6102 Unit 2B: Exchange, transport and reproduction
Exchanges with the environment & Exchange processes

1- understand what materials need to be exchanged; respiratory gases; nutrients; excretory products; understand the relationship of size and surface area to volume

Materials exchanged between living things and the environment:
Respiratory gases: O_2 absorbed, CO_2 released.
Nutrients: In plants - CO_2, H_2O, minerals (Nitrates, phosphates, sulphates, potassium, sodium, magnesium, ammonium, etc.)
In animals: carbohydrates, proteins, lipids, vitamins, minerals, H_2O.
Excretory products: urea, CO_2, excess water and salts, dead cells, etc.

Small organisms have a **large** surface area : volume ratio.
Large organisms have a **small** SA : volume ratio.

- Small / unicellular organisms can exchange substances with environment by diffusion / active transport from body surface.
- Large / multi-cellular organisms need special exchange and transport systems. This is because exchange from the body surface would not be efficient enough to exchange materials at the required rate because of the small surface area to volume ratio. The large size also increases the diffusion distance, so that a molecule would take a long time to move from the surface to the centre of the body by diffusion.

2- understand the features of exchange surfaces which and passive and active transport;
Exchange surfaces usually have:
- Large surface area to volume ratio to enable more efficient exchange by increasing the surface area and reducing the diffusion distance. This may be achieved by folding of tissues (eg: villi) or by presence of microvilli / brush borders on cell surfaces (eg: epithelial cells in proximal convoluted tubule); outgrowths – root hair cells.
- Thin wall– to decrease diffusion distance(eg: alveoli).Single layer of epithelium.
- Large number of mitochondria – to provide ATP (energy) for active uptake. Eg: intestinal villi, proximal convoluted tubule, root hair cells.

3- understand the special features of gas exchange surfaces;
All gas exchange surfaces have some common features which enable more efficient / rapid exchange of gases by diffusion:
- Large SA : volume ratio – more surface for diffusion.
- Thin walled: decreases diffusion distances.
- Moist and permeable - so that gases first dissolve in moisture and then diffuse, the moisture acts as a diffusion medium.
- They are able to maintain a concentration gradient – to increase rate of diffusion.

Eg: mesophyll cells of leaves, alveoli in lungs, gills in fishes.

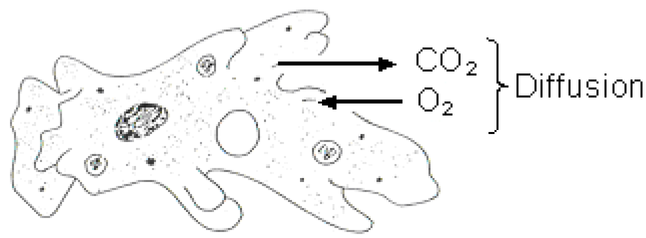
4- understand the need for ventilation mechanisms;

Ventilation is the movement of air over the gas exchange surface. This helps to maintain a continuous concentration gradient so that exchange can continue by diffusion, more rapidly. Eg: Breathing, passing of water over gills, waving movement of tubifex worms and chironomous larvae, etc.

Gas exchange in protozoa

5- Understand how gas exchange is achieved in a protozoan.

Gases are exchanged with the environment directly across the cell surface membrane. The small size (large SA: Vol ratio) provides a large S.A for diffusion and decreases the diffusion distance.



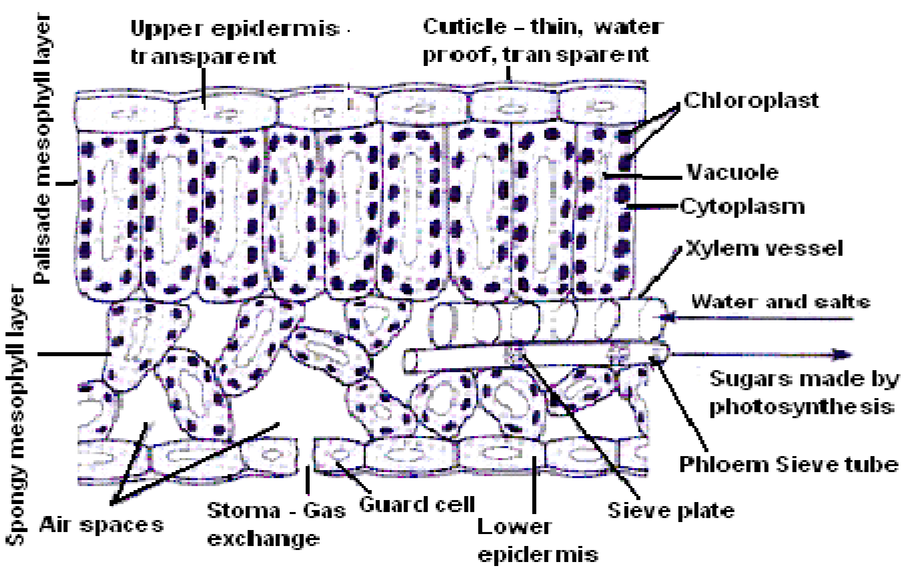
▲ <u>***Diffusion of oxygen and carbon dioxide in Protozoan (amoeba).***</u>

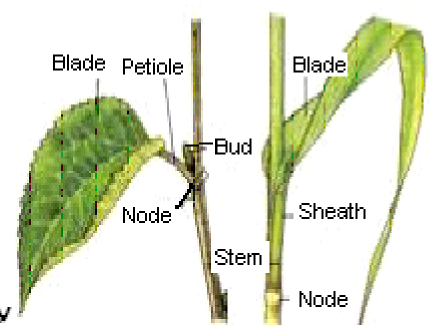
Gas exchange in flowering plants

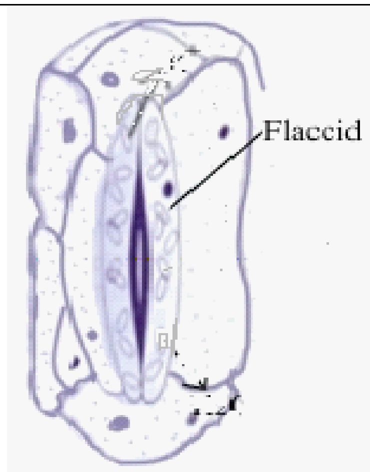
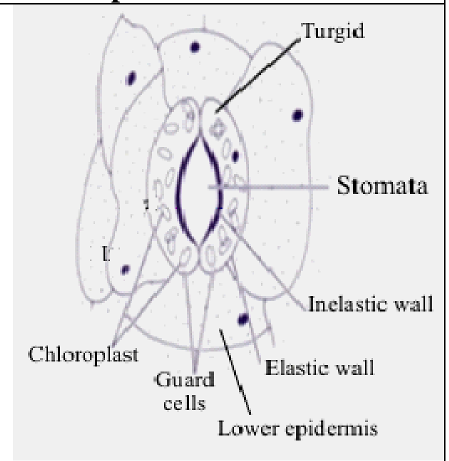
6- Describe the internal and external structure of a mesophyte leaf. Understand the structure and roles of stomata and the mechanism of stomatal opening in terms of change in ions concentrations leading to changes in turgidity; understand how gases exchange is achieved.

Mesophyte leaf

- Plants exchange gases by <u>diffusion</u>.
- Mesophyll cells have air spaces to increase surface area for diffusion, thin cell walls and cytoplasm to reduce diffusion distance.
- Concentration gradient is maintained due to gases being used up / produced in respiration / photosynthesis.
- Stomata allow entry / exit of gases so that a concentration gradient can be maintained.



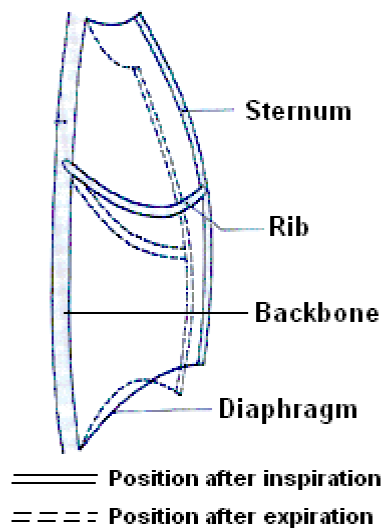


Stomata closed	Stomata opened
• K^+ ions move out of guard cells. • Water potential of guard cells increase. • H_2O moves out of the guard cells by osmosis.  • Guard cells become flaccid and less curved, causing the stomata to close.	• H^+ ions are pumped out of guard cells, causing a negative potential inside the guard cell. • K^+ ions move into guard cells down electrochemical gradient.  • Water potential of guard cells decreases. H_2O moves in from epidermal cells. • Guard cells become turgid and more curved, due to unequal elasticity of cell wall. So stomata Open.

Gas exchange in humans

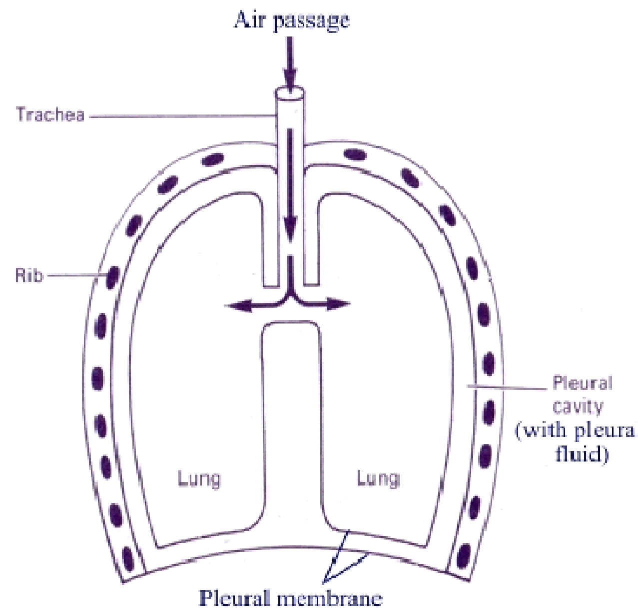
7- recall the structure of the thorax; understand the mechanism of ventilation, including the role of the pleural membranes;

Thorax/thoracic cavity is the region of the body cavity (coelom) lying above the diaphragm. It is surrounded by ribs, sternum and vertebral column (rib cage). The lungs and heart are found in the thoracic cavity. Ventilation (breathing movements) is achieved by the combined action of ribs, intercostal muscles and diaphragm.



During inspiration / inhalation	During exhalation / expiration
• External intercostal muscles contract. • Internal intercostal muscles relax. • Ribs and sternum pulled outwards/upwards. • Diaphragm contracts, becomes flattened. • Volume of thoracic cavity increases causing pressure to become less than atmospheric pressure, so that air rushes into lungs.	• Internal intercostal muscles contract. • External intercostal muscles relax. • Ribs and sternum pulled inwards. • Diaphragm becomes dome shaped. • Volume of thoracic cavity decreases. • Pressure in lungs becomes greater than atmospheric pressure, so air is pushed out of the lungs.

Pleural membranes surround the lungs. There are 2 pleural membranes – the outer parietal pleural membrane and the inner visceral pleural membrane. The membranes secrete a fluid, which remains in the pleural cavity, between both membranes. This lubricates the pleura and reduces friction as the membranes rub against each other during breathing movements.



8- understand how breathing is controlled; understand vital capacity and tidal volume;

Breathing is controlled by <u>respiratory centers</u> in the hindbrain (<u>medulla oblongata</u>), which controls the rate and depth of breathing. The respiratory centre has two parts:

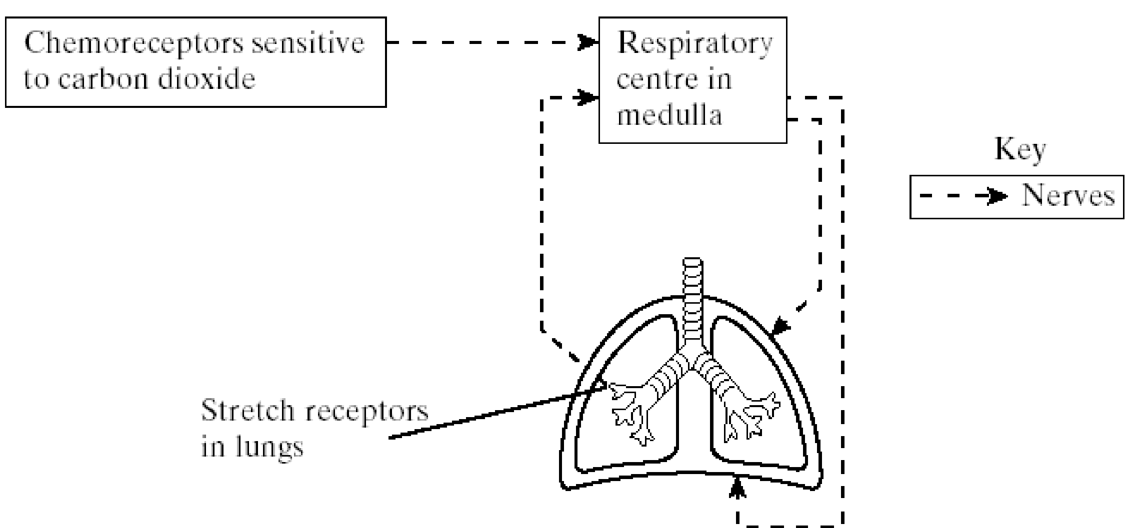
<u>Inspiratory center:</u> increases the rate and depth of inspiration (during exercise / when CO_2 concentration of blood increases).

<u>Expiratory centres:</u> Inhibits inspiration and stimulates expiration.

<u>Receptor:</u> Stretch receptors in bronchial tree, chemoreceptors in blood vessels and brain.

<u>Effectors:</u> Intercostal muscles, diaphragm.

The basic rhythm of respiration is controlled by medulla. However the rate can be altered to meet the demands of specific situations, by the respiratory center.



