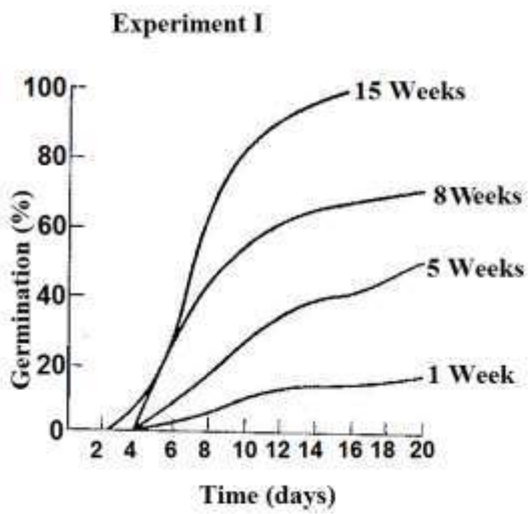
(f) What is the significance of the two experiments to an agriculturalist? ***(03 marks)***

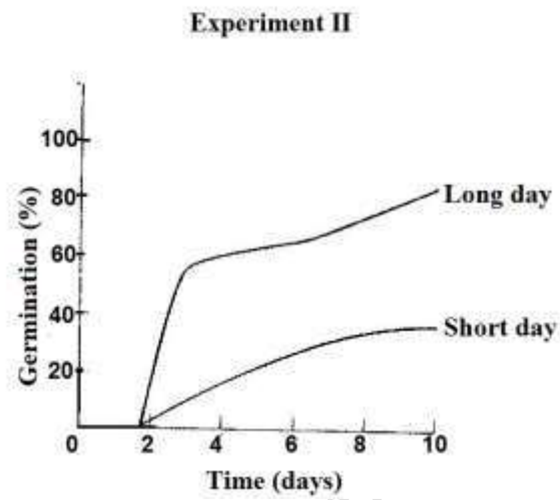
Question 8.

Experiments were performed to investigate some of the factors which influence flowering of a short day plant species, and the onset of germination of seeds of the same species.

Experiment I was on the effect of increasing time of dry storage on the germination of the species seeds. All the seeds were kept at 15°C. Each curve represents a germination test on a seed sample stored for the number of weeks indicated.

Experiment II was on the germination of seeds under long-day illumination cycles (20 hours light: 4hours dark) & short day cycles (20 hours dark: 4 hours light) separately.





Experiment III was on the germination of seeds during an eight day period. Before starting the investigation, some of the seeds and some of the intact fruits were treated as indicated in the table below:

Treatment	*Percentage germination by day*			
	2	**4**	**6**	**8**
Intact fruits in air	0	6	10	10
Fruits with pericarp cut	0	12	28	38
Naked seeds in air	0	14	30	42
Seeds with testa pricked	14	45	53	53
Seeds in oxygen	40	56	72	78
Pricked seeds in oxygen	25	62	70	84

(a). Compare the percentage germination of the two seed samples in Experiment II. ***(03 marks)***
(b) Explain the effect of:
(i) Varying illumination cycles on seed germination in Experiment II. ***(10 marks)***
(ii) Exposed a brief flash of light in the middle of the dark period in Experiment II on flowering of the plant.
(c) State what would be the effect of illumination on the flowering when the same treatment of the plant in Experiment II was subjected to:
(i) A long day plant. ***(02 marks)***
(ii) A day neutral plant. ***(01 marks)***
(d) Explain effect of changing the period of day storage in Experiment I on seed germination ***(07 marks)***
(e) (i) Describe the effect of different seed treatments on seed germination in Experiment III. ***(03 marks)***
(ii) Account for the observed influence in Experiment III. ***(04 marks)***
(d) What are the advantages of spores over seeds in reproduction? ***(06 marks)***

Question 9.

Figure below shows the percentage seed germination for each sample In experiment three, four seed samples were as indicated in table 1. Study the information and use it to answer the questions that follow

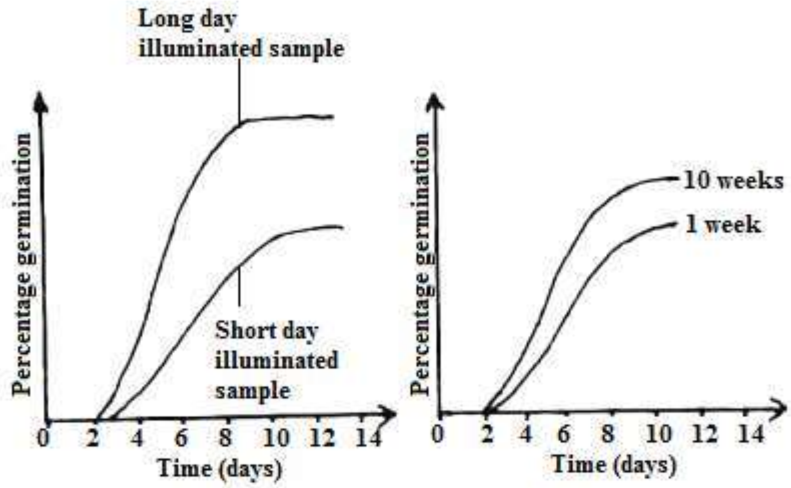


Fig 1 Fig 2

Treatment of seeds	Percentage germination by day			
Time in days	2	4	6	8
Seeds in air	0	14	30	42
Seeds with testa pricked off in air	14	45	53	53
Seeds in oxygen	40	56	72	78
Seeds with testa pricked off in oxygen	62	74	83	87

(a).Compare the percentage germination of the two seed samples in figure 1 above ***(03 marks)***

Germination for both seed samples begins at the second day; percentage germination of long day illuminated seed samples is higher (at any given time) than that of short day illuminated seed samples. The germination for both seed samples follows the same trend;

(b) Explain the effect of;

(i). Exposing a brief flash of light in the middle of the dark period in experiment one on flowering of the plant. ***(04 marks)***

The plant will not flower/flowering will be delayed as the short light period/flash of light caused short day the pla-nts; conversion of phytochrome 660 to phytochrome 730; which inhibits flowering of short day plants

OR

The flash of light separated the long dark period into two short dark periods; and each was short/ the-re was no si-ngle long dark period; to allow flowering of a short day plant.

(ii).Varying illumination cycles in experiment one on germination of seeds ***(10 marks)***

Long periods of light/illumination with light increases seed germination; and the short periods reduce seed germi-nation. Light induces the production of plant hormones/germination promoters/gibberellic acid or gibberellins wh-ich stimulates germination; This is done through the interaction of two phytochrome pigments phytochrome 660 (P660) and phytochrome 730 (P730). During periods of long hours of illumination, P660 is converted to phytoc-hrome 730(P730) which induces the production of plant hormones including gibberellic acid hence germination of seeds is increased; During periods of short hours of illumination, P730 is converted to P630; which inhibits production of gibberellic acid hence germination of seeds is reduced.

(c) State what would be the effect of illumination the flowering when the same treatment of the plant in ex-periment one was subjected to:

(i). A long day plant ***(02 marks)***

When subjected to a short day illumination, the plant did not flower; when exposed to a flash of light the plant fl-owered;

(ii) A day neutral plant ***(01 marks)***

The plant will not flower when subjected to a short day illumination or exposed to a flash of light

(d).Explain the effect of changing the period of dry storage in experiment two on the germination of seeds

Long period of dry seed storage increases the germination of seeds; and the short period of dry seed storage decreases the germination of seeds; Long period of dry seed storage increases the growth of immature embryo/ after ripening period; and decreases the germination inhibitors/ abscissic acid; but increases the accumulation of germination promoters/ gibberellic acid/ gibberellins: which mobilizes food reserves during germination and germination of seeds increases;

(e)(i)Describe the effect of treating the seeds in experiment three on germination of seeds ***(03 marks)***

Increasing exposure of the seeds/ embryo to air and oxygen; induced more rapid seed germination and when; air was substituted by oxygen the rate of germination was further increased.

(ii).Explain how germination was influenced in experiment three ***(04 marks)***

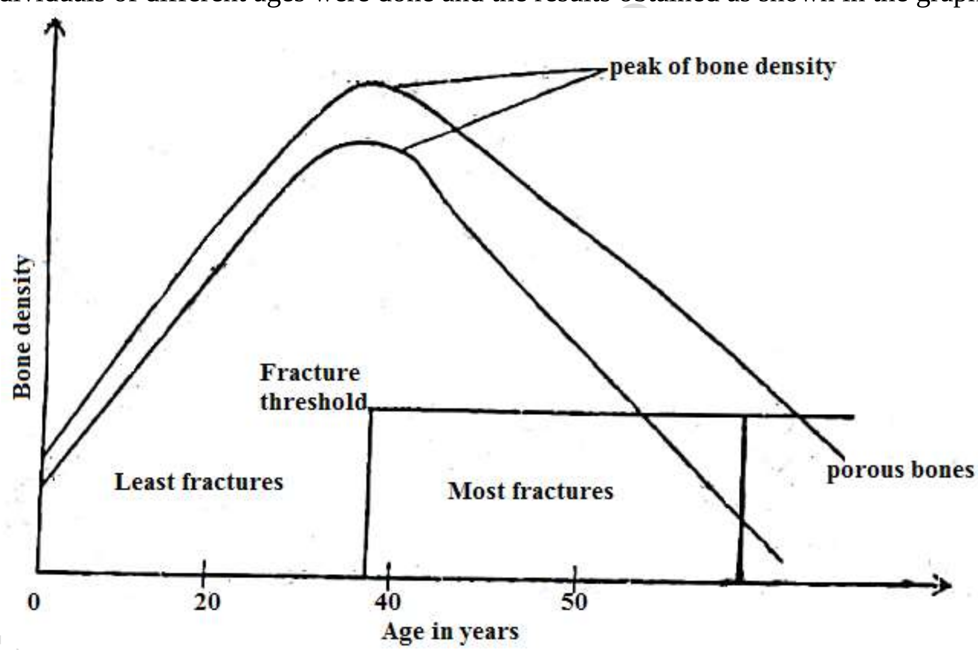
Germination involves growth which requires energy released by respiration; which occurs in presence of oxygen; hence increasing exposure of seeds to air and oxygen produced more energy required for germination and the rate of germination increases;

(f).What advantages do spores have over seeds in reproduction? ***(06 marks)***

The spores have less food stores hence light and can be dispersed to longer distances away from the parent plant reducing on to overcrowding and the risk of attack by the diseases of the parent plant. The spores are resistant to adverse environmental conditions so can survive and germinate when the conditions are favourable. The less food reduces the chances of fed on by animals/ pests; hence remaining viable for longer period of time. Spores are produced by meiosis and generally identical to the parents hence conserving the traits from generation to generation;

Question 10.

Osteoporosis a brittle bone disease characterized by the degeneration of bone mass resulting from sense scene in man. After an investigation and a study of categories of individuals of different age men and women the bone density of each individuals of different ages were done and the results obtained as shown in the graph.



Compare the two trends of graphs ***(04 marks)***

Similarities

- Both attain a peak of bone density at 40 years
- Both generally increase from 0 to 40 years

Differences

- Initially men have a higher bone density than women.
- Men attain a higher peak bone density

(i). Explain the trend observed in men. ***(04 marks)***

Initially men have a higher bone density because of a high rate of growth of the bones. The rapid increase in the bone density due to a high rate of uptake of calcium in the guts and the increasing level of testosterone hormone which brings about a higher growth in bones and the body size at the age of 20 years. The decrease in the bone density is due to the onset of osteoporosis as a result of aging; rate of calcium loss is higher than uptake in the gut.

(ii).Explain the difference in the trend between men and women ***(08 marks)***

Women have a low bone density because of a lower rate of growth compared to men; the increase in bone density is due to increasing levels oestrogen to regulate the menstrual cycle; the decrease in the bone density is due to on-set of osteoporosis and menopause which results in little or no oestrogen produced in the post menstrual cycle and also a higher rate of calcium loss than uptake.

(b).Explain how the development of osteoporosis is related to diet and exercise. ***(08 marks)***

The diet lacking calcium .and vitamin D results in low absorption in the gut and hence low uptake into the bones resulting into decrease in the bone density and hence setting osteoporosis. Strenuous exercise affects the growth of the bones because of too much tensional and compression force subjected to the bones; exert a wear and tear effect; lead to osteoporosis.

(b)(i). Suggest and explain the other causes of osteoporosis in humans ***(11 marks)***

• Small body frame which results into low bone density.
• Life style habits such as smoking, alcoholism these affect the rate of absorption and metabolism.
• Heredity; some individuals' genes are programmed for early aging.
• Certain drugs such as corticosteroids, heparin that cause hormonal imbalance affecting Ca^{2+} uptake
• Chronic diseases such as cancer which eat up bones
• Low exposure to oestrogen i.e late menarche and early menopause
• Malabsorption disorders such as coeliac disease
• Hyperthyroidism
• Diabetes mellitus
• Immobilization
• B cell disorders such as multiple myeloma

(ii).State the likely effects of osteoporosis in humans ***(08 marks)***

• Back pain
• Loss of weight
• Muscle joint pain
• Broken/ brittle finger nails
• Inactivity/ reduced range of movements
• Changes in height.
• Hunched posture
• Bone fractures/ fragility fractures

The table below shows the daily calcium intake recommended by one of the statutory body of health to different age brackets in human

Population town groups	Calcium intake or daily mg
Children 7-12 years	800
Women over 45 years old not on HRT	1000
Women over 45 years old not on HRT	1500
Pregnant and lactating teenagers	1500
Pregnant and lactating women over 45 years	1200
Men over 45 years	1500

(c)(i).Compare the calcium ion intake of children between 7-12 years & men over 45 years ***(02 marks)***

• Children between 7 to 12 years have the lowest calcium intake
• Men over 45 years have a calcium intake that is almost twice that of children between 7 and 12 years

(c)(ii).Explain the above comparison in (c)(i) above ***(04 marks)***

Children have a higher uptake of calcium in the gut and less loss from the bones compared to men. As such, men over 45 years are recommended to take in more calcium.

(c)(ii).Outline likely causes of osteoporosis in children between 7-12 years & men over 45 years ***(02 marks)***

• Low levels of testosterone which results in little growth of the bones;

• Bone demineralization disorders such as hyperparathyroidism

(e). How can the level of calcium be maintained constant? ***(10 marks)***

Low blood calcium level stimulates the parathyroid glands (surrounding the thyroid gland) to secrete parathormone (parathyroid) hormone which increases the calcium level and decreases the hydrogen phosphate (HPO_4^{2-}) level through promoting bone breakdown by osteoclasts, calcium retention by kidneys, excretion of hydrogen phosphate (HPO_4^{2-}) in urine by kidneys, activation of vitamin D, which in turn stimulates the absorption of calcium from the gut. High blood calcium level stimulates the thyroid gland to secrete calcitonin hormone, which increases bone buildup by osteoblasts so as to reduce calcium level.

(f). Explain the importance of sun bathing in the strengthening of the bones ***(02 marks)***

Sun bathing is a source of ultra-violet rays which stimulate skin cells to synthesize Vitamin D. Vitamin D is essential in the bone metabolism as it stimulates the uptake of calcium ions into bones as well as reducing bone resorption.

Essay questions and answers

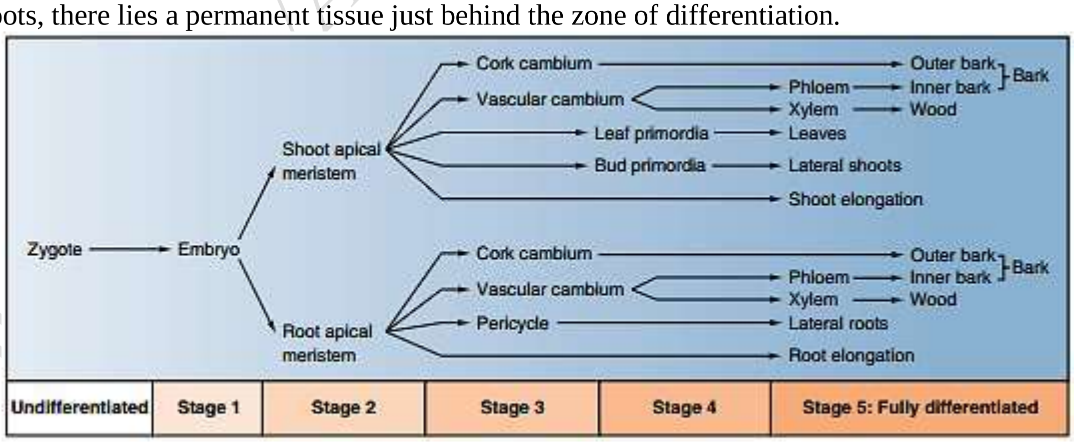
Question 1.

(a).Describe the process of primary growth in cotyledonous plants ***(16 marks)***

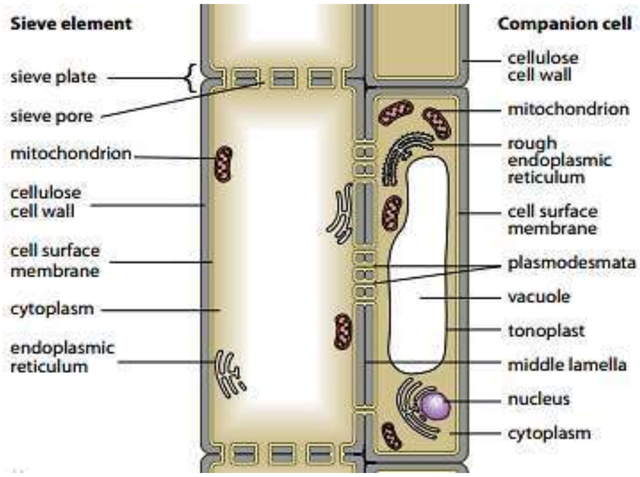
(b).How is the structure of the phloem related to function? ***(04 marks)***

(a).

Regions of primary growth exist in the shoot and root apical meristems. Cells within the apical meristems undergo rapid mitotic division, followed by cellular expansion and eventual differentiation. In the apical meristem, cells in the tunica divide in a plane perpendicular to the surface; giving a regular cellular arrangement; and in a fashion that lengthens the plant. Those in the corpus/body divide in several planes giving a haphazard appearance of cells. As new cells form, older ones get placed back in the region of cell expansion. Small vacuoles form within these cells; coalesce; form large vacuoles and expand due to osmotic intake of water; cells enlarge; later these cells enter a region of differentiation where they differentiate into; Protoderm that lies around the outside of the stem; develops into the epidermis; some epidermal cells form root hairs; procambium lies just inside the protoderm; develops into primary xylem and primary phloem. In the roots procambium also gives rise to pericycle; from which lateral roots radiate; and ground meristem from which cortex and pith composed of parenchyma, collenchyma and sclerenchyma cells form. In the stem, apical meristem gives rise to leaf primordia on either sides; these grow; envelope the apex forms the apical bud which protects delicate meristematic tissues. Axillary bud forms in the angle between the leaves and the main axis of the stem. Leaves and axillary buds occur at regular intervals called nodes; region of main stem in between forms the internode. In the root, apical meristem is covered by root cap. In both stem and roots, there lies a permanent tissue just behind the zone of differentiation.



(b).



• Numerous sieve pores within the sieve plate; allows continuity of flow of organic matter
• Companion cell with numerous mitochondria; provides necessary energy for active transport of organic materials.
• Sieve plate; rigid; prevents walls of the sieve tube elements from falling apart when loaded with lots of sugars.
• Plasmodesmata; form channels that connect companion cells with sieve tube elements; allows ATP exchange from the companion cells to the sieve tube elements
• Numerous cytoplasmic strands; facilitate movement of sugars by peristaltic waves
• Wide lumen of the sieve tube element; ensures movement of organic materials in bulk
• Living cytoplasmic components in the sieve tube elements; which allows for cytoplasmic streaming; a mechanism important in phloem transport.
• Peripherally located cytoplasm; creates enough luminal space in the sieve tube elements; minimizes flow resistance; thus allows bulk flow of sugars.

Question 2.

(a).Discuss why some seeds are not able to germinate immediately they are dispersed from their parent plants when optimum conditions of germination are provided ***(06 marks)***
(b).Explain the importance of seed dormancy in plants ***(08 marks)***
(c).Explain why dormancy is more common in weeds and annual plants than in tropical trees. ***(06 marks)***

(a).

• **Hard seed coat;** may be impermeable to water and oxygen or mechanically resistant; impedes emergence of plumule and radicle.
• **Embryo factor;** embryo may be dormant, immature/rudimentary or damaged.
• **Germination inhibitors;** germination may be impeded by high concentration of germination inhibitors like Abscissic acid (ABA), cyanide in apple seeds.
• Pre-mature growth of the seed and may require an after ripening period during the dry season. If not given, the seed can't germinate.
• Light insufficiency;
• Unfavourable temperature

(b).

• Enables the plant survive adverse conditions; only germinate under favourable environmental conditions
• Allows ample time for dispersal; and over longer distances.
• Prevents germination of all seeds at the same time which may otherwise predispose them to intense competition
• Improves species survival of seed propagated plants.
• Permits rapid reduction in the concentration of the germination inhibitors like ABA
• Allows increase in the concentration of germination promoters like gibberellins
• Reserves soluble food products;
• Permits full maturity of the embryo.
• Prevents seeds from germinating in pods

(c).

Weeds and animals are in seasonal habitats; dormancy ensures that they do not lose all seed reserves by simultaneous germination; under temporary suitable conditions; when the seedlings might all be wiped out; by succeeding periods of drought; so remain dormant until favourable season; Conditions on the forest floor are suitable for germination throughout the year; so have little need of dormancy;

Question 3.

(a).Distinguish between growth and development *(02 marks)*
(b).Giving examples, describe the different patterns of growth *(06 marks)*
(c).Describe secondary growth in a dicotyledonous plant *(12 marks)*

(a).

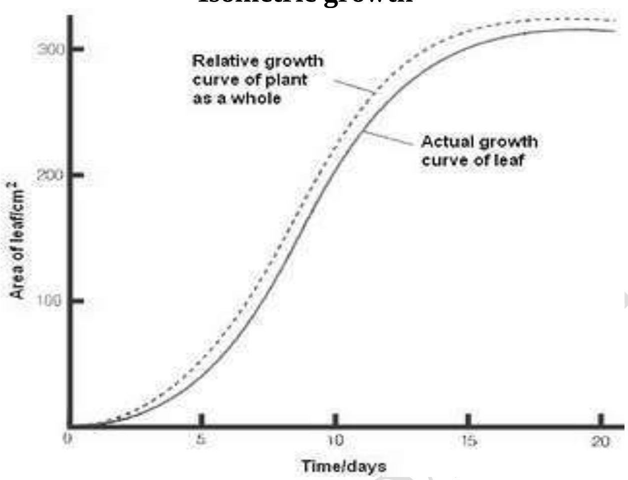
Growth is the permanent increase in size and dry weight of an organism that occurs during the course of its development while development is the increase in the complexity of cells and tissues to perform a specialized function.

(b).

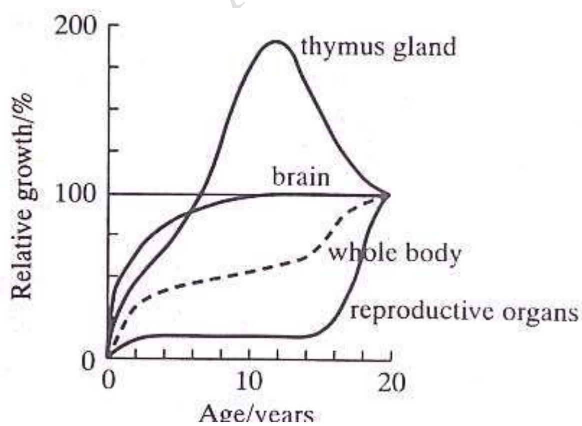
Isometric growth; type of growth in which parts of the organism grow at the same rate. A change in size is not accompanied by a change in the shape of the external features. Therefore, the proportion of the body parts compared to the entire body remains constant e.g growth pattern in fish and the growth pattern in cucumber leaf.

Allometric growth; Different parts of the organism grow at their own particular rates; higher or lower than the growth rate of the organism's body as a whole. A change in size is accompanied by a change in shape and structures of the organism e.g the growth pattern in most mammals like humans.

Isometric growth



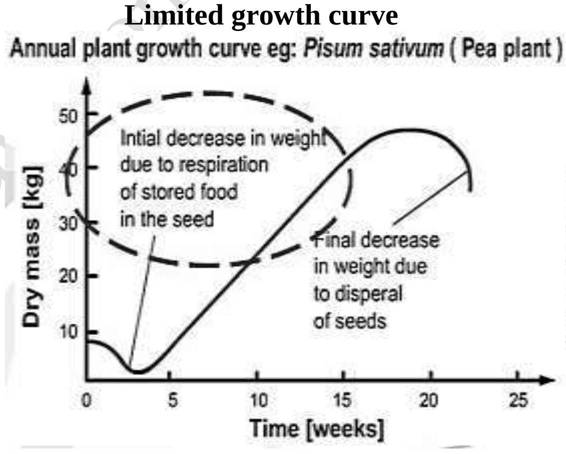
Allometric growth



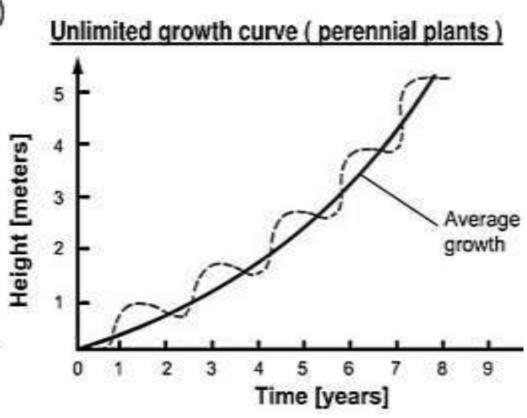
Continuous/ unlimited growth; Organism exhibits an unlimited growth pattern, in which rate of growth just slows down with increasing age. Occurs in fungi, algae, fish, reptiles, many invertebrates and perennial plants.

Limited growth; Organism initially registers a positive growth then gets limited after a period of maximum growth, followed by negative growth/ senescence before death of the organism. It is exhibited by annual plants.

Limited growth curve

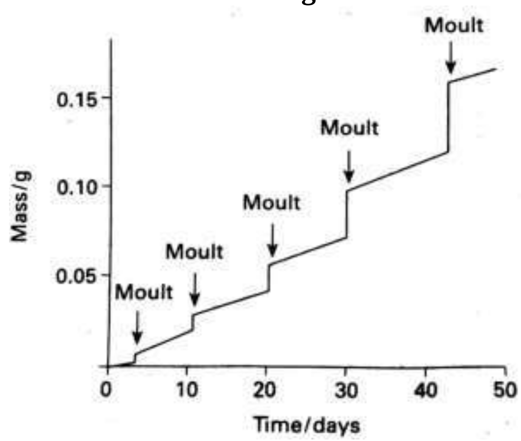


Unlimited growth curve



Intermittent growth; marked by intervals of complete growth quietude (no growth) between two adjacent periods of activity i.e stops and starts at irregular intervals. This growth pattern is seen in insects which undergo moulting or ecdysis. When the insect is not moulting; its exoskeleton is hard limiting the growth of the insect.

Intermittent growth



(c).

Secondary growth increases the girth of the plant, results from activity of lateral meristems brought about by division of the meristematic cells located between the xylem and phloem tissues i.e vascular cambium and cork cambium and phellagen. Vascular cambium is initially restricted to a series of a group of cells between the xylem and the phloem but these later join to form cambium ring. Vascular cambium consists of the fusiform initials and the ray initials Fusiform initials divide to give rise to the vascular bundles i.e secondary phloem to the outside and secondary xylem to the inside of the fusiform initials. More secondary xylem than secondary phloem is formed; so phloem together with the cambium is pushed to the outside. Secondary phloem contains sieve tube elements, companion cells, sclerenchyma fibres, sclereids and parenchyma cells. Secondary xylem is more lignified. Ray initials mitotically divide between adjacent vascular bundles; forms parenchyma cells; which form rays between the cortex and pith (neighboring xylem and phloem); parenchyma cells are not lignified to allow horizontal trans-port of water and solutes inside the thickened stem; also maintains a living link between the pith and the cortex; rays also store food. Cork cambium divide, gives rise to cork; to the outside beneath the epidermis due to suberisation. The unsuberised to the outside of the phellogen forms the lenticels for gaseous exchange. The inner side of the phellogen divides mitotically to form secondary unsuberised cortex/ phelloderm. Phellogen, phellen and phelloderm form the periderm. Phloem and the periderm forms the bark.

Question 4.

(a)Explain what is meant by the following terms and give relevant examples of each

(i). Hemimetabolous *(03 marks)*

(ii).Holometabolous *(03 marks)*

(b).Outline the hormonal control of ecdysis and metamorphosis in insects *(14 marks)*

(a)(i).

Hemimetabolous /incomplete metamorphosis; insect develops in repeated stages called instars and the juvenile form resembles the adult. Egg develops into an adult via a series of nymphs (miniature adults without wings). Moulting and growth taking place between each nymphal stages. Examples of insects that demonstrate this include; cockroaches, grasshoppers, termites, ear wigs.

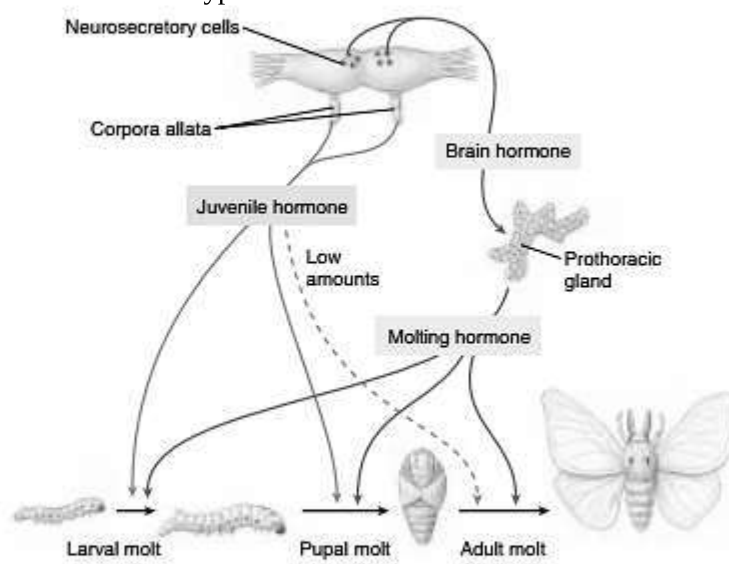
(a)(ii).

Holometabolous/complete metamorphosis has a pupal stage between the larval and the adult forms. Here the dominant stage is the larva which markedly differs from the adults and the dormant one is the pupal stage. Egg usually hatches to larva which also matures to pupa that finally develops into an adult. Examples include houseflies, mosquitoes etc

(b).

Moulting/ecdysis; Distension of the gut following a meal causes secretion of prothoracotrophic hormone from the neurosecretory cells of the brain get stored in the corpora cardiaca; passes down to the prothoracic gland. A considerable concentration of this brain hormone stimulates the prothoracic gland to secrete ecdysone (moulting hormone) a steroid hormone which activates genes that switch on the protein synthesis machinery in the epidermal cells; synthesize enzymes that degrade the old cuticle that cause growth and lay down a new adult cuticle.

Metamorphosis; Corpus allatum within brain secretes juvenile hormone. Juvenile hormone potentiated by moulting hormone produces a cuticle characteristic of the juvenile stage, nymph or larva. Towards the end of metamorphosis secretion of juvenile hormone ceases and moulting hormone in the absence of juvenile hormone causes epidermal cells to lay down a newer adult type of cuticle.



Question 5.

(a).Explain how organisms have overcome the challenges of being multicellular *(12 marks)*

(b).Explain the relevances of animal movement from one place to another. *(08 marks)*

(a).