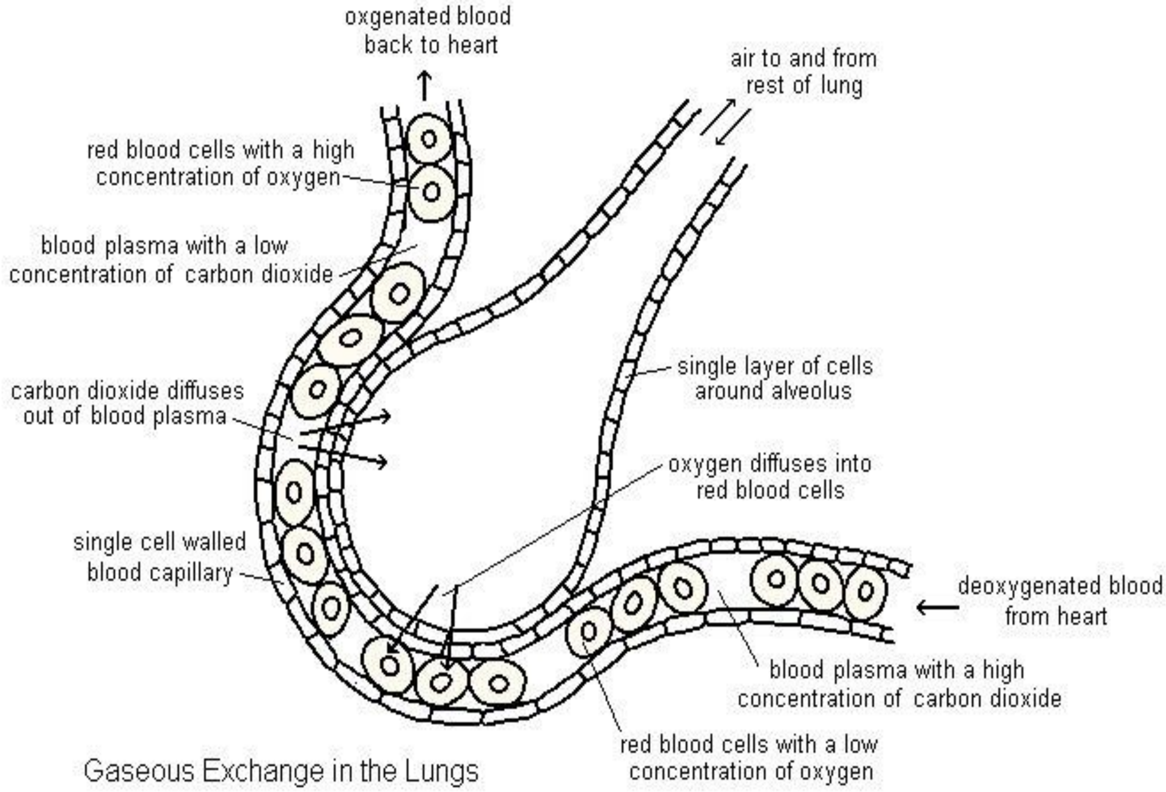
Ventilation rate = Tidal volume x number of breaths per minute

<u>Tidal volume:</u> the volume of air breathed in or out of lungs per breath. It is about $0.5dm^3$ at rest, but varies with each individual; It increases during exercise.

<u>Vital capacity:</u> the maximum volume of air that can be forcibly expired after a maximal intake of air. It varies between 3 dm^3 to 6 dm^3 depending on size and fitness of the person.

9- Recall the structure of alveoli and understand their role in gas exchange; explain the function of surfactants; know that breathing is controlled by the respiratory center in the brain.

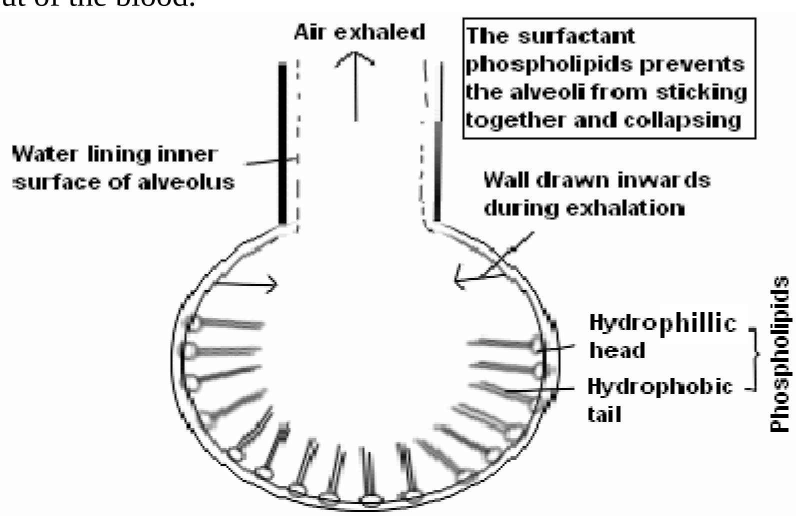
- ***Practical work should include the use of simple respirometer (refer to practical sheet)***



Gaseous Exchange in the Lungs

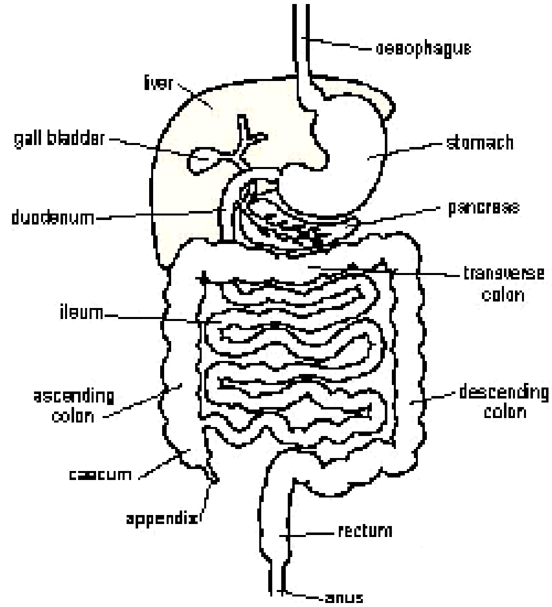
The main role of alveoli is gas exchange between air and blood. Each alveolus is surrounded by a network of capillaries. The alveolus and capillaries are made up of a single layer of epithelial cells. This decreases the diffusion distance. The flow of blood in the capillaries and ventilation helps to maintain a concentration gradient between air in alveolus and blood in the capillaries. This ensures that Oxygen diffuses into the blood and CO_2 diffuses out of the blood.

The surfactant is a mixture of phospholipid molecules present on the inner surface of the alveoli. The lung surfactant prevents the alveoli from collapsing (due to cohesive forces of water molecules) during exhalation. This makes inflation of the alveoli easy. Some babies born without surfactant in the lungs die from exhaustion. This is because they need to spend too much energy to inflate the lungs. This is called the respiratory distress syndrome.



10- Describe the structure of the alimentary canal in relation to digestion and absorption;

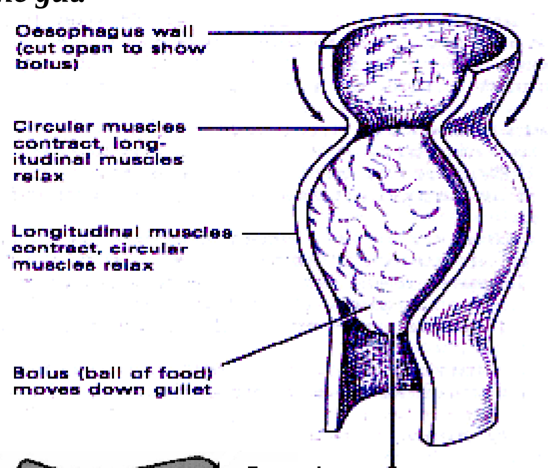
The alimentary canal is a tube running from the mouth to the anus. It is specially adapted for digestion and absorption of food. Digestion begins in the mouth and is completed in the ileum. Digestion may be physical (without changing the chemical composition eg: chewing / mastication and emulsification of fats by bile) or chemical (using hydrolytic enzymes to convert large complex organic molecules into simpler organic molecules). Enzymes are secreted by the walls of the alimentary canal (as in stomach and ileum) or by exocrine gland (like salivary glands and pancreas). The liver secretes bile for emulsification of fats. The main parts of the alimentary canal are mouth, pharynx, oesophagus, stomach, small intestine, (duodenum and ileum), large intestine, rectum and anus. The wall of the alimentary canal has the same basic structure throughout its length. Epithelial cells line the lumen of the gut. It is glandular and secretes mucus and specific enzymes for digestion. In many regions the gut lining is highly folded into villi to increase the surface area for digestion and absorption.

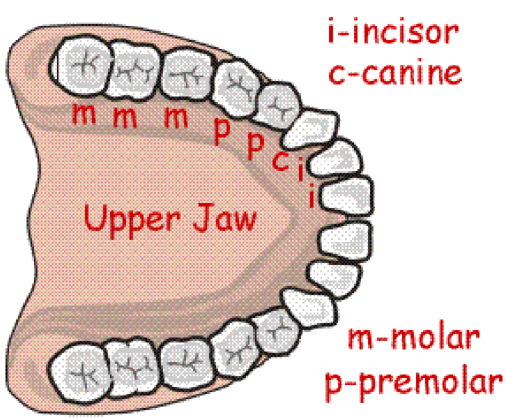


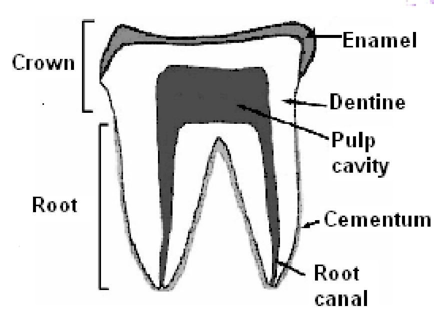
The Human Digestive System

11- Describe mastication and movement of food along the gut.

Mastication is the chewing of food. This increases the surface area for enzyme action and also makes it easy to swallow. The teeth play an important role in grinding of food. The tongue helps to manipulate the food during mastication. The food is made into a bolus and swallowed. It is then squeezed down the oesophagus by rhythmic contraction of circular and longitudinal muscles of the oesophagus, called **Peristalsis**.



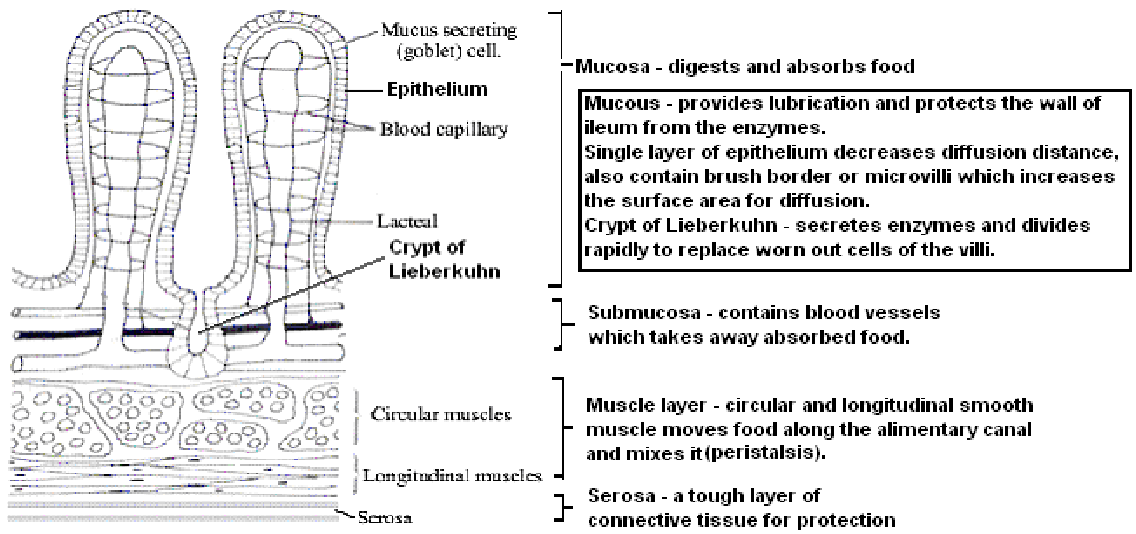




Cross section of a tooth

12- describe the histology of the ileum wall; understand the sources and effects of secretions concerned with the digestion of carbohydrates;

Substrate	**Enzymes**	**Source**	**Place of action**	**Product**
Starch	Salivary amylase	Salivary gland	Mouth	*Maltose*
Starch	Pancreatic amylase	Pancreas	Duodenum	*Maltose*
Maltose	Maltase	Ileum wall(mucosa)	Ileum	*Glucose*
Sucrose	Sucrase	Ileum wall (mucosa)	Ileum	*Glucose + fructose*
Lactose	Lactase	Ileum wall (mucosa)	Ileum	*Glucose and galactose*



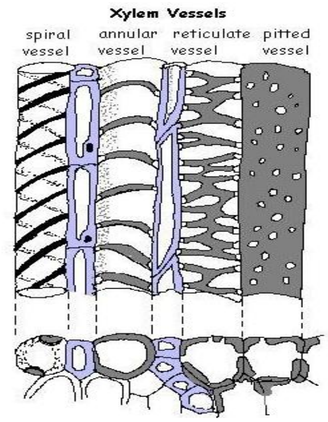
2B.2 Transport systems

13- understand the need for transport systems in relation to size and surface area to volume ratio; the concept of mass flow and the movement of molecules within organisms;

Large multi-cellular organisms have a very small surface area to volume ratio. Exchange of substances by diffusion directly from the body surface would be too slow and inefficient due to the large diffusion distance. Thus there are special transport systems. In plants and large organism substances are usually transported by <u>mass flow</u>. This is the movement of substances down the pressure gradients, where there is mass / bulk movement of particles. Eg: blood in blood vessels, sap in xylem and phloem.

14- Describe the structure of the vascular tissues; xylem tissue composed of vessels, tracheids, fibres and xylem parenchyma; understand the role of vessels in relation to transport; phloem tissue composed of sieve tube elements, companion cells, phloem fibres and phloem parenchyma; the role of sieve tube elements and companion cells in relation to transport.

Vascular tissues are <u>tube-like</u> tissues, which are specially designed for transporting substances by mass flow.



<u>XYLEM TISSUE:</u>

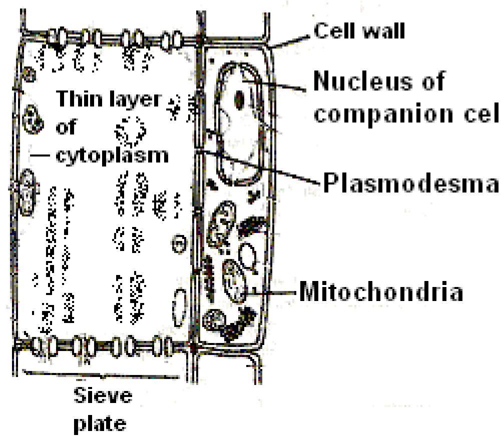
- xylem vessels
- tracheids
- fibres
- xylem parenchyma

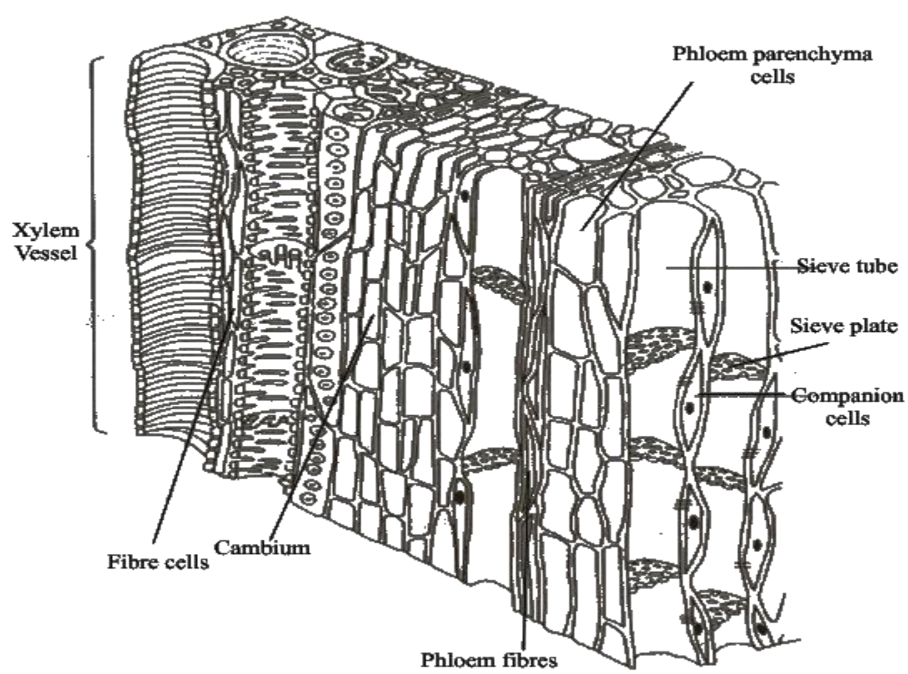
Xylem vessels - These are tubes like vessels with no cytoplasm, no nucleus, no cell membrane, no cross walls. They have highly lignified cell walls, with lateral pits. They form a continuous system of tubes from roots to all parts of the plant, the lignin provides mechanical support. Lateral pits allow lateral movements of water and minerals from one vessel to another.

<u>PHLOEM TISSUE:</u>

- sieve tube elements
- companion cells
- phloem fibres
- Phloem parenchyma.

Sieve tube elements have no nucleus, but thin layer of cytoplasm is present. They are supported and kept alive by companion cells. Each sieve tube element is connected to another by sieve plates. This allows mass flow. Companion cells have a lot of mitochondria and are connected to sieve tube elements by numerous plasmodesmata.

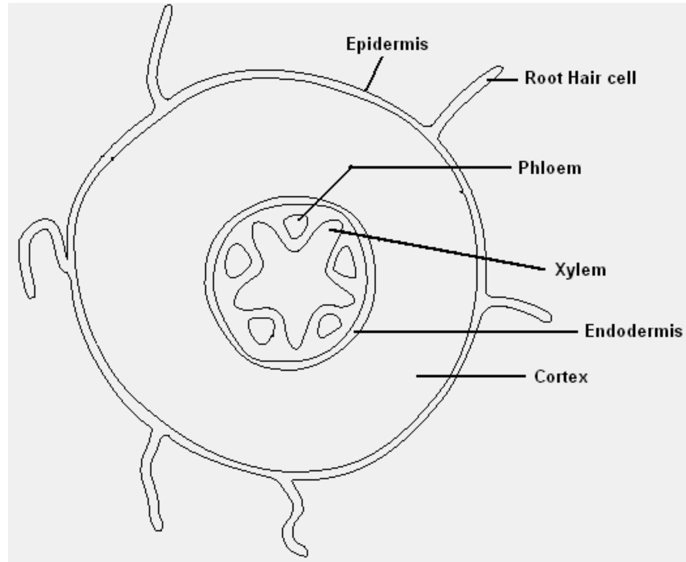




15- describe the structure of a dicotyledonous root; understand the uptake of water and its transport across the root to the xylem;

Structure of dicot roots

- Water is absorbed into the root hair cells by osmosis.
- The root hair cells increase the surfaces are to volume ratio for absorption.
- They have lower water potential then the water in soil.
- They have thin cell walls to decrease diffusion distance.
- Low water potential of the root hair cells is maintained by transpiration pull and also active uptake of minerals.



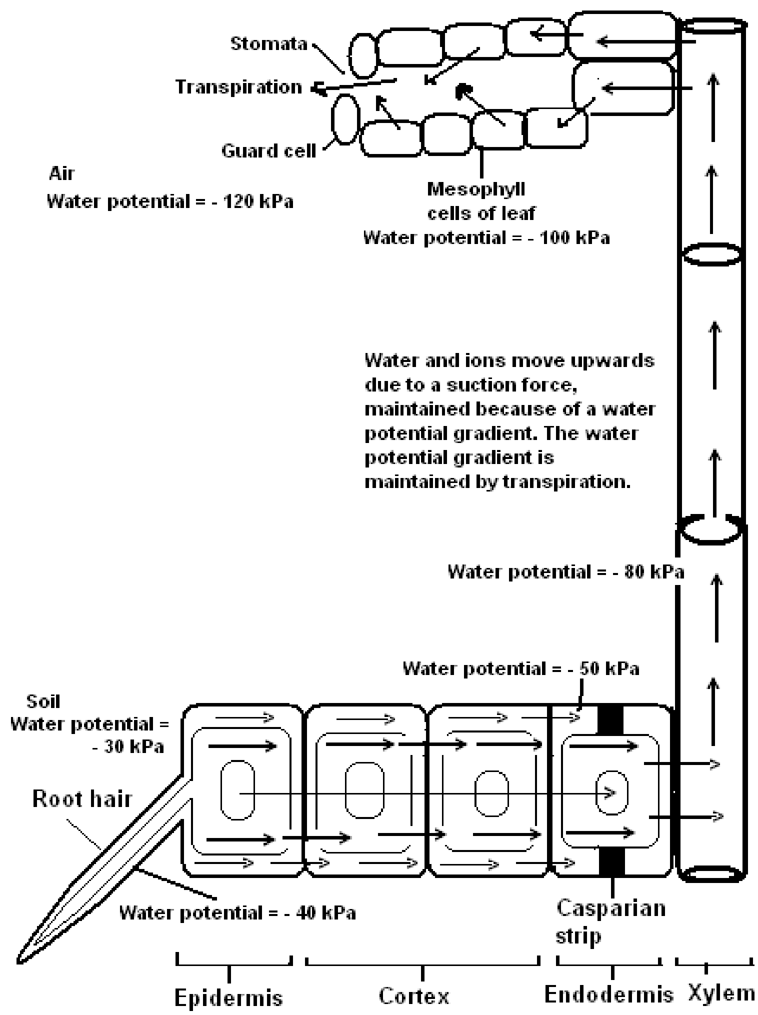
16- understand the way in which water is moved through the plant the apoplast symplast and vacuolar pathways, the role of the endodermis;

Water is transported from the root hair cells to the root xylem, across the cortex cells and endodermis. The water may pass through three routes to the xylem:

1- **Apoplast** – through cell walls (interrupted by casparian strip of endodermis) by diffusion. Transpiration pull helps to maintain a water potential gradient.

2- **Symplast** – through the cytoplasm of adjacent cells by osmosis, or, by diffusion through plasmodesmata, down the water potential gradient.

3- **Vacuolar pathway** – passing through vacuoles as well as cytoplasm, down the water potential gradient (osmosis & diffusion).



Role of endodermis

The endodermis has a waterproof layer in the cell wall, called ***casparian strip*** (made of suberin). This prevents water from passing through cell wall of the endodermis. The water is forced to enter endodermal cytoplasm. The endodermis secretes mineral ions into root xylem by active tranport. These processes maintain a water potential gradient between the endodermis and root xylem so that water is pushed into root xylem, down a water potential gradient, by osmosis. This is called the **root pressure**.

17- understand the structure of vessels in relation to the cohesive and adhesive forces of water and their contribution to the movement of water through the plant;

18- describe the functioning and understand the roles of the transpiration stream; roles of stomata; understand the effects of different environmental conditions on the transpiration stream;

- ***<u>Practical work to include demonstrations and measurements of transpiration's using a photometer; stomatal counts;</u>***

<u>Transport of water through xylem vessels.</u>

Water is transported through the xylem vessels by mass flow. The hollow / tube-like vessels, with lignified walls carry water from a high pressure potential (in the roots) to a low pressure potential (in the leaves). The pressure potential gradient is maintained by:

- **<u>Root pressure:</u>** *refer to role of endodermis*.
- **<u>Transpiration pull:</u>** transpiration causes water potential of leaf cells to be lower than root cells. Thus, there is a continuous water potential gradient between the root and leaves. This causes water to flow continuously from roots to the leaves, down the water potential gradient. Since the upward movement of water is brought about by transpiration, it is called transpiration pull. The water flows as a continuous stream from roots to leaves. This stream is called the transpiration stream. The forces of cohesion between water molecules, prevents the column of water from splitting.
- **<u>Capillarity / adhesion:</u>** the xylem vessels are very narrow. The walls of the xylem vessels attract water molecules (adhesion – force of attraction between molecules of different substances). This enables water to be drawn through the xylem vessels (capillary action).

<u>Factors affecting transpiration stream.</u>

<u>Light intensity:</u> more light intensity ⟶ stomata open wider ⟶ more transpiration ⟶ more uptake of water from roots to leaves ⟶ more photosynthesis.

<u>Wind velocity</u>: more wind velocity ⟶ more transpiration ⟶ increased water uptake.

<u>Temperature</u>: higher temperature ⟶ more evaporation ⟶ more transpiration ⟶ more water uptake.

<u>Humidity</u>: increased humidity ⟶ less transpiration ⟶ less water uptake.

If water loss by transpiration exceeds water uptake by roots (water stress) then stomata closes. Water uptake will decrease as water potential gradient between roots and leaves will be less.

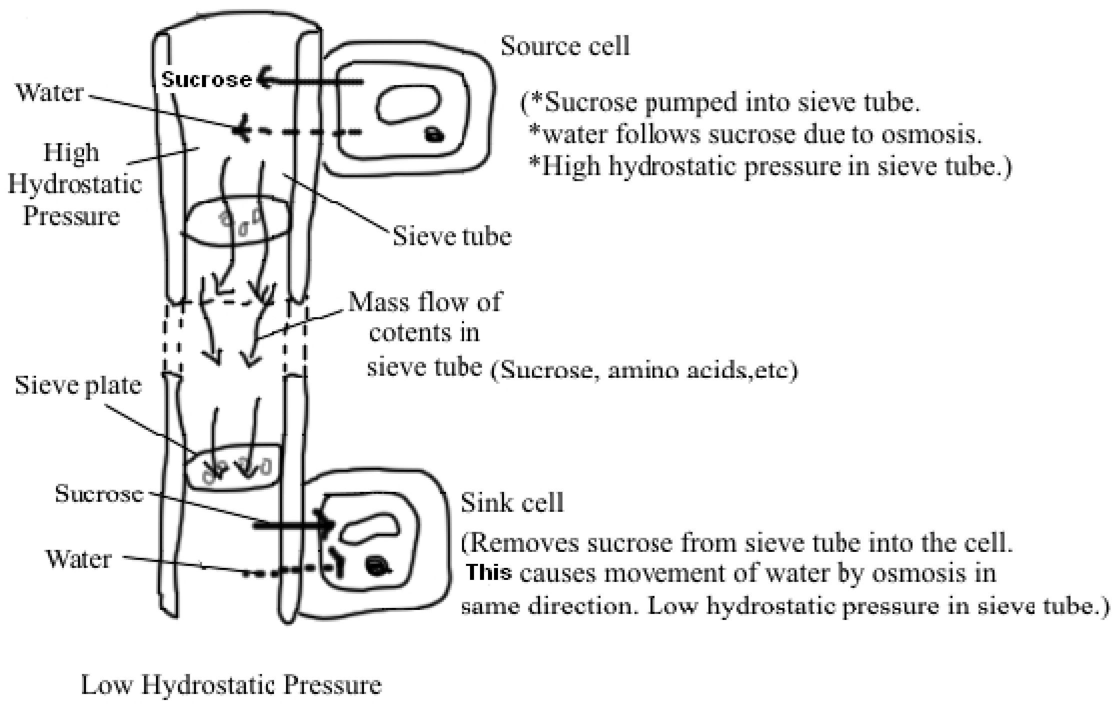
19- understand the roles of diffusion and active transport in the uptake of mineral ions by root; understand the transport of mineral ions through the plants;

Mineral ions are obtained from the soil. Root hair cells absorb mineral ions through transporter protein in the cell surface membrane. Some ions move into the root down their concentration gradient by diffusion, or against the concentration gradient, by active transport. Roots also use active transport to pump sodium out of the root. This creates an electrochemical gradient for other positive ions to move into the cell. The transporter proteins are specific and absorb only specific ions. From the root hair cell the ions move through the apoplast, symplast and vacuolar pathways along with water (in solution). They are actively secreted from endodermal cells into the xylem vessels. They are transported through xylem vessels by mass flow.

20- understand the translocation of organic solute; appreciate the difference between the transport of water and organic solute; relate the structure and arrangement of sieve tube elements companion cells and transfer cells to the movement of organic solutes;

Role of sieve tube, transfer cells and companion cells in transport.

- Sieve tubes are specially adapted for mass flow. The sieve plates have pores to allow mass flow of substances from one sieve tube elements to the next. The sieve plates also prevent sieve tubes from splitting due to the hydrostatic pressure during mass flow. The lack of a nucleus and the presence of peripheral cytoplasm provide less obstruction for mass flow.
- Companion cells are closely associated to sieve tube and provide materials needed to sustain the sieve tubes. They are connected to sieve tubes by plasmodesma.
- Transfer cells: these are modified companion cells, which have a large surface area and numerous mitochondria. Their main function is loading of sucrose from source cells to sieve tube and unloading of sucrose from sieve tube to sink cells by active transport.