Challenge	Solution
Challenge of support	Organisms have developed bones, cartilage, chitin, xylem, some have become aquatic.
Challenge of wastes	Developed excretory systems with efficient organs of excretion
Small surface area to volume ratio	Development of internal/ external surfaces/ organs that increase surface area to volume ratio e.g gill/ lungs, leaves in plants.
Greater food requirement	Plants make their centres hollow/ fill it with dead tissues e.g xylem. Well - developed digestive systems in animals; different feeding modalities.
Challenges of reproduction	Long gestation periods, internal fertilization, lay many eggs, embryonic development in the placenta.
Challenge of transport	Development of circulatory system, transport pigments like hemoglobin, development of vascular bundles in plants
Escape from predation	Large size, camourflage, mimicry, swift movements to escape away from predators, thorns in plants, chemicals like alkaloids.
Challenge of control and co-ordination and	Developed nervous and endocrine system, etiolation in plants.

(b).

• Search for food; animals, being heterotrophic, move in search for food.
• Escape from predators and harmful stimuli.
• Search for mates; to ensure effective reproduction.
• Reduce competition prevent overcrowding and intraspecific competition
• Search for shelter and new territories

• Reduce vulnerability to diseases e.g small scattered populations are less likely to suffer epidemics of diseases.
• Escape from waste products; whose toxicity may be life threatening to the organisms.

Question 6.

(a).Distinguish between primary growth and secondary growth in plants ***(06 marks)***
(b).Explain the ecological significance of tropic responses in plants ***(10 marks)***
(c).Explain why shoots of grass plants continue to grow after being cut at their tips ***(04 marks)***

(a).

Primary growth in plants	Secondary growth in plants
Increase in the length of the plant	Increase in girth/ thickness
Apical meristems involved.	Vascular cambium and cork cambium involved
Occurs in monocots	Occurs in dicots and gymnosperms
No secondary tissues formed	There is secondary tissue formation
No lenticel formation	Lenticels formed
No lignification	There is lignification

(b).

Positive phototropic responses of the plant enable photosynthetic organs (leaves) access light so as to effect photosynthesis and this increases the gross productivity of primary producers.
Positive geo and hydrotropism of the roots; ensures access towards water; an important raw for photosynthesis; gross productivity of the primary producers is increased.
Tendrils are positively haptotropic; thus twine around other plants for support and access to light.
Pollen tubes are positively chemotropic and negatively aerotropic; grow towards the ovule to effect fertilisation; increasing the reproductive rate of plants; population rises.
Diageotropic response of plants parts like rhizomes and runners enable colonization of new areas; to avoid overcrowding.

(c).

Slashing doesnot stop growth of the grass shoot. Grass plants possess intercalary meristems at the internodes/ between leaf nodes whose continuous mitotic divisions promote longitudinal growth of their stem even after the apical meristems have been cut off.

Question 7.

(a).Describe the different forms of dormancy in plants and animals ***(10 marks)***
(b).What are the main causes of seed dormancy and how they can be overcome? ***(04 marks)***
(c). Explain the biological significance of the various modalities of dormancy in plants and animals

(a).

Diapause; is a state of arrested development exhibited by many insects and many aquatic organisms occurring at any stage of their life cycle. It is induced by the photoperiod especially during winter when the photoperiod shortens. Diapause is controlled by internal factors regulated by the environment during which growth promoting hormone is either not produced or produced in inadequate concentrations.
Hibernation; is a period of relatively low metabolic activity associated with periods of low temperatures. During hibernation, the body temperature falls to that of the environment. Metabolic rate and rate of several other physiological processes decrease; enabling survival of the organism at the time of food shortage.
Aestivation; occurs in certain fish like lung fish and some amphibia in response to hot conditions. The organism undergoes a period of metabolic inactivity which enables them survive conditions of extreme dehydration.
Seed dormancy; is a period of suspended growth in seeds. Enables seeds germinate under favourable conditions.
Bud dormancy; is a period of suspended growth in buds; enables development of fruits and foliage leaves in favourable conditions.

(b).

Cause of seed dormancy	Method of breaking seed dormancy
Hard resistant and impermeable seed coat	Scarification
Germination inhibitors like Abscissic acid.	Soaking the seed in germination promoters like gibberellins

Premature growth/ immature embryo	Subjecting seeds to an after growth/ripening period
Harsh environmental conditions	Cold treatment, stratification.
Insufficient light/ unfavourable temperature	Subjecting the seed to light

(c).

• Survive adverse conditions such as drought and extreme cold (winter)
• Withstand periods of food shortage
• Allows adequate time for distribution of propagues (spores, eggs) by the dispersal agents.
• Seed dormancy allows germination to occur under favourable conditions.
• Bud dormancy enables new foliage, flowers to develop after a period of suspended growth.
• Aestivation enables organisms survive conditions of extreme dehydration
• Allows time for any necessary internal changes e.g decrease in ABA concentration and rise in gibberellin concentration in preparation for germination.

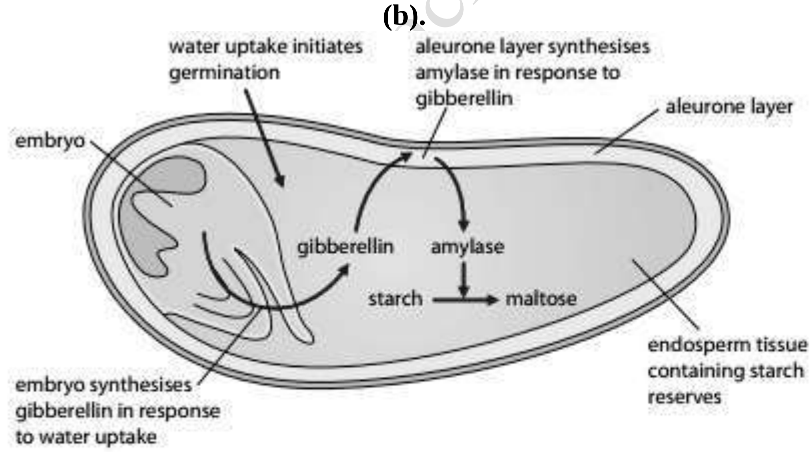
Question 8.

(a).State and explain the conditions required for germination to occur ***(06 marks)***
(b).Explain the events that take place during the process of germination ***(12 marks)***
(c).Describe the various types of seed dormancy exhibited by seed producing plants ***(02 marks)***

(a).

Warmth/ moderate temperature; offers an optimum temperature for enzyme activity thereby increasing the rate of enzyme catalysed biochemical reactions.
Oxygen; required for aerobic respiration to release energy inform of ATP for tissue growth and development.
Water; activates several germination enzymes that hydrolyse stored food substances into soluble forms that are utilized in tissue growth and development of the embryo. Water also causes swelling of the colloidal substances resulting in strong imbibitional forces resulting in rupture of the testa/ pericarp of the seed. Water also offers a medium for transportation of soluble substances.

(b).



Imbibition of water hydrates the embryo, cotyledons and endosperm, Water softens the testa, stimulates release of gibberellins from the embryo. Gibberellins activate several hydrolytic enzymes in the areurone layer that then break down corresponding substrates within the energy stores (cotyledons or endosperm). The enzymes include those for respiration; releases energy, activated carbohydrases like α-amylase; do break down polysaccharides like starch to simple sugars like glucose, proteases break down proteins to amino acids, lipases that break down lipids to fatty acids and glycerols. The soluble products are then translocated to the growth regions of the embryo. Glucose may be oxidized to release energy or polymerized to structural carbohydrates like cellulose. Amino acids are used in the synthesis of both structural components of the protoplasm and functional proteins e.g enzymes. Rapid cellular proliferation, elongation and differentiation within the embryo causes emergence of the plumule and radicle out of the testa.

(c).

Innate (primary dormancy): In this type of dormancy seeds after dispersal cannot germinate immediately and majority of seeds fall under this category. Such seeds only germinate after a period of after ripening or storage. This period leads to changes which are needed to improve germination.
Induced dormancy (secondary dormancy): The seeds achieve dormancy because of one factor missing.
Enforced dormancy: Is the one which is thrust onto the seeds by storage e.g. stores, refrigerators. Etc.

Question 9.

(a).What is the role of the apical meristem in root growth. *(07 marks)*
(b).Describe the formation of secondary tissues in cotyledonous plants. *(13 marks)*

(a).

- The apical meristem in the roots gives rise to primary tissues of the root.
- Its root cap protects the delicate growing tissues in the root tip.
- Cell division and expansion in the root apical meristem contributes to the overall elongation of the root.
- Cell differentiation gives rise to the different kinds of root tissues.
- Primary vascular tissue growth contributes to increase girth of the root.
- Lignification of some differentiated tissues contributes to strength of the root.

(b).

Secondary tissue formation in cotyledonous plants is achieved by activities of lateral meristem and constitutes secondary growth. Such growth leads to increase in diameter of the plant and is also called secondary thickening. The lateral meristems from which secondary tissues develop include; vascular cambium and cork cambium (phellogen)

Activities of vascular cambium.

Vascular cambium divides by mitosis into three layers of cells. The inner layer eventually differentiates into secondary xylem and the outer layer into secondary phloem. The middle layer remains meristematic. After cambial division the cells expand & vacuolated and finally different into phloem elements (sieves tubes, companion cells) located towards the cortex and xylem elements (tracheids and fibers) located towards the pith. Sieves tube elements and xylem elements get strengthened by lignification to produce mature vascular tissues.

Activities of cork cambium (phellogen).

Phellogen divides in a tangential plane from both its inner and outer face to produce three layers of cells around the circumference of the plant. The outer layer is called cork. The middle layer consists of active phellogen & the inner, phelloderm (secondary cortex), cork phellogen together from the periderm.

Question 10.

(a).Outline the features of the larval stage *(03 marks)*
(b).Explain the roles of the larval stage in growth and development of organisms *(05 marks)*
(c).Account for the allometric growth pattern exhibited by the major different organs of a human being.

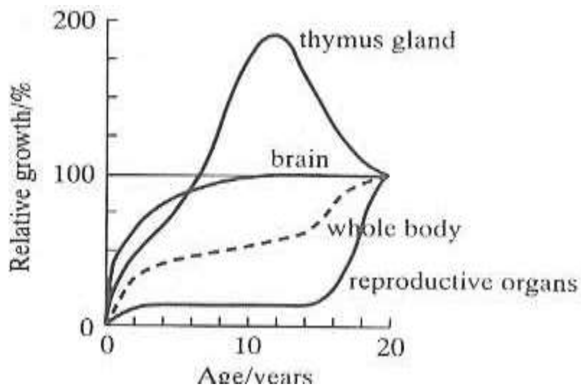
(a).

- They are different in structure from the adult so can exploit different habitats.
- They live an independent life from the adult and are self-supporting.
- They do not reproduce sexually; most reproduce asexually.

(b).

- It serves as a dispersal phase which helps to distribute species.
- It is an important intensive feeding and growth phase in the life cycle of the organism.
- It is a phase of multiplication by asexual reproduction.
- It is a transition stage during which the organism has ability to adapt to the environmental conditions
- It occupies a different habitat & has different feeding habits from adult increasing their ecological range.
- Mode through which parasitic organisms move from one host to another.

(c).



Thymus gland/ lymphoid tissue; size of the gland rapidly increases to its peak from infancy through early childhood because the immune system is not yet developed so the thymus gland grows at a faster rate to allow maturation of T-lymphocytes that can provide immunity to the new born against infections. The size of the thymus gland then decreases rapidly towards late childhood/early adulthood and remains constant throughout the entire adulthood because the immune system is fully developed and the stem cells within the bone marrow can produce sufficient amounts of lymphocytes that can meet the immune demands of the body.
Brain; Brain grows at a faster rate from infancy throughout early childhood to mid childhood because of the great need to co-ordinate various body activities for appropriate growth and development. Alot of learning in childhood due to the new environment also fosters rapid growth. Later from mid childhood towards adulthood, brain growth increases gradually because the size of the cranium becomes limited with age and this also limits brain growth until when the adult size gets attained. Brain size then remains constant throughout the entire adulthood.
Reproductive organs; From infancy through early childhood, the size of the reproductive organs more or less remains constant and remain undeveloped because the sex hormones responsible for their growth and development are not yet in sufficient amounts. However, from adolescence stage (puberty to adulthood), the reproductive organs grow at a faster rate because these hormones begin getting secreted; thus promoting emergence of secondary sex characteristics one of which is increased genital growth.

Question 11.

(a).Briefly describe the various stages of vertebrate development ***(06 marks)***
(b).State the developmental fates of the primary germ cell layers in vertebrates ***(03 marks)***
(c)(i).What role do hereditary factors play in the growth and development of organisms? ***(04 marks)***
(c)(ii).Describe the formation of vascular tissues in a herbaceous dicotyledonous stem. ***(06 marks)***

(a).

Fertilization; the haploid male and female gametes fuse to form a diploid zygote.
Cleavage; the zygote rapidly divides into many cells, with no overall increase in size.
Gastrulation; the cells of the embryo move, forming three primary cell layers: ectoderm, mesoderm, and endoderm.
Neurulation; in all chordates, the first organ to form is the notochord; second is the dorsal nerve cord.
Neural crest cell formation; during neurulation, the neural crest is produced as the neural tube. The neural crest gives rise to several uniquely vertebrate structures.
Organogenesis; cells from the three primary layers combine in various ways to produce the organs of the body.

(b).

Ectoderm; epidermis, central nervous system, sense organs, neural crest
Mesoderm; skeleton, muscles, blood vessels, heart, gonads
Endoderm; lining of digestive and respiratory tracts; liver, pancreas.

(c)(i).

Genes code for proteins which could be structural or functional. Structural proteins determine the physical properties of cells or organisms e.g. microtubule, muscle, and hair proteins. Functional proteins like enzymes, hormones, determine cellular metabolism which in turn affect growth rates. Genotypes (recessive or dominant) determine phenotypes and metabolism of organisms.

(c)(ii).

Apical meristematic cells close to root and shoot apex divide mitotically to form irregularly shaped, thin walled, densely protoplasmic, small vacuoled, large nucleoid cells. Primary xylem is formed from the embryo and resultant meristems while primary phloem develops from procambium. To form xylem vessels, the new cells elongate, completely vacuolate to death, lose end walls to form continuous columns, side walls get lignified. To form sieve tubes of phloem, sieve plates form at end walls, but protoplasmic contents are retained, companion cells form alongside sieve tubes.

Question 12.

(a).State the advantages of complete metamorphosis over incomplete metamorphosis ***(03 marks)***
(b).Account for the physiological changes that occur during pregnancy up to lactation ***(10 marks)***

(a).

• Reduced competition between adult and larval stages; since these are fed on different materials.
• Different stages in complete metamorphosis may have different predators; therefore, there exists a higher chance of survival once a certain stage is passed.
• Pupal stage allows dormancy to exist in complete metamorphosis; which is a survival strategy especially if conditions are not favourable.

(b).

Pregnancy begins with the blastocyst embedding in the endometrium/ implantation; Outer layer of the blastocyst secretes the hormone Human Chorionic gonadotrophin (HCG); which maintains the corpus luteum. The corpus luteum maintains a steady secretion of oestrogen and high level of progesterone; which inhibits follicle stimulating hormone production; thus offsetting the menstrual cycle; preventing further development of the Graafian follicles. The endometrium becomes highly vascularized to ensure sufficient supply of nutrients and respiratory gases to the developing embryo; as well as removal of metabolic wastes via the chorionic villi. Human placental lactogen cause increase in the size of the mammary glands; in preparation for lactation. The uterus also expands to accommodate the developing embryo. In the last three months of pregnancy, oestrogen increases faster than progesterone; then followed by a sudden decrease in the progesterone and oestrogen levels which stimulate the posterior pituitary gland to secrete oxytocin; that initiates uterine contractions at the time of delivery. Relaxin also secreted from the placenta enables ripening of the cervix as well as relaxation of the elastic fibres. Prolactin hormone secreted by the anterior pituitary gland; stimulates mammary glands to secrete milk.

Question 13.

(a).Outline the environmental and physiological factors behind development of dormancy in seeds ***(10 marks)***
(b).State the various ways in which dormancy due to hard seed coat can be broken ***(05 marks)***
(c).Explain the importance of an after-ripening period ***(05 marks)***

(a).

Environment factors
• Lack of adequate water supply
• Lack of adequate oxygen
• Requirement for light in case of positively photoblastic seeds
• Requirement for dark in case of negatively photoblastic seeds.
• Requirement for suitable temperature range i.e. at high temperature, water is not available and at very low temperature, water is frozen.

Internal physiological state of the seeds
• Embryological immaturity
• Embryological dormancy
• Presence of germination inhibitors like abscissic acid.
• Absence of germination promoters such as gibberellic acid, cytokines, etc.
• General requirement of an after ripening period.

(b).

• Break down by microorganisms in soil for example bacterial and fungi.
• Digestive action of enzymes of mammals and birds eg for seeds of red pepper, passion fruits, etc.
• Exposure to alternating high and low temperature
• Treatment of seeds using appropriate chemicals e.g. concentrated sulphuric acid and alcohol.

• Clipping or breaking off pieces of seed coats.

(c).

• Allows completion of embryological development i.e when the embryo is immature.
• Allows physical and chemical changes take place within the seed leading to improved germination.
• Allows wearing off of germination inhibitors like Abscissic acid (ABA) in the seeds
• Gives times for synthesis of germination stimulators like gibberellic acid.
• Allows build up and mobilization of food storage reserve in preparation for germination.

Question 14.

(a).Distinguish between longevity and dormancy of seeds ***(03 marks)***
(b).Briefly describe the different parameters used in the measurement of plant growth highlighting the limitations of each ***(17 marks)***

(a).

Longevity of seeds is the time the seeds last before they lose ability to germinate following shading from the parent plants. The wild species seeds last longer than the cultivated relatives. Seed dormancy on the other hand is a state in which a viable seed fails to germinate under conditions considered to be adequate for germination.

(b).

Size: This includes length, area or volume of a single cell, tissue or organ or organism. This parameter is difficult to measure when a plant becomes so complex. Measurement of size is applicable to early stages of development.
Fresh weight: This is the weight of a plant including water. However, this method is misleading because the water content of a plant fluctuates with time of the day. This method is also destructive to the plant as it involves uprooting the plants so it is not applicable to larger rooted plants.
Dry weight: This is the weight of a plant excluding water. It is a method widely used. It is more accurate than fresh weight method. However, its short comings include; being destructive to the plant as it requires drying, possibility of loss of material during the process of weighing and drying which gives inaccurate results, some volatile materials may be lost during the drying process and loss of weight because of use of stored food for embryo respiration.
Length: Applied to simple plant organs such as the stem, increase in length of leaves, length of branches and length of roots. This method is restricted to early stages of plant growth.
Area: This is applied to leaf area and simple leaves. This method is appropriate to plants with complex morphology.
Quantitative changes in protoplasm; This method gives the fundamental measure of growth in plants however the method has short comings and these include the method being very difficult to manipulate
Complexity of the plant; It is measured by increase in number of various organs e.g. leaves, flowers, fruits etc. this can be taken as a measure of growth but the method becomes difficult in case of very large plants.
Differentiation; This is when you determine the change in number of types of cells as the plant grows. This method requires the use of microscope. Normally a cell divides, it expands and then differentiates. However the method is destructive to plants.

Question 15.

(a).Explain the various factors affecting growth in living organisms ***(14 marks)***
(b).Outline the roles of water as a requirement for seed germination ***(06 marks)***

(a).

External / environmental factors
Nutrients; Growth of an organism increases in the availability of nutrients and decreases when nutrients are in short supply since nutrients are used in the build-up of new protoplasm and organic matter. Also nutrients can be oxidized to provide energy required for growth.
Water: Most enzyme controlled reactions are activated by the presence of water which is used to transport necessary materials in both plants and animals which require an aqueous means.
Accumulation of metabolic waste products (excretory substances): Growth may be inhibited by metabolic waste products which are toxic to the body cells.
Temperature: Growth depends on bio-chemical reactions which are catalyzed by enzymes. Temperature affects growth by affecting enzymes which catalyzes the chemical reactions in the body. Increase in temperature to the optimum increases the rate of growth, beyond which retardation of growth occurs.

Light: In plants, light affects growth by affecting the rate of photosynthesis which adds more organic matter to the plant. Therefore, increase in light intensity in green plants increases the rate of growth and decrease in light intensity decreases the rate of growth.
pH: The pH affects the activity of enzymes which catalyzes reactions in the body. This can result into decrease in growth of an organism.
Oxygen: Oxygen is useful in aerobic respiration and provides energy for growth. Environments with high oxygen tensions favour growth while those with low oxygen tensions inhibit growth.
Carbondioxide: In animals, carbon dioxide is a waste product of metabolism. If allowed to accumulate, it can le-ad to a decrease in the rate of growth while in plants carbon dioxide is a raw material for photosynthesis therefore increase in carbon dioxide concentration increases the rate of growth.

Internal factors

Hormones: In animals, the presence of growth hormones and thyroxin in blood increases the rate of growth while in plants the presence of auxins also increases the rate of growth.
Hereditary factors: Growth is under the control of genes which determines the particular size of an organism.

(b).

- Activates release of germination promoters such as gibberellins
- It activates the enzymes within the seed to hydrolyze the stored food.
- It makes the seed swell, soft and the testa to bursts.
- It dissolves the stored food.
- It is a medium in which all the chemical and enzymatic reactions proceed.
- It is a medium of translocating dissolved food substances to the developing embryo.
- Water is needed for the development of cell vacuoles. Large cell vacuoles contribute to increase in size of cells.

Question 16.

(a).Outline different ways moulting hormone and juvenile hormones exert their effects ***(07 marks)***
(b). Describe how insect larvae are adapted to successful life ***(03 marks)***
(c). State the common features exhibited by the larval forms of both amphibians and insects ***(10 marks)***

(a).

Moulting hormone alone causes epidermal cells to produce the adult cuticle. It has the following effects;
- It activates the genes needed to produce enzymes necessary for growth
- It raises the metabolic rate
- It increases the rate at which amino acids are built up into proteins in the growing tissue.

Juvenile hormone and its effects
- It influences the epidermal cells to lay down a cuticle characteristic of a juvenile stage, nymph or larvae.
- It causes retention of larval characteristics
- It suppresses genes responsible for producing adult structures
- It suppresses metamorphosis therefore stops secreting the juvenile hormone.

(b).

- They have well developed feeding devices which enable them to feed and grow.
- Ability to sense changes in their environment enables them to escape adverse conditions
- Their colour usually blends well with their environment and enables them to escape predators
- Some are hairy and so do not lose excess heat
- Their ability to move in their environment enables them to avoid adverse conditions and move towards suitable ones such as food, water and warm surrounding.

(c)(i).

- They are incapable of sexual reproduction and only in essential instances do some insect larvae undergo asexual reproduction
- They are different from adults in structure
- They can live an independent life feeding and defending themselves in a way different from those in adult i.e. in tadpoles, the animal is herbivorous with a long alimentary canal and in adults; the animal is carnivorous with a short alimentary canal.

Question 17.

(a).Explain the absence of the yolk sac in the development of the human foetus yet it is an important structure in development of birds. ***(04 marks)***
(b).Outline some of the;
(i). reproductive adaptations of birds to a terrestrial life ***(04 marks)***
(ii).differences between the physiological effects of red and far-red light in plants ***(06 marks)***
(c).Explain the role of temperature in plant growth ***(06 marks)***

(a).

The yolk sac is a source of nourishment throughout the development of the embryo in birds. In humans, nourishment to foetus is provided by the placenta thus no need for yolk sac. In human embryo the yolk sac produces red blood cells but this function is soon taken over by the liver. The yolk sac then degenerates.

(b)(i).

• Internal fertilisation increases chances of reproductive success.
• Shelled eggs are laid in which the embryo grows with nutrients and protected.
• Birds incubate their eggs keeping them at right temperatures for growth.
• Birds exhibit sexual dimorphism (well-developed courtship behaviour); ensures that mating occurs at a right time.

(b)(ii).

Red light	**Far red light**
It inhibits elongation of the stem	It stimulates elongation of the stem
It stimulates leaf expansion	It inhibits leaf expansion
changes phytochrome red to phytochrome far-red	It changes phytochrome red to phytochrome far-red
Stimulates flowering in long day plants	It inhibits flowering in long day plants
Inhibits flowering in short day plants	Promotes flowering in short day plants
Stimulates germination of some seeds	Inhibits germination in some seeds e.g. lettuce seeds

(c)(ii).

Temperature controls germination and directly affects the rate of metabolism and cell division. Flowering of temperate plants may be brought about by subjecting germinating seeds to cold treatment (vernalisation). The cold stimulates gibberellins acid which initiates flowering.

Question 18.

(a).What is meant by annual rings? ***(02 marks)***
(b).State the characteristics of secondary xylem and phloem ***(10 marks)***
(c)(i).Describe the secondary growth changes undergone by phellogen in plants ***(07 marks)***

(a).

Annual rings are distinct concentric rings of wood indicating one year's growth seen in transverse section of stems and roots of woody plants.

(b).

Characteristics of secondary xylem
• Consists of tracheids, vessels, xylem fibres, xylem parenchyma cells and xylem ray cells
• The elements of secondary xylem are generally shorter than those of primary xylem
• Shows a clear distinction into axial and radial system; which is absent in primary xylem.
• Axial system has vertical rows of cells with their long axis parallel to the long axis of the plant organ.
• The radial system is made up of xylem rays.

Characteristics of secondary phloem
• Consists of sieve elements, companion cells, phloem parenchyma and phloem cells.
• Sieve tubes possess two types of sieve plates; simple or compound depending on the species
• Phloem parenchyma are elongated and have pointed ends
• Phloem fibres give mechanical rigidity to the phloem
• Translocates organic food substances to sites of utilization.

(c)(i).

Cork cambium divide, gives rise to cork; to the outside beneath the epidermis due to suberisation. The unsuberised to the outside of the phellogen forms the lenticels for gaseous exchange. The inner side of the phellogen divides mitotically to form secondary unsuberised cortex/ phelloderm. Phellogen, phellen and phelloderm form the periderm. Phloem and the periderm forms the bark.

Question 19.

(a).Explain the effect of photoperiod on metamorphosis in a named arthropod or amphibian ***(04 marks)***
(b).Outline particular set of conditions that must be satisfied before seeds begin growth ***(05 marks)***
(c)(i).State the various significances of larval forms in living organisms ***(07 marks)***
(c)(ii)What are the different stages in the secondary thickening of a dicot stem? ***(04 marks)***

(a).

Increase in day length in a toad stimulates the hypothalamus to secrete Thyrotropin releasing hormone which stimulates the anterior pituitary gland to secrete thyroid stimulating hormone which initiate metamorphic changes. Decrease in day length results in the reverse.

(b).

• Period of sustained cold
• Period of time to allow certain very slow chemical processes to occur
• Certain amount of light above a given intensity
• Partial breakdown of the seed coat (testa) eg by the digestive processes of animals
• The heat of a flare fire.

(c)(i).

• Larvae are responsible for feeding and growth prior to the formation of the adult
• In specialised cases, the larvae are capable of asexual reproduction
• The larvae help to disperse slow moving echinoderms e.g. in starfish, ciliated planula etc
• Ciliated miracidia enables parasitic flukes to get from host to host
• Reduction in competition since they have different mechanisms and feed on different food types.
• The larval stage helps in survival of the organism during adverse conditions
• They are small and motile and are responsible for species distribution which is especially important in animals that have restricted mobility because they are slow moving, sessile or parasitic.

(c)(ii).

• Formation of cambium between vascular bundles forming a complete ring of cambium
• Cambium divides into secondary phloem to the outside and secondary xylem to the inside of the stem
• Development of cork cambium which divides to form secondary cortex and cork.
• Development of lenticels; channels of gaseous exchange in the stem.

Question 20.

(a)Describe how food ingestion stimulates larval development into an adult grasshopper ***(12 marks)***
(b).Explain the significance of neuro-secretion in man. ***(08 marks)***

(a).

Distension of the gut following a meal causes secretion of prothoracotrophic hormone from the neurosecretory cells of the brain get stored in the corpora cardiaca; passes down to the prothoracic gland. A considerable concentration of this brain hormone stimulates the prothoracic gland to secrete ecydysone (moulting hormone); a steroid hormone which activates genes that switch on the protein synthesis machinery in the epidermal cells; synthesize enzymes that degrade the old cuticle; cause growth and lay down a newer cuticle. During Metamorphosis; the corpus allatum within the brain secretes juvenile hormone. Juvenile hormone potentiated by moulting hormone produces a cuticle characteristic of the nymphal stage. These series of nymphal stages occur until towards the end of metamorphosis where secretion of juvenile hormone ceases such that moulting hormone in the absence of juvenile hormone causes epidermal cells to lay down a newer adult type of cuticle.

(b).

The neuroendocrine cells, located in the hypothalamus, have axons that terminate in the posterior pituitary gland and median eminence and secrete several neurohormones, including antidiuretic hormone (ADH), oxytocin and releasing hormones, which control the secretion of anterior pituitary hormones.

• Antidiuretic hormone; brings about renal water retention; also causes vasoconstriction
• Oxytocin; brings about uterine contractions during labour and milk ejection after pregnancy.
• Thyrotropin releasing hormone; stimulates release of thyroid stimulating hormone by the pituitary gland

- Corticotropin releasing hormone; stimulates release of corticotrophins by the pituitary gland
- Gonadotropin releasing hormone stimulates release of gonadotrophins (FSH& LH) by pituitary gland
- Growth hormone releasing hormone stimulates release of growth hormone by the pituitary gland.
- Somatostatin/growth hormone inhibiting hormone; inhibits release of growth hormone
- Dopamine; as a prolactostatin to inhibit prolactin secretion.
- Follistatin; suppress FSH secretion
- Cortistatins; suppress release of corticotrophins
- Melanocyte inhibiting factors/ melanostatins; inhibit release of melanocyte stimulating hormone

Question 21.

(a).Describe the structural and physiological characteristics of cells of meristematic tissue. ***(03 marks)***
(b).Distinguish between apical and lateral meristems. ***(03 marks)***
(c) Describe the structural adaptations of vascular tissue for support. ***(14 marks)***

(**a**)

Structural characteristics
- Meristematic tissues consist of small cuboid cells with dense cytoplasm**;**
- Thin walls**;**
- Many small vacuoles**;**
- Undifferentiated plastids**;**
- Usually the cells are rectangular or oval.
- Cell wall is made of cellulose and is thin.
- Nucleus is large and the cytoplasm is denser.
- Usually there is no intercellular space in meristematic tissue, so the cells are arranged compactly.

Physiological characteristics
- Cells possess the power of cell division.

(b).

Apical meristems	Lateral meristems
Cause increase in height/length of the plant	Cause increase in girth/diameter/width of the stem**;**
Lead to formation of primary tissues	Lead to formation of secondary tissues**;**
Located at root and shoot tips	Located inside the sides of a stem**;**

(c).

Xylem 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; arranged in groups to offer firmness;
Xylem also comprises of the trachieds; and vessel elements; that are also lignified to offer strength;
In stems vessels are at the peripheral of the stem for support;
Trachieds have tapering ends that interlock with neighboring trachieds for firm support;
In roots vessels run longitudinally as separate rods to resist collapsing due to tugging strains caused by bending of aerial parts;
Mature xylem completes development by annular or spiral or reticulate lignification to increase support;

Question 22.

(a).Describe the role of the apical meristem in growth of Dicotyledonous plants. ***(08 marks)***
(b).Explain how the hormonal control of growth is achieved in plants. ***(12 marks)***

(a).

Rapid mitotic division of the apical meristem results into irreversible Increase in length; in the regions of the cell division, neatly arranged cells divide rapidly to form epidermis while the corpus cells divide rapidly to form many daughter cells. In the region of cell expansion, these cells undergo vacuolation and increase in size/expands; some of the vacuolated cells differentiate into parenchyma and collenchymas; while others arrange themselves end to end to form a meristematic strands of cells called procambium; in the region of differentiation, cells of the procambium towards inside divide rapidly to form protoxylem then metaxylem while cells of the procambium towards the outside divide rapidly to form protophloem and metaphloem. Metaxylem and metaphloem form vascular bundles in the permanent zone.