Transport in mammals

21- understand the outline functions of circulatory system in the transport of respiratory gases, metabolites, metabolic wastes and hormones; describe the double circulatory system;

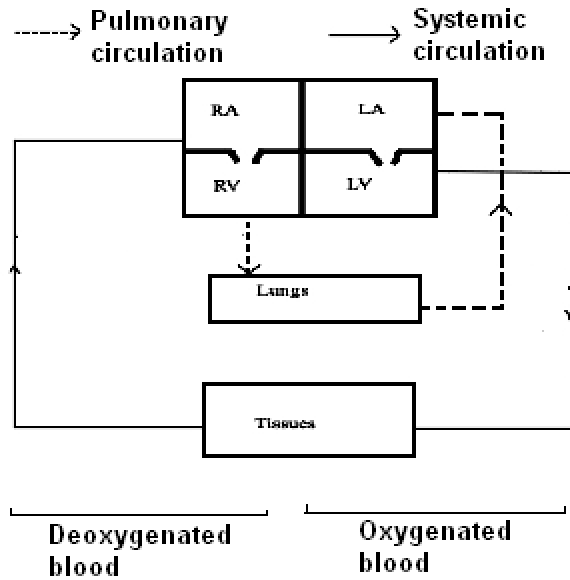
The main function of the circulatory system in mammals is the transport of respiratory gases (CO_2 , O_2), metabolites (vitamins, minerals, glucose, amino acids, etc), metabolic wastes, (urea, CO_2, creatinine, etc) and hormones (insulin, glucagon, FSH, adrenaline, etc, from endocrine gland to target cells).

<u>Double circulatory system</u> – the mammalian circulatory system consists of to two circulations:

1- Systemic circulation

2- Pulmonary circulation.

- **Systemic circulation** is the pumping of oxygenated blood to all the organ system of the body. It is a *high pressure circulation* originating from the left ventricle and terminating at the right atrium, which receives deoxygenated blood from the organ systems / tissues.
- **Pulmonary circulation** is the pumping of deoxygenated blood to the lungs. It is a *low-pressure circulation* originating from the left ventricle and terminating at the left atrium, which receives oxygenated blood from the lungs.



22- describe the structure of the mammalian heart and coronary circulation;

Coronary circulation supplied blood to the cardiac muscles. The coronary artery branches from the aorta and enters the heart muscles. It splits into capillaries and exchange of materials takes place between the blood and tissues. The capillaries reunite to form veins, which pour blood back into the right atrium through the coronary sinus. About 5% of the total cardiac output goes to coronary circulation.

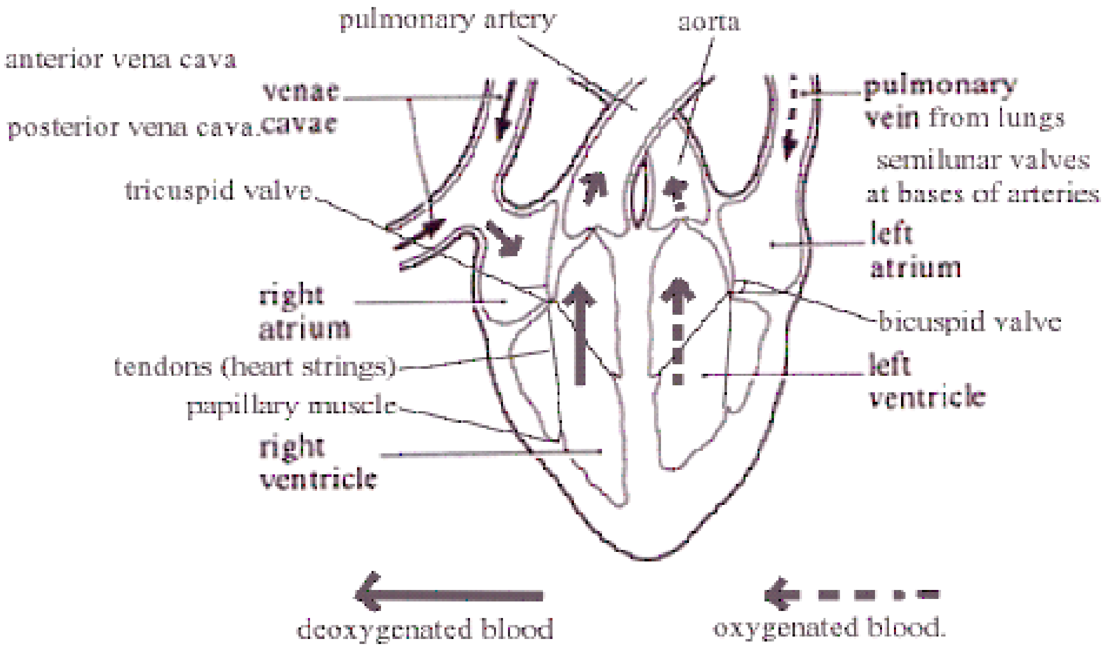
Structure of mammalian heart: The heart is enclosed in membrane called the pericardial membrane, which contain pericardial fluid between them. The wall of the heart is made up three distinct layers:

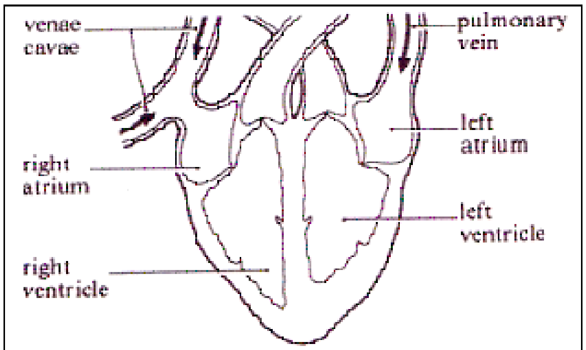
- The outer epicardium – consisting of flattened epithelial cells and supporting connective tissue.
- A thick layer of myocardium – consisting of cardiac muscles cells.
- An inner endocardium – made up of flattened epithelial cells and connective tissue.

The interior of the heart has 4 chambers: Two atria (upper chambers) and two ventricles (lower chambers). The atria receive blood from veins and pump it into ventricles. The ventricles pump blood away from the heart, into arteries. The walls of the left ventricles are much thicker as they have to exert a greater pressure to pump blood to all parts of the body. The right ventricles exert a much lower pressure as the lungs are close by and pulmonary tissues are very delicate.

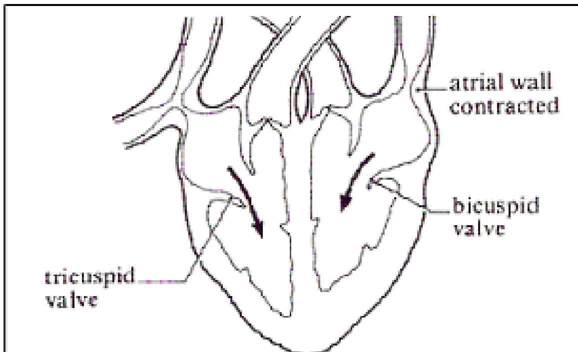
Semi-lunar valves present at the origin of the arteries prevent backflow of blood from arteries into ventricles.

Atria-ventricular valves prevent backflow of blood from ventricles to atria. The chordae tendinnae prevent the atria ventricle valves from flipping into the ventricles. The papillary muscles maintain the tension on the chordae tendinnae (refer to diagrams).

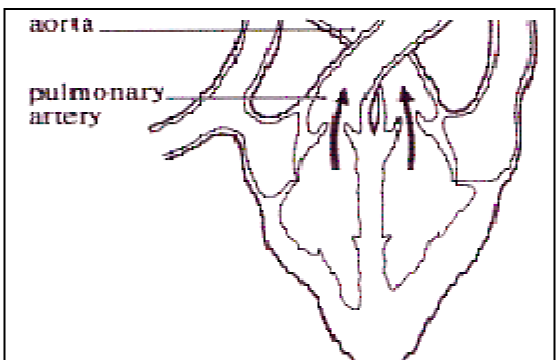




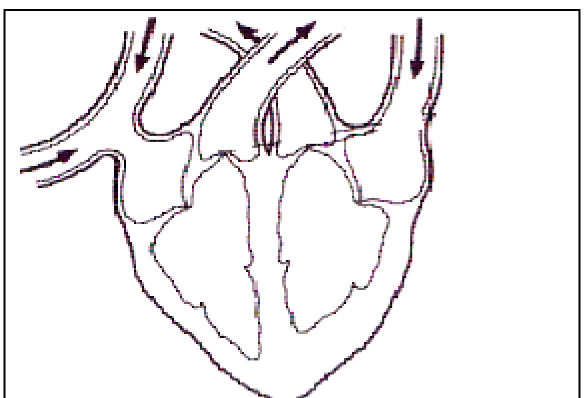
Atria in a state of diastole and filling with blood



Atrial systole forces blood into the ventricles. Bicuspid and tricuspid valves open



Atria relax, ventricles contract (systole). Blood propelled into aorta and pulmonary artery.



Complete diastole - all four chambers relax

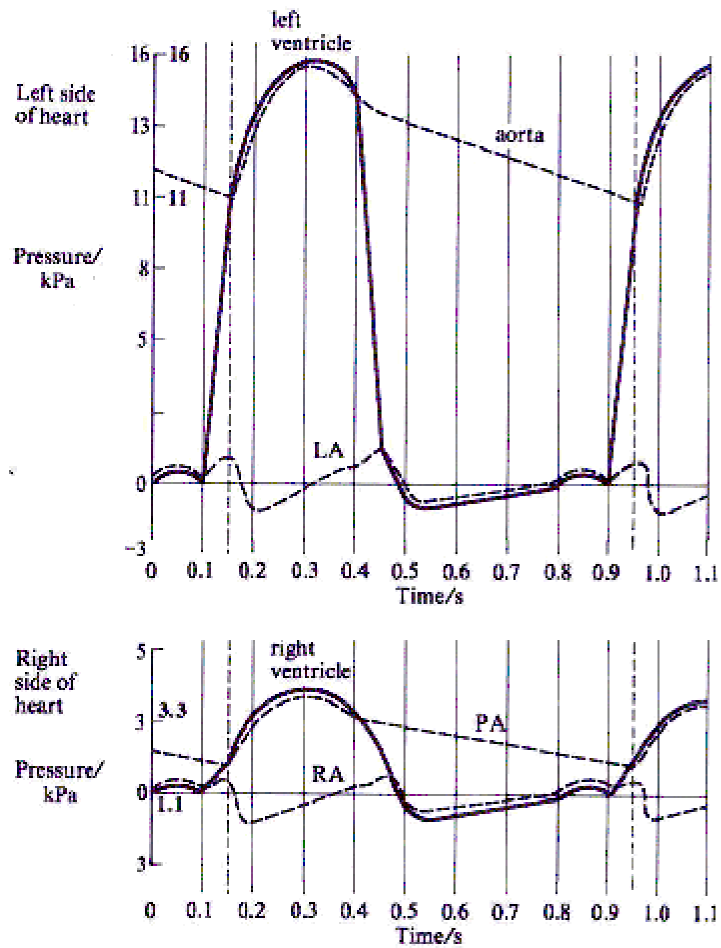
<u>Cardiac cycle</u>

23- Understand the cardiac cycle, myogenic stimulation; understand how the cardiac cycle is coordinated.

The cardiac cycle is the rhythmic contraction and relaxation of the atria and ventricles during one complete heartbeat.

The cardiac cycle can be divided in to 3 main stages:

1) **Atrial systole, ventricular diastole (0.13 sec)** – blood passes from atria to ventricles through atrio-ventricular valves.
2) **Ventricular systole, atrial diastole (0.3 sec)** – blood passes from ventricles into arteries through semi-lunar valves. Atria are being refilled.
3) **Complete diastole (0.4 sec)** – atria are being filled with blood from veins. Blood slowly oozes into ventricles from atria.
   - **OPENING and CLOSING of valves: The <u>semi-lunar valves</u> are <u>open</u> whenever pressure in the <u>ventricles</u> is <u>greater</u> than pressure in the arteries. At all other times semi-lunar valves are closed.**
   - **<u>Atria ventricular valves</u> are <u>open</u> whenever the pressure in <u>atria</u> is <u>greater</u> than pressure in <u>ventricles</u>. At all other times the atrio-ventricular valves are closed.**