(b).

Water; chilling temperature and high concentration of phytochrome far-red (P_{fr}/P700) activates the embryo in the seeds; to secrete the hormones gibberellins; gibberellins stimulate synthesis of hydrolytic enzymes; which catalyze breakdown of food reserves in the seeds into soluble products which are translocated into embryo to cause seed germination; gibberellins also stimulates cell elongation and differentiation.

Light stimulus; stimulates secretion of hormone auxin at the tip of the shoot; which stimulates shoot growth when in high concentration; through cell elongation; it also initiates root growth in low amounts; but high concentration of auxin of auxin from the tip of the shoot causes apical dominance; Auxins permit vacuolation which results in cell expansion. In high concentration, auxins inhibit root growth and promote shoot growth in high concentration.

In mature plants, cytokinins are produced in the roots and move into the shoot; where in presence of auxins; they stimulate rapid cell division; Abscissic (ABA) is made in leaves, stems/fruits/ seeds from carotenoids pigments in the chloroplasts; it inhibits growth and development in seeds; causes abscission of leaves/ fruits; ageing process (senescence).

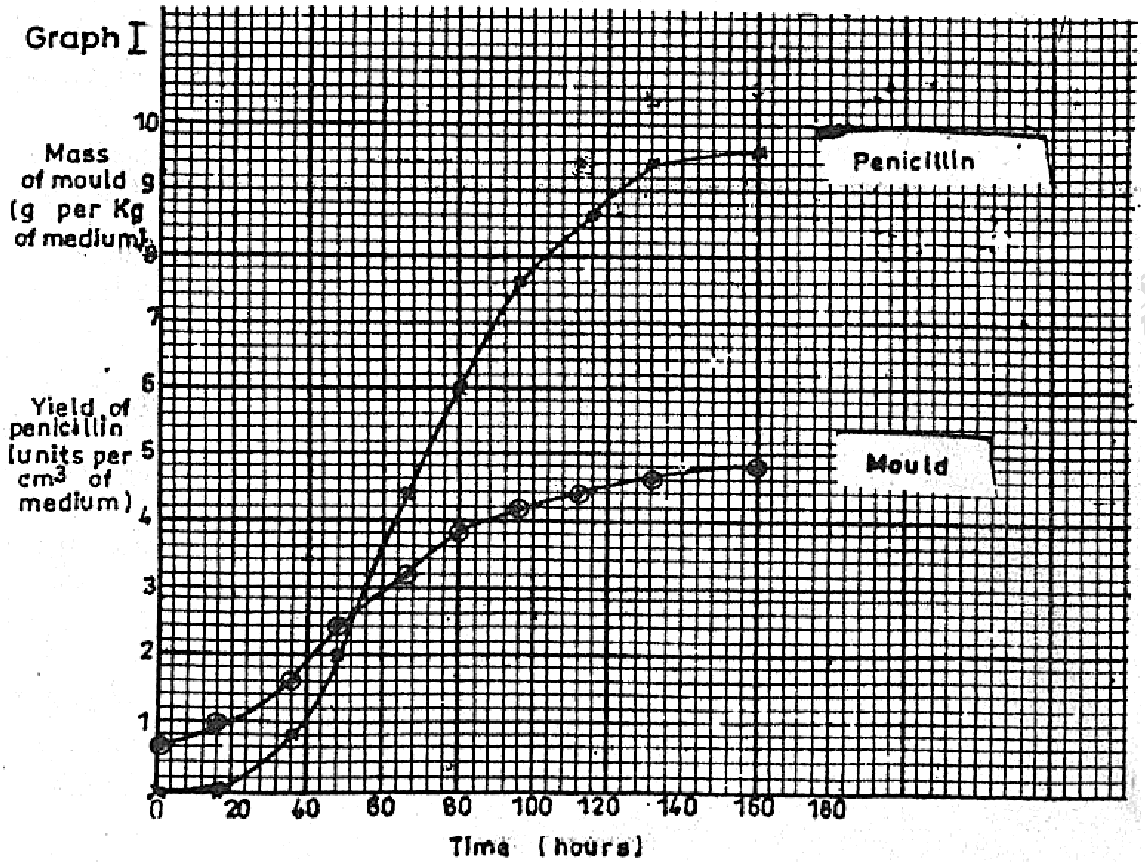
Changes in the day length (photoperiodism); stimulates synthesis of hormones florigen in leaves transported via phloem into the buds at the shoot to promote flowering in plants. Chilling temperatures; stimulate synthesis of the hormones vernalin which promote process of flowering in some plants;

Chapter 16; Levels of organisation & diversity of life

Growth of two micro-organisms in culture media and yield of their products was analyzed. The table below shows the growth of the yeast Saccharomyces and the yield of its product ethanol.

Time (hours)	Mass of yeast (g per dm^3 of medium)	Yield of ethanol (g per 100 cm^3 of medium)
0	1.0	0.2
2	1.4	0.4
4	2.4	0.6
6	4.2	1.3
8	5.9	2.5
10	6.2	2.8
12	6.1	2.6
14	5.8	2.2

Graph 1 shows the growth of the ascomycete mould Penicillium and the yield of its product penicillin. Use the data to answer the questions that follow:



(a).Represent the information in the table graphically. ***(06 marks)***

Use your graph and graph I, to answer questions (b)–(f).

(b).Describe the patterns of growth of the mould and the yeast. ***(06 marks)***

(c).Give two differences in the growth pattern of the mould and the yeast. ***(04 marks)***

(d).Explain what is happening in the growth of yeast population during each of the following periods:

(i).1–2 hours

(ii).4-6 hours

(iii)8 – 10 hours

(iv)12 – 14 hours ***(08 marks)***

(e).Describe the relationship between the

(i).growth of the mould and the yield of penicillin

(ii).growth of the yeast and production of ethanol ***(04 marks)***

(f).State three ways in which the pattern of accumulation of penicillin in graph I differs from the pattern of accumulation of ethanol on your graph.

(g).Ethanol is a direct product of metabolic processes essential for the life of the organism. Penicillin is a product of metabolic processes which are not essential to keep the organism alive. Suggest how the differences in the patterns of accumulation of these two products may be related to their differing roles in the metabolism of the producer organisms.

(h).State the economic importance of Saccharomyces and Penicillium. ***(04 marks)***

Essay questions and answers

Question 1.

(a).Explain what is meant by a species ***(04 marks)***

(b).State the relevances of classifying living organisms ***(05 marks)***

(c).Outline the characteristics of mitochondria that support the idea that they were once independent prokaryotes ***(05 marks)***

(a).

A species is a group of organisms; sharing a common gene pool; with similar morphology or characteristics; capable of interbreeding; to produce viable off springs. A species is at times capable of interspecific hybridization; i.e dissimilar organisms interbreeding for example a horse-donkey mating resulting in a mule. Interspecific hybrids are sometimes fertile and reproduce sexually; or infertile and reproduce asexually;

(b).

• Classification arranges organisms in groups;
• Classification allows easy identification of organisms;
• Classification allows effective communication; all scientists use the same terminology
• Classification permits prediction of related taxa based on common characteristics
• Classification reveals evolutionary links/ shared derived characteristics/ inherited from common ancestors
• Classification avoids problem of convergence/ ignores analogues
• Classification emphasizes homologous structures/ traits derived from a common ancestor

(c).

• Mitochondria have their own DNA and ribosomes; conduct their own protein synthesis
• Mitochondrial DNA is circular
• Mitochondrial DNA lacks histones
• Mitochondrial DNA lacks introns
• Mitochondria replicates independently of the host cell nucleus
• Mitochondrial size is similar to that of prokaryotes
• Mitochondrial ribosomes are similar in size and antibiotic sensitivity to those in prokaryotes

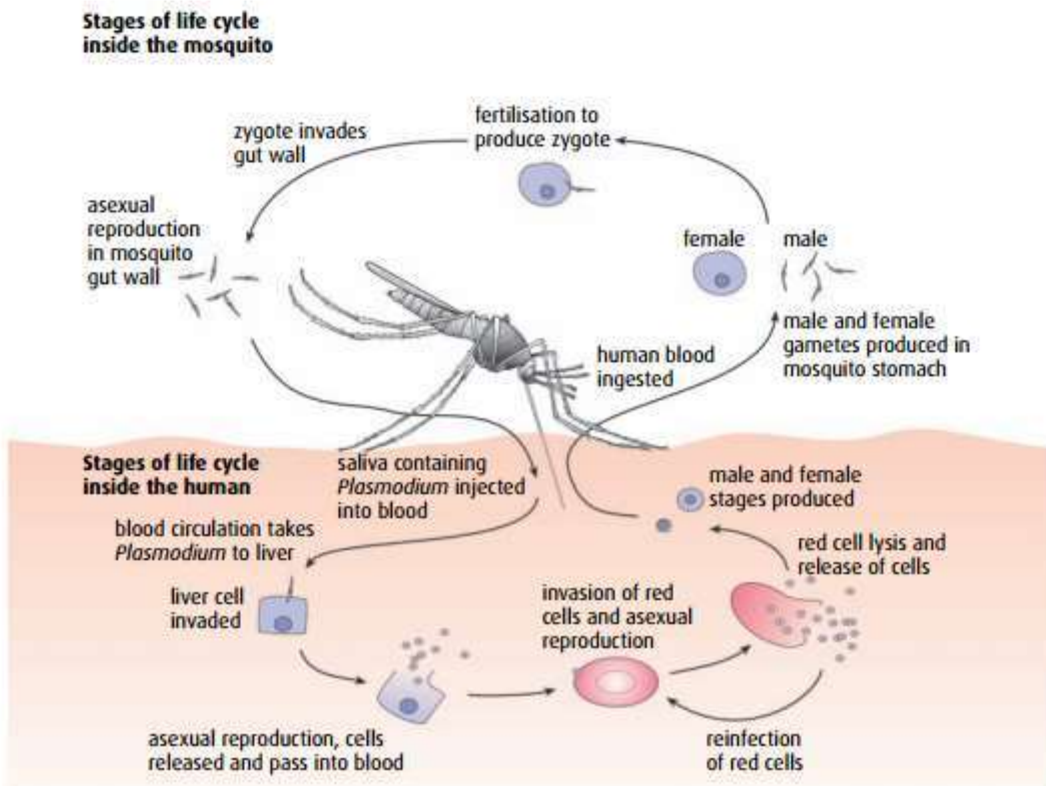
Question 2.

(a) What are the adaptations of the plasmodia to its parasitic mode of life ***(03 marks)***
(b) Describe the life cycle of plasmodia ***(11 marks)***
(c) Why is malaria still such an unrelenting disease in sub-Saharan Africa? ***(06 marks)***

(a).

• Has alternative hosts increasing chances of survival
• Produces many propagules i.e. merozoites and sporozoites to increase chances of survival
• Reproduce asexually allows their rapid multiplication for survival from generation to generation.
• Plasmodium has a short generational period or life cycle; increases chances of reproduction.
• Exist in different generations; increase chances of survival.
• Carried by a vector the female anopheles mosquito; ensures effective transmission to the primary host.
• Plasmodium zygote is vermiform in shape; enhance appropriate penetration through the gut wall.
• Encysted zygotes; which protects the sporocyst from immune attacks.
• Produces numerous sporozoites; increase propagation and survival
• Plasmodium exhibits alternation of generation; reduce competition for life requirements.
• The organisms are very small in size; hence has less resource requirements.

(b).



Malaria parasite life cycle involves humans as intermediate host & adult female anopheles mosquito as definitive host. During a blood meal, a malaria-infected female Anopheles mosquito releases sporozoites into human blood. On reaching the liver, sporozoites infect liver cells and mature into schizonts, which rupture and release merozoites. After this initial replication in the liver (exo-erythrocytic schizogony), the parasites undergo asexual multiplication in the erythrocytes (erythrocytic schizogony). Merozoites infect red blood cells, the ring stage trophozoites mature into schizonts, which rupture releasing merozoites. Some parasites differentiate into sexual erythrocytic stages (gametocytes). Blood stage parasites are responsible for the clinical manifestations of the disease. The gametocytes, male (microgametocytes) and female (macrogametocytes), are ingested by an Anopheles mosquito during a blood meal. The parasites' multiplication in the mosquito is known as the sporogonic cycle. While in the mosquito's stomach, the microgametes penetrate the macrogametes-generating zygotes. Zygotes become motile and elongated (ookinetes), invade the midgut wall of the mosquito to develop into oocysts. Oocysts grow, rupture, and release sporozoites, which enter the mosquito's salivary glands. Inoculation of the sporozoites into a new human host perpetuates the malaria life cycle.

(c).

• Suitable warm temperatures of the tropical climate; favours growth and development of both the sporozoites and mosquitoes at large; ensuring rapid multiplication of both plasmodia and mosquito vectors;
• Plasmodium has undergone constant mutations; making it hard for development of malaria vaccine
• Misuse of drugs encourage drug resistance of plasmodia to anti-malarial drugs
• Low socio-economic status complicates treatment due to failure of patients to buy effective medication.
• Ineffective management of malaria inform of mis-diagnosis and improper treatment.
• Poor sanitation like stagnant water; keeps breeding sites for vectors;
• Plasmodium parasites exhibit antigen shifting; thereby defeating the host's immune system

Question 3.

(a)Compare the adaptation of life on land shown by insects and mammals. ***(08 marks)***
(b)Describe the adaptation of aquatic organisms for existence in their habitat ***(12 marks)***

(a).

Similarities

• Both exhibit internal fertilization; to increase chances of reproductive success.
• Both have an internal respiratory system with moist linings; minimize water loss from the respiratory surfaces;
• Both have hinged skeletons to permit muscular movements
• Both excrete less toxic and less soluble nitrogenous wastes to conserve water
• Both demonstrate a variety of nutritional modalities such as parasitism, herbivory etc; to exploit the various food sources in the different niches.
• In both, some organisms exhibit periodic episodes of dormancy inform of hibernation and aestivation to survive adverse environmental conditions.
• In both, migratory and nocturnal behaviour enable some organisms survive adverse environmental conditions.

Differences

To overcome the challenge of water loss /water conservation
• Insects possess water proof cuticle while mammals have hairs, keratinized skin epithelia, scales
• Evolution of Malpighian tubules in insects while kidneys in mammals;
• Insects pass out water insoluble excreta like uric acid while mammals excrete urea; sparingly water soluble;

To increase chances of reproductive success
• Insects exhibit oviparity (egg laying) while mammals exhibit viviparity (embryonic development in the placenta);

Secure food, nutrients and minerals.
• Insects possess modified mouth parts(chewing, piercing and sucking mouth parts); while animals have heterodont teeth and strong jaws; to consume a variety of foods in different niches;

To solve locomotion challenges
• Insects possess cutinous exo-skeletons while mammals possess endo-skeletons that form flexible frameworks th-at facilitate locomotion;

To solve the problem of temperature regulation
• Mammals have evolved homeothermy while insects are poikilothermic.

(b).

• Aquatic plants generally lack a cuticle reducing diffusion distance & therefore gaseous exchange occurs over the whole surface
• Protozoa and other animals with a large surface area to volume ratio; can also exchange gases by diffusion over the whole surface;
• Aquatic organisms with smaller surface area to volume ratio have developed gills to provide an efficient transp-ort system to carry gases to and fro respiring tissues and a special exchange surface with a large surface area to volume ratio
• Produce large number of offspring to increase chances of survival as fertilized eggs are in great danger of being eaten or carried far from suitable habitat;
• Marine invertebrates their tissues are isotonic with sea water, so there is no net loss or gain of water fresh water proticsts have contractile vacuoles to get rid of excess water;
• Marine teleost excrete trimethylamine oxide that requires less water for excretion to conserve water within their bodies;
• Plants are found on upper regions of deep water masses to obtain light energy required for photosynthesis;
• Plants in deeper regions have red and brown pigments to absorb light with high penetrative power e.g. light in blue region of the spectrum;
• Plants are always attached to rocks to maintain suitable position for photosynthesis;
• Plants have air bladders for floatation to expose the plants to sunlight required for photosynthesis;
• Bodies stream-lined in shape; minimize water resistance during locomotion.
• Locomotory organs of fish/ turtles are modified into fins to swim in water easily.
• Some aquatic organisms like amphibians have webs; increase surface area for swimming.
• Aquatic animals like turtles have fin like organs called paddles for swimming and whales have the flippers as the swimming organ.
• Body is covered by scales which make the body soft and slippery so as to escape from the enemies
• Some fishes have air/swim bladder for adjusting them in the different depths of water permitting buoyancy.
• Light coloured body and upper side dark coloured; camourflage from predators

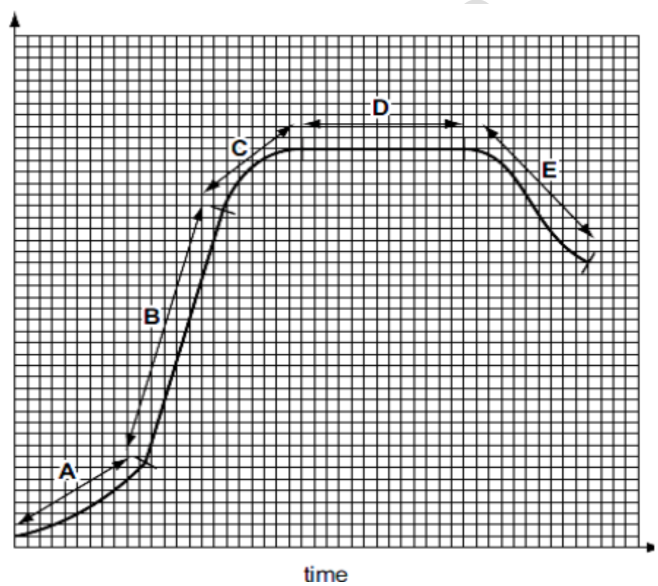
• Lay numerous eggs; increase chances of reproductive success;
• Hydrophytes like water lilies, water hyacinth; have numerous stomata on the upper leaf surface and few or none on the lower surface, hydathodes for exuding water, broad and spongy leaves for floating on water surface and for increasing surface area for trapping sunlight.

Question 4.

(a)(i).Briefly describe and explain the classical growth curve exhibited by a bacteria
(a)(ii).How does a bacterial cell differ from that of a higher plant ***(06 marks)***
(b).Giving examples, describe the different nutritional groups of bacteria ***(07 marks)***
(c).Discuss the importance of bacteria in nature ***(07 marks)***

(a)(i).

Lag phase (A); The population increases gradually as the bacteria are still adapting to their new environment and growth has not yet achieved the maximum rate. The bacteria also synthesizes new substances.
Log phase (B); The population increases rapidly with time. The bacteria have adapted to the environment and enzymes have been synthesised to digest food which is in abundance so as to support the rapidly increasing population.
Decelerating phase (D); There is slow population growth because food has reduced.
Stationary phase (E); The population remains constant with time because the death rate equals to the rate of formation of new cells due to; stiff competition for decreasing food, depletion of oxygen (reduction of oxygen) and accumulation of toxic wastes from metabolism.
Phase of decline (F); The population declines slowly because cells stop multiplying due to exhaustion of oxygen, accumulation of wastes and exhaustion of nutrients.



(a)(ii).

Bacterial cell	Higher plant cell
No distinct nucleus	Has a distinct nucleus
Smaller in size	Larger in size
No cell vacuole	Has a cell vacuole
Membrane bound organelles absent	Membrane bound organelles present
Cell walls made up of peptidoglycans	Cell wall made up of cellulose
DNA nor incorporated into chromosomes and occur in a single circular strand.	DNA has a double helical strands incorporated into chromosomes.

(b).

Photoautotrophic/ photosynthetic bacteria; these use light energy to synthesize food eg the blue-green bacteria and cyanobacteria have photopigments eg bacteriochlorophyll

Chemosynthetic bacteria; use inorganic compounds like hydrogen sulphide, ammonia, iron; that they oxidize to reduce water molecule as the source of energy eg the iron bacteria which oxidizes ferrous compounds to ferric compounds. Others include nitrosomonas, Nitrobacter, purple sulphur bacteria etc.
Heterotrophic bacteria; obtain energy from living organic matter through their break down activity eg some free living parasitic and saprophytic bacteria.

(c).

- Participate in breakdown and nutrient recycling eg nitrogen, carbon and phosphorous cycle
- Bacteria are involved in food processing eg in manufacture of yorghurt, cheese, vinegar etc
- Used in manufacturing industries eg tannings and making soap powder
- Some are sources of drugs like antibiotics eg streptomycin.
- They can easily be cultured for research eg E-coli.
- Parasitic bacteria cause diseases eg tuberculosis in humans caused by mycobacterium tuberculosis.
- Sewage treatment.
- Production of biogas.
- Silage formation,
- Curing of tea, tobacco and retting flax
- Formation of vitamin B_{12} and K
- Many bacteria cause food spoilage/decay
- Bacteria form symbiotic relationships with other living organisms eg rhizobium with the root nodules of legumes; an interaction that aids nitrogen fixation.

Question 5.

(a).Distinguish between a life cycle and alternation of generations. ***(02 marks)***
(b).Give an account of alternation of generation in a named bryophyte or pteridophyte ***(12 marks)***
(c).Discuss the significance of alternation of generations in life cycle of plants ***(06 marks)***

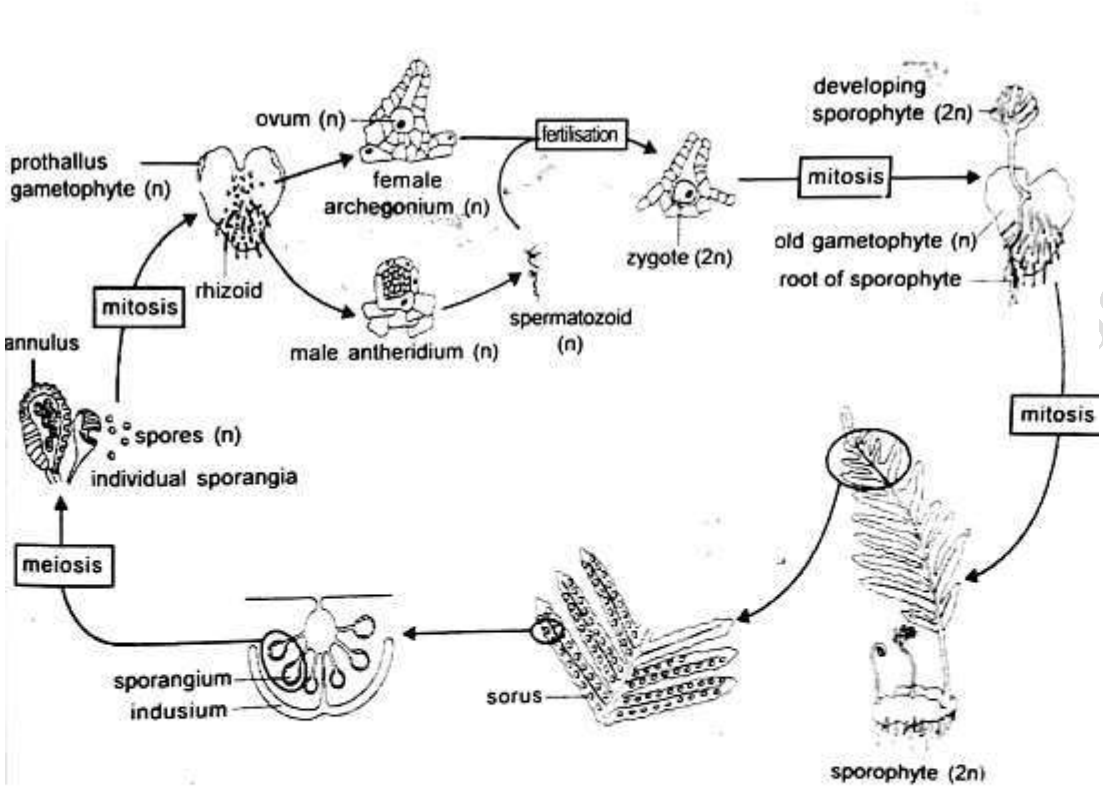
(a).

Life cycle is the progressive sequence of changes an organism goes through from fertilization till death while alternation of generations is the occurrence within the lifecycle of an organism two or more distinct forms (generations); a haploid gametophyte and a diploid sporophyte; which differ from each other in appearance, method of reproduction and genetic constitution.

(b).

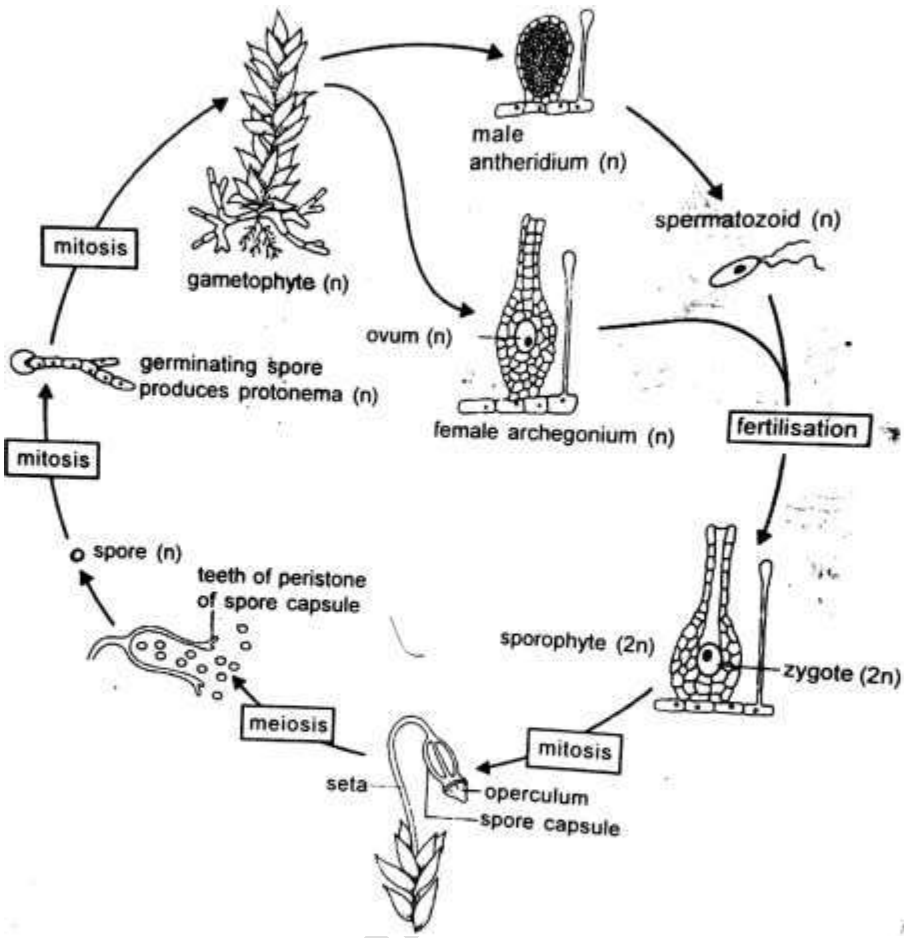
Alternation of generation (life cycle) of a moss e.g Funaria- a bryophyte

A moss e g Funaria consist of two distinct forms in the life cycle i.e the haploid gametophyte which is dominant and sexual stage, and the diploid sporophyte which is the asexual and less conspicuous stage. A gametophyte may bear both sex organs; the antheridia (sperm producing) and archegonia (egg producing) or they may be borne on separate gametophyte plants. On maturing; the antheridia shed sperms antherozoids that are aided by rain splashes to reach the open neck of the archegonia, get chemically attracted e.g sucrose enables them to reach archegonia. The haploid antherozoids fuse with the haploid eggs (oospheres) to form diploid zygotes (oospores) The zygotes develop into diploid sporophytes, which remain attached and surviving on gametophytes. At maturity, the sporophyte produces haploid spores by meiosis within the spore capsule, which splits open when dry and the spores are dispersed off by wind. On landing on moist land, each spore germinates into a green filamentous protonema which produces buds that grow into the new haploid gametophyte.



Alternation of generation of a fern e.g Dryopteris–a pteridophyte

Consists of two distinct forms of life cycle; the haploid sporophyte which is the dominant and asexual stage & the haploid gametophyte which is the sexual and less conspicuous stage. Diploid spore cells inside the sporangium divide by meiosis to produce haploid spores. When mature, a protective covering (indusium) shrinks and the exposed sporangium wall begins to dry out. The walls then rupture and the spores are discharged from the sporangium. If moisture is present, each spore germinates into heart shaped prothallus (gametophyte) anchored to the soil by rhizoids. At the underside of the prothallus is a bisexual gametophyte that bears antheridia and archegonia which produces sperms and eggs by mitosis respectively. After rupture of the antheridia, the ciliated sperms swim through water to fertilize eggs at the base of the archegonia; and the diploid zygote formed grows into a young sporophyte which remains supported on the prothallus until it is self-supporting.



(c).

- Enables exploitation of different habitats in the ecosystem by different generations.
- Promotes rapid multiplication of species since spores are enormously produced.
- Enables plants to cope better with adverse environmental conditions for survival.
- Reduces chances of extinction of a species since the different generations are independent.
- Brings about genetic variability by meiosis during spore formation
- Mitosis during gamete formation maintains the plant genome by producing haploid gametes.
- Different habitats of the ecosystem are exploited by the different generations
- Reduces chances of extinction.

Question 6.

(a).State the advantages and disadvantages of propagation by seed *(06 marks)*
(b).Compare the alternation of generation in a named pteridophyte and bryophyte *(10 marks)*
(c).Explain the significance of the sporophyte generation. *(04 marks)*

(a).

Advantages of propagation by seeds.

- Enables plant to be better adapted to terrestrial environment since water is less required for sexual reproduction.
- Embryo is protected within seeds; increase chances of reproductive germination.
- There is food reserved for embryo growth within the cotyledons or the endosperm
- Seeds are easy to store, disperse and transport.
- Seeds are products of sexual reproduction characterized by mixing of genes; form variants of hybrid vigour.
- Plants mature early are tolerant to unfavourable environmental conditions
- Allows for mixing of genes which increases the hybrid vigour
- There is increased resistance to diseases

Disadvantages of propagation by seeds
• Seeds are easily destroyed by pests like insects and animals.
• Seeds have limited food reserves
• Requires selection of suitable seeds i.e seeds of high hybrid vigor.
• Dispersal maynot be easy because of the large size of some seeds.
• Initial inputs are expensive
• Dispersal may not be easy because of the large size of seeds usually

(b).

Similarities

• In both, there is one dominant stage and the other stage is relatively inconspicuous.
• In both, moist, or aquatic environments are required.
• In both, gametophyte bears sperm producing antheridia and egg producing archegonia.
• In both, spores are formed in specialized spore bearing sporangium.
• In both, spores are dispersed by explosive mechanisms.
• In both, sporophytes are diploid and gametophytes are haploid.
• In both, spores are produced by meiosis and gametes by mitosis.
• In both, there is asexual and sexual reproduction.
• In both the male gametes are motile while eggs are non-motile
• In both, male gametes from the antheridia are brought into contact with eggs in the archegonia by chemotaxis.

Differences

Alternation of generations in a moss e.g Funaria.	**Alternation of generations in a fern e.g Dryopteris**
Sporophyte is dependent upon the gametophyte nutritionally	Sporophyte is self-supporting plant.
Each spore germinates first into protonema, which transforms into gametophyte	Each spore germinates directly into gametophyte
Gametophyte is a dominant generation	Sporophyte is the dominant generation
Both male and female reproductive organs may be borne on the same or separate gametophyte plants	Both male and female reproductive organs are borne on the same gametophyte (prothallus)
Depends on water for plant growth, transfer of sperms, support & spore dispersal and spore germination.	Dependence on water is less, mainly for swimming of sperms and germination of spores.
The sperms are biflagellate	The sperms are ciliated
Gametophytes may or may not bear both sexual reproductive organs	Gametophytes always bears both sexual reproductive organs

Question 7.