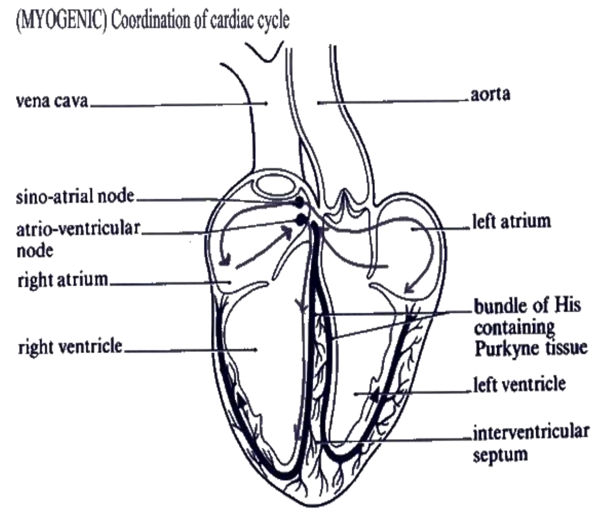
SYSTOLE means CONTRACTION

DIASTOLE means RELAXATION

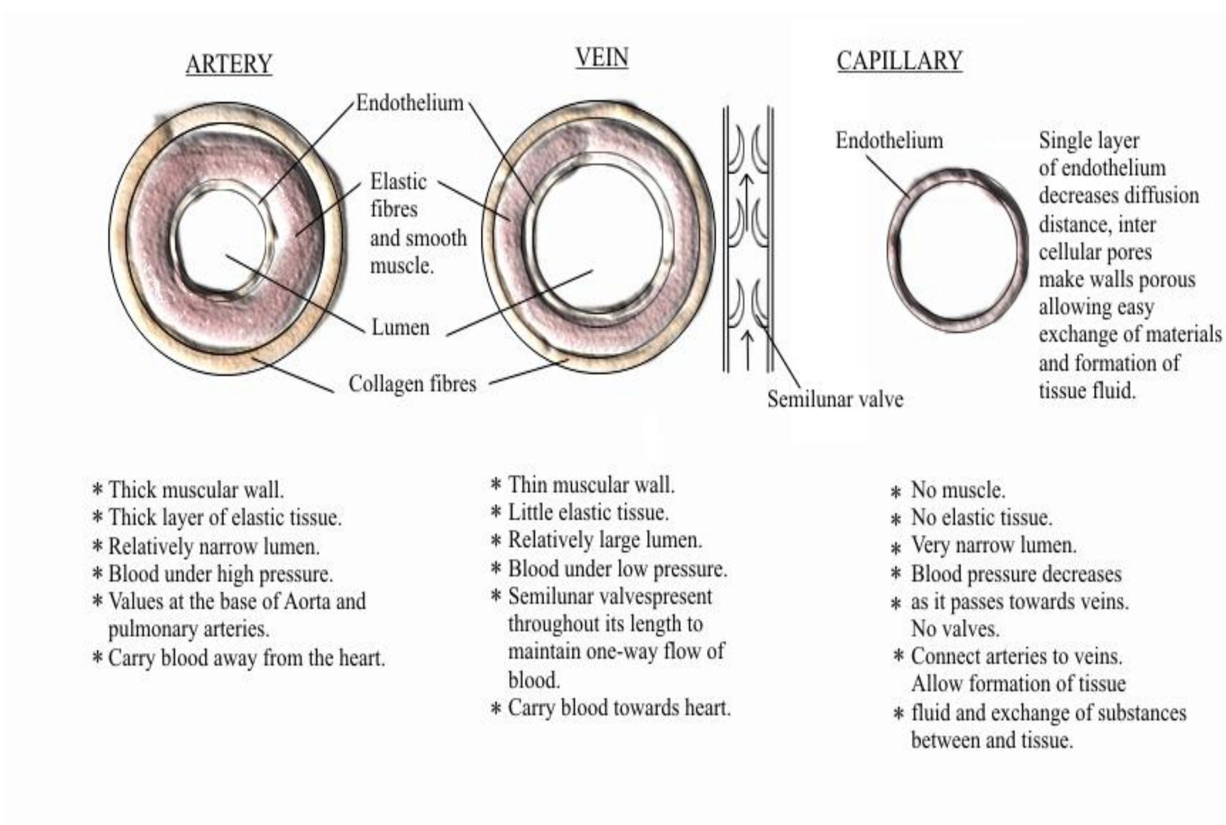
Myogenic stimulation of the cardiac cycle means that the stimulus for the contraction of cardiac muscles is generated within the heart itself (not generated by brain or spinal cord). This is evident from the fact that isolated cardiac muscle cells will continue to contract and relax rhythmically when placed in an isotonic solution, without any electrical stimulation. This indicates that cardiac muscles are self-excitatory (myogenic). However, the rate of heartbeat can be altered by the nervous system or hormones (like adrenaline).

Coordination of heartbeat (cardiac cycle)

The impulse for heart originates at the sino atrial node (SAN). This impulse (wave of excitation) spreads through the atrial muscles (intercalated discs of cardiac muscles enhance the transmission of excitation), causing atrial systole. The impulse is than taken up by the Atrio-Ventricular Node (AVN) and passed down to the apex of the heart, by the bundle of His. The wave of excitation then spreads into the ventricular walls (through the Purkinje fibres) causing ventricular systole. The lack of conducting tissue between SAN and AVN causes a time delay. So that ventricular systole begins only after completion of atrial systole.



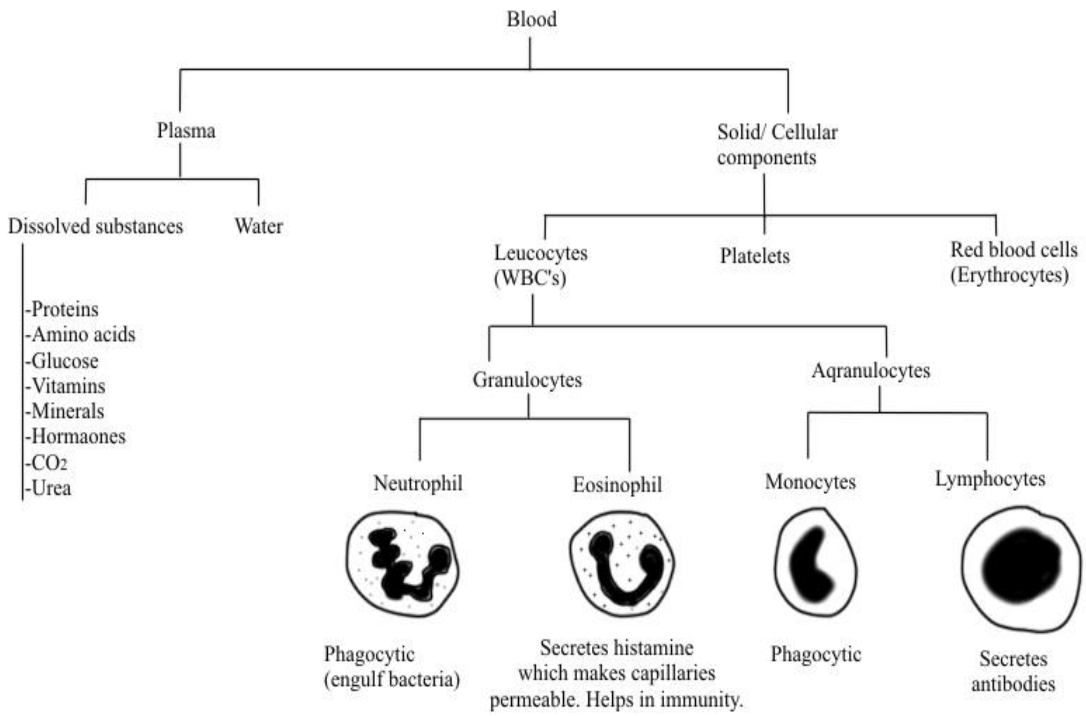
24- Describe the structure and roles of arteries, veins and capillaries;



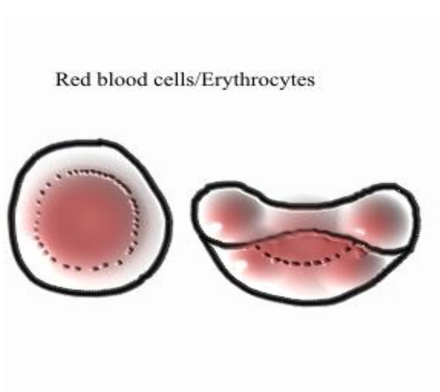
Blood and body fluid

25- describe the composition of blood as plasma and cells, to include erythrocytes and leucocytes (neutrophils, eosinophils, monocytes and lymphocytes):

27- understand the role of leucocytes in phagocytosis and secretion of antibodies;



describe the structure of erythrocytes and understand their role in transport



Red blood cells / erythrocytes are disc shaped biconcave cells, without a nucleus. The cells are filled with a red pigment called haemoglobin. The main function of haemoglobin is to carry oxygen. It also carries some amount of CO_2 , as carbamino-haemoglobin. Haemoglobin consists of 4 polypeptide chains: 2 alpha chains and 2 beta chains. Each chain is attached to a haem (iron containing) group, which can combine with one O_2 molecules.

$$Hb + 4O_2 \underset{\text{Low } O_2 \text{ pPr}}{\overset{\text{High } O_2 \text{ pPr}}{\rightleftarrows}} HbO_8$$

28- understand the transport of oxygen and carbon dioxide;

The shape of RBCs increases the surface area to volume ratio for exchange of respiratory gases. The lack of nucleus also enables the cells to pass through the narrow lumen of the capillaries.

Transport of oxygen: oxygen is carried from lungs to the body tissues in the form of oxyhaemoglobin. Hamemoglobin combines with O_2 in the lungs, where the O_2 partial pressure is high, to form oxyhaemoglobin. This is carried to the tissues, where the O_2 partial pressure is low $p(O_2)$ or high $p(CO_2)$, haemoglobin has a lower affinity for O_2. So oxyhaemoglobin dissociate to form oxygen and haemoglobin. The oxygen then diffuses into the tissues and is used for respiration.

(Loading of oxygen)

High p(oxygen)-in lungs

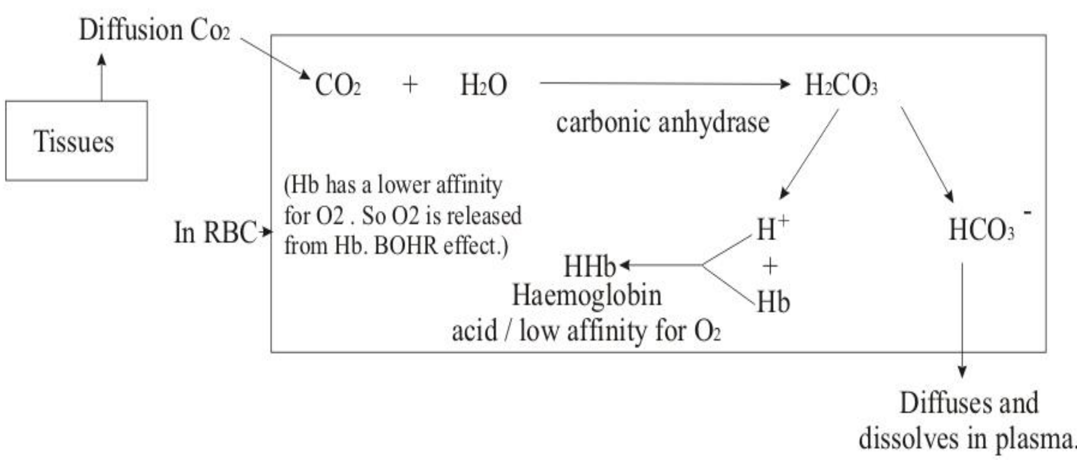
Haemoglobin + Oxygen ⟷ Oxyhaemoglobin

Low p(oxygen)-in tissue

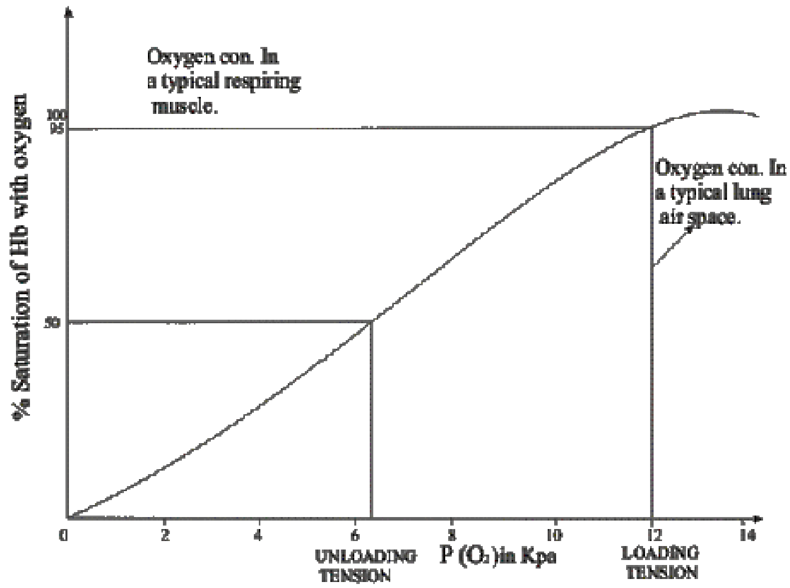
(Unloading of oxygen)

<u>Transport of carbon dioxide:</u>

- About 5% of CO_2 dissolves in plasma and is transported from tissues to lungs as molecular CO_2.
- About 10% of CO_2 combines with the amino group of haemoglobin to form carbamino-haemoglobin, which dissociates in lungs to release CO_2.
- About 85% of CO_2 is carried in the form of hydrogen carbonates, dissolved in the plasma.



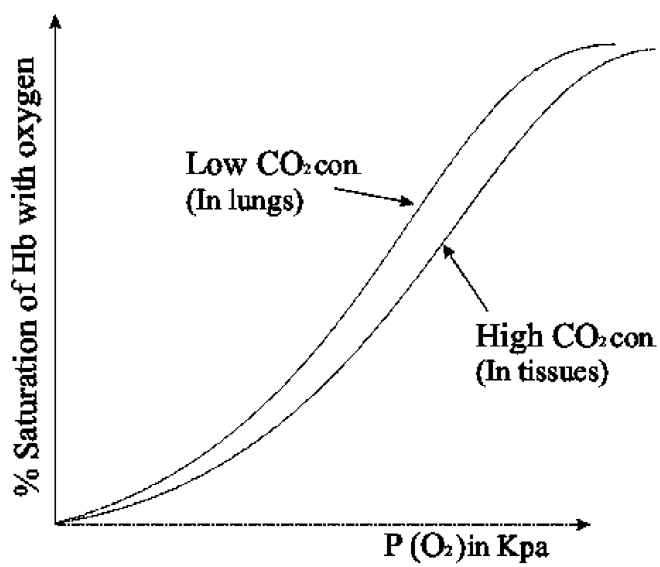
29- Understand and interpret dissociation curves of haemoglobin and the Bohr effect;



At low p(O_2), haemoglobin has a very low affinity for O_2 . So the slope has a very low gradient. At this time haemoglobin is combining with the first O_2 molecule (each haemoglobin can combine with $4O_2$ molecules). When the first O_2 molecule combines with haemoglobin, it causes the haemoglobin molecules to change shape (allosterism). This change in shape of the haemoglobin molecules makes it easier for the 2^{nd}, 3^{rd} and 4^{th} O_2 molecules to combine with haemoglobin, so the curve become steeper – until all the haemoglobin molecules are completely saturated. The steep part of the curve is very significant because it indicates that haemoglobin will release a lot of O_2 even for a small change in p(O_2). This allows Hb to release O_2 to tissues more rapidly.

- Loading tension – p(O_2) when Hb is 95% saturated
- Unloading tension – p(O_2) when Hb is 50% saturated (each Hb molecules is combined with $2O_2$ molecules).

BOHR EFFECT: the shifting of the O_2 dissociation curve to the right, due to increase in p(CO_2) (CO_2 concentration). This increases the loading and unloading tension, so that haemoglobin has a lower affinity for O_2 (refer to transport of CO_2). The result is that haemoglobin gives up O_2 more readily to tissue where CO_2 concentration is high, eg: in rapidly respiring tissues like liver and muscles.

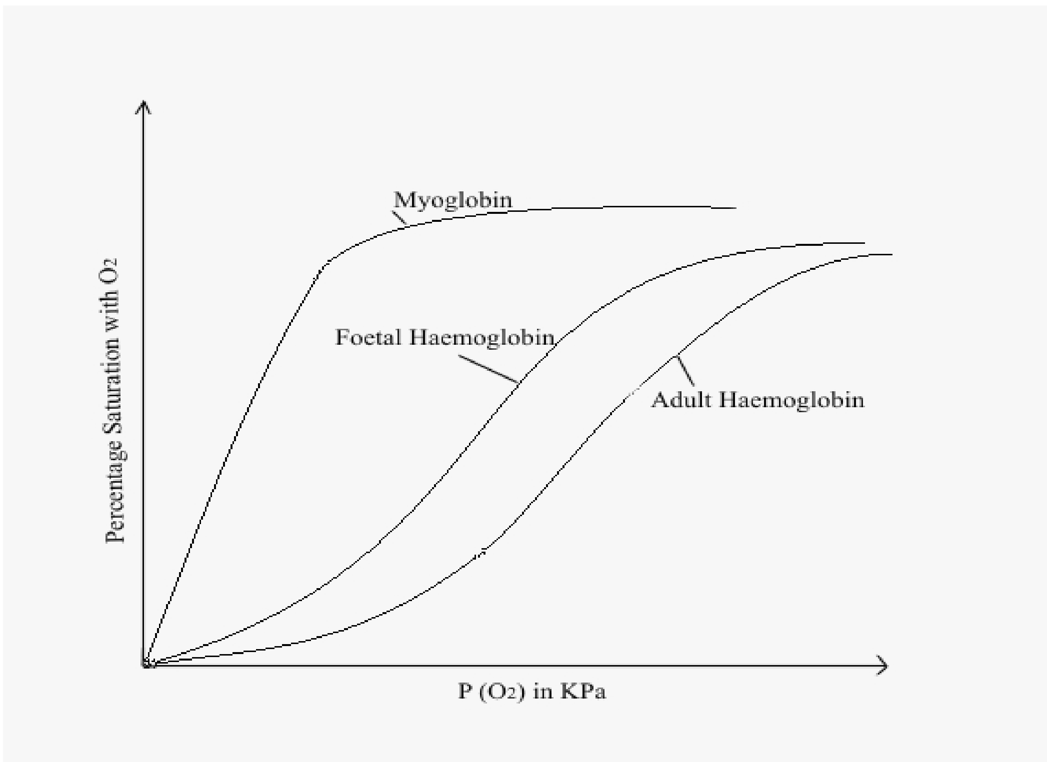


30- Describe the roles of respiratory pigments (haemoglobin, fetal haemoglobin and myoglobin): Understand and interpret dissociation curves of haemoglobin and the Bohr effect:

ROLES OF RESPIRATORY PIGMENTS

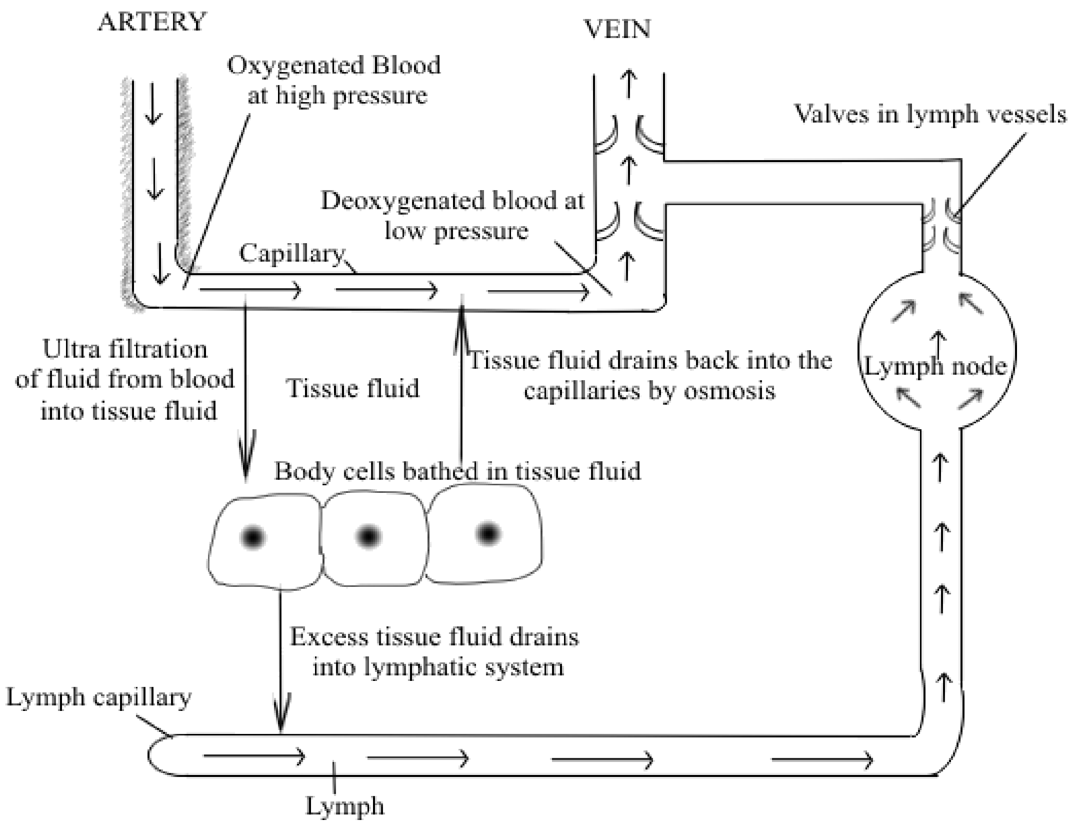
Respiratory pigments have the ability to combine with O_2 temporarily and release it to tissues for respiration, when O_2 concentrations are low.

Myoglobin is a respiratory pigment which stores oxygen in the muscles. It is made up of a single polypeptide chain associated with one Haem (iron containing) group. It has a very high affinity of oxygen. It can take up oxygen released by hemoglobin in tissues, and store this oxygen in the form of oxy-myoglobin. When $p(O_2)$ is very low then O_2 can be released to continue aerobic respiration. eg; during exercise. Foetal hemoglobin also has a greater affinity for oxygen, compared to adult hemoglobin. This allows fetal hemoglobin to take up O_2 more readily than maternal hemoglobin at any given $p(O_2)$. This ensures that the fetus can get a continuous supply of O_2 from maternal blood in the placenta.



31- Describe the interchange of materials between capillaries and tissue fluid, including the formation and reabsorption of tissue fluid.

Tissue fluid is a transport medium between blood in the capillaries and tissues. It carries O_2, H_2O and nutrients from capillaries to tissues, water, salts, CO_2 and other wastes flow back from tissue to capillaries. These substances can pass from capillaries to tissue fluid and vice versa by ultrafiltration osmosis, diffusion etc.



FORMATION AND REABSORPTION OF TISSUE FLUID

Tissue fluid is formed from blood at the arterial end of the capillaries. The high blood pressure, thin and porous walls of the capillaries causes the liquid component of blood (except large proteins) to be squeezed out of the capillaries.

The tissue fluid (about 85%) is reabsorbed at the venous ends of the capillaries mainly by osmosis. Solutes move along the Pressure gradient caused by difference in water potential between the inside and outside of the capillaries. The remaining 15% of tissue fluid is collected by lymph vessels / capillaries which pour tissue fluid/lymph back into the veins.

Oedema is the accumulation of tissue fluid, causing swelling. This may occur due to;

1. Blockage of lymph vessels
2. Increased permeability of capillaries
3. Increased in blood pressure
4. Lack of proteins in the plasma.

32- Understand that species are adapted to survive in particular environmental conditions.
33- Understand the relationship of the external features of the organisms to the physical characteristics of a specific habitat.
34- Describe the xeromorphic adaptations in flowering plants; hydrophytes.

Every species has special adaptations to enable it to survive in particular environmental conditions. e.g.; polar bears have thick layers of adipose tissue (fats), which keeps them warm during the cold arctic winter. Camels are specially adapted to survive in the deserts. The long loop of Henle, broad flat feet and specialized metabolism which enables them to make use of metabolic water, etc. helps them to survive hot dry desert climates. The physical characteristics of a specific habitat influence the external features of organisms. e.g. Bottom dwelling fishes are dorso-ventrally flattened and the mouth is present on the ventral surface. Pine trees have needles to prevent snow from accumulating on leaves. Butterflies with sucking mouth parts to suck nectar from flowers, fore limbs of dolphin's modified into flippers, beaks in birds to suit different feeding habits -hooked in carnivores birds, long beaks in fishing birds, etc.

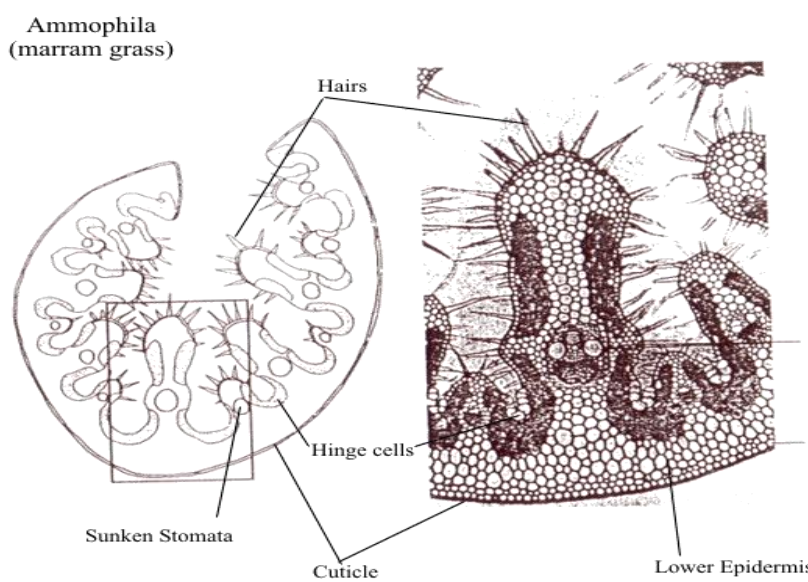
XEROMORPHIC ADAPTATIONS IN FLOWERING PLANTS

Xerophytes are plants which have special adaptations to survive in dry / desert climates, where water is scarce. The adaptations they possess are called xeromorphic adaptations. These plants have special adaptations to;

- Reduce transpiration rate
- store water (succulents)
- Resist desiccation.

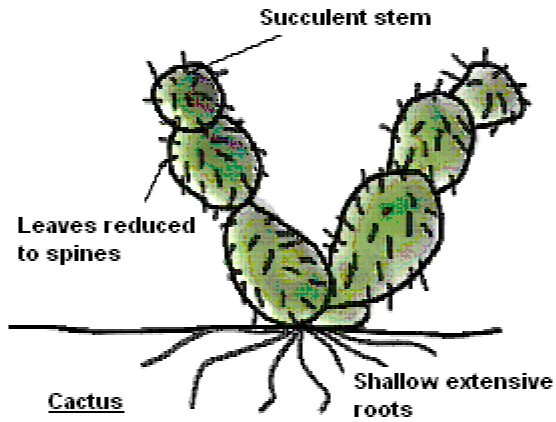
Some features that help to reduce transpiration rate are;

- Thick cuticle reduces cuticular transpiration. Eg. Heather(Erica) and Holly (Ilex)
- Rolling of leaves - Traps moist air within the leaf, decreasing the rate of diffusion of water vapour. Hinge cells dry up rapidly, contract and cause rolling of leaves. eg; Ammophilia (marram grass).
- Layers of protective hairs on leaf (pubescence) -Traps moist air, increasing the diffusion path, so reducing transpiration. eg; marram grass.
- Depression of stomata (in sunken pits) - lengthens the diffusion path by trapping still, moist air above the stomata, so reducing transpiration. eg; Holly



- Reduction in number / absence of leaves limits water loss to the stem, which has fewer stomata .These stems are flattened and green, so that they can photosynthesise. eg; most cacti (opuntia.) leaves may be reduced into spines.

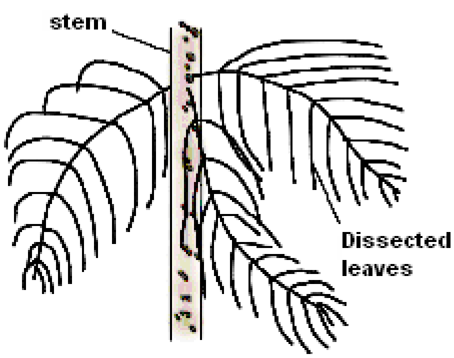
- Shedding of leaves in times of water scarcity .eg; deciduous plants shed leaves in winter.
- Succulence - The ability of plants to absorb water rapidly when it is available and store it for use in periods of drought (water scarcity). The water is taken up by a shallow but extensive root system, allowing efficient absorption when the soil is moist. The 15m high American cactus can take up 2 tonnes of water in a single day following a storm. This is stored in the fleshy (succulent) stem,
- Resistance to desiccation - reduction of transpiration surface through loss or reduction of leaves. eg. deciduous plants and cacti.

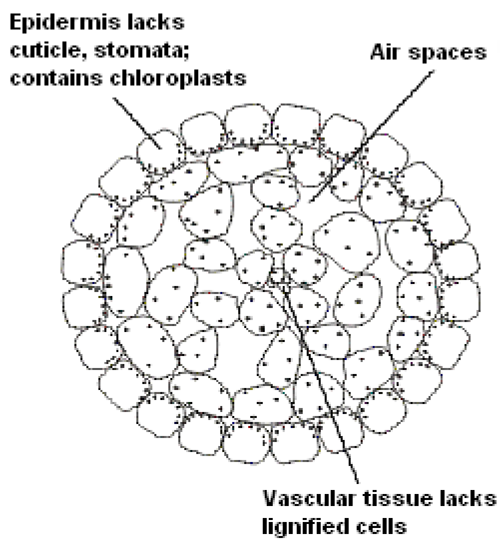


Hydrophytes are plants which are specially adapted to grow in places where water is freely available (aquatic plants). They may be:

01- Completely submerged. ***E.g.:*** *Canadian* pondweed (Elodea), Milfoil (MyriophyIlum).