(a)Explain how ferns are better adapted to terrestrial life than mosses ***(08 marks)***
(b)How does temperature influence the following processes in plants
(i).Plant growth ***(07 marks)***
(ii)Plant distribution ***(05 marks)***

(a).

• Ferns, unlike mosses, have rhizomes/horizontal underground stems for reproduction as well as surviving unfavo-urable conditions.
• Sporophyte generations of ferns unlike those of mosses, have true roots for anchorage and transportation of abs-orbed minerals and water from the substratum.
• Ferns produce more spores than mosses for greater reproductive rates.
• Ferns have broader leaves; present a larger surface area for photosynthesis.
• Sporophyte generations of ferns are nutritionally independent; while that of mosses depend on the gametophyte plant for nutrients.
• Sporophyte of ferns, unlike mosses have true vascular tissues for transport and translocation of materials
• Ferns unlike mosses have true stems to support the leaves so as to obtain light
• Leaves of ferns unlike those of mosses have a water proof cuticle; to prevent desiccation.

(b)(i).

Temperature acts as a limiting factor; in growth and development of the plant by influencing rate of cell division, cell metabolism (photosynthesis/ respiration/excretion) because it affects the rate of enzyme activities; which doubles for every 10ºC within the enzyme working range. Above the working/optimum range, enzymes are denatured while below the working range, enzymes are inactivated. Low temperature stimulates flowering/germination in some plants.

(b)(ii).

CAM plants and C_4 plants which are tolerant to higher temperatures are more abundant in hot temperature areas like deserts and tropics respectively/ low or mid altitude areas. C_3 plants grow more efficiently in cooler environment like in temperate regions/ high altitudes as they fix carbondioxide better at lower temperatures. Some aquatic plants can withstand very high temperatures and can thrive in hot springs; some can withstand very cold temperatures in snow.

Question 8.

(a).With the aid of a table, compare the features of the different plant phyla *(10 marks)*

(b).How does life cycle in a moss differs from that of a typical flowering plant *(10 marks)*

(a).

Features	**Bryophyta**	**Pteridophyta**	**Gymnospermae**	**Angiospermae**
Dominant phase	Gametophyte	Sporophyte	Sporophyte	Sporophyte
Ploidy of main plant body	Haploid	Diploid	Diploid	Diploid
Differentiation of the body	Thallus and rhizoids	Root, stems and leaves	Roots, stems and leaves	Roots, stems and leaves
Vascular bundles	Absent	Present	Present	Present
Nature of spores	Homospores	Homospores or heterospores	Heterospores	Heterospores
Seeds and their coverings	Seeds absent	Seeds absent	Seeks naked without covering	Seeds with a covering.
Flowers	Absent	Absent	Absent	Present

(b).

Life cycle in a moss plant(Bryophyte)	**Life cycle in a flowering plant**
Dominant generation is the gametophyte	Dominant generation is the sporophyte.
Water is much essential for fertilisation	Water is not essential in fertilisation
Homosporous	Heterosporous
Flagellated male gametes	Non flagellated male gametes
Has haploid and diploid stages only	Have haploid, diploid and triploid stages
No flowers produced	Produce flowers in which sporangia and spores develop
Involves single fertilisation	Involves double fertilisation
Spores are produced by the sporophyte in a spore capsule.	Spores are produced by the sporophyte in the anthers and the embryo sacs.
Male gametes are carried by water	Male gametes are carried by pollen grains

Question 9.

(a).Compare the features of angiosperms and gymnosperms *(10 marks)*

(b).Describe the events occurring in the life cycle of in a flowering plant *(10 marks)*

(a).

Similarities

In both,

- Embryo sac enclosed in the ovule
- Sporophyte is dominant and gametophyte is much reduced (inconspicuous).
- There are separate male and female spores.

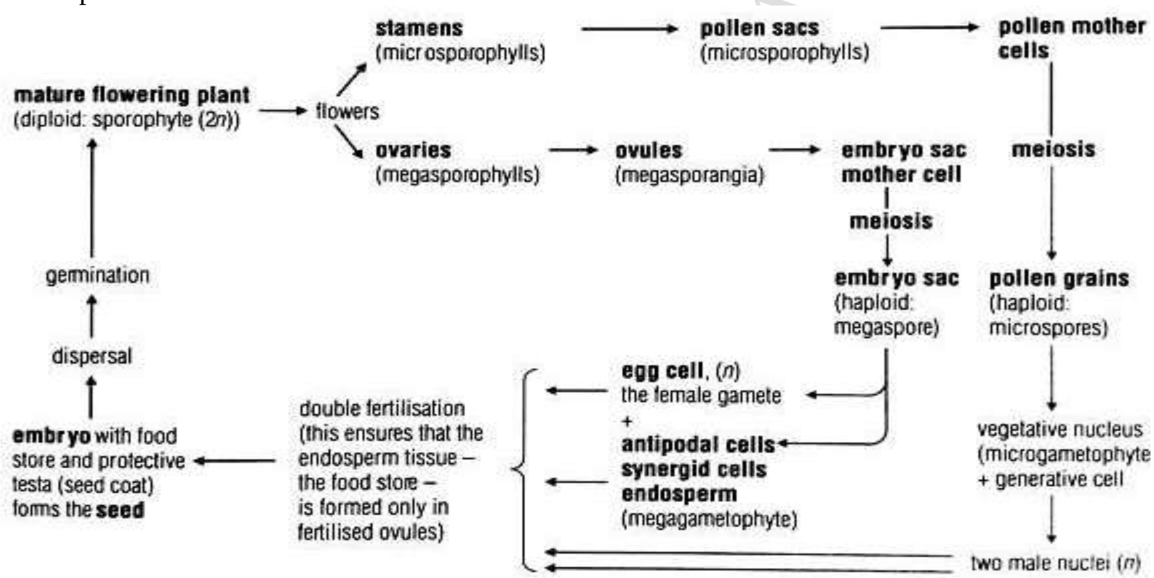
• The pollen tube is present
• Fertilised embryo develops into a seed/ produce seed.
• Xylem and phloem present/ vascular tissue present
• There are non-motile gametes.

Differences

Angiosperms	Gymnosperms
Ovule is protected by the ovary	Ovule is unprotected
Stigma and style present (flowers present)	Stigma and style absent (flowers absent)
Cones absent	Cones present
Fruits formed after fertilisation	No fruits formed
Companion cells present in the phloem	No companion cells
Xylem has tracheids and vessels	Only tracheids present, no vessels
Tracheids present in xylem	Vessels or tracheids absent
Phloem tissue contains sieve tube & companion cells	Phloem contain sieve cells

(b).

Eggs form within the embryo sac inside the ovules, which, in turn, are enclosed in the carpels. The pollen grains, meanwhile, are formed within the sporangia of the anthers and are shed. Fertilization is a double process. A sperm and an egg come together, producing a zygote; at the same time, another sperm fuses with the polar nuclei to produce the endosperm.



Question 10.

(a)Fungi and plants were originally classified in the same kingdom
(i).Which features made this classification possible *(03 marks)*
(ii).Describe the features of fungi that made it necessary to place them in their own kingdom *(05 marks)*
(b).Explain why the fungi are wide spread and in vast numbers *(06 marks)*
(c).What is the economic importance of fungi *(06 marks)*

(a)(i).

• Rigid cell wall; possessed by both fungi and plants
• Both fungi and plants are sessile/ non-motile
• Conspicuous microscopic reproductive bodies (spores) possessed by both fungi and some lower plants like mosses.
• Roots/ root like structures present in plants and fungi respectively fix the organism's body into the sub- stratum.

(a)(ii).

• Rigid cell walls made up of chitin and glucans unlike plant cell walls that are made up of cellulose
• Heterotrophic nutrition; unlike plants whose nutrition is autotrophic

• Have multinucleated cell/ coenocytic
• Mitochondria of fungi have flattened cristae
• Nutrition is absorptive and extracellular unlike in plants and animals whose nutrition is intracellular
• Reproduction by means of spores unlike in most plants that reproduce sexually
• Have mycelium made up of a network of hyphae; that are either aseptate or septate
• Organisms are non-motile
• Motile spores in fungi that are uniflagellated; unlike those in plants that are multiflagellated
• Most fungi are unicellular unlike in most plants and animals that are multicellular
• Carbohydrates in fungi are stored as glycogen unlike in plants that store starch
• Fungi lack true roots; instead possess root like structures (rhizoids/ false roots)
• Fungi undergo nuclear mitosis
• Fungi lack an efficient system of long distance transport of water and nutrients like xylem and phloem in plants

(b).

• Fungi produce vast number of spores which increases chances of reproduction
• Fungi exhibit various modes of nutrition e.g saprophytism, parasitism, mutualism etc
• Spores are light; easily dispersed over long distances by wind
• The fungi live in association with other organisms like Mycorrhiza
• Zygospores can remain dormant for a long time; survive adverse conditions
• Reproduce both sexually and asexually
• Cell walls are impregnated with water proof chitin that resists dessication
• Fungi can tolerate a wide range of pH, temperature and osmotic potential
• Spores are small and have small food stores
• Fungi utilize a wide range of substrates; able to digest carbohydrates, lipids and proteins.

(c).

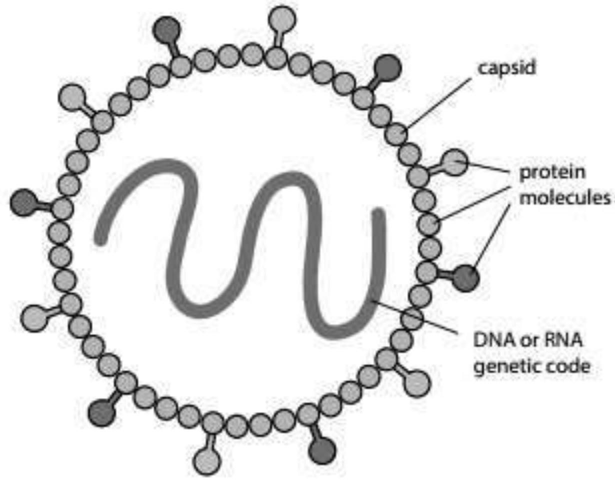
• Source of food e.g mushrooms
• Saprophytic fungi act as decomposers of sewage and organic matter aiding nutrient recycling.
• Fermentation process like alcoholic beverages, cheese making and bread baking.
• Fungi are used to produce antibiotics like penicillins that treat bacterial infections
• Cause diseases like phytophora infestans that cause potato blight, candida albicans; cause candidiasis
• For experimental uses especially genetics investigation research
• Mycorrhiza is important in plant nutrient absorption; key in nutrient recycling.
• Fermentation of Aspergillus forms citric acid used in lemonade formation
• Fungi causes decomposition of stored food and deterioration of natural materials like leather
• Some are poisonous to man
• They cause skin irritations e.g. ringworms.
• Mycorrhizal association in forest development may help in Water intake/absorption

Question 11.

Viruses are at times regarded as living and non-living at the same time.
(a).Describe the basic structure of a virus ***(06 marks)***
(b).Outline the core characteristics of viruses ***(06 marks)***
(c).Give reasons that justify viruses as
(i) Living organisms ***(05 marks)***
(ii).Non-living ***(03 marks)***

(a).

It is made up of the core that forms the inner region in which the genetic material (DNA or RNA) is found. DNA or RNA may be single stranded or double stranded. The capsid forms the protective coat of protein surrounding the core and is made up of subunits called capsomeres. Some viruses are enveloped and others naked. Viruses are morphologically heterogeneous; occurring as rod, spherical or polyhedral.



(b).

- They lack a cellular structure i.e. they are acellular
- They are the smallest living things 200-300nm in diameter
- They are obligate endoparasites i.e. they can only live parasitically inside other cells.
- They depend on host cells for reproduction
- Viruses are highly specific i.e. each virus recognizes and infects a particular host.
- Most viruses enter their hosts by phagocytosis and pinocytosis.
- Can be crystallized
- They exhibit a variety of shapes.
- They possess genetic material
- They can mutate and hence evolve
- They carry out protein synthesis in host cells

(c)(i).

- They are capable self-replication when inside host cells
- They can transmit characteristics to the next generation.

(c)(ii).

- They can be crystallized
- They lack enzyme systems
- They cannot metabolize unless they are inside host cells
- They lack an enzyme system

Question 12.

(a).Briefly describe the nutritional classification of bacteria ***(14 marks)***
(b).Outline the economic importance of bacteria ***(06 marks)***

(a).

Autotrophic bacteria; these bacteria manufacture their own organic food from carbondioxide.
Photoautotrophic (photosynthetic) bacteria use energy of sun light to convert carbondioxide into carbohydrates e.g the blue-green bacteria, sulphur bacteria and cyano-bacteria.
Chemoautotrophic (chemosynthetic) bacteria use energy from chemical reactions to convert carbon dioxide into carbohydrates. Inorganic substances such as ammonia, methane and hydrogen sulphide are oxidized to release energy. E.g nitrosomonas and Nitrobacter
Heterotrophic bacteria; they feed on already made organic food but in different ways.
Chemo-heterotrophic bacteria obtain energy from chemicals in food.
Saptrotrophic bacteria obtain food from dead and decayed organic matter. Such bacteria secrete enzymes into the food, and absorb the soluble products of extra cellular digestion with the saptrotrophic body for assimilation.
Parasitic bacteria live on other organisms (hosts) from which they obtain food as the host suffers harm.

Mutualistic bacteria live in close associations with other organisms e.g. in the root nodules of legumes e.g Escherichia coli contribute vitamins B and K groups. Rhizobium fixes nitrogen into the plants as it is provided with a shelter.

(b).

• They are cultured for research purposes.
• They facilitate the making of foods like yoghurt, cheese and vinegar
• They are used for making antibiotics, amino acids and enzymes.
• In humans, vitamin K & B are produced by symbiotic bacteria (E. Coli) as in animals used to break down cellulose.
• They cause decomposition of dead organic matter, hence enabling their disposal.
• They take part in nutrient recycling e.g. the nitrogen cycle, carbon cycle and the phosphorous cycle.
• On the other hand, bacteria cause food to get spoilt
• Bacteria like Thiobacillus and Disulphovibrio produces sulphuric acid which destroy underground metal pipes.

Question 13.

(a).Outline the basic characteristics of;
(i). Bryophytes *(04 marks)*
(ii).Pteridophytes *(04 marks)*
(iii)fungi. *(04 marks)*
(b).Compare a moss and a fern *(08 marks)*

(a)(i).

• They lack vascular tissues
• They lack true roots, stems or leaves
• Their body is a thallus which is differentiated into simple ―leaves and stems‖
• Alternation of generation occurs and the gametophyte generation is dominant
• The gametophyte is anchored by thallus rhizoids which grow from the stem.

(a)(ii).

• The vascular tissue (xylem and phloem) are present.
• The leaves (fronds) are relatively large creating large surface area; increasing photosynthetic surface of the plant
• Spores are produced in sporangia (singular; sporangium), usually in clusters called sori.
• Alternation of generation occurs and the sporophyte is dominant
• The gametophyte is reduced to a small simple prothallus
• The sporophyte generation possess true roots, stems and leaves.
• The roots penetrate the soil to absorb water and dissolved mineral salts.

(a)(iii).

• Eukaryotic; with glycogen stores;
• Chitinous cell wall;
• External digestion/ secretes enzymes externally;
• Heterotrophic/ saprophytic/ no plastids (chloroplasts / amyloplasts)
• Bear spores; hyphae/ mycelium;
• Multi-nucleate/ coenocytic/ aseptate bodies of fungi form a network of tiny filaments called hyphae;
• Fungal hyphae form an Interwoven mass (mycelium) that infiltrates the substratum.
• Hyphae are divided into cells by cross walls or septa while some fungi lack septa (coenocytic fungi)

(b).

Similarities
• Both form spores
• Both grow in damp soils/ organic matter
• Alternation of generation occurs in both
• In both the gametophyte is anchored by the rhizoids

Differences

Moss	Fern
No vascular tissue	Vascular tissue
No sorus	Sorus present at leaf underside

Spore capsule present	No spore capsule
Saprophyte is attached to gametophyte	Gametophyte is attached to sporophyte
It lacks true roots, leaves and stems	True roots, stems and leaves are present
No rhizoids	Rhizoid present
Gametophyte not heart shaped	Gametophyte is heart shaped prothallus
Leaves are simple and small	Leaves are relatively large

Question 14.

(a).Outline the differences between the different classes of angiosperms ***(06 marks)***

(b).How are the following adapted to a terrestrial life

(i). Seed bearing plants ***(06 marks)***

(ii).Animals ***(08 marks)***

(a).

Monocots	Dicots
Embryo sac has one seed leaf (cotyledon)	Embryo sac has two seed leaves (cotyledons)
Have scattered vascular bundles in the stem	Have a ring of vascular bundles in the stem
Flower parts are usually in 3‘s or multiples of 3	Flower parts are usually in 4‘s or 5‘s or multiples of 4 or 5
Calyx and corolla are not usually easily distinguishable	Calyx and corolla are easily distinguishable
They are usually wind pollinated	They are often insect pollinated
Have narrow leaves with parallel venation	Have broad leaves with network venation
Lack vascular cambium	Has vascular cambium

(b)(i)

• Leaves possess stomata for gaseous exchange

• Leaves and stems are covered by a waxy cuticle which minimizes water loss

• They possess true roots which enable water and dissolved mineral salts to be absorbed

• Undergo secondary growth which enable seed bearing plants to compete effectively for light and other resources

• The fertilised ovule (seed) is retained for some time on the parent plant (sporophyte) from which it obtains protection and food before dispersal.

• Fertilisation is not dependent on water therefore reduces necessity for water inside the sporophyte which is well adapted for terrestrial life.

(b)(ii).

• Developed moist gaseous exchange surface coupled with breathing mechanisms to use plenty of gaseous oxygen available in the terrestrial environment.

• Amphibians are restricted to damp habitats, reptiles, birds, mammals and insects have a water tight surface layer which enables them to inhabit dry areas and avoid dessication.

• Reptiles and birds produce a semi-solid nitrogenous waste containing uric acid which requires less water.

• Internal fertilisation and production of shelled eggs in reptiles and internal development in mammals enables them to conserve water and become fully terrestrial.

• Animals have developed skeletons for support in air and muscular mechanisms for locomotion.

• Amphibians, reptiles, birds and mammals have limbs built on the pentadactyl basic plan; enables the body to be lifted off the ground and propel the animal forward.

• Birds and mammals have evolved homeothermy others poikilothermy; to achieve the thermoregulation.

Question 15.

(a).Distinguish between bilateral and radial symmetrical body ***(02 marks)***

(b).State the advantages and disadvantages of;

(i). Unicellularity ***(06 marks)***

(ii).Multicellularity ***(09 marks)***

(iii)Explain the significance of possessing a mesoderm in a living organisms ***(03 marks)***

(a).

Bilateral symmetrical body is one which can be divided into two identical halves along one plane only while radial symmetrical body is one which can be cut along more than one plane to produce halves that are identical to each other.

(b)(i).

Advantages of unicellularity in organisms

- Their small size enables living in a variety of habitats
- There is less food intake
- They have short life cycles.
- There is no need for the development of complex excretory organs since they take in less food.
- No necessity for development of complex circulatory and gaseous exchange structures since simple diffusion combines with their large surface area to volume ratio
- There is no need for development of complex support systems like cartilage, bones, xylem

Disadvantages of unicellularity

- Easily predated upon due to small size.
- Lack differentiated cells thus less specialised and are less efficient.
- They have little scope for competition with multicellular organisms.
- They lack adequate food stores; which may lead to adverse consequences.
- They cannot easily replace their damaged cells.
- Cannot exploit different environments due to large surface area to volume ratio especially in cold condition.

(b)(ii).

Advantages of Multicellularity

- Worn out cells are easily replaced by cell division
- Multicellularity allows tissue specialization which increases efficiency in performing body activities
- Have diversity in demonstrating different life styles and patterns of behaviour
- More responsive to stimuli.
- Allows association of body organs and systems; such that the body operates as a single unit.
- Have complex physiological mechanisms which enable maintenance of a relative constant internal environment
- Have a larger complex support system; increase chances of catching prey but also reduces chances of predation
- Have an efficient sensory system due to tissue specialization; enables animals to escape from predators quickly.

Disadvantages of Multicellularity

- They require large quantities of food
- They require specialised locomotory structures to enable efficient movement.
- They produce a large quantity of waste products hence a necessity for development of complex excretory systems
- Difficulty obtaining shelter due to their large sizes.
- Due to large size, they are easily detected by predators
- They have a small surface area to volume ratio that requires development of transport systems since simple diffusion cannot supply enough nutrients to the animal.

(c).

- It allows triploblastic organisms to increase in size and thus results into the considerable separation of the alimentary canal from the body wall
- Used in forming a variety of organs which may combine together and contribute towards an organ system of organization.
- It enables the improvement of muscular activity by triploblastic organisms; necessary because of their increased size which renders the use of flagella or cilia inappropriate.

Question 16.

(a).What are the problems of large size in animals? ***(08 marks)***

(b) Explain how the problems of large size in animals have been overcome. ***(12 marks)***

(a).

- Big body mass requiring more support;
- Require greater amounts of food;
- Movement is difficult;

• Reduced surface area to volume ratio;
• Transport between surface and centre is difficult as cells are far apart;
• More wastes to dispose off/ Need for homeostasis/ excretion;
• Difficult to shelter from predation/ vulnerable to predators due to conspicuousness;
• Coordination challenges;

(b).

• More support; They have bones/ cartilage; chitin, xylem or become aquatic;
• Greater amounts of food; the centre is made hollow or fill it with dead tissues like xylem;
• Movement is difficult; have become sessile or slow moving, return to water; e.g. whale.
• Waste disposal; they have developed excretory system;
• Shelter from predators; big size itself deters predators; camouflage; mimicry
• Reduced surface area to volume ratio is increased by having external/ internal surfaces eg. gills, lungs & long gut;
• Transport between surface and centre; animals have developed blood system, circulate fluids, develop transport mechanisms eg respiratory pigments, phloem and xylem in plants.

Question 17.

(a).Write short notes on the following;
(i). Diploblastic body plan *(02 marks)*
(ii).Triploblastic coelomate body plan *(03 marks)*
(iii)Triploblastic acoelomate body plan *(02 marks)*
(b).Suggest the biological significance of the coelom *(05 marks)*
(c).What factors have led to the huge success of plants in colonizing terrestrial habitat *(08 marks)*

(a)(i).

Diploblastic body plan consists of two body layers; the ectoderm on the outside and endoderm on the inside; the two layers being separated by the mesoglea and enclose an inner body cavity called the enteron e.g in hydra, sea anemone.

(a)(ii).

This consists of three basic body layers; ectoderm, mesoderm and endoderm; with the coelom which is an extensive internal body cavity; filled with coelomic fluid. The coelom splits the mesoderm into two layers; the somatic mesoderm and splanchnic mesoderm. The endoderm encloses the gut on the inner surface; coelom separates the gut wall from the body wall e.g in the nematodes, annelids and chordates.

(a)(iii).

This body plan consists of three body layers i.e the mesoderm completely fills the space between the outer body layer, the ectoderm and the inner body layers the endoderm.

(b).

• Coelom separates gut wall from the body wall so that muscular movements in the two walls occur independently
• Produces a cavity where organs grow, develop and function independently of each other,
• Coelomic fluid can act as hydrostatic skeleton e.g in annelids offering support, size, protection and locomotion.
• With the coelom increase in size, complexity is possible; though this presents additional problems requiring transport and coordination system.
• Coelomic fluid may be used to circulate food, wastes and respiratory gases.

(c).

• Delicate gametophyte is greatly reduced in size & time; completely dependent on dominant sporophyte.
• They produce more microspores which are easily dispersed.
• They produce non-swimming male gametes; therefore fertilisation is water independent; they have evolved a pollen tube which grows and delivers the male gamete to the female gamete.
• They produce seeds which store food utilized during germination, protect embryo, dispersed widely and allow colonization of new colonies and are able to survive adverse conditions.
• Many flowering plants show secondary growth; form wood; ensure support.
• They development of the root system enable them obtain water from the soil
• The epidermal covering of water proof cuticle or cork protects these plants from dessication
• The stomata and lenticels allow efficient gaseous exchange.

Question 18.

(a).What is a gametophyte *(01 marks)*

(b).Compare the life cycle of a pteridophyte and an angiosperm *(15 marks)*

(c)(i). Suggest two reasons why dioecious plants (those with separate sexes) are rarer than monoecious plants, despite the advantages of cross-pollination. *(02 marks)*

(c)(ii).In what main respects are mosses and ferns poorly adapted to life on land *(03 marks)*

(a).

Gametophyte is a haploid structure producing male and female gametes by mitosis.

(b).

Similarities

• Both have a spore producing plant called a sporophyte which is diploid.
• Both have gamete producing structure called a gametophyte; which is haploid.
• Both demonstrate alternation of generations.
• Both produce haploid gametes by mitosis
• Both produce diploid spores by meiosis
• Both have sporophytic generation as the dominant generations.
• For both, the gametophyte is highly reduced.
• For both, fertilisation involves chemotaxis
• For both, sporophyte has conducting tissues.

Differences

Pteridophytes	Angiosperms
Gametophyte lives independent of the sporophyte.	Gametophyte is supported and protected by the sporophyte
Need water for fertilisation	Water not required for fertilisation
One type of spore	Two types i.e microspores (pollen grains and megaspores (embryo sac)
One type of sporangium	Two types of sporangia i.e megasporangium (anther) and microsporangium (ovule)
Sporophyte lacks vessels and companion cells.	Have vessels and companion cells
Grows best in moist places	Adapted to dry conditions
Single fertilisation	Double fertilisation
Lacks seeds	Have seeds
Flagellated male gametes	Non-flagellated male gametes

(c)(ii).

• Half of the individuals in dioecious plants do not produce seeds as all individuals in monoecious plants bear seeds.
• Alot of pollen is wasted in dioecious plants because the male and female plants are not necessarily together.

(c)(ii).

• Sexual reproduction is dependent on water since involves freely swimming sperms.
• The gametophyte thallus is susceptible to dessication.
• Plants are often relatively intolerant to high light intensity.

Question 19.

Discuss the adaptations in plants that contribute to their success in a terrestrial environment in reference to each of the following.

(a).Desiccation *(12 marks)*

(b).Distribution of water throughout the plant. *(04 marks)*

(c).Reproduction *(04 marks)*

(a).

• To reduce desiccation, plants have a thick cuticle, a waxy covering on stems and leaves
• Have sunken stomata; reduces transpiration
• Some plants like CAM plants reduce water loss by reversing stomatal rhythms.

• Plants like primrose demonstrate pubescence (possess hairy leaf laminae); insulate against water losses
• Drought deciduous plants do periodic shed off of leaves during the dry season; reduce rate of transpiration.
• Xerophytes like cacti are succulent; for reservoir water storage.
• Leaves of xerophytes like cacti are reduced to spines; reduce surface area for water loss
• Produce Abscissic acid; cause stomatal closure; counteracting water stress by reducing transpiration
• Small size of the leaves reduce surface area exposed to light
• Sunken stomata of xerophytes reduce water loss through transpiration
• Drought enduring plants like desert brittle bush possess glandular trichomes which secretes a resin that coats the leaf surface thus limiting water loss through transpiration.
• Extensive root system; which either spread over the surface soil or penetrate deeper layers; to absorb adequate amount of water.
• Some xerophytes possess leaves that are folded/ rolled/ curled in reducing the area exposed to sunlight thus minimizing water loss through transpiration.
• Shiny foliage possessed by plants such as reflective desert brittlebush and Hawaiian silver sword; increase the plant's reflectance of light; reducing water loss via transpiration.

(b).

• Mosses (and other bryophytes) are small; with cells so close to each other; facilitate transport of water.
• Mosses are only limited to wet habitats; which are continous water sources.
• More advanced plants possess a vascular system that consists of xylem for the transport of water.
• Roots are an adaptation for obtaining water from the soil, whereas stems are specialized for transporting water to the leaves, which are specialized for photosynthesis.

(c).

• Primitive aquatic and land plants possess flagellated sperms which can swim to the egg.
• In conifers and flowering plants, sperm are packaged into pollen, allowing wind and animal pollination.
• Flowering plants effect a successful reproduction process through pollen tube
• Variety of dispersal mechanisms to effect a successful reproduction process

Question 20.

The diversity of animals originates from variations. Describe the attributes used in the phylogenetic classification of animals. ***(20 marks)***

Tissue complexity; Most animals collectively called the eumetazoa, have closely functioning cells organized into tissues. Two (diploblastic) or three (triploblastic) layers of tissue called germ layers may be present. The three germ layers, the ectoderm, mesoderm and endoderm develop into various organs during embryonic development. In another group of animals, the parazoa, cells are not organized into true tissues, and organs do not develop.
Body symmetry; Animals have either radial symmetry or bilateral symmetry. In radial symmetry, organisms have only one orientation, front and back (or top and bottom). They display a circular body pattern. Organisms with bilateral symmetry have a top (dorsal side), bottom (ventral side), head (anterior end), and tail (posterior end).
Cephalization; In animals with bilateral symmetry, there is a progressively greater increase in nerve tissue concentration at the anterior end (head) as organisms increase in complexity. For example, brains have developed with accessory sensory organs for seeing, smelling, tasting, and feeling (antennae).
Gastrovascular cavity; Gastrovascular cavities, or guts, are areas where food is digested. If they have one opening, they are saclike, and the types of processes that can occur are limited. Two openings designate a digestive tract, allowing specialized activities to occur as food travels from beginning to end.
Coelom; During the embryonic development in more advanced animals, a cavity called a coelom develops from tissue derived from the mesoderm germ layer. The fluid-filled coelom cushions the internal organs and allows for their expansion and contraction. Acoelomate animals lack a coelom, while pseudocoelomate animals have a cavity that is not completely lined by mesoderm-derived tissue.
Segmentation; Many animals, such as insects and certain worms, have segmented body parts. In some cases the body parts are the same & repeat while in other cases, the body parts are modified & adopt specialized functions.
Protostomes and deuterostomes; During the early development of the zygote, cell divisions, or cleavages, take place in an orderly fashion. Specific cleavage patterns emerge that result in the development of particular embryonic

features. Two markedly different developmental patterns occur producing two groups of animals, the protostomes and deuterostomes.

Question 21.

(a).Outline the characteristics unique to bacteria ***(04 marks)***
(b).Discuss how bacteria show great diversity in their mode of life ***(12 marks)***
(c)(i).Explain what is meant by normal flora ***(01 marks)***
(c)(ii)Explain the various ways normal flora play a role in maintenance of health as well as causing disease

(a).

• Lack distinct nucleus (membrane); lack nuclear membrane
• Freely suspended nucleic acid (DNA or RNA) in the cytoplasm/ Naked DNA
• No spindle fibre formation during cell division
• Lack membrane bound organelle
• Lack prominent vacuole
• Possess rigid cell wall impregnated with peptidoglycans/ murein
• Possess mesosomes for respiration.
• Reproduce by binary fission

(b).

Diversity according to the nutritional modality
• Blue-green bacteria, sulphur bacteria and cyanobacteria are photoautotrophic (photosynthetic);
• Nitrosomonas and nitrobacter are chemoautotrophic (chemosynthetic);
• Rhizobia are mutualistic/ symbiotic bacteria; live in close associations with root nodules of legumes
• Chemo-heterotrophic bacteria obtain energy from chemicals in food.
• Saptrotrophic bacteria obtain their food from dead and decayed organic matter.
• Parasitic bacteria live on other organisms (hosts) from which they obtain food as the host suffers harm.
Diversity according to environment favourable
• Some bacteria like staphylococcus aureus are typical aerobes; thrive in areas of high oxygen content
• Some bacteria like Pseudomonas aeruginosa are obligate aerobes; thrive in areas of low oxygen content
• Some bacteria like Escherichia coli are facultative anaerobes; equally grow well in both aerobic and anaerobic conditions.
• Some bacteria like Clostridium histolyticum are aerotolerant organisms; predominantly grow in anaerobic conditions but can also tolerate aerobic conditions to some degree.
• Some bacteria like Campylobacter jejuni are microaerophilic organisms; require reduced oxygen concentration (approximately 5%) to grow optimally.
• Bacteria like Bacteroides fragilis & Clostridium perfringens are obligate anaerobes; thrive in an almost total absence of oxygen.
• Bacteria like Clostridium jejuni capnophilic; need carbondioxide for optimal growth.