02-partially submerged. ***Eg:*** *Water* lilies (Nymphaea) and water crowfoot (Ranunculus).





<u>Some special adaptations of completely submerged hydrophytes are;</u>

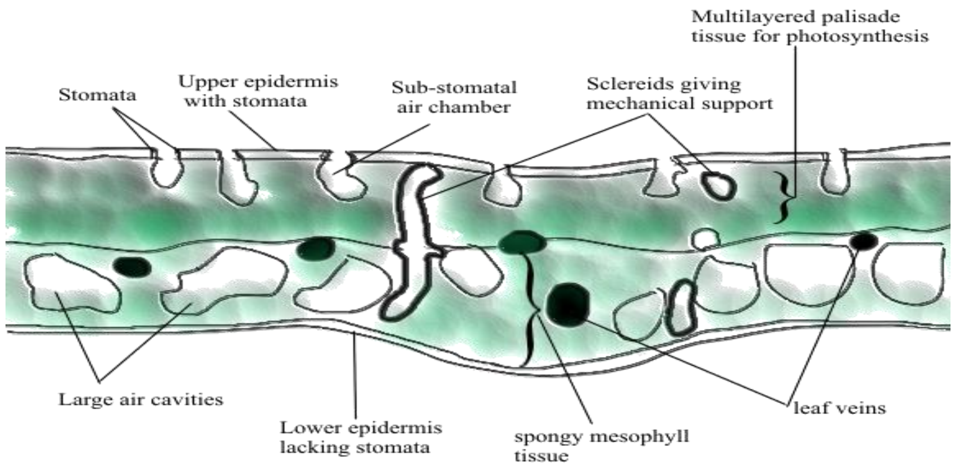
- No cuticle - to allow efficient gas exchange.
- No stomata - so that gases cannot escape. The gases remain trapped in leaves, contributing to buoyancy and storage of gases, which is scarce.
- Small leaves / dissected lamina reduce the resistance to flow of water, which would otherwise damage the leaves. Also increases surface area to volume ratio for gas exchange by diffusion.
- Air spaces store gases for respiration and photosynthesis. They also provide buoyancy to keep leaves near the surface, to absorb maximum sunlight for photosynthesis.
- Reduced root system - as the plant absorbs water and minerals from its body surface. Also because anchorage is not important.
- Reduced vascular and supporting tissues - as water provides buoyancy there is no need for supporting tissues. Moreover, rigid stems and leaves would offer more resistance to water

movement, increasing the chances of damage.

<u>Special adaptations in partially submerged plants are</u>;

- Stomata on upper surface, not on lower surface to increase rate of gas exchange
- Thick palisade mesophyll layer to absorb maximum light for photosynthesis.
- Elongated lignified cells (sclereids) prevent leaf from rolling up, so that it can absorb maximum sunlight for photosynthesis.

Partially submerged leaf(lily)

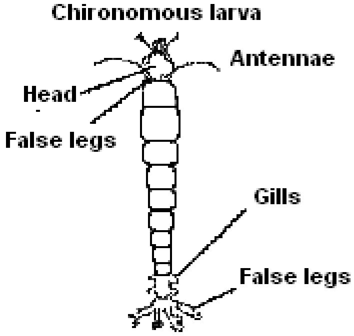


35. Describe the structural and physiological adaptations shown by invertebrates to the varying oxygen concentrations found in fresh water;

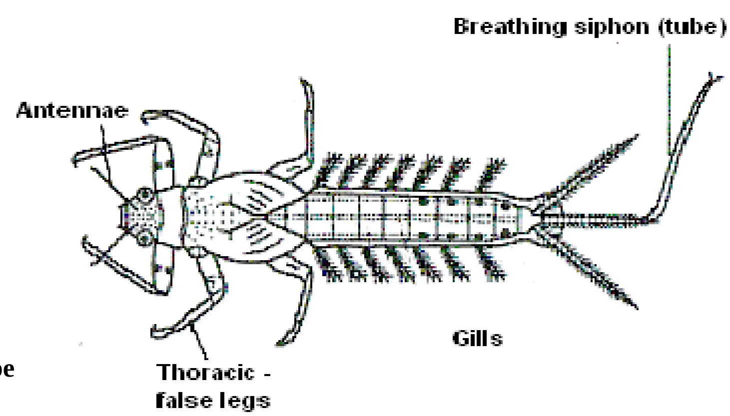
36. Describe specific examples of features to include external gills, direct access to air, and presence of respiratory pigments.

Some factors which affect the oxygen concentration of water are;
Turbulence (water movement.), temperature, photosynthesis, Biochemical oxygen demand (BOD). Moreover O_2 has a low solubility in water. Thus, the O_2 concentration of water is usually low and variable. Some features that help aquatic invertebrates to cope with varying O_2 concentrations in frehwater habitats are:

Chironomous larva

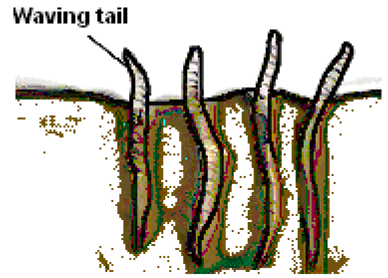


- Large surface area to volume ratio (small size): Increases surface area and decreases diffusion distance for more rapid exchange of gases by diffusion. eg; Amoeba, chironomous larva.
- Have flattened bodies: lowers diffusion distance so that O_2 absorbed from the surface can rapidly reach all parts of the body. e.g.; planaria (flatworms).



- Presence of Tracheal gills: these are outgrowth of the tracheal system in aquatic insects/larvae. They increase the surface area for O_2 absorption by diffusion. eg ; chironomous larva, midgefly larva, caddis fly larva.

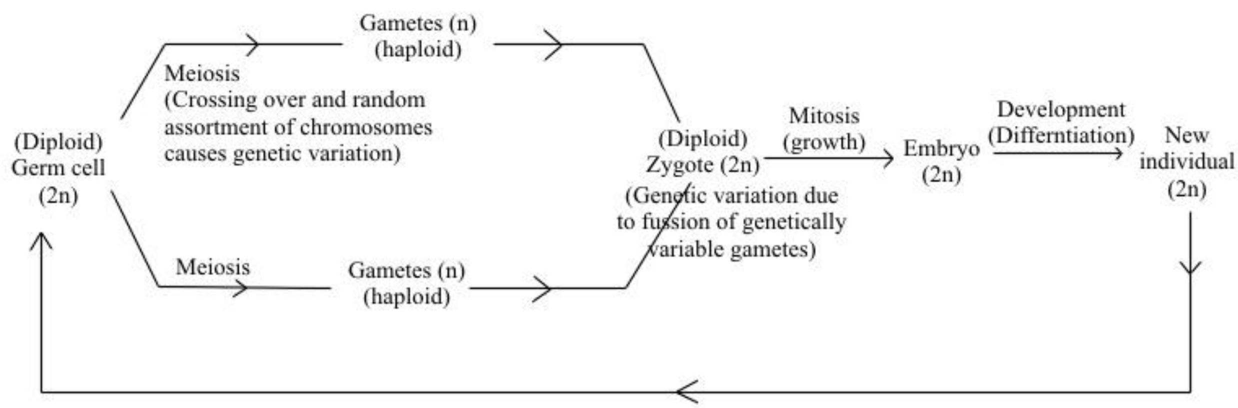
- Presence of breathing tubes/siphons; these are tubes which are used for breathing air. They protrude out of the water surface. The open end of the tube has hair like processes which prevent entry of water (water logging). eg; Rat tailed maggot, Gnat larva
- Waving of tails: This helps to maintain a concentration gradient, increasing rate of gas exchange. eg; Tubifex worms, chironomous larva.

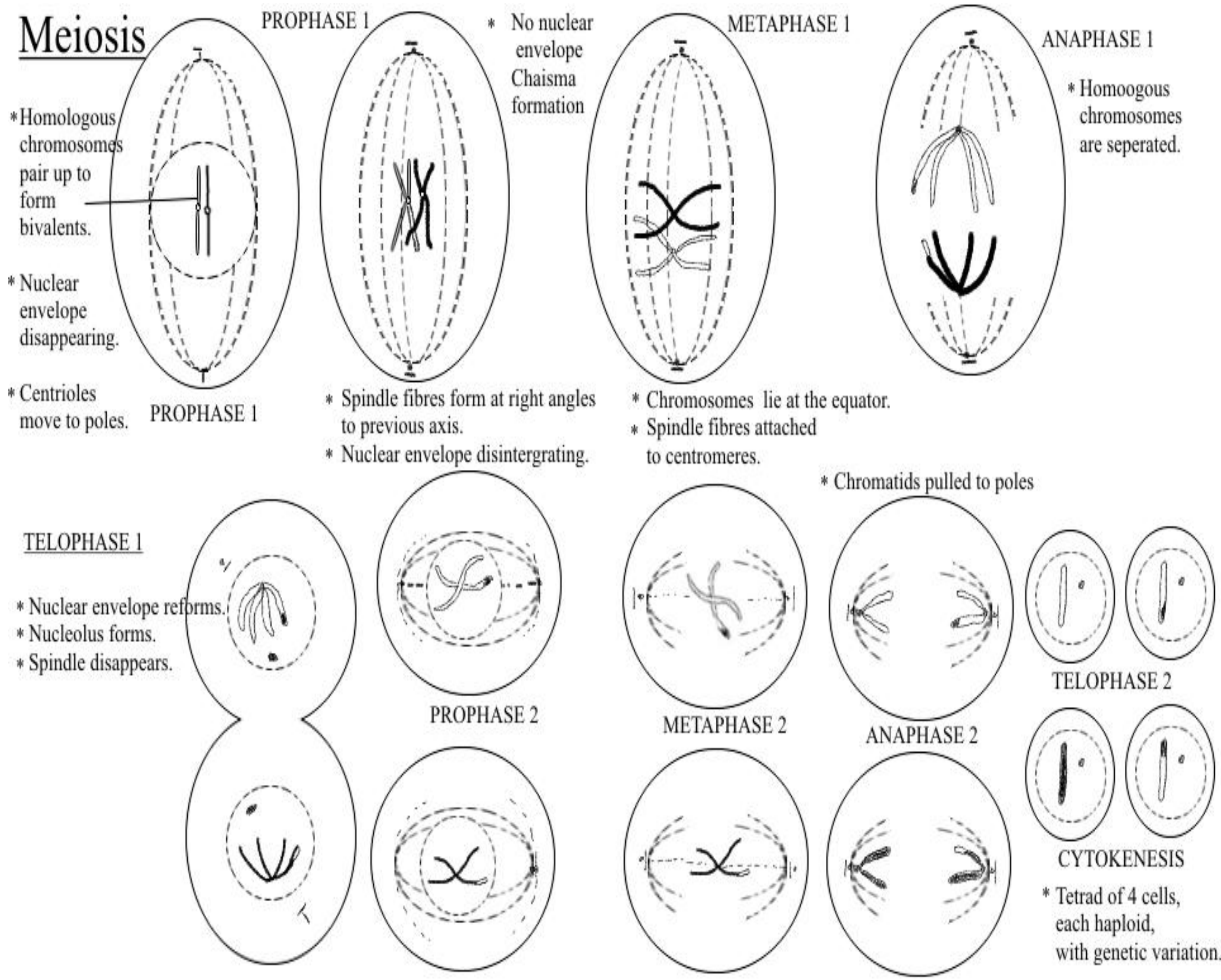


Partially buried tubifex worms in soil at the bottom of aquatic habitats

- Presence of respiratory pigments: Hemoglobin may be present which absorbs oxygen at very low $P(O_2)$. e.g.; Tubifex worms and chironomous larva. This enables these organisms to survive in very low oxygen concentration, making them good indicators of organic pollution. Refer to indicator species in unit 3.
- Some insects trap air bubbles below the abdomen before going underwater.eg; water beetle, water boatman.
- Presence of lungs: some molluscs (snails) can store air in the mantle cavity, which serves as a lung. These organisms have to come to the surface to breath air. eg; planorbis (has heamoglobin), limnea (no heamoglobin),

37. Know that offspring result from the fusion of gametes, forming a zygote; understand that this fusion of gametes leads to gamete variation in offspring.
38. Recall that gamete formation involves a reduction division (meiosis) and understand its significance as the division of a diploid nucleus to give haploid nuclei: understand the behaviour of chromosomes during the first and second division of meiosis including chiasmata formation (names and details of stages of prophase are not required).
39. Understand that haploid and diploid phases occur in the lifecycles of organisms.