(c)(i).

Normal flora refers to the various bacteria & fungi that are permanent residents of certain body sites especially skin, oropharynx, colon and vagina.

(c)(ii).

• They can cause disease, especially in immunocompromised and debilitated individuals. Although these organisms are non-pathogens in their usual sites, they can be pathogens in other parts of the body.
• They constitute a protective host defense mechanism. The nonpathogenic resident bacteria occupy attachment sites on the skin and mucosa that can interfere with colonization by pathogenic bacteria.
• They may serve a nutritional function. The intestinal bacteria produce several B vitamins and vitamin K.

Question 22.

Describe the adaptations of vertebrates to a terrestrial life. ***(20 marks)***
Adaptations to address osmotic and thermoregulatory challenges
• Birds and mammals have evolved homeothermy others poikilothermy; to achieve the thermoregulation.
• Body covering like fur, feathers, water proof cuticles; keratinized skin epithelia; prevent dehydration
• Excretion of water conserving excreta like urea, uric acid, TMO; to prevent dehydration

• Metabolic water from stored fats e.g in camels; achieve adequate hydration
• Nocturnal behaviour; minimize water loss through evaporation
• Migratory behaviour in response to seasonal changes; permit escape from unfavourable conditions
• Elongated loop of Henle in birds/ mammals like the kangaroo cat.
• Hyper secretion of ADH by mammals; for adequate retention of water
• Possess tissues tolerant to water stress;
• Amphibians are restricted to damp habitats, reptiles, birds, mammals and insects have a water tight surface layer which enables them to inhabit dry areas and avoid dessication.

Adaptations to solve challenge of reproduction

• Internal fertilisation in mammals and birds enables them increase chances of reproductive success
• Internal development of embryo in placental mammals; protects embryo against any form of damage.
• Oviparity and ovoviparity in birds, reptiles and amphibians to increase chances of reproductive success.
• Development of secondary sex characteristics; potentiates effective courtship displays
• Seasonal breeding cycles that restrict copulation to times that will ensure birth in favourable conditions.
• Female receptiveness to the male only when ovulation is taking; or even being stimulated by copulation
• Suckling; provides new born with fairy secure food source suitable for early development
• Parental care; allows development of the young in controlled and protected conditions with maximum use of the learned behaviours like imprinting.

Adaptations to solve challenge of gaseous exchange

• Developed moist gaseous exchange surface coupled with breathing mechanisms to use plenty of oxygen.
• Vertebrates have internal respiratory system with moist linings; minimize water loss.

Adaptations to solve challenge of locomotion and support

• Animals have developed skeletons for support in air and muscular mechanisms for locomotion.
• Vertebrates have limbs built on the pentadactyl basic plan; enables the body of the vertebrate to be lifted off the ground and propel it forward.

Adaptations to solve challenge of nutrition

• Vertebrates demonstrate a variety of nutritional modalities such as parasitism, herbivory etc; to exploit the various food sources in the different niches.
• Some vertebrates exhibit periodic episodes of dormancy inform of hibernation and aestivation to survive adverse environmental conditions; as well as minimizing food consumption
• Mammals have heterodont teeth and strong jaws; to consume a variety of foods in different niches;

Question 23.

(a).Distinguish between ectotrophic and endotrophic mycorrhiza *(04 marks)*
(b) Describe the nutritional groups of fungi, giving an example in each case. *(16 marks)*

(a).

In ectotrophic mycorrhiza, the fungus forms a sheath covering lateral roots of forest trees such as oaks, conifers, while depending on photosynthesis by the tree to provide organic materials while in endotrophic mycorrhiza, most of fungi is inside the root of the forest trees like orchids with the fungi digesting lignin and cellulose in the soil; and passing the end products into the roots of plants.

(b).

Saprophytic fungi; The saprophytic fungi live on dead organic materials produced by the decay of animal & plant tissues. Examples include; Mucor, Rhizopus, Penicillium. The saprophytic fungi absorb their food from the substratum by ordinary vegetative hyphae which penetrate the substratum.

Parasitic fungi; The parasitic fungi absorb their food material from the living tissues of the hosts on which they parasitize. Such parasitic fungi are quite harmful to their hosts and cause many serious diseases. Examples include phytophora infestans; which parasitize potatoes; and cause potato blight.

Symbiotic fungi; These live in close association with higher plants where they are mutually beneficial to each other eg the lichens and mycorrhiza. The lichens are the resultants of the symbiotic association of algae and fungi in which the algal partner synthesizes the organic food and the fungal partner is responsible for the absorption of inorganic nutrients and water. Certain fungi develop on or in the roots of higher plants and the mycorrhiza are developed The fungi absorb their food from the roots and in response are beneficial to the plants.

Predaceous fungi: These are animal trapping fungi which have developed special mechanisms for capturing small animals for food. Several species of fungi in the genera Arthrobotrys, Dactylella and Dactylaria employ this method. Some predacious fungi secrete a sticky substance on the surface of their hyphae to which a passing small animal adheres. Haustorium-like hyphae then grow into the body of the animal and absorb food.

Question 24.

(a) How are filicinophytes better adapted to a terrestrial life than bryophytes? ***(06 marks)***
(b).Explain the significance of the gametophyte and sporophyte generation in a named;
(i). gametophyte generation of a named bryophyte ***(07 marks)***
(ii).sporophyte generation of a named pteridophyte ***(07 marks)***

(a).

• Filicinophytes like ferns, unlike bryophytes like mosses, have rhizomes/horizontal underground stems for reproduction as well as surviving unfavourable conditions.
• Sporophyte generation of filicinophytes unlike that of mosses, have true roots for anchorage and transportation of absorbed minerals and water from the substratum.
• Filicinophytes produce more spores than bryophytes for greater reproductive rates.
• Filicinophytes, unlike bryophytes have broader leaves; present a larger surface area for photosynthesis.
• Sporophyte generations of filicinophytes are nutritionally independent; while that of bryophytes depend on the gametophyte plant for nutrients.
• Filicinophytes, unlike bryophytes have true vascular tissues for transport and translocation of materials
• Filicinophytes unlike bryophytes have true stems to support the leaves so as to obtain light
• Leaves of filicinophytes unlike those of bryophytes have a water proof cuticle; to prevent desiccation.

(b)(i).

Significance of the gametophyte generation in a bryophyte like moss e.g Funaria

The haploid gametophyte is the dominant and sexual stage that may bear both sex organs; the antheridia (sperm producing) and archegonia (egg producing) or may be borne on separate gametophyte plants. On maturing, the antheridia shed sperms antherozoids that are aided by rain splashes to reach the open neck of the archegonia, get chemically attracted e.g sucrose enables them to reach the archegonia. The haploid antherozoids fuse with the haploid eggs (oospheres) to form diploid zygotes (oospores). The zygotes develop into diploid sporophytes.

(b)(ii).

Significance of the sporophyte generation in a pteridophyte like a fern e.g Dryopteris

Diploid sporophyte is the dominant and asexual stage; diploid spore cells inside the sporangium divide by meiosis to produce haploid spores. When mature, a protective covering (indusium) shrinks & the exposed sporangium wall begins to dry out. The walls then rupture and the spores are discharged from the sporangium. If moisture is present, each spore germinates into heart shaped prothallus (gametophyte) anchored to the soil by rhizoids.

Question 25.

(a).Describe the possible variations that reveal the relative importance of the sporophyte and gametophyte generations in different organisms ***(10 marks)***
(b).Explain the significance of
(i).Sporophyte generation in a named bryophyte ***(05 marks)***
(ii)Gametophyte generation in a named pteridophyte ***(05 marks)***

(a).

Homomorphy or isomorphy; in which both the gametophyte and sporophyte are equally important Filamentous algae of the genus Cladophora, which are predominantly found in fresh water, have diploid sporophytes and haploid gametophytes which are externally indistinguishable.
Gametophytic; have dominant gametophyte eg in liverworts and mosses. The diploid sporophyte is not capable of an independent existence, gaining most of its nutrition from the parent gametophyte.
Sporophytic; have dominant sporophytes eg in ferns, both the sporophyte and the gametophyte are capable of living independently, but the dominant form is the diploid sporophyte. The haploid gametophyte is much smaller & simpler in structure. In seed plants, the gametophyte is even more reduced gaining all its nutrition from the sporophyte.

(b)(i).

Significance of the sporophyte generation in a bryophyte like a moss e.g Funaria

The sporophyte generation is the asexual and less conspicuous stage, which remain attached and surviving on gametophytes. At maturity, the sporophyte produces haploid spores by meiosis within the spore capsule, which splits open when dry and the spores are dispersed off by wind. On landing on moist land, each spore germinates into a green filamentous protonema which produces buds that then grow into the new haploid gametophyte.

(b)(ii).

Significance of the gametophyte generation in a pteridophyte like a fern e.g Dryopteris

The haploid gametophyte which is the sexual and less conspicuous stage situated at the underside of the prothallus is bisexual; bearing antheridia and archegonia which produces sperms and eggs by mitosis respectively. After rupture of the antheridia, the ciliated sperms swim through water to fertilize eggs at the base of the archegonia and the diploid zygote formed grows into a young sporophyte which remains supported on the prothallus until it is self-supporting.

Question 26.

(a)(i).Explain what is meant by plasmids of bacteria ***(03 marks)***

(a)(ii)Outline the different ways plasmids offer extra survival advantages to bacteria ***(04 marks)***

(b).Resistance to antimicrobial drugs has emerged as a global threat to patient management. Outline the causes of antibacterial resistance ***(07 marks)***

(c).State the advantages of using plasmids as vectors ***(06 marks)***

(a)(i).

Bacterial plasmids is a small self-replicating circle of extra DNA. It possesses a few genes which generally give bacteria extra survival advantages.

(a)(ii).

• Plasmids confer resistance of micro-organisms to antibiotics
• Confers resistance to disinfectants
• Confers bacteria ability to use complex chemicals in food like hydrocarbons
• Fermentation of milk to cheese by lactic acid bacteria.

(b).

• Overuse of broad spectrum antibiotics
• Incorrect diagnosis
• Unnecessary prescriptions
• Improper use of antibiotics by patients.
• Use of antibiotics in livestock as food additives for better growth
• Wrong regimens/ drugs.
• Inappropriate diagnostic procedure (improper specimen collection, transport, failure to use culture & sensitivity tests)

(c).

• They exist naturally in bacteria, which are able to take them up from their surroundings
• They are small so that they are easy to use
• They can be produced artificially by combining lengths of DNA from different sources
• They are double stranded so genes from prokaryotes and from eukaryotes can be inserted into them
• They replicate independently within bacteria to clone any genes that are inserted into them
• They can be transferred between different bacterial species.

Question 27.

(a).How are the following different;

(i). fungi different from bacteria? ***(06 marks)***

(ii) tobacco mosaic virus and T2 bacteriophage ***(04 marks)***

(b).Explain why HIV/ AIDS has remained a global challenge towards health of humans? ***(06 marks)***

(c).Outline the different mechanisms through which HIV is transmitted ***(04 marks)***

(a)(i).

Fungi	Bacteria
Lacks photosynthetic pigments	Some contain photosynthetic pigments

Has membrane bound organelles	Lacks membrane bound organelles
Distinct nucleus	Lacks a distinct nucleus
Many chromosomes	Circular strand of DNA
Larger ribosomes	Smaller ribosomes
Cell walls made of chitin	Cellwall made of murein/ peptidoglycans

(a)(ii).

Tobacco mosaic virus	T_2 bacteriophage
Capsid has helical structure	Icosahedral head and tail
No tail fibres	Tail fibres/ base plates
Simple cylindrical rod shape	More complex structure
Contains RNA	Contains DNA

(b).

• The natural host range of HIV is limited to humans.
• HIV exhibits a high degree of antigenic variation; hinders development of an effective HIV vaccine.
• The high mutation rate; due to the virus' ability to rapidly respond to selective pressure imposed by host immune system.
• Reverse transcriptase; HIV contains reverse transcriptase enzyme which directs the host cell to synthesize viral DNA on a template of viral RNA which when incorporated into the host DNA acts as a gene.
• HIV isolates are themselves highly variable; vaccine needed ought to be broad enough to cater for the variability.

(c).

• Sexual contact with body fluids of an infected partner and by transfer of infected blood.
• Mother to child transmission either across the placenta, at birth
• Breastfeeding on milk from infected mother.
• Blood transfusion.

Question 28.

(a).Explain why;
(i). megaspores are large while microspores are small ***(06 marks)***
(ii) the chances of survival and development of wind-blown pollen grains (microspores) are much less than the spores of ferns ***(02 marks)***
(b).Compare the spores of a moss plant with the pollen grains of angiosperms ***(12 marks)***

(a)(i).

Megaspore is large because it must contain sufficient food reserves to support the female gametophyte and subsequent development of the embryo sporophyte until latter becomes self-supporting. Microspores on the other hand are small; hence can be produced economically in vast numbers and are light enough to be carried by air currents; thus increasing chances of male gametes that they contain reaching the female parts of the plants;

(a)(ii).

The spore of a fern can develop wherever it lands provided the conditions are moist and fertile. Pollen grains on the other hand, must reach the female parts of the sporophyte;

(b).

Similarities
• Both are reproductive haploid structures
• Both are microscopic
• Both are structurally identical.

Differences

Spores of moss	Pollen grains of angiosperms
Can be large female spores (megaspores) or small male spores(microspores)	Small male spores(microspores)
Can be produced from the microspore mother cells	Produced from microspore mother cells
Lacks exine and intine	Have outer coats exine and intine

Grows into a multicellular gametophyte with 2 reproductive bodies (give rise to sperms and eggs)	Contains a gametophyte that can produce sperms to fertilise egg within the pistil

Question 29.

(a)(i).Define the term systematics. *(01 marks)*
(a)(ii)Why is taxonomy important in biological studies? *(03 marks)*
(b)(i).Distinguish clearly between phenetic and phylogenetic classification *(04 marks)*
(b)(ii)Using features observable at cellular level, show how the five kingdom system was adapted for use in taxonomy. *(08 marks)*
(c).Why are viruses excluded in the five kingdom system of classification? *(04 marks)*

(a)(i).

Systematics is a branch of taxonomy that is devoted to placement of living things into biological groups called taxa.

(a)(ii).

• To develop a system that enables us to cope with the increasing complexity of the living world.
• To emphasize and appreciate the ideas of evolutionary relationships between organisms.
• To simplify the study of living thing.

(b)(i).

Phenetic classification	Phylogenetic classification
Uses a few easily observable features	Uses many features even requiring sophisticated Observation techniques
All features of the organism are of equal importance	not all features of an organism are of equal importance
Designed for convenience & practical purposes	Designed for research purposes
No fossil evidence required	Fossil, biochemical, anatomical, ethological evidence is required
Does not call for evolutionary relationships	Focus more on evolutionary relationships

(b)(ii).

• Early classification schemes had a two kingdom system placing emphasis on methods of nutrition.
• Later cellular structure classified organisms into eukaryotes and prokaryotes
• Eukaryotes possess nuclei while prokaryotes lack the nuclear membrane.
• Viruses were put out of the scheme because their structure was atypical of cells.
• Prokaryotes form kingdom Monera based on naked DNA & lack of membrane bound organelles
• Most physiological reactions occur on membranes associated with the cell surface.
• Plants are exclusively multicellular photoautotrophic eukaryotes whose cells are bound by cell walls.
• Animals are multicellular heterotrophic ingestive organisms without cell walls.
• Protoctista are a controversial group of organisms with a cross section of all the eukaryotic features
• Eukaryotes now give rise to three kingdoms; unified by presence of membrane bound organelles and a DNA associated with proteins forming chromosomes
• Fungi are unicellular & multicellular heterotrophic absorptive organisms with cells strengthened by chitin in cell walls

(c).

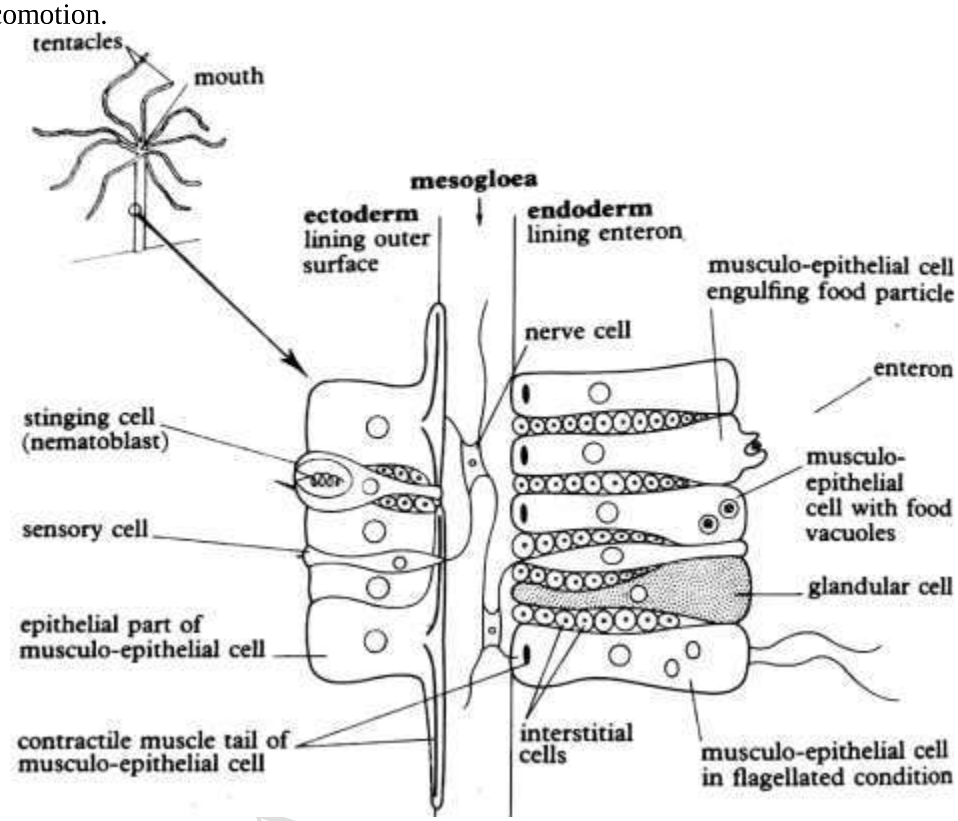
• Viruses don't have the structure of cells.
• Viruses keep changing their genetic material from RNA to DNA
• Viruses are crystallizable
• Viruses only reproduce inside the host (intracellulary)

Question 30.

(a).With reference to hydra, explain what is meant by physiological division of labour *(12 marks)*
(b).Explain
(i). why bilateral symmetry has adaptive value for actively motile animals? *(04 marks)*
(ii).the selective advantage of radial symmetry for sessile and free-floating animals. *(04 marks)*

(a).

Physiological division of labour is a phenomenon in which different cells are specialised both structurally and physiologically to perform different functions. Hydra exhibits division of labour because it demonstrates a differentiation of its parts. Its ectoderm is protective, muscular and sensory; its nematocysts are used for defence and for obtaining food; ectoderm of the basal disc is glandular fixing the hydra with the sub-stratum; its central parts can produce gas bubbles which help it float; the endoderm is digestive, vascular, muscular and also secretory; The interstitial cells form the gonads and replace both ectodermal and endo-dermal cells. The enteron carries on digestion and circulation. The mouth serves for ingestion of food and egestion of wastes; the tentacles are for obtaining food and for locomotion.



(b)(i).

If an animal is active in seeking food, shelter and reproductive mates, it requires an active, directed movement done by an elongated body form with head (anterior) and tail (posterior) ends. In addition, one side of the body faces up (dorsal), and the other side, specialized for locomotion, faces down (ventral) i.e bilaterally symmetrical animal.

(b)(ii).

Radial symmetry allows for animals to reach out in all directions from one center such as during feeding. This is an advantage since they don't have a high degree of controllable movement even during feeding Radial symmetric animals are able to receive stimuli from all directions (Sensory receptors are evenly distributed around the body) which have efficient defense mechanisms due to their radial symmetric distribution.

Question 31.

(a).Explain the economic importances of algae ***(08 marks)***

(b).Outline different ways annelids like earthworms contribute to soil formation and improvement

(c).State the major events involved in the life cycles of named virulent & template phages ***(09 marks)***

(a).

- Carbon fixation; provide primary productivity especially in the aquatic food chains
- Oxygen release in both the atmosphere and aquatic food chains.
- Algae act as food source in some parts of the world
- Some forms of algae act as fertilisers on coastal farms.
- Green algae provide oxygen for the aerobic bacteria which breakdown sewage

• Algal bloom due to eutrophication; cause oxygen depletion in water; reduce aquatic biodiversity
• Unicellular algae like Chlorella are easy to cultivate and can be used as a source of a single cell protein for human and animal consumption
• Derivatives of alginic acid found in the cell walls of brown algae are non-toxic and readily form gels. These alginates are used as thickeners in ice cream, hand cream, polish, medicine, pain, ceramic glazes and confectionery.

(b).

• Tunnels improve aeration and drainage
• Pull dead vegetation into the soil where decay by saprobionts takes place
• Actively participate in the mixing of soil layers
• Aid addition of organic matter by excretion and death
• Secretions of the gut neutralise acid soils
• Improve tilth of the soil by passing soil through the gut.

(c).

Life cycle of a lytic (virulent) phage eg T_2 phage

• Phage particle approaches the bacterial cell
• Phage attaches to bacterial wall; DNA injected into bacterial cell; and protein coat left outside
• Phage DNA inside bacterial cell multiplies using bacteria genome
• Phage DNA induces formation of protein coats
• Eventually bacterial cells burst (lysis) releasing exact copies of the original phage.

Life cycle of template/ lysogenic phage eg λ phage

• The DNA of λ phage gets injected into the bacterial cell
• The DNA of λ phage become incorporated into the bacterial DNA
• The bacterial cell divides to produce two cells whose DNA still incorporates the DNA of λ phage
• Each cell continues to divide many times to give large numbers of cells which may, under special circumstances enter a lytic phase whereby lytic phage replication takes place.
• The cell bursts (undergoes lysis) and the phage particles escape.

Question 32.

(a).Write short notes on the following;
(i). Bilateral symmetry *(02 marks)*
(ii) Polymorphism *(02 marks)*
(iii)Cephalization *(02 marks)*
(b). Explain the structural features that have enabled bryophytes to adapt to terrestrial life *(08 marks)*
(c).Describe the structural differences between gymnosperms and angiosperms *(06 marks)*

(a)(i).

Bilateral symmetry is the division of a body plan of an organism into two equal halves along the central axis.

(a)(ii).

Polymorphism is the occurrence of two or more distinct forms of the same organism

(a)(iii).

Development of the head with the concentration of the sense organs and nervous control at the anterior end.

(b).

• Sexually involve fusion of real gametes
• Have rhizoids for anchorage
• Have resistant spores for reproduction
• Have gametegia to give further protection against dessication
• Have waxy cuticle; prevent dessication.

(c).

Gymnosperms	Angiosperms
Flowerless	Produce flowers
Naked seeds	Seeds in a fruit formed from the ovary
Have narrow needle like leaves	Have true leaves, leaves and stems

Have simple vascular bundles	Have well developed vascular bundles

Question 33.

With specific reference to kingdom Animalia;

(a).Explain the relevance of;

(i).Metameric segmentation ***(03 marks)***

(ii).Cephalization ***(04 marks)***

(iii).The coelom ***(04 marks)***

(b). Explain the evolutionary advancements associated with;

(i).Desiccation ***(04 marks)***

(ii).Reproduction. ***(05 marks)***

(a)(i).

• Improves body efficiency through division of labor since various body compartments can be designated to carry out particular functions.
• Portions of the body can function independently to improve the overall fitness of the body.
• It also allows increase in complexity of the body.

(a)(ii).

• Allows development of a central nervous system with a brain for proper coordination;
• It allows different species of animals to collect information about a wide array of environments such as presence of food, predators, and mates.

(a)(iii).

• Separation of the gut from the body wall from the gut thus allowing muscular activity of the gut to be free from peristaltic interference.
• Provision of a cavity in which internal organs develop and function independently.
• Allowing increase in size and complexity
• Performing the role of a hydrostatic skeleton which supports and moves the animal.
• Coelomic fluid may contribute to circulation of nutrients and food.

(b)(i).

• There is lesser possibility of drying up in water. It only requires prevention of desiccation while on land.
• Water proof integuments like keratinized surfaces of skin, feathers, hair & chitin cuticles of arthropods
• Laying cleidoic/ shelled eggs which protect embryos from extreme dry environmental conditions.
• Hibernation to lower metabolic rates during extreme environmental conditions.
• Elimination of nitrogenous waste in the forms which require less water to be remove.

(b)(ii).

• In water, sexual reproduction requires discharge of gametes into surrounding water; external fertilization. This exposes the embryo to mechanical damage.
• Terrestrial life can't support this and it necessitates internal fertilization and development.
• Animals evolved with an intromittent organ; the penis for the introduction of sperms into the body of the female.
• Females evolved with mesodermal cavities which provide for development and nourishment of the embryo while its being protected from mechanical damage.
• Placental mammals are viviparous; they produce young ones at an advanced stage of development enabling them to get used to the environment.
• Birds are oviparous; lay cleidoic eggs in which protection of the young is ensured.
• Parental care to the young offered by mammary glands and those assisted in foraging and feeding.

Biology practical
Arthropod (Cockroach)

You are provided with the specimen (cockroach) which is freshly killed

(a).Classify the specimen as far as possible and state the characteristics that make the specimen to belong to the mentioned taxa ***(05 marks)***

Taxa		Justifying reasons
Kingdom	Animalia	• Has modified mouth parts for heterotrophic nutrition • Limbs for locomotion
Phylum	Arthropoda	• Possession of an exoskeleton • Segmented body • Jointed appendages like limbs.
Class	Insecta	• Possession of 3 main body parts (head, thorax& abdomen) • Possession of three pairs of limbs; Three thoracic segments (prothorax, mesothorax & metathorax); • Pair of antennae and compound eyes
Order	Dictyoptera	• Possession of a long segmented, tapering antennae • Possession of a dorso-ventrally flattened body • A pair of segmented anal cerci. • Possession of chewing mouth parts
Family	Blattidae	• Possession of an oval and dorso-ventrally flattened body • Thorax covered by a large plate (protonum); that partly extends over the head

Genus is Periplaneta and species is americana

(b)(i).State the habitat of the organism ***(01 marks)***

Dark warm places/ crevices or cracks;

(b)(ii).How is the specimen adapted to survive in its habitat mentioned in (b)(i) above? ***(04 marks)***

• Body is dorso ventrally flattened to enable it enter and hide into small cracks to avoid predation.
• The hard curved claws ensure firm grip on rough surfaces during locomotion.
• Arolium ensures firm grip on smooth structures during locomotion.
• Arolium ensures firm grip on smooth structures during locomotion.
• Their dark brown colour is for camouflage hence not easily seen by predators
• The long antennae for detecting stimuli at a distance and in all directions respectively.
• Mandibles are hard, sharp and toothed to cut food.
• The body cuticle is waxy, preventing desiccation of the animal.
• The spines on the limbs for protection against its enemies/ predators
• The hind legs are long for fast locomotion on land.
• The broad membranous inner wings for easy flight in air.
• The thicker outer wings for protection of the inner flight wings and body against physical injuries.
• The segmented body for increased flexibility during locomotion.
• The large compound eyes for increased surface area for increased sensitivity to light.

(c). From your observations of the external features, state with reasons the sex of the specimen ***(01 marks)***

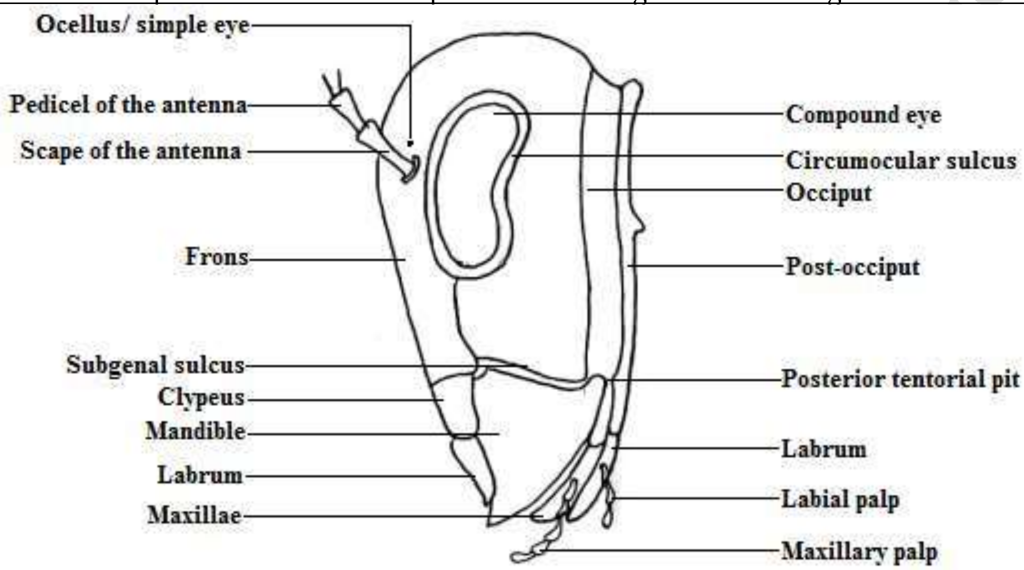
Male; because of the anal style; narrow abdomen; and uneven segments of the antennae at the base
Females; because of broad abdomen; podical plates/ ovipositors/ oothecal chambers.
Note*; Pointed gonapophyses in males & blunt/ round ended gonadopophyses in females are internal*

(d)(i).With the help of a hand lens, examine the head of the specimen. Using any four observable features of the head, explain how each of them enables the animal to survive in its habitat ***(04 marks)***

• Labrum curved to prevent food from falling out of the mouth.
• Long antennae for feeling at a distance/ for sensitivity
• Segmented antennae for flexibility and ease movement in all directions.
• Tapering antennae to easily swing in all directions.
• Serrated mouth parts/ tooth edges to increase surface area for chewing
• Compound eyes that are large/ protruding/ curves outwards for wide field of view.
• Hairy maxillary palps for increasing sensitivity
• Long palps for reaching food at a distance.
• Segmented palps for flexibility/ to push food into the mouth.

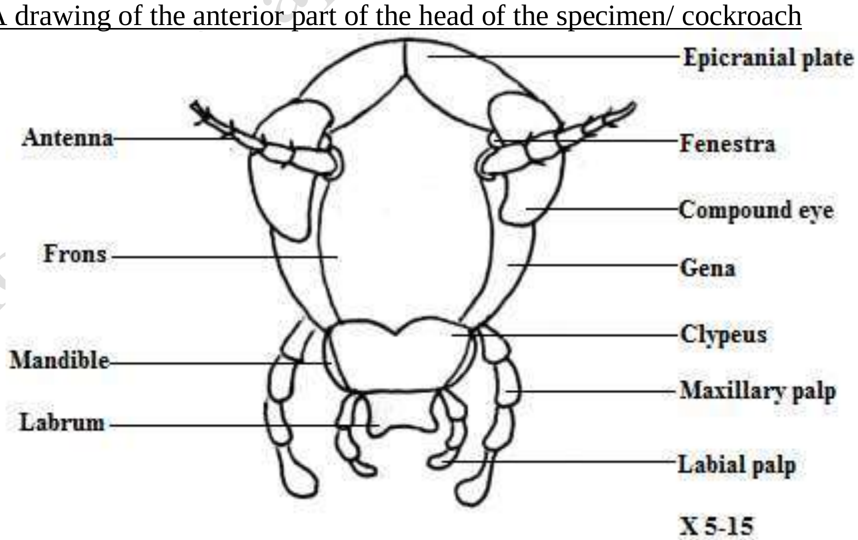
Observe the lateral part of the head using a hand lens. Draw and label including the first two segments of the antennae ***(12 marks)***

A drawing of the lateral part of the head of the specimen including the first two segments of the antenna



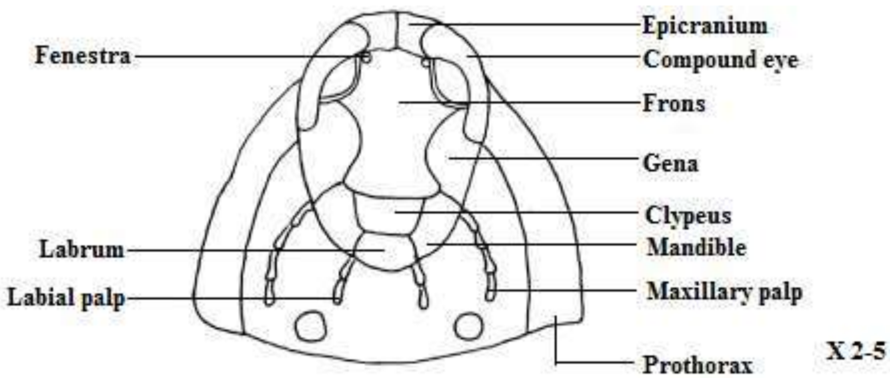
(d)(ii).Observe the anterior part of the head using a hand lens. Draw and label ***(11 marks)***

A drawing of the anterior part of the head of the specimen/ cockroach



(d)(iii). Place the specimen ventral side upper most and cut off the antennae and the limbs. Observe the head and the first thoracic segment. Draw and label the specimen as observed anteriorly ***(12 marks)***

A drawing of the anterior view of the head and the first thoracic segment of the specimen/ cockroach

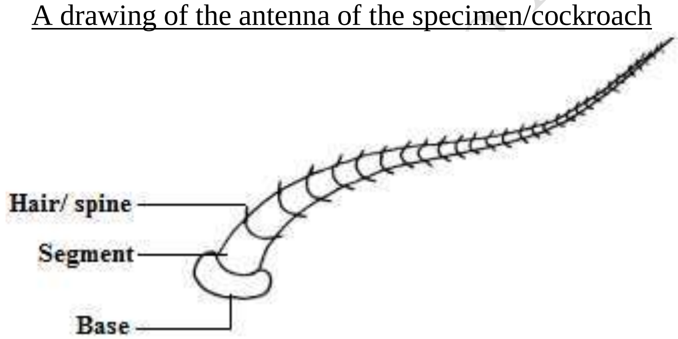


(e)(i). Using a hand lens, examine the antennae of the specimen and state how they are adapted to the habitat of the specimen ***(02 marks)***

- Long; to feel/ sense at longer distances/ long to increase surface area for sensitivity.
- Segmented/ jointed for flexibility/ easy movement.
- Tapering to reduce weight and bring balance so as to ease movement.
- Thin/ slender to ease movement
- Broad base for firm attachment onto the head
- Has a socket at the base of the head for increased flexibility

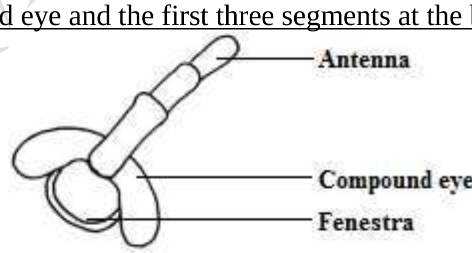
(e)(ii).Using a hand lens, examine one antenna. Draw and label ***(05 marks)***

<u>A drawing of the antenna of the specimen/cockroach</u>



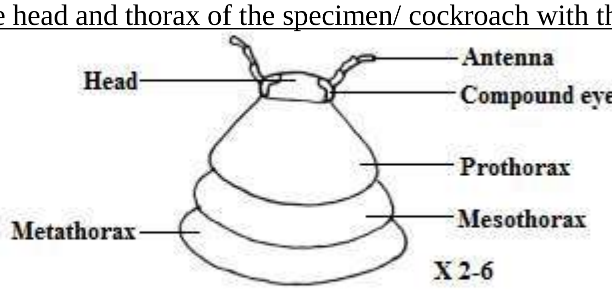
(e)(iii). Using a hand lens, examine the left compound eye of the specimen including the first three segments of one antenna, from the base. Draw and label the structures observed ***(05 marks)***

<u>A drawing of the left compound eye and the first three segments at the base of antenna of the specimen.</u>



(f). Pin the specimen dorsal side uppermost and cut off its wings. Draw and label structures of the head and the thorax excluding the limbs ***(08 marks)***

<u>A drawing of the head and thorax of the specimen/ cockroach with the limbs excluded</u>



(g).Cut off the head of the specimen, then cut out one eye with as little tissue under as possible. Place the eye on the slide and with the cut side downwards. View under low power of the microscope.

(i). Describe the structure and arrangement of the eye units ***(05 marks)***

It consists of hexagonal/ polygonal; large; numerous; closely packed eyelets/ ommatidia which are adjacent to each other regularly/ parallel arranged.

(ii).Draw four adjacent eye units. Do not label ***(06 marks)***

A drawing of four adjacent eye units of the specimen/ cockroach

(iii).What is the significance of the above arrangement in (g)(i) above ***(02 marks)***

• The numerous ommatidia increase the field of view and sensitivity of the compound eye to light
• The thick walls and close packing of the ommatidia increases rigidity of the eye

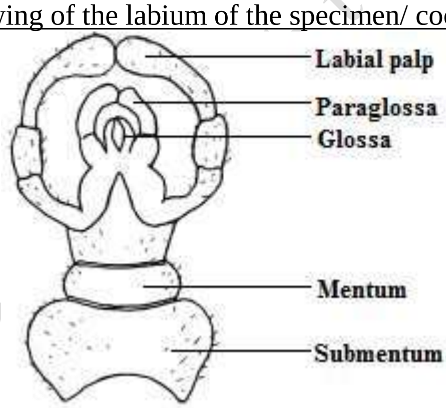
(h).With the ventral surface of the specimen facing you, hold the specimen in the neck region. Locate the lower lip (labium) of the mouth which is a flattened plate on the floor. Hold it from the base with the help of a pair of forceps and pull it out. Observe with a hand lens.

(i). How is the mouth part pulled out adapted to its functions ***(03 marks)***

• Possession of hairy labial palps to increase sensitivity for food
• Sharp glossa for cutting food
• Segmented labial palp for flexibility when holding food

(ii).Draw and label the mouth part in (h)(i) above ***(07 marks)***

A drawing of the labium of the specimen/ cockroach



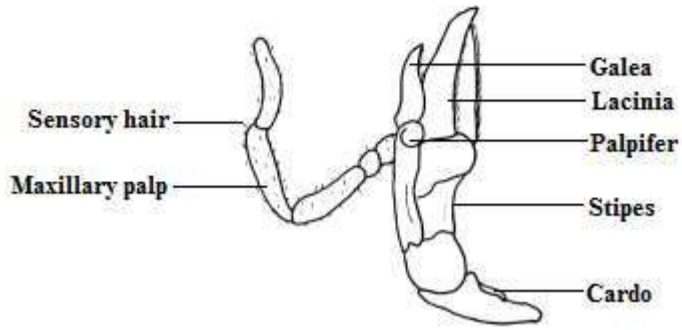
(i). Carefully cut off the whole left maxilla with the specimen still in ventral side upper most. Observe using a hand lens.

(i). State how it is adapted to perform its functions ***(04 marks)***

• Segmented and long palps for pushing/ grasping food into the mouth
• Hairy to increase sensitivity to food
• Having the lacinia and galea are hooked for holding food
• Have lacinia with sharp edges for cutting

(ii).Draw and label ***(09 marks)***

A drawing of the left maxilla of the specimen/ cockroach



(j).Carefully remove the left mandible of the specimen and observe using a hand lens.

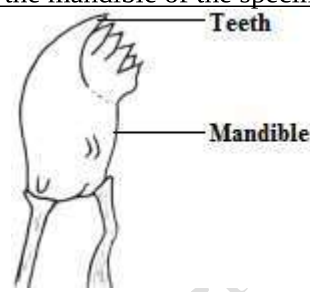
(i). State how it is adapted to perform its functions ***(02 marks)***

• Sharp toothed edge for cutting and crushing food materials

• Attached to powerful adductor & abductor muscles; facilitate their side to side movement during feeding

(ii).Draw and label the mouth part in (j)(i) above ***(04 marks)***

<u>A drawing of the mandible of the specimen/ cockroach</u>



(k). Carefully remove the hypopharynx and observe using a hand lens.

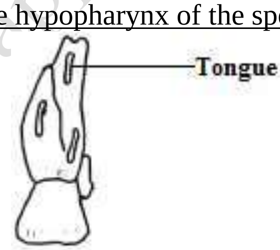
(i). State how it is adapted to perform its functions ***(02 marks)***

• Small and conical; to serve as a tongue

• Close proximity with the salivary gland; directs saliva towards the food the pre-oral cavity

(ii).Draw and label the mouth part in (k)(i) above ***(03 marks)***

<u>A drawing of the hypopharynx of the specimen/ cockroach</u>



(l).Finally take out the upper lip (labrum) and observe using a hand lens

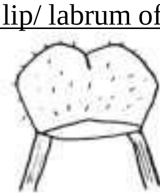
(i). How is it adapted to perform its functions ***(02 marks)***

• Broad and chitinous; enables it hold food particles during feeding

• Hairy to increase sensitivity for holding food

(ii).Draw and label ***(02 marks)***

<u>A drawing of the upper lip/ labrum of the specimen/ cockroach</u>



(m)(i).Turn the specimen dorsal side upper most and examine the wings when pulled outwards. Describe the structure and function of;

Outer wings ***(03 marks)***

Long; narrow; hard; straight; brown; opaque; elongated; oblong with a parallel venation to form a tegmina that offers protection

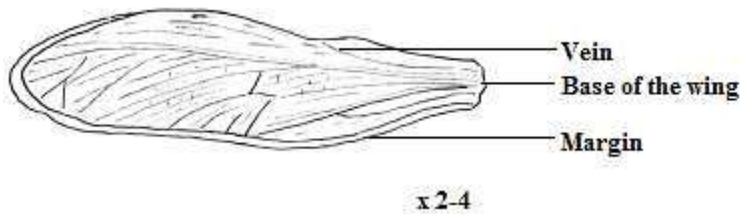
Inner wings *(03 marks)*

Thin; broad; membranous; notch margin; folded; supported by a branching network of net veins. The three main braches of veins allow circulation of air hence making the wings light for flight.

(m)(ii).Draw and label each of the wings described in (m)(i) above

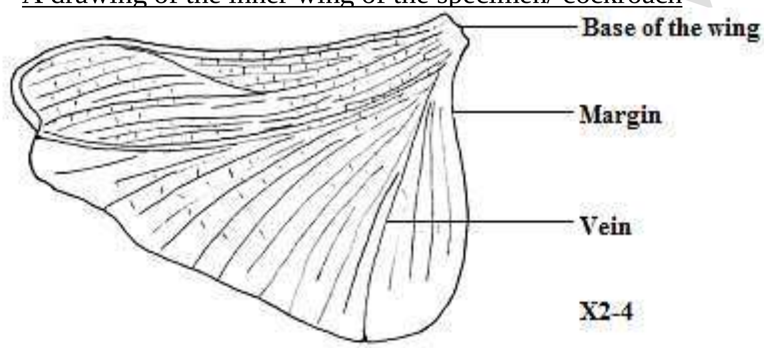
Outer wings *(03 marks)*

A drawing of the outer wing of the specimen/ cockroach



Inner wings *(03 marks)*

A drawing of the inner wing of the specimen/ cockroach

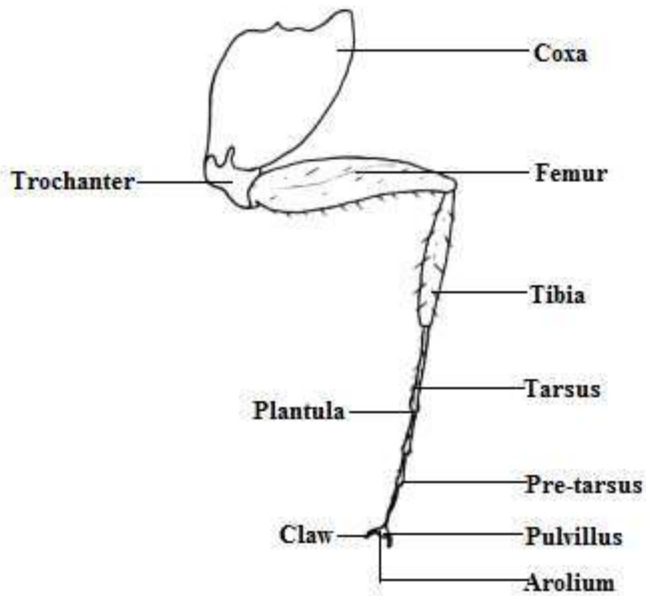


(n)(i).Examine the hind limb using hand lens and state it is adapted to perform its functions *(02 marks)*

- Jointed for flexibility during locomotion
- Pointed spines for defence/ protection against enemies.
- Pointed claws for tight grip on rough surfaces.
- Plantulae/ arolium/ glandular pads for secretion of sticky substance for grip on slippery surfaces.
- Dull coloured for camourflage
- Broad coxae for generation of propulsive force during locomotion
- Long femur/ tibia to generate propulsive force for locomotion/ movement.

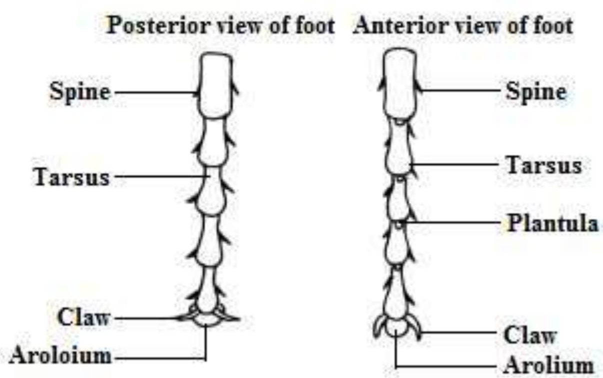
(n)(ii).Carefully cut & remove the right hind limb of the specimen. With the cut limb dorsal side upper most, draw & label *(05 marks)*

A drawing showing the right hind limb of the specimen when placed dorsal side uppermost



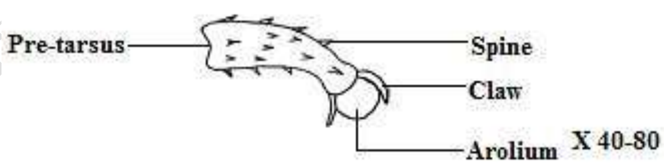
(n)(iii).Cut off the foot from the hind limb of the specimen. Observe it with a hand lens. Draw and label the structures observed with the foot oriented anteriorly and posteriorly ***(06 marks)***

<u>Drawings of the structures observed on the foot oriented anteriorly and posteriorly of the specimen/cockroach</u>



(n)(iv).Cut off the foot from the hind limb of the specimen. Observe it under a low power microscope. Draw and label the pre-tarsus and its associated structures ***(05 marks)***

<u>A drawing of the pre-tarsus and the associated structures of the specimen/ cockroach</u>

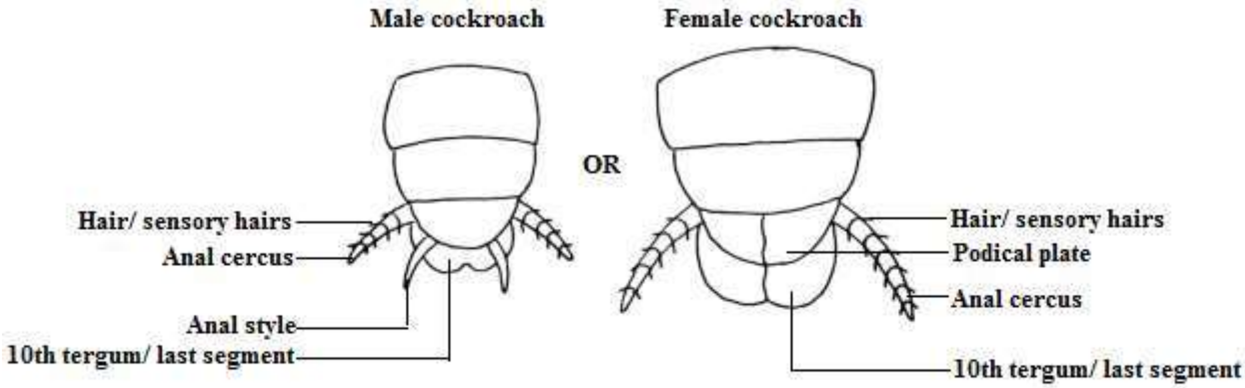


(n)(v). How do structures observed in (n)(iv) above enable the pre-tarsus carry out its functions ***(03 marks)***

- It has pointed/ curved claws for firm grip on rough surfaces
- Has arolium/ glandular pad; that secretes sticky substance that allows grip in smooth surfaces
- Has pointed spines for defence

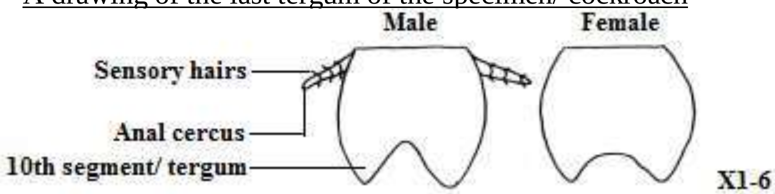
(o)(i). Place the specimen ventral side uppermost. Draw and label the end of the abdomen ***(05 marks)***

<u>A drawing of the end of the abdomen of the specimen/ cockroach</u>



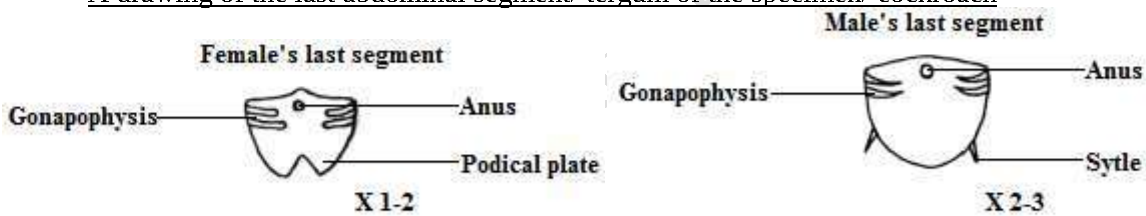
(o)(ii). Examine the last tergum of the specimen from the ventral side. Draw and label ***(06 marks)***

<u>A drawing of the last tergum of the specimen/ cockroach</u>



(o)(iii).Lift the last abdominal segment/ tergum with forceps and cut it off. Draw and label the observed structures on the last segment. ***(04 marks)***

<u>A drawing of the last abdominal segment/ tergum of the specimen/ cockroach</u>



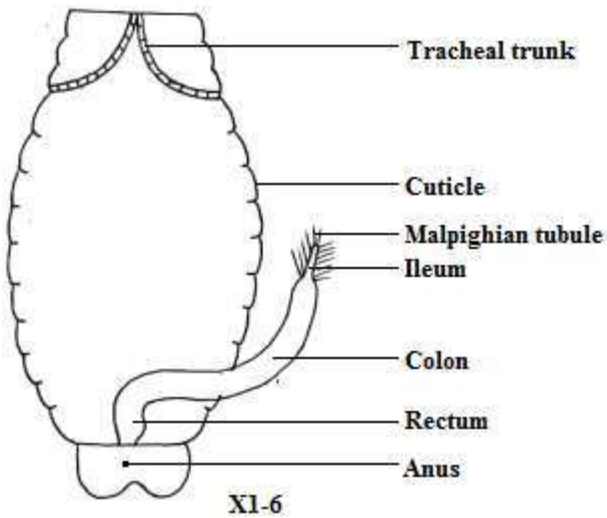
(o)(iv).From the observed structures in (o)(iii) above, state with reasons the sex of the specimen ***(02 marks)***

Female;
- Podical plate
- Blunt ended gonapophyses

Male;
- Anal style
- Sharp/ pointed gonapophyses

(p)(i).With the dorsal side upper most, dissect the specimen to display the structures used from removal of undigested and excretory materials from the specimen's body. Draw and label ***(10 marks)***

<u>A drawing showing the structures for the removal of undigested and excretory materials from the body of the specimen/ cockroach</u>



X1-6

By further dissection, cut out the tracheal truck from the specimen. Observe it under low power microscope

(i).Describe its structures ***(02 marks)***

• It is ringed/ formed by a ringed structure
• It is hollow/ tubular
• It is long

(ii).What is the significance of your observations in (i) above to the specimen? ***(02 marks)***

• Ringed to keep it open for passage of respiratory gases
• Hollow/ tubular to allow passage of respiratory gases
• Long to convey/ reach respiratory tissues at a far distance/ all parts of the body

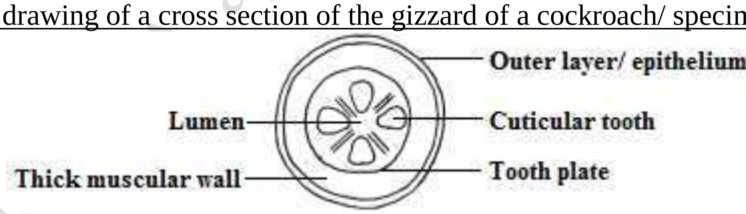
Cut out the gizzard of the specimen

(i). How is the gizzard adapted to its functions ***(03 marks)***

• Folded inner lining to increase surface area for digestion of food
• Toothed/ six ridges for physical/ mechanical digestion
• Thick muscular walls to generate powerful contraction during crushing of food

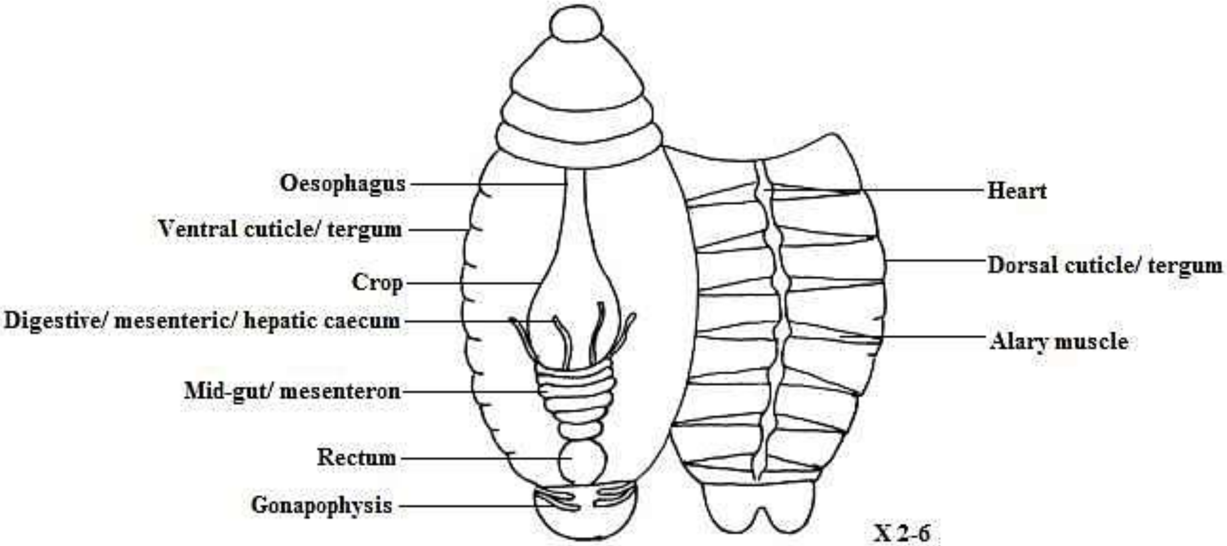
(ii). Cut a cross section of the gizzard. Draw and label ***(06 marks)***

A drawing of a cross section of the gizzard of a cockroach/ specimen



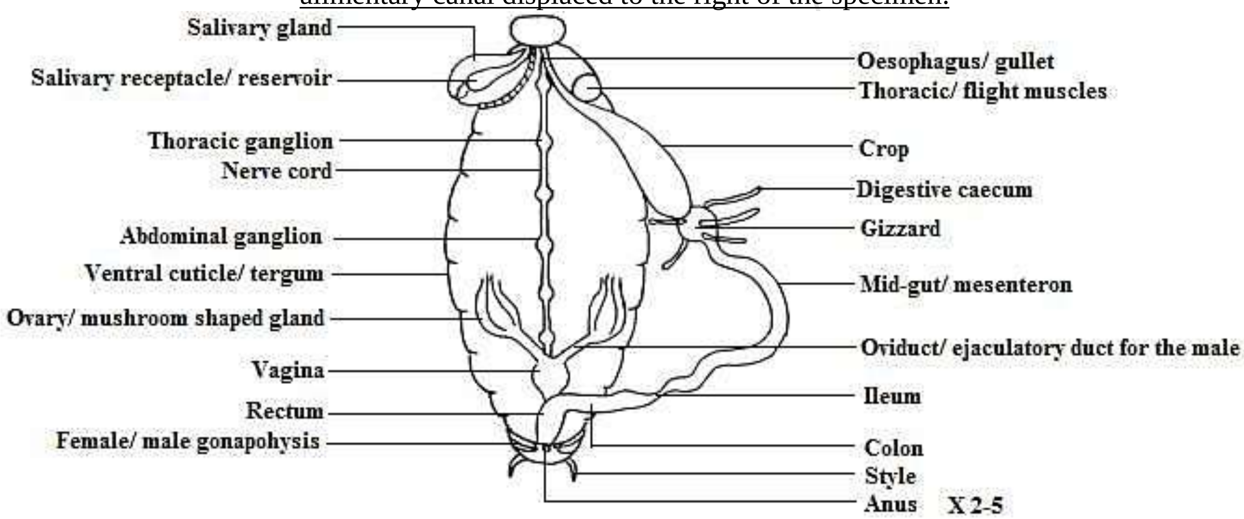
Pin the specimen with the dorsal side upper most. Dissect along the left lateral line of the abdomen. Display the dorsal cuticle and clear fat tissue. Without displacing any other structures, draw and label your dissection

A drawing showing structures exposed on the dorsal and ventral cuticle of the specimen without displacing any other structures



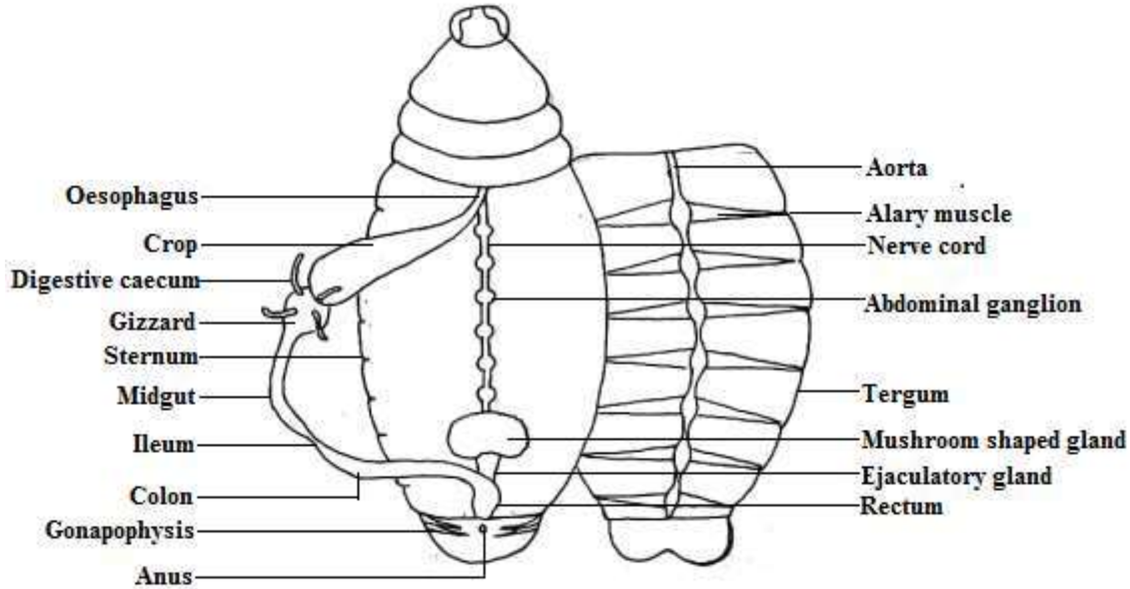
Displace the alimentary canal to the right of the specimen. Remove all unnecessary tissues to display all the parts of the alimentary canal and structures of the ventral cuticle. Draw and label ***(24 marks)***

<u>A drawing of the structures exposed on the ventral and dorsal abdomen cuticles of specimen/ cockroach with the alimentary canal displaced to the right of the specimen.</u>



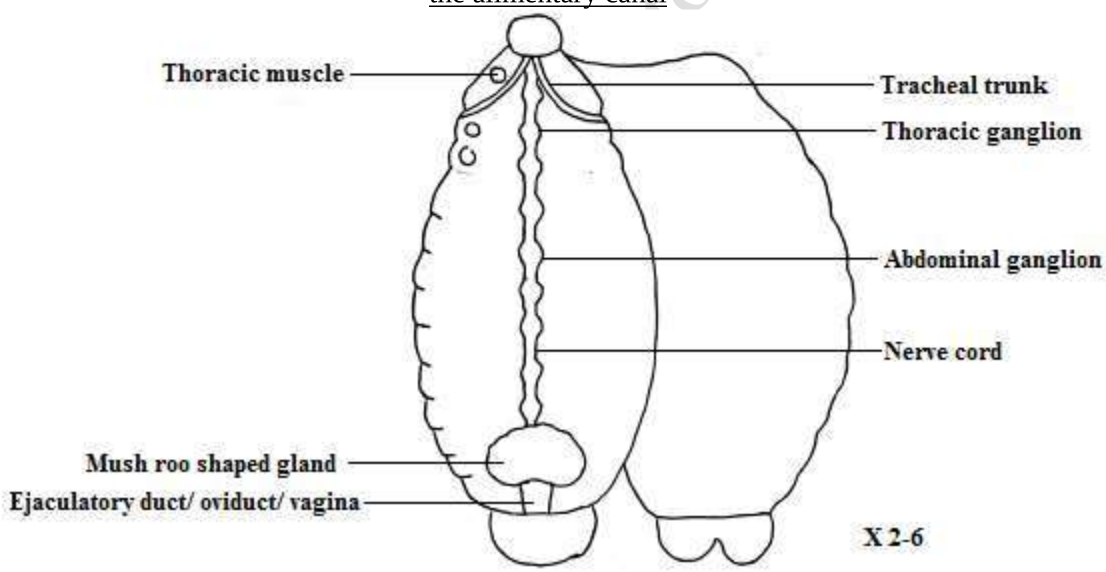
Dissect the specimen along the right lateral line of the abdomen. Displace the dorsal cuticle & clear off any fat tissue. Gently displace the alimentary canal to the left of the specimen. Draw and label the exposed structures ***(20 marks)***

<u>A drawing showing the structures on the ventral and dorsal cuticle of the specimen with the alimentary canal displaced to the left of the specimen.</u>



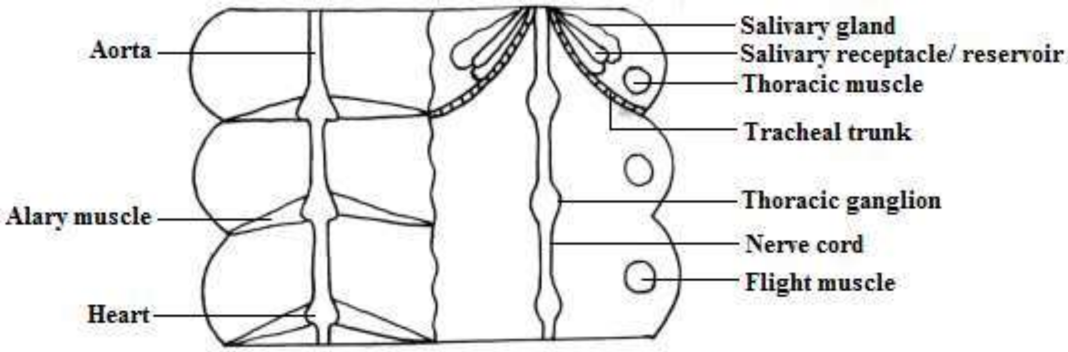
Cut and remove the whole alimentary canal to clearly display structures on the ventral cuticle. Draw & label the structures associated with the ventral cuticle, anterior to the last abdominal segment ***(13 marks)***

<u>A drawing of the structures on the ventral cuticle of the specimen anterior to the last abdominal segment without the alimentary canal</u>



Cut out the gut and remove unnecessary tissue to display the structures in the thoracic region. Deflect the dorsal cuticle to the left. Draw and label ***(14 marks)***

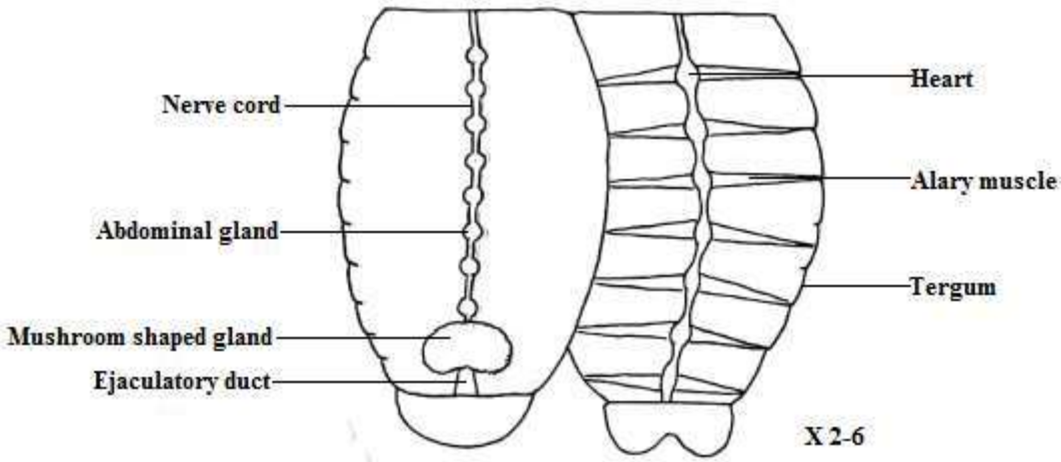
<u>A drawing showing structures on the thoracic tergum and sternum/ dorsal of the ventral cuticles/ thoracic cuticle of the specimen/ cockroach with the gut/ alimentary canal removed/ cut out.</u>



X 1-5

Dissect the specimen along the left lateral line of the abdomen. Displace the tergum and cut out the alimentary canal. Remove any excess fat tissue to display the structures of the sternum & tergum. Draw and label

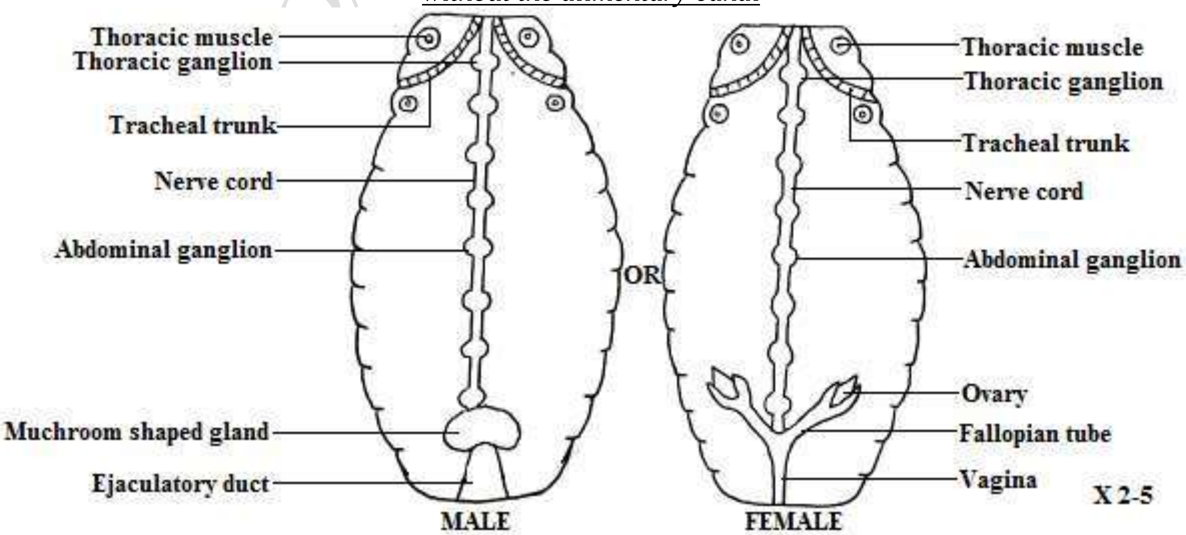
<u>A drawing showing specimen showing structures on the abdominal sternum and tergum with the alimentary canal cut out</u>



X 2-6

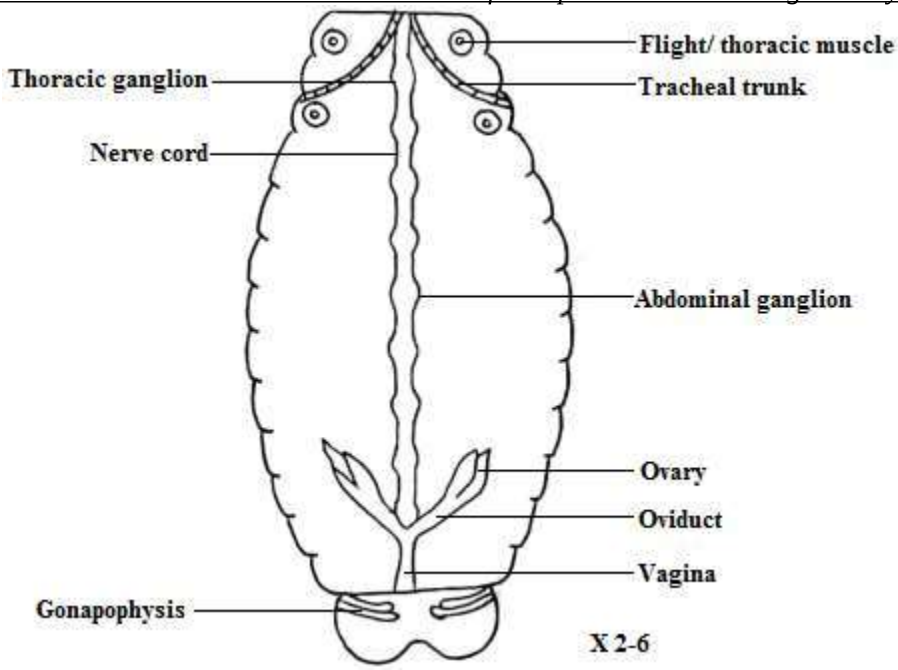
Dissect to cut and remove the whole alimentary canal to clearly display structures on the ventral cuticle. Draw and label the structures associated with the ventral cuticle anterior to the last abdominal segment.

<u>A drawing showing the structures on the ventral cuticle of the specimen anterior to the last abdominal segment without the alimentary canal</u>



With the dorsal side upper most, dissect the specimen to remove the digestive system. Display the structures remaining on the ventral cuticle. Draw and label ***(12 marks)***

<u>*Drawing of structures on the ventral cuticle/ sternum of the specimen with the digestive system removed*</u>



Amphibian(toad/frog)

(a)(i).With reasons classify the specimen provided from the kingdom to family ***(05 marks)***

Taxa		Justifying reasons for the classification
Kingdom	Animalia	Feed on already manufactured food
Phylum	Chordata	Possession of notochord, pentadactyl limbs, coccyx
Class	Amphibia	Moist skin, inhabit both water and land.
Order	Anura	Well-developed elongated hind limbs , lack tails
Family	Bufonidae	Possession of dry leathery skin and short legs.
Genus	Bufo/ Rana	
Species	Regularis/temporaria	

(a)(ii).Suggest whether your specimen is a toad or a frog giving reasons for your answer. ***(03 marks)***

Toad; because of possession of;
- A rough warty and dry skin
- Dark brown or black body surface
- Hind limbs that are averagely long but very muscular and folded onto the body.

Frog because of possession of;
- Smooth, shiny and moist skin surface
- The body surface that is mottled green with black or dark brown patches
- Long, slender and flexible hind limbs; highly folded onto the body.

(b) State the sex of the animal giving reasons for your answer ***(02 marks)***

Male

<u>Reasons;</u>
- Dark part on the throat (due to vocal cords)
- Possession of nupitial pad in the inner side of the hands

Female

<u>Reasons</u>
• Possession of a wide abdomen
• Creamy appearance

(c) Describe the habitat of the specimen given above ***(02 marks)***

Frog ; found in damp areas; e.g damp grasses, damp ditches, ponds or slow flowing streams etc
Toad; moist environments e.g behind water pots or near water storage tanks etc.

Describe the suitability/ adaptability of the toad for survival

(i). on a moist land habitat ***(05 marks)***

• Moist skin dissolves respiratory gases hence quickening their diffusion.
• The muscularised hind limbs generate a strong propulsive force for leaping.
• The dorso-laterally positioned eyes enable a wide field of vision for food.
• Darker colouration dorsally and lighter colouration ventrally enable camouflage
• Both fore and hind feet possess large, yellowish bumps called tubercles, which enable digging burrows in the ground for hiding from predators.

(ii). in water ***(04 marks)***

• Closeness of nostrils to the tip of the snout enables breathing when the rest of body is submerged.
• The head tapers anteriorly and widens posteriorly to reduce water resistance during locomotion.
• Transparent nictitating membrane protects eye ball but without interrupting continuity of vision when under water.
• The muscularised hind limbs generate a strong propulsive force for swimming.

(d)(i). Measure the length of the fore and hind limbs then record in table 1 below. Express the results as a ratio of length of fore limb to length of hind limb ***(02 marks)***

Length in mm	Fore limb	Hind limb
	20-30	40-130
Ratio	1	2

(ii).State the significance of the ratio ***(02 marks)***

The hind limb is twice as long/ longer than the fore limb to generate propulsive force for swimming/ hopping/ locomotion/ leaping.
The fore limb is shorter/ half the length of the hind limb for shock absorption on landing or locomotion.

(iii) Examine both the hind limb and fore limb of the specimen and state ways they are adapted for survival of the specimen in its habitat ***(03 marks)***

Hind limbs

• Long/ muscular to generate propulsive force for locomotion.
• Hind limbs have two prominent joints for flexibility required to generate a strong propulsive force.
• Numerous poison glands to secrete poison for defence
• Dull colour/ brown patches for camourflage
• Webbed toes; increase surface area to reduce resistance for swimming
• Long digits of varying length to increase grip
• Numerous mucus glands to secrete mucus; moistening the skin for gaseous exchange.

Fore limbs

• Fore limbs are short and stout with one prominent for shock absorption during landing after the jump
• Ventral-laterally attached to the anterior part of the body for support of body above ground when at rest.

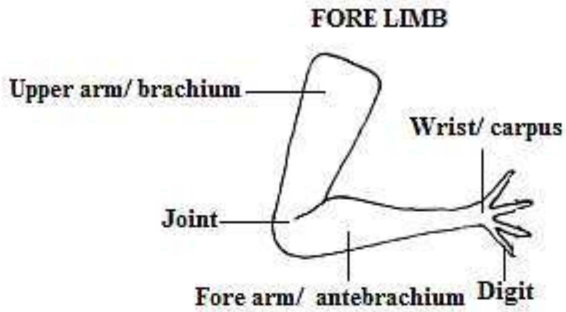
(iv) State the observable comparable features between the fore limb and the hind limb ***(05 marks)***

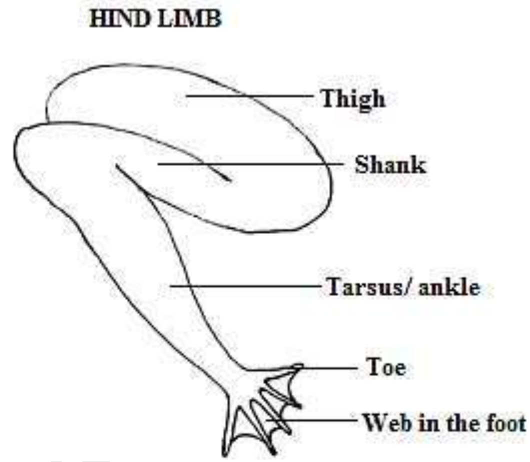
Similarities
• Both have digits
• Both are jointed
• Both have poison glands
• Both have phalanges in the digits
• Both have digits variable in length

Fore limb	Hind limb

• One prominent joint • Shorter • Toes not webbed • Four well developed digits • Less muscular • Two man regions; upper arm and fore arm • L-shaped	• Two prominent joints • Longer • Toes webbed • Five well developed digits • Very muscular • Three main regions; thigh, shank and foot • Z-shaped

(v) Examine the limbs of specimen & draw a fore limb & hind limb to the same magnification ***(14 marks)***





(vi) Explain the significance of the differences between the fore limb and the hind limb to the node of life of the specimen ***(04 marks)***
• Hind limb is webbed to provide a large surface area; for pushing the animal forward.
• Longer hind limb for jumping
• Short fore limbs for shock absorption when landing
(e) Examine the specimen and give five observable adaptive features that enable the specimen survive in its habitat ***(05 marks)***
• Dorso-laterally positioned/ large/ bulging/ protruding eyes for wide vision.
• Long /muscular hind limbs for propulsive force/ forward thrust when jumping/ swimming/ locomotion.
• Short stout/ well-built fore limbs to act as shock absorbers when landing/support at rest.
• Pointed/ triangular/ streamlined head to ease swimming with minimal resistance
• Webbed hind feet/ toes/ digits for swimming
• Dull/ dark skin (upper/ dorsal part)/ pale ventral or lower side for camourflage.
• Wide gape/ opening of the buccal cavity for consumption of large sized preys.
• Nostrils/ external nares for breathing when submerged in water.
• Large/ numerous poison glands for defence/ protection/ make it unpalatable.
• Nictitating membrane to protect the moist eye against mechanical damage
• External eardrum/ tympanic membrane for hearing.
• Jointed limbs for flexibility during movement or locomotion.
• Mucus glands for secretion of mucus; that moistens the skin for gaseous exchange/ thermoregulation.
(f) Observe the head of the specimen and;
(i) Describe its shape ***(03 marks)***
Triangular shape; dorso-ventrally flattened; tapers towards the snout/ tapers to a blunt end anteriorly and broadens posteriorly; and is directly attached to the trunk extending to the shoulder region.
(ii).How is the location/ position of the head onto the body significant to the specimen ***(02 marks)***
Attached at the anterior part of trunk directly without a neck; reduces air resistance during locomotion
(iii) Measure the thickness, width and length of the head ***(03 marks)***
Thickness; 1.0 (0.5-1.5) cm
Width; 3.0 (1-3) cm

Length;   4.0 (2-5) cm

(iii) State the ratio of;

Thickness to width *(01 marks)*

1:3

Thickness to length *(01 marks)*

1:4

(iv).What is the significance of the shape and proportions of the head in relation to its mode of life? *(02 marks)*

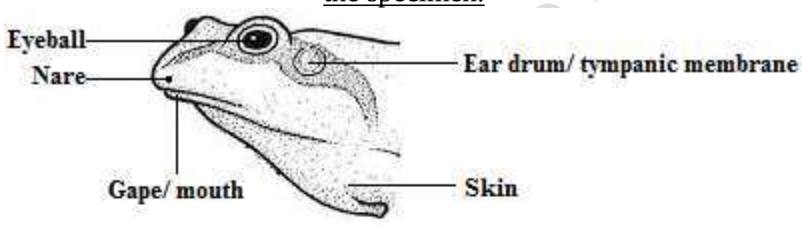
It offers a streamlined shape; to ease movement/ swimming/ burrowing/ move with minimal resistance

(v) State how the head of the specimen is adapted for survival in its habitat *(04 marks)*

- Possession of poison glands for defence
- Possession of a nictitating membrane for cleaning and protection of the eye.
- Triangular head/ tapers anteriorly for easy swimming and burrowing with minimal resistance
- Protruding eyes/ dorso-laterally located eyes for wide field of view/ clear vision
- Large mouth; provides a wide gape for capturing preys.
- Nostrils/ nares at the tip of the snout; for breathing when submerged in water
- Brown/ green/ grey patches/ dull coloured for camourflage
- Flat eardrum/ tympanic membrane/ no pinnae for streamlined shape; enable easy swimming

(vi) Observe the structural features on the head from the left hand side. Draw and label the features concerned with sensitivity and feeding *(07 marks)*

A drawing showing the structural features for sensitivity and feeding located on the left hand side of the head of the specimen.



X 1-5

(g) Using dissection instruments, hold the tongue of the specimen and examine it. How is this tongue adapted to its function? *(03 marks)*

- Long and elastic to trap insects at relatively far distances.
- Tongue is sticky; enables tight trapping of small animals
- Tongue is forked to increase surface for efficient trapping of the preys.
- Tongue is connected to hyoglossus muscles; whose effect enables tongue to be flicked over a wide arc

Examine the skin of the specimen. Describe;

(i). the prominent features and how they are relevant to the specimen *(06 marks)*

- Warts and protrusions called parotoid glands secrete a viscous, white substance which discourages predation.
- Dull coloured dorsally but light coloured ventrally; conceals the toad from predators while in the habitat.
- Moist; enables dissolution of respiratory gases hence quickening their diffusion.
- Tough; reduces the rate of drying/ water evaporation which would interfere with cutaneous gaseous exchange.
- Thin; increases the diffusion rate of respiratory gases and water by osmosis.
- Two protrusions called **parotoid glands** immediately posterior to the eyes but lying dorsally on the head; secrete a viscous substance that repels predators.

(ii).The positioning of the skin on the body and its significance to the specimen *(02 marks)*

Skin covers whole body; enables the whole body to be protected from predators and from heat loss.

(h) Examine the dorsal and ventral skin surface of the abdominal region of the specimen.

(i) Outline the structural differences between the dorsal and ventral skin surfaces *(04 marks)*

Dorsal skin surface	Ventral skin surface
Fewer glands	Numerous glands
Dark colouration	Pale colouration

Larger swellings/ glands	Small swellings or glands
Tightly held on the body wall	Loosely held on the body wall

(ii) State the relevance of the structural differences in (h)(i) above ***(02 marks)***

Dorsal surface is more exposed to danger than the ventral surface; thus the dorsal surface is more highly protected than the ventral surface.

(i). Pin the specimen with the ventral side uppermost. Dissect & remove the skin, taking note of how its attached to the underlying body wall.

(i) Describe the attachment of the skin to the body wall ***(03 marks)***

Skin is firmly attached to the body wall at the pectoral fore limbs; pelvic/ hind limbs and the throat region while loosely attached; within the abdomen.

(ii). Suggest the significance of the way skin is attached to body wall as described in (i)(i) above ***(03 marks)***

Loose attachment has fluid filled space; that facilitates gaseous exchange; while firm attachment helps to support/ hold the skin onto the body of the animal.

(iii) How is the skin of the specimen adapted to function ***(04 marks)***

- Soft and moist to allow gaseous exchange to allow gaseous exchange when submerged in water.
- Loosely attached around the abdominal region; creates a fluid filled space for dissolution of gases.
- Skin is thin to reduce diffusion distance of gases.
- Skin is highly vascularized; hence creates steep concentration gradient for material/ gaseous exchange.
- Warty and slimy; making it slippery; easily escapes from the predators
- Dark mottled skin dorsally for camourflage against predators in multi-coloured or dark environments.
- Creamy nature of the ventral part; to avoid predation in aquatic habitat.
- Dorsal part of the skin is tough and hard; protecting the delicate internal organs from injury.
- Swollen poison glands on the dorsal part of the skin; secrete poison that repels potential predators

(iv) Dissect the specimen to pull the skin off the body wall. How is it adapted to the process of gaseous exchange? ***(03 marks)***

- Highly vascularized; create a steep concentration gradient for efficient gaseous exchange
- Thin to reduce diffusion distance for the respiratory gases.
- Loosely attached to the body wall at abdominal region; create fluid filled space for dissolution of gases.

(j) Observe the main blood circulation of the skin.

(i) Describe the pattern of blood circulation on the skin ***(03 marks)***

One main blood vessel/ musculo-cutaneous vein from the attachment of fore limbs; big sized; receives venous tributaries from many smaller blood vessels; closely attached to the skin; spread all over the skin.

(ii) Give the significance of the pattern of blood circulation described in (j)(i) above ***(03 marks)***

Blood vessels attached to the skin to reduce distance; for diffusion of gases. Blood vessels form a network to increase surface area; and are loosely attached to the skin to reduce distance; for diffusion of gases.

(k) Examine the eyes of the specimen. Relate their structure and location to function for the successful survival of the specimen in its habitat ***(03 marks)***

<u>Structure</u>

- Large and bulging/ protruding for a wide field of view
- Covered by a nictitating membrane which secretes a lubricant fluid; prevents the eyes from drying.

<u>Location</u>

- Dorso-laterally located on the posterior part of the head to view in all directions.

(l) With the help of dissecting instruments, open the mouth of the specimen, then get hold of the structure within the floor of the buccal cavity, pull it and release. How is it significant to feeding? ***(03 marks)***

Elongated; forked; elastic or stretchable attached at the tip of the floor of the buccal cavity with the free end pointing backwards for it to be easily flipped out inorder to capture flying insects/ preys and taken into the mouth.

(m) Examine the following parts of the specimen. Relate their structure and location to function for the successful survival of the specimen in its habitat.

(i)Tympanic membrane (ear drum) ***(03 marks)***

- Thin rounded part of the skin; for collection of sound waves.
- Prominent circular patches of tough membranous tissue; tightly outstretched; captures maximum waves

• Located dorso-laterally behind the eyes; enables detection of airborne sound from many directions

(ii)Nostril/nares *(02 marks)*

• Two small rounded openings at the tip of the snout; for gaseous exchange when submerged in water.

• Each of the two is anteriorly positioned close to the tip of the snout immediately above the mouth; to detect smells of food or enemies before the rest of the body gets close.

(iii)Vemorine and maxillary teeth *(02 marks)*

Present on the floor of buccal cavity; provide enough surface area for grip of the prey at the floor of buccal cavity.

(iv).Cloacal aperture *(03 marks)*

• It is narrow opening; allows passage of materials

• It is narrow to regulate egestion.

• It is elastic aperture/ opening to enable materials both of small and large size of size to exit the body

• It is at the posterior end of the trunk just dorsal to the junction of the hind limbs enables the wastes and gametes to be discharged appropriately.

Examine the mouth of the specimen.

(i).Describe the positioning and structure of the mouth when closed *(02 marks)*

It is terminal at the anterior end of head

It is wide and tight-lipped.

(ii).How is the structure of the mouth when open significant to the specimen? *(01 marks)*

Wide gapped; to accommodate large sized preys

(n) Open up the buccal cavity of the specimen to expose the inner structures.

(i)State the adaptation of the buccal cavity to perform its structures *(06 marks)*

• Sharp teeth for firm grip/ killing of the prey

• Wide gape; allows ingestion of large pieces of food/ preys.

• A pair of internal naris for breathing when submerged in water.

• Sticky and forked tongue for capturing preys

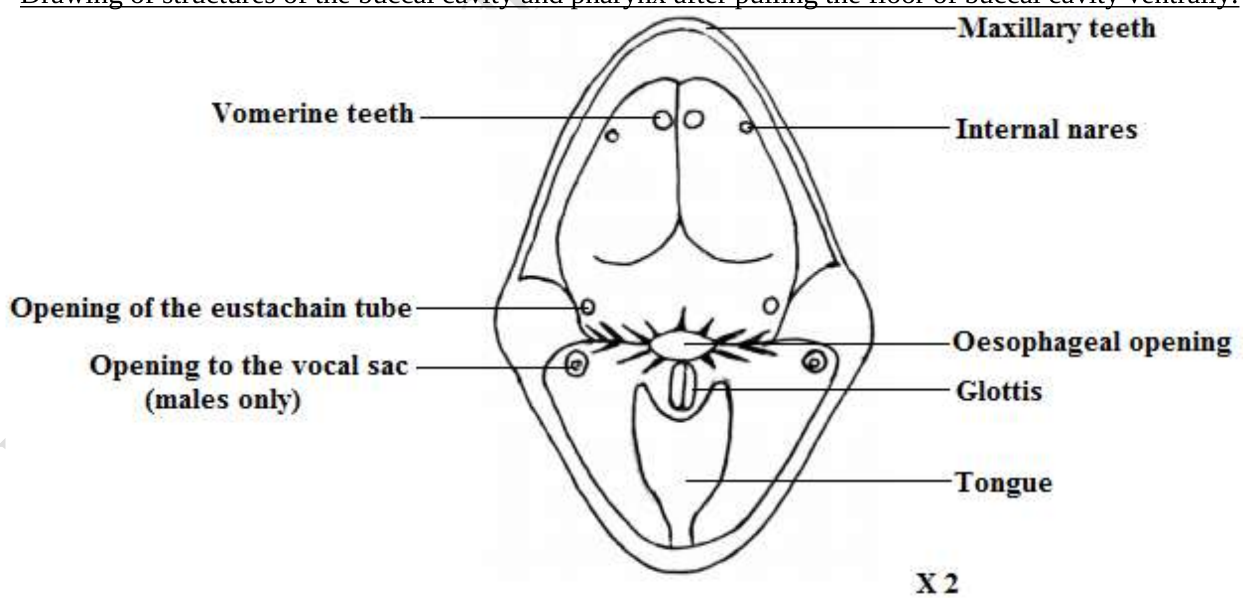
• Eustachain tube for equalization of pressure

• Glottis for passage of respiratory gases and to and from the lungs.

• Pair of large eye balls that press against the prey for easy swallowing.

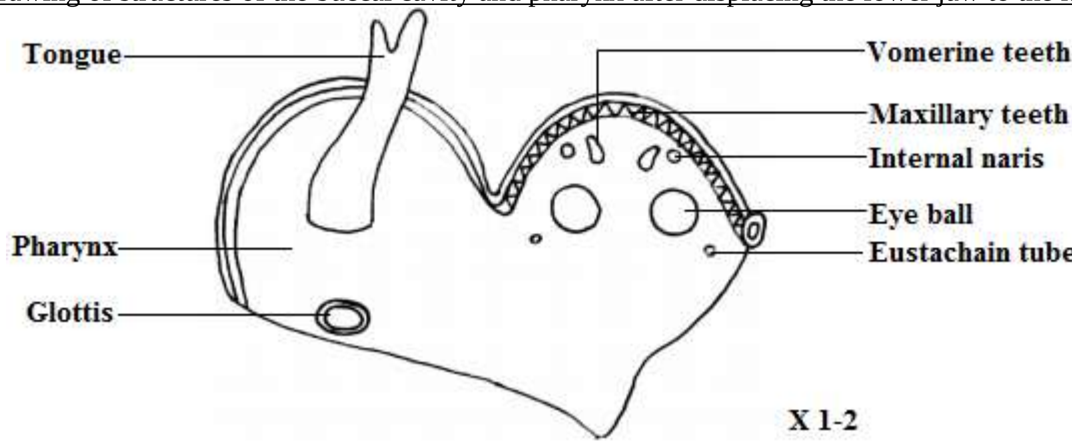
(ii) By pulling the floor of the buccal cavity ventrally, draw and label the interior of the buccal cavity

<u>Drawing of structures of the buccal cavity and pharynx after pulling the floor of buccal cavity ventrally.</u>



Open the mouth, using a pair of forceps get hold of the tongue, pull and pin it out. Display the structures of the buccal cavity and pharynx by cutting through the left angle of the jaw and displacing the lower jaw to your left. Draw and label the structures displayed. *(10 marks)*

Drawing of structures of the buccal cavity and pharynx after displacing the lower jaw to the right

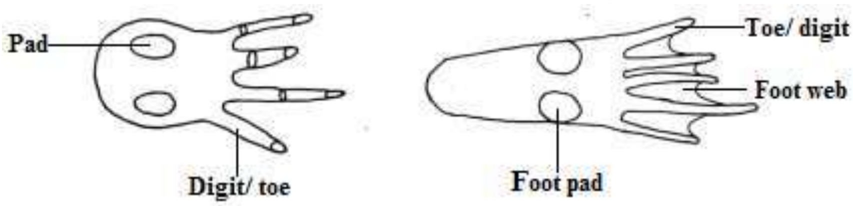


Drawing of structures of the buccal cavity and pharynx after displacing the lower jaw to the right

(o) Draw and label the ventral side of the left fore foot and left hind foot of the specimen. Both drawings should be at the same magnification ***(07 marks)***

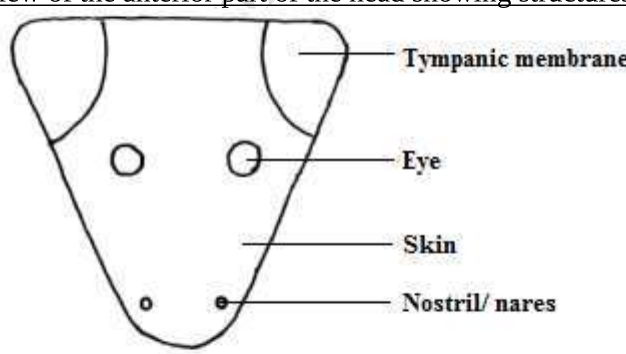
Drawings showing the ventral side of the left fore foot and left hind foot of the specimen

Fore foot **hind foot**



(p) Examine the head of the specimen, draw and label the dorsal view of the anterior part of the head to show structures of sensitivity ***(05 marks)***

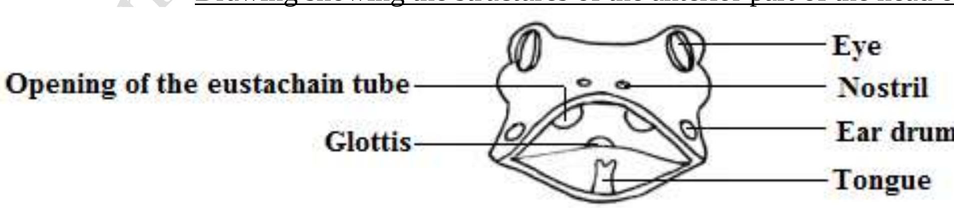
Drawing showing the dorsal view of the anterior part of the head showing structures of sensitivity of specimen K.



Examine the head of the specimen. Draw and label structures observed when the head is oriented;

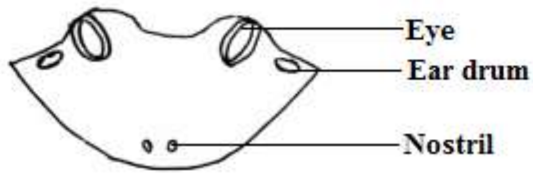
(i). Anteriorly with the mouth open

Drawing showing the structures of the anterior part of the head of the specimen.



(ii).Anteriorly with the mouth closed

Drawing showing the structures of the anterior part of the head of the specimen with its mouth closed.

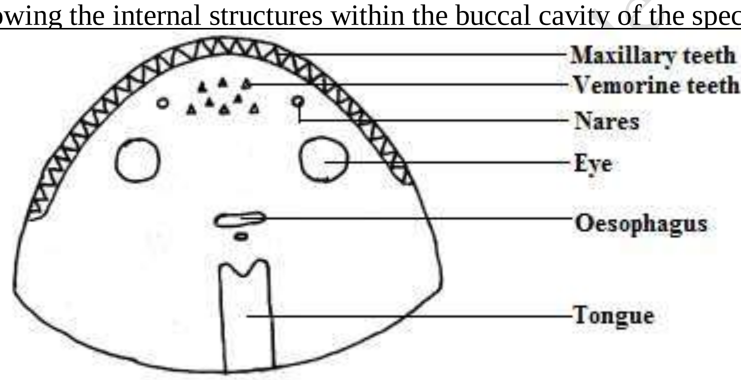


(iii).Laterally, mouth open and tongue pulled out

Drawing showing the structures of the lateral part of the head of the specimen with the mouth open and tongue pulled out.

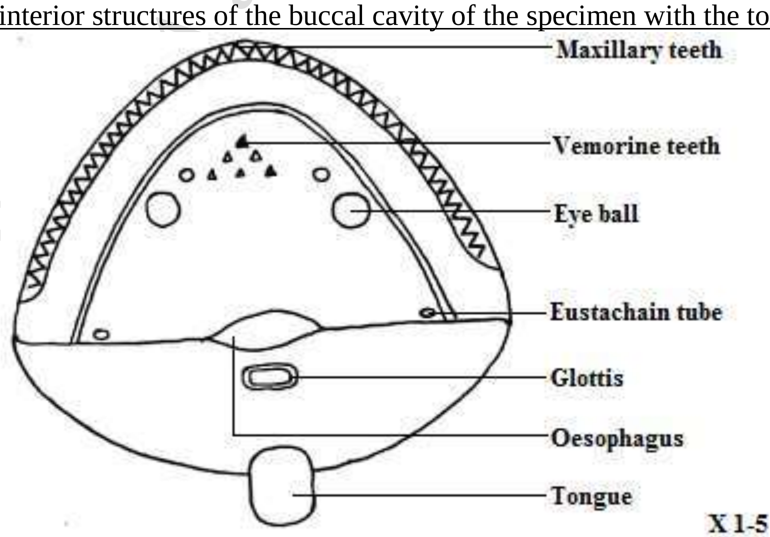
Using dissection instruments, open the mouth of the specimen to expose internal structures within the buccal cavity. Draw and label. ***(08 marks)***

Drawing showing the internal structures within the buccal cavity of the specimen



Open the buccal cavity of the specimen to expose the inner structures. Draw and label the interior of the b-uccal cavity when the tongue is pulled at the front. ***(11 marks)***

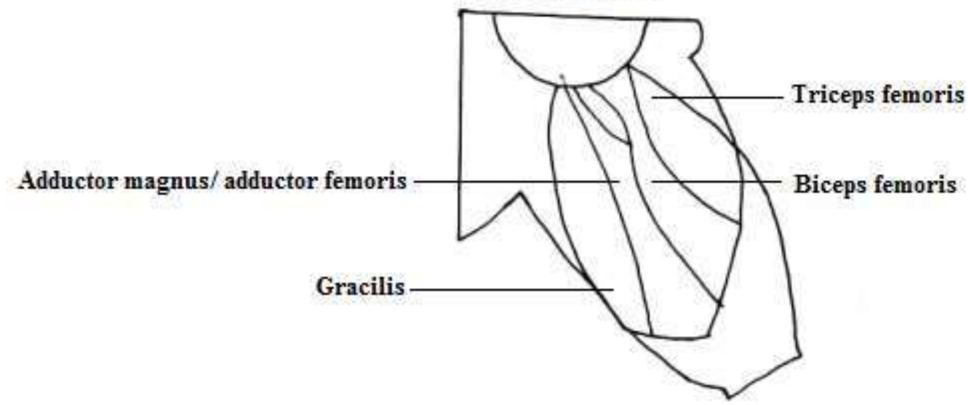
A drawing showing the interior structures of the buccal cavity of the specimen with the tongue pulled at the front.



Dissect the specimen to display the main superficial muscles of the left thigh of the specimen. Draw and label

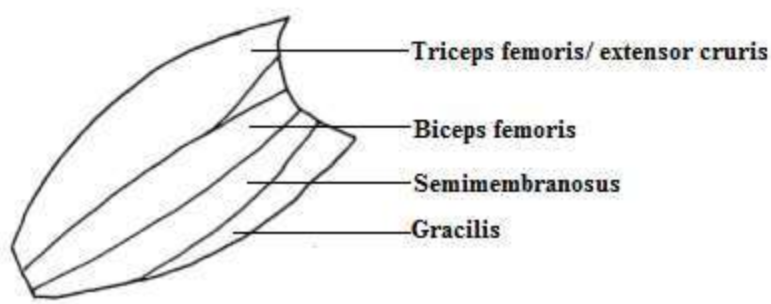
A drawing showing the main superficial muscles of the left thigh of the specimen (toad/ frog)

VENTRAL VIEW



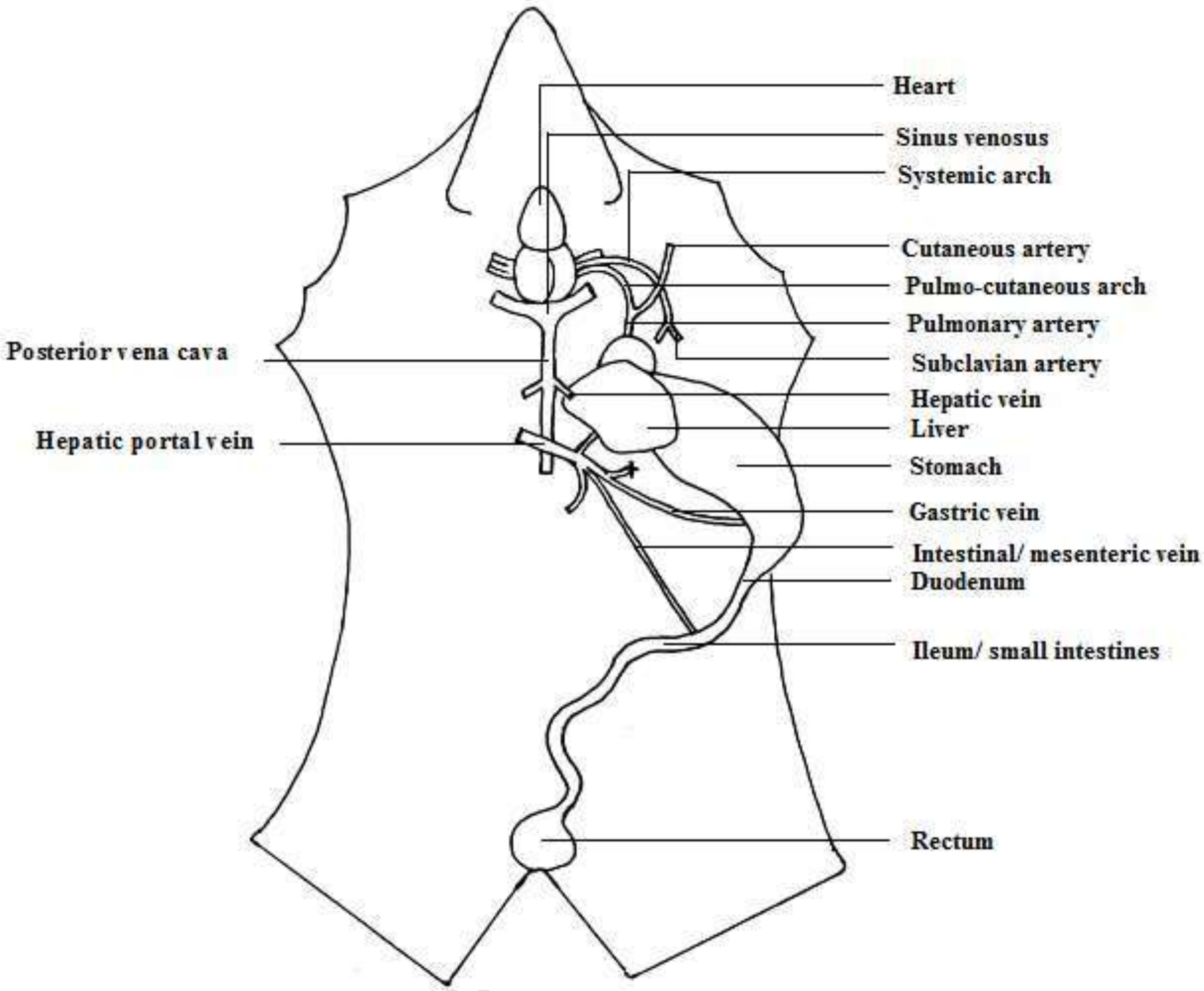
Or

DORSAL VIEW



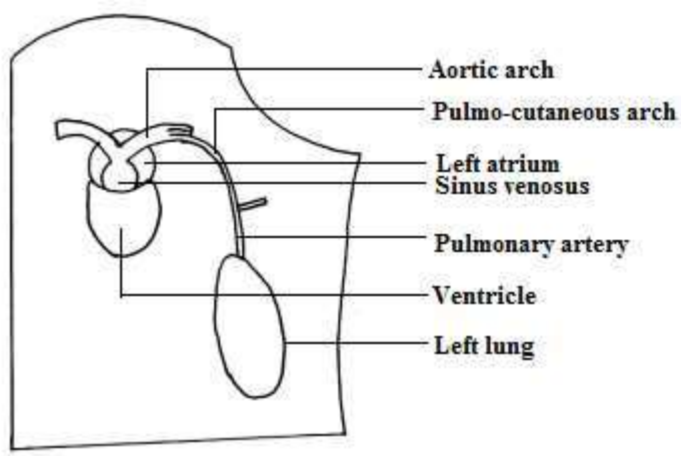
Dissect the specimen to display;
(i).The blood vessels that drain blood from the alimentary canal its associated organs back to the heart, with the alimentary canal displaced to your right and the heart turned upwards and pinned through the ventricles
(ii). The blood vessels that take blood from the heart to the thoracic region of the animal
Draw and label your dissection showing (i) and (ii) on one diagram ***(20 marks)***

Drawing of blood vessels that drain blood from the alimentary canal and its associated organs and the blood vessels that take blood from the heart to the thoracic region of specimen R with its heart turned upwards



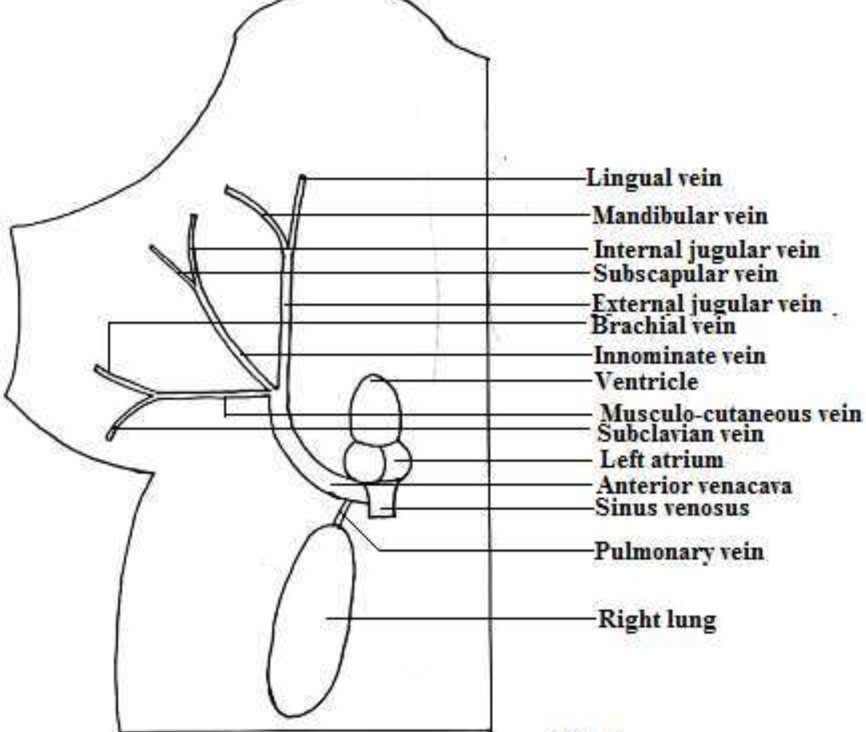
Dissect the specimen to display the;
(i). blood vessels taking blood to the lung of the animal.
Draw and label ***(16 marks)***

<u>Drawing showing blood vessels taking blood to the left lung of the specimen/ toad/ frog</u>



(ii).Blood vessels returning blood from the right side of the head and chest region of the animal to the heart

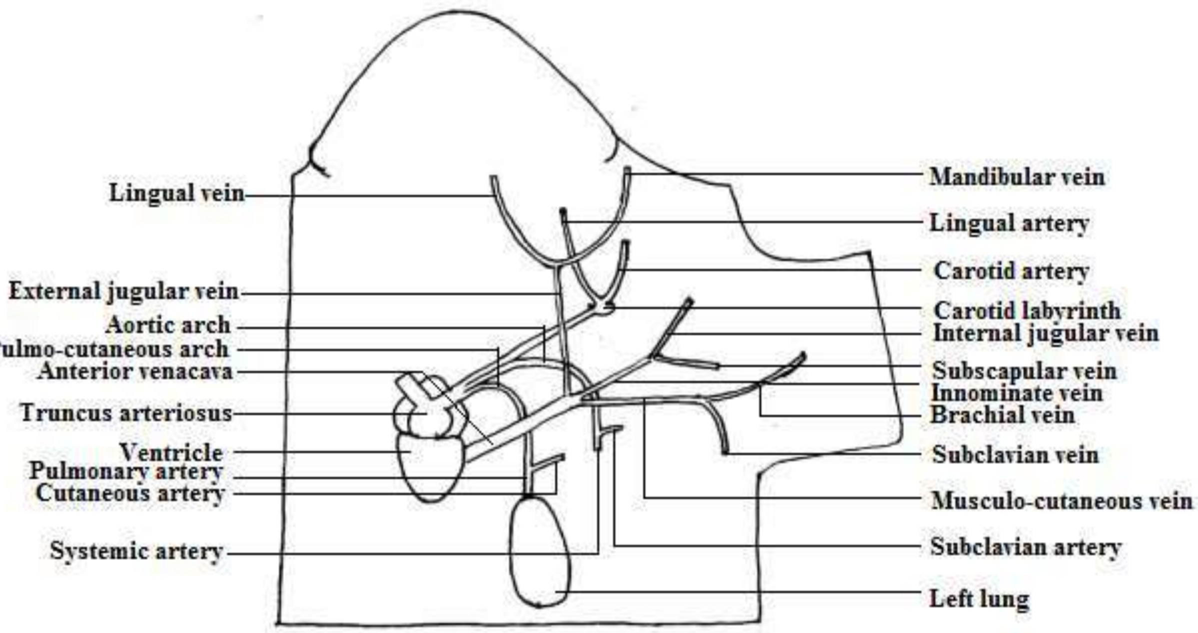
<u>Drawing showing blood vessels/ veins returning blood from the right side of the head and chest region to the heart of the specimen/ toad/ frog</u>



X 1-5

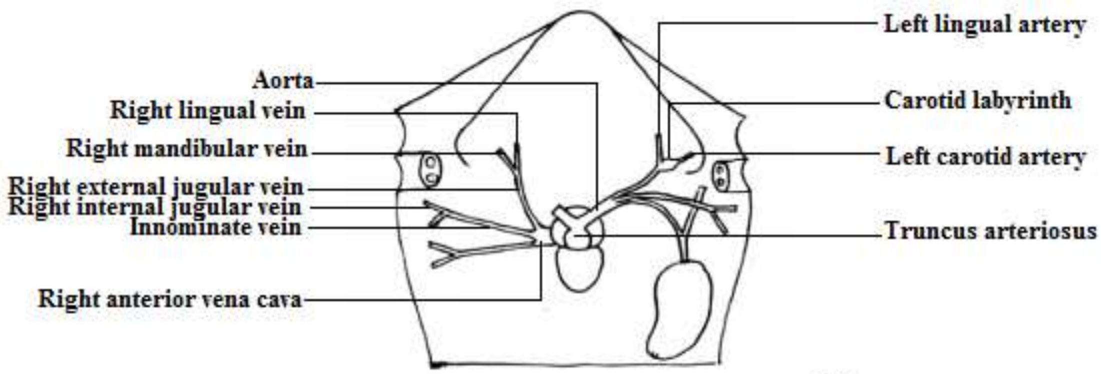
Dissect the specimen to display blood vessels associated with the head region and the thoracic region on the left of the specimen with the heart in its undisplaced position ***(24 marks)***

A drawing showing blood vessels associated with the head and thoracic region on the left of the specimen with the heart in its undisplaced position



Dissect the specimen to display blood vessels draining blood from the right side and those supplying the left side of the head with the heart in the undisplaced state. Draw and label ***(16 marks)***

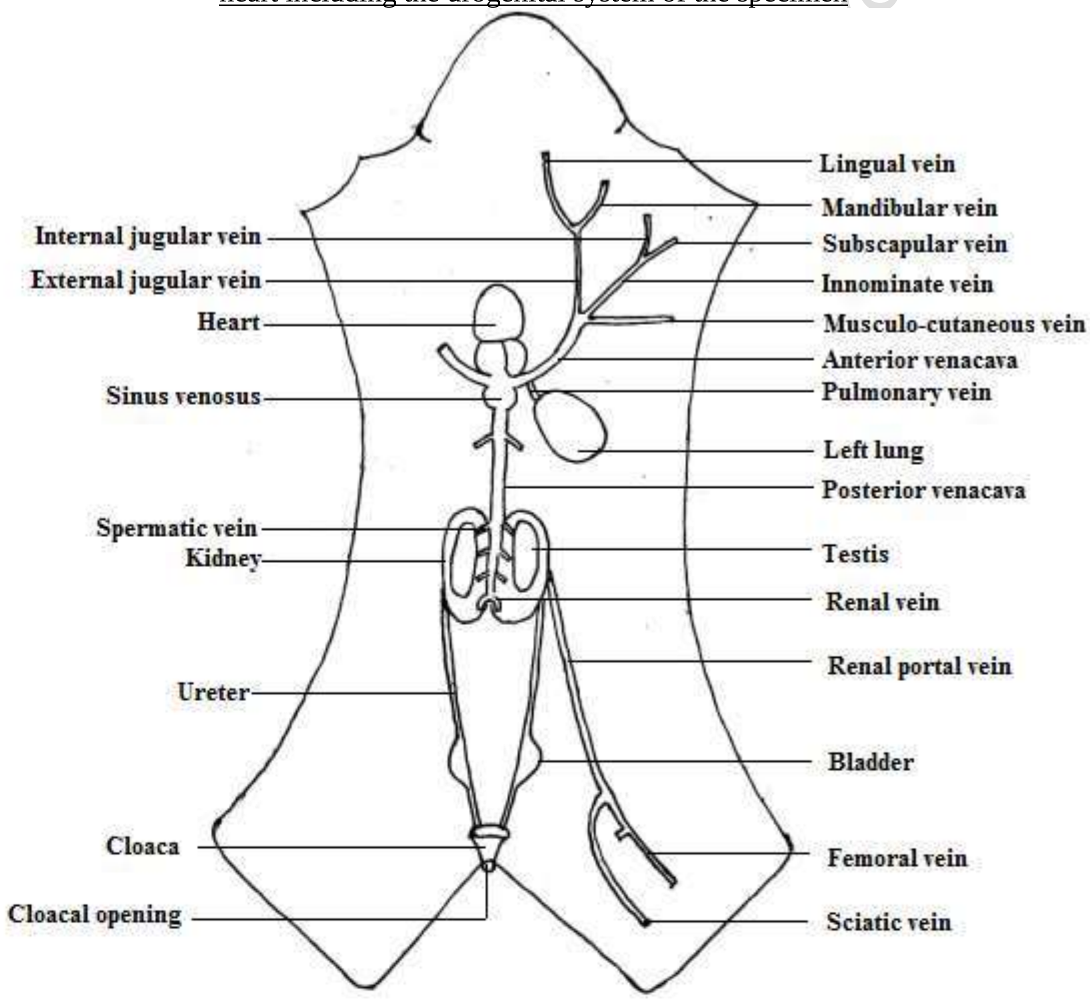
A drawing showing blood vessels draining blood from the right side and those supplying the left side of the head with the heart in the undisplaced state.



X 1

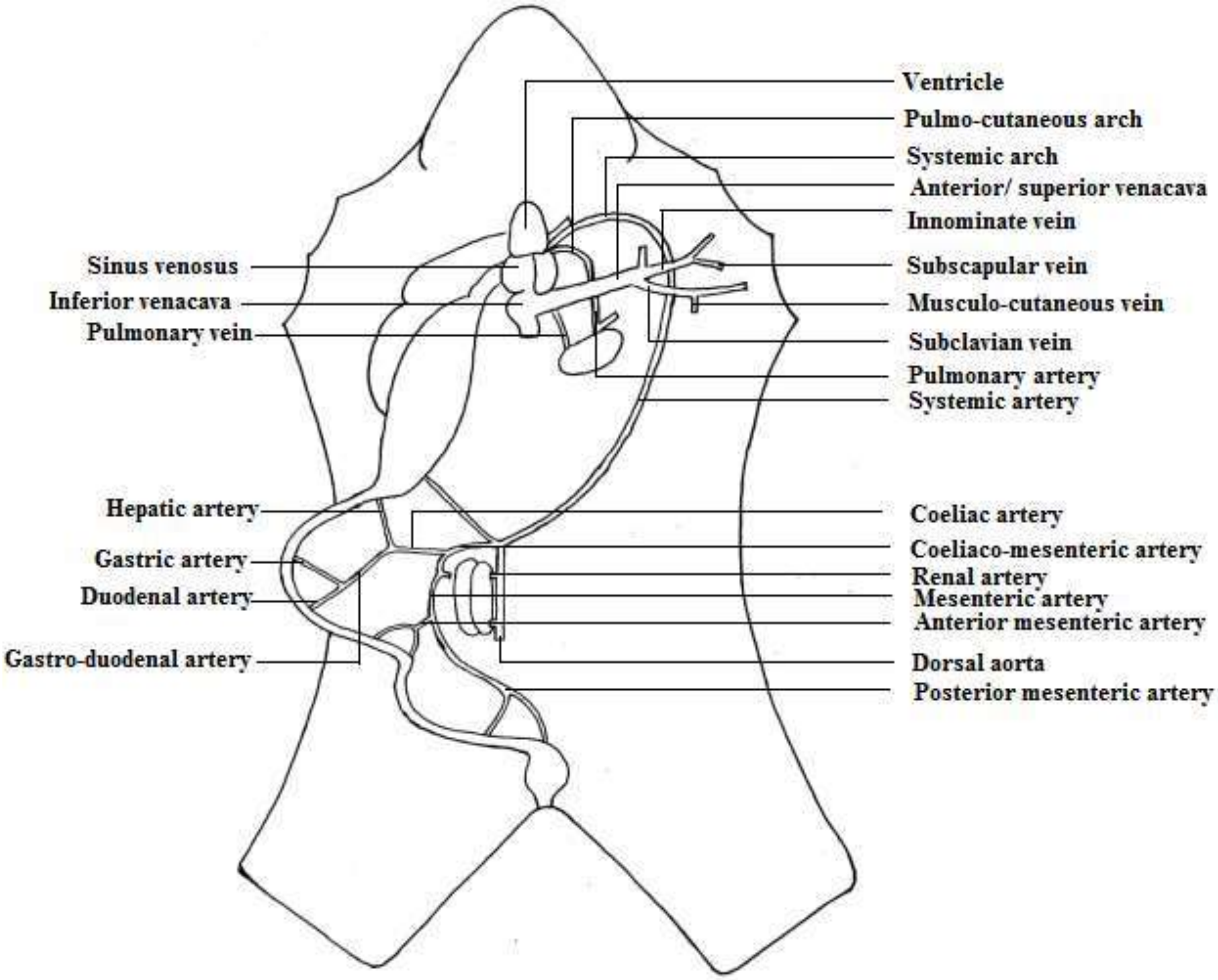
Dissect the specimen to display blood vessels draining blood from the left head region, left lung and left hind limb back to the heart including the urogenital system ***(28 marks)***

A drawing showing blood vessels draining blood from the left head region, left lung and left hind limb back to the heart including the urogenital system of the specimen



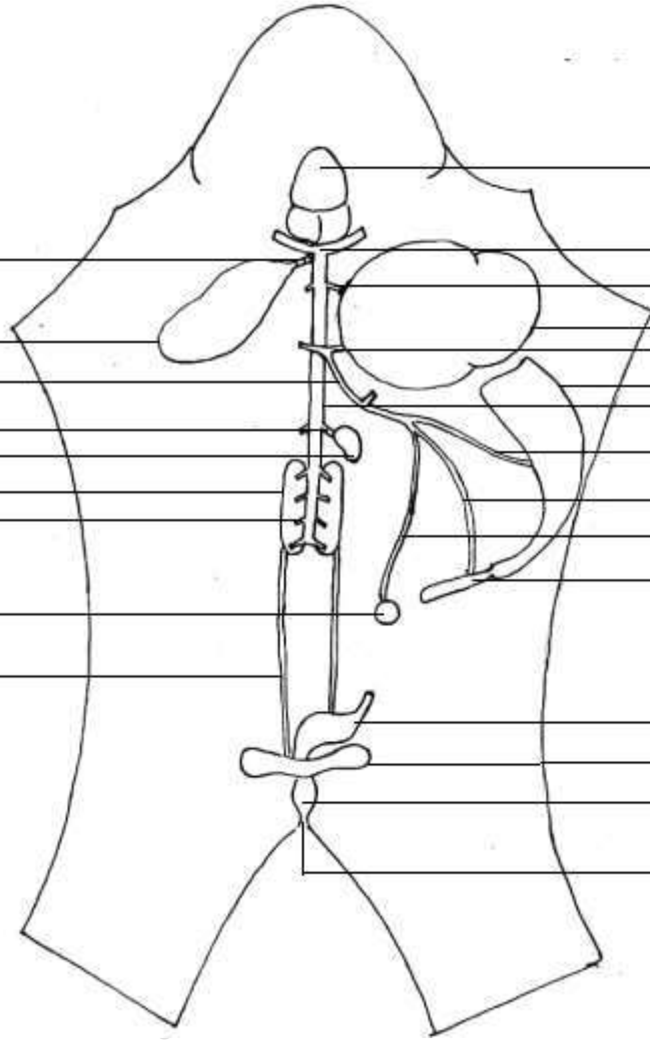
Dissect the specimen to expose the heart. Turn the heart over to display the main blood vessels returning blood from the trunk region to the heart and those supplying the structures for absorption of nutrient and excretion. Draw and label your dissection ***(28 marks)***

A drawing of main blood vessels returning blood from the trunk region to the heart and those supplying structures for absorption of nutrients and excretory organs when the heart of specimen is turned over



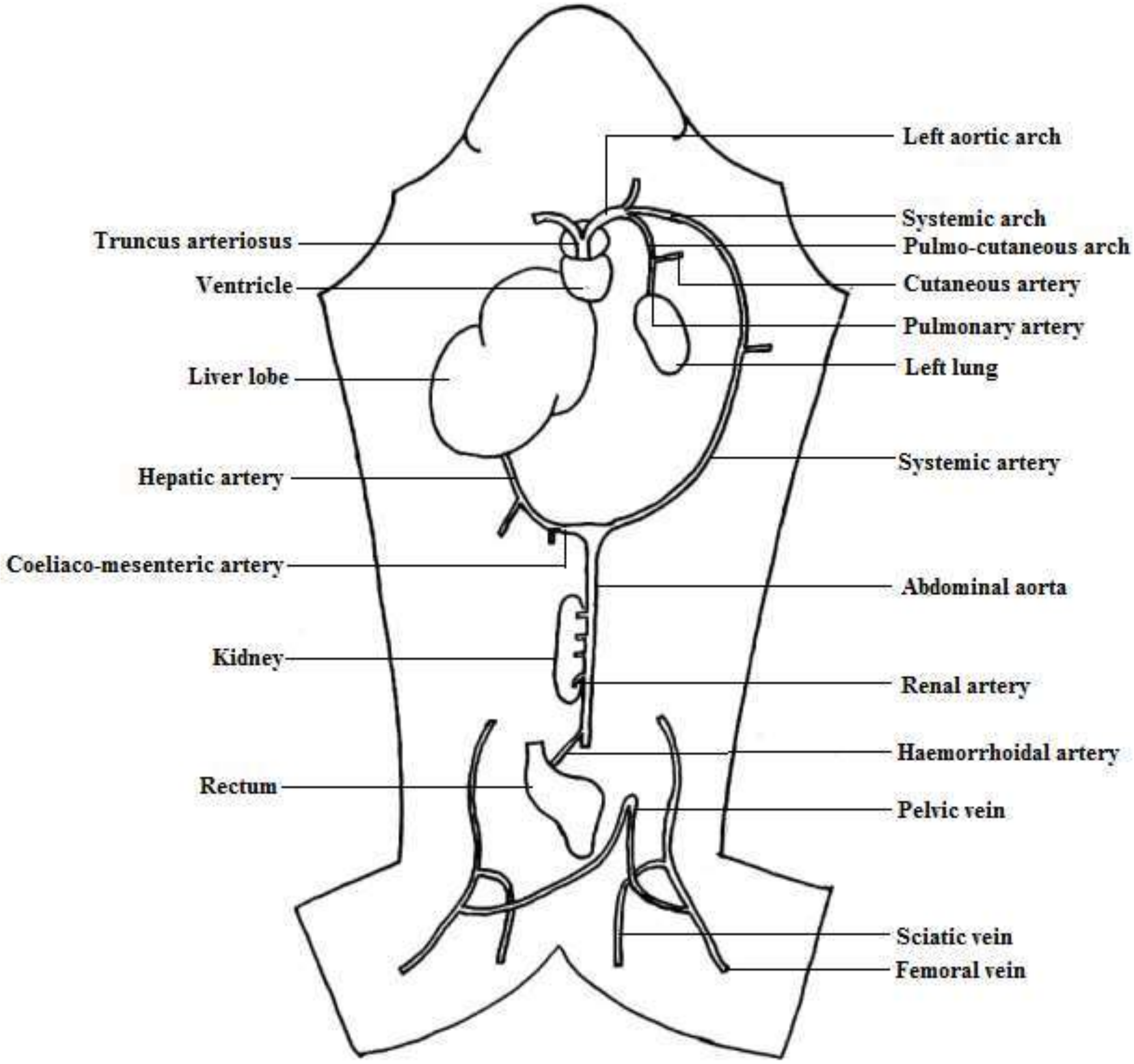
Dissect the specimen further to display
(i). Blood vessels carrying blood from organs located on the left half of the abdominal cavity back to the heart
(ii)The structures used for the elimination of unwanted materials from the body.
With the heart displaced anteriorly, draw and label the blood vessels and structures displayed in (i) and (ii) on one diagram ***(27 marks)***

<u>A drawing of blood vessels carrying blood from organs located on the left half of the abdominal cavity back to the heart, and structures used for elimination of unwanted materials from the body of specimen T/ toad/ frog with the heart displaced anteriorly.</u>



Dissect to display blood vessels that;
Carry blood into the structures for removal of wastes from the body of the specimen and those that drain the hind limbs and the pelvic region. Draw and label the structures displayed on the same drawing to include the heart in the ventral view ***(27 marks)***

A drawing showing blood vessels supplying structures responsible for removal of wastes from the body and those draining blood from the hind limbs and pelvic region of specimen with its heart in the dorsal view


Left aortic arch
Truncus arteriosus
Systemic arch
Pulmo-cutaneous arch
Ventricle
Cutaneous artery
Pulmonary artery
Liver lobe
Left lung
Systemic artery
Hepatic artery
Coeliaco-mesenteric artery
Abdominal aorta
Kidney
Renal artery
Haemorrhoidal artery
Rectum
Pelvic vein
Sciatic vein
Femoral vein