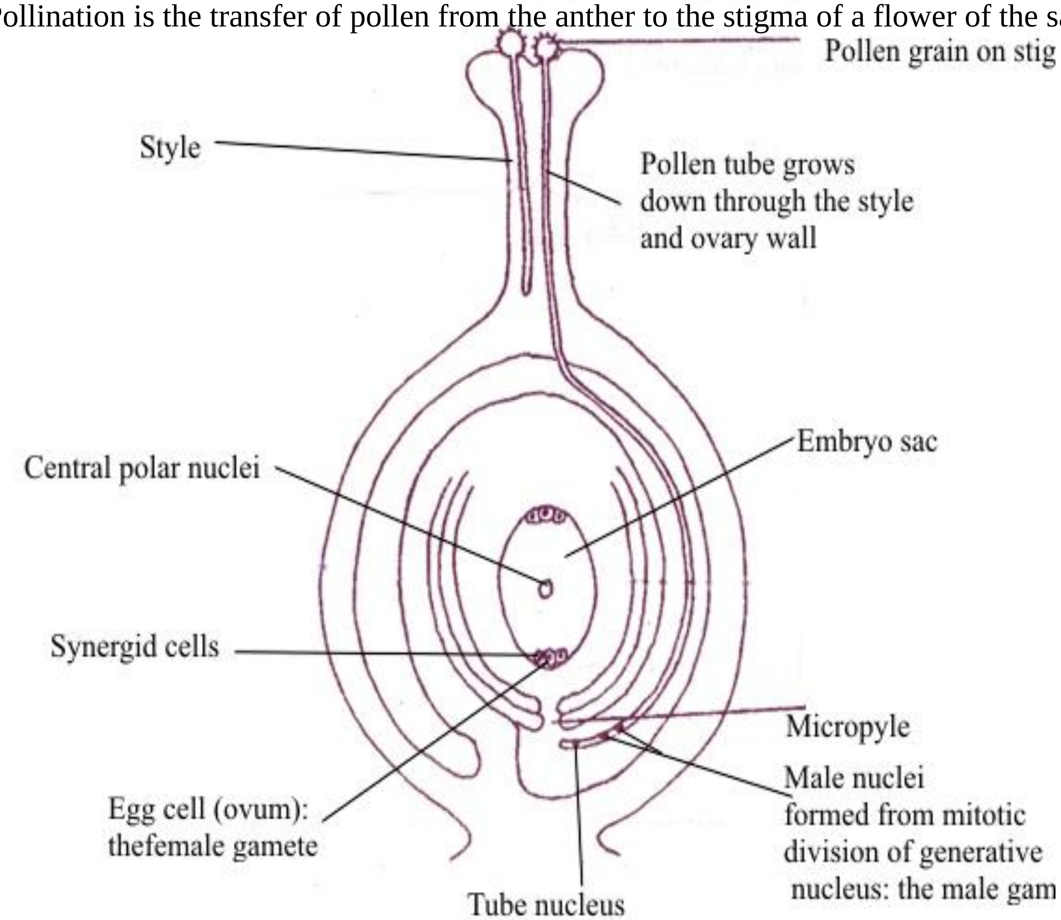



Meiosis
*Homologous chromosomes pair up to form bivalents.
* Nuclear envelope disappearing.
* Centrioles move to poles.
PROPHASE 1
PROPHASE 1
* No nuclear envelope Chaisma formation
* Spindle fibres form at right angles to previous axis.
* Nuclear envelope disintergrating.
METAPHASE 1
* Chromosomes lie at the equator.
* Spindle fibres attached to centromeres.
ANAPHASE 1
* Homoogous chromosomes are seperated.
* Chromatids pulled to poles
TELOPHASE 1
* Nuclear envelope reforms.
* Nucleolus forms.
* Spindle disappears.
PROPHASE 2
METAPHASE 2
ANAPHASE 2
TELOPHASE 2
CYTOKENESIS
* Tetrad of 4 cells, each haploid, with genetic variation.

40. Describe the structure and functions of the principal parts of an insect-pollinated dicotyledonous flower and a grass.
41. Describe pollination and the events leading to fertilization, understand the adaptations related to insect and wind pollination.

<u>POLLINATION AND FERTILIZATION</u>

Pollination is the transfer of pollen from the anther to the stigma of a flower of the same species.

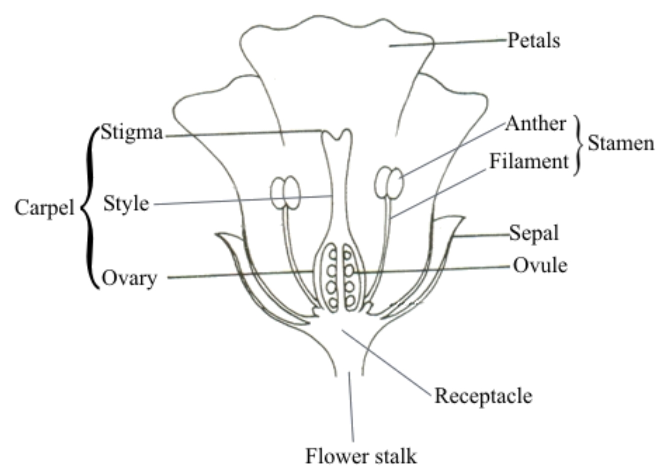


<u>SELF POLLINATION</u>

It is the transfer of pollen from the anther of a flower to the stigma of the same flower or to the stigma of another flower on the same plant. e.g.; Garden pea

<u>CROSS POLLINATION</u>

It is the transfer of pollen from the anther of a flower on another plant of the same species. e.g.; Willow, Holly, Poplar.



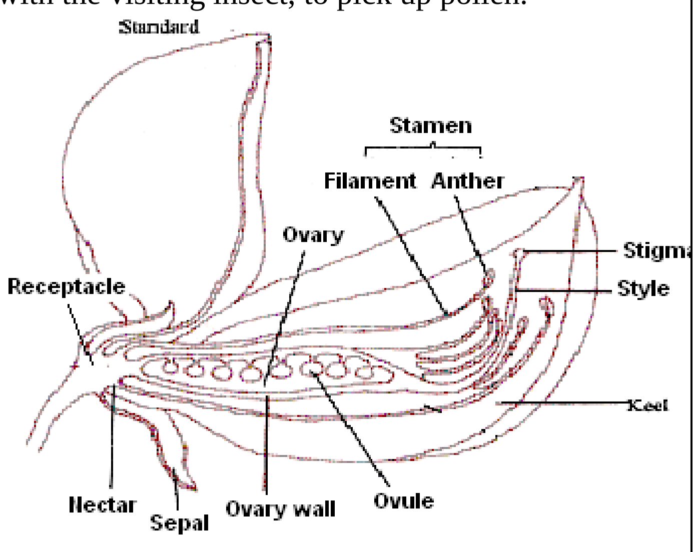
- After pollination the epidermal cells of the stigma secrete sucrose solution, which stimulates growth of the pollen tube. The pollen tube penetrates the tissues of the style to reach the micropyle. The pollen tube has two main functions;

1 It delivers the male nucleus (gamete) from pollen grains into the embryo sac (where female gamete is present), so that fertilization can occur.
2 Pollen tube secretes auxins which stimulates development of ovary into fruits.

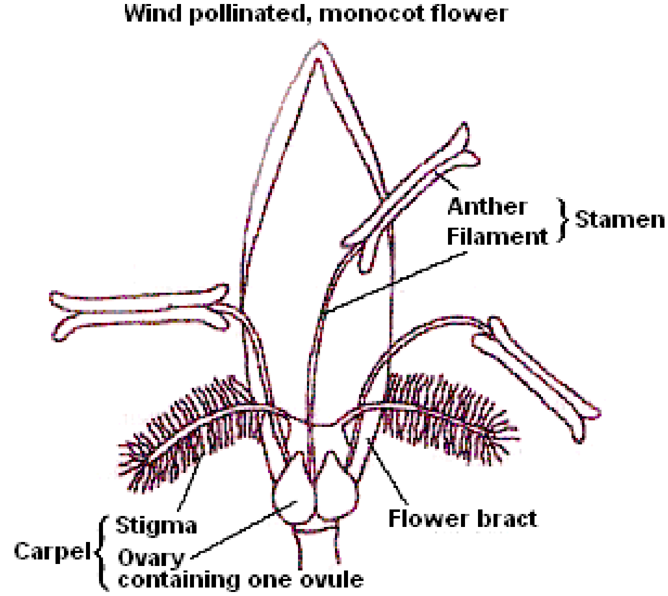
- The growth of pollen tube into the embryo sac is controlled by enzymes, secreted by the tube nucleus. These enzymes soften middle lamella between style cells. Moreover, the pollen tube is negatively aero tropic, positively hydrotropic and positively chemotropic to chemicals secreted by the micropyle.
- The pollen tube contains 3nuclei_1 tube nucleus and 2 male nuclei.
- When pollen tube enters the embryo sac through the micropyle, the tube nucleus degenerate. one male nucleus(n) fuses with egg cell nucleus(n) to form a diploid zygote.(2n).The other male nucleus (n) combines with the two polar nuclei(2n) to form a triploid (3n) endosperm nucleus. This is called double fertilization.

ADAPTATIONS IN WIND AND INSECT POLLINATED FLOWERS

INSECT POLLINATED FLOWER	WIND POLLINATED FLOWER
01-large, brightly coloured petals to attract insects and act as a platform.	01-petals are small, if present not brightly coloured.
02-Nectaries produce sweet, scented nectar, which insects feed upon.	02-Nectaries absent.
03_Stamens enclosed within the flower, usually in a position to transfer pollen onto the body of a visiting insect.	03_Stamens hang out of the flower (pendulous) to disperse pollen into the wind. Anthers are usually large to produce large quantities of pollen.
04_larger pollen grains, with sculptured walls to help it attach to body of insect. Fewer pollen produced as chances of pollination are more. 05_stigma is small and enclosed within the flower. Positioned in such a way that it comes into contact with the visiting insect, to pick up pollen.	04_ Small, light, smooth pollen grains to be easily carried by wind. large number of pollen are produced to increase chances of pollination. 05_Long, feathery, branched stigma hanging out of the flower to trap pollen from the wind.



Wind pollinated, monocot flower



42. Describe and appreciate the significance of the mechanisms for ensuring cross-pollination; protandry, protogyny and dioecious plants.

Cross pollination increases genetic variation in the species, because it involves genetic material from two different parent plants. The increased genetic variation increases the chances of survival of the species. Plants have developed certain mechanisms to prevent self pollination and favours cross pollination.

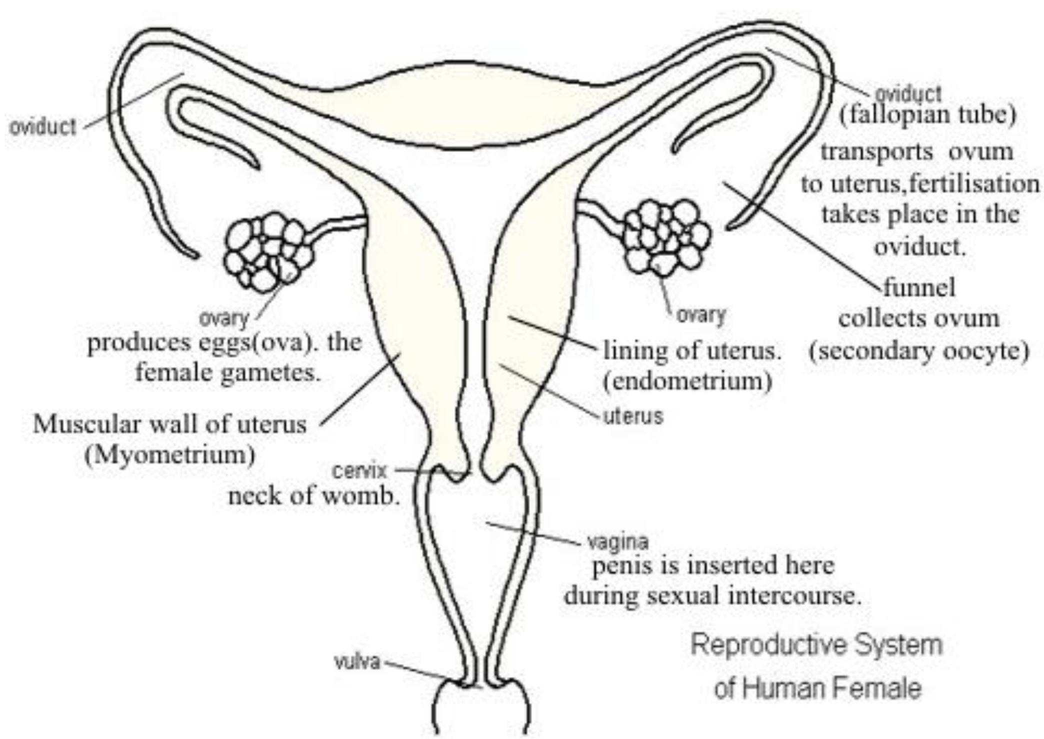
1_Dioecious plants; these plants have male and female flowers on different plants, so self pollination is impossible .e.g.; Poplar, Willow, Holly

2 Dichogamy_; Male and female parts of the flower mature at different times.

A_ Protandry; The stamens ripen before carpel's become mature so that the stigmas of the flower are not receptive to pollen. e.g.; sage, white nettle

B_Protogyny; The carpels mature before the stamens, so the stigma of the flower is receptive to pollen before the anthers dehiscise(rupture). e.g.; bluebell, wild aram.

43. Describe the structure and functions of the male and female reproductive systems.

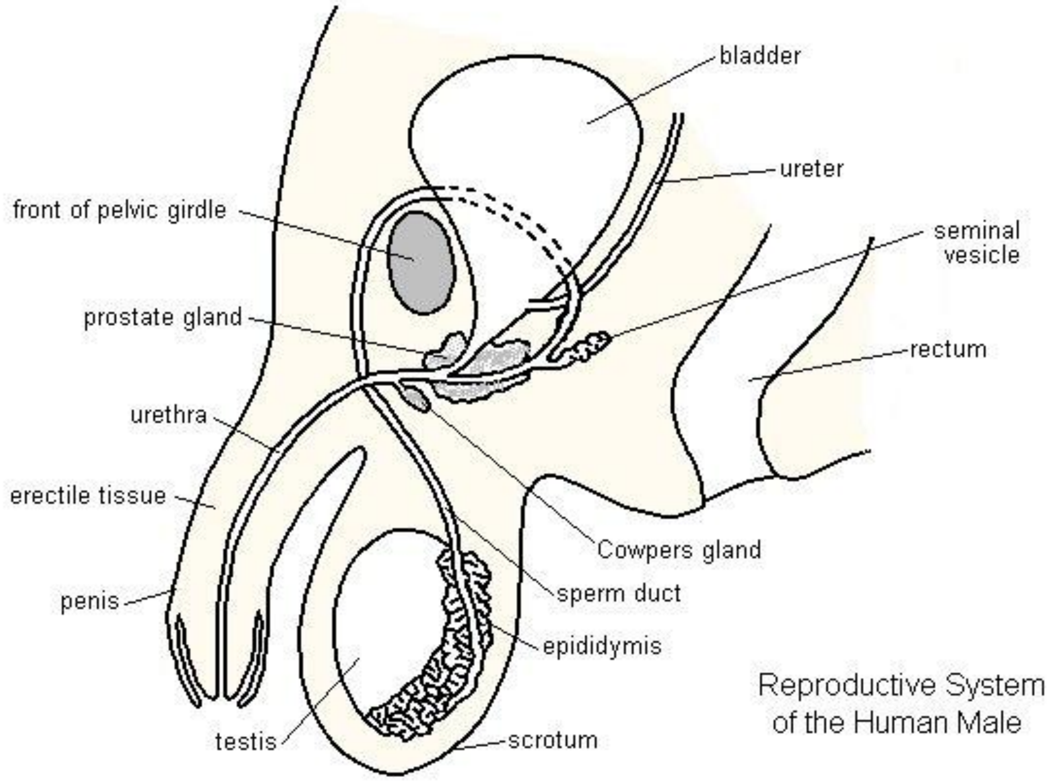


Reproductive System of Human Female

Ovary- also produces oestrogen and progesterone.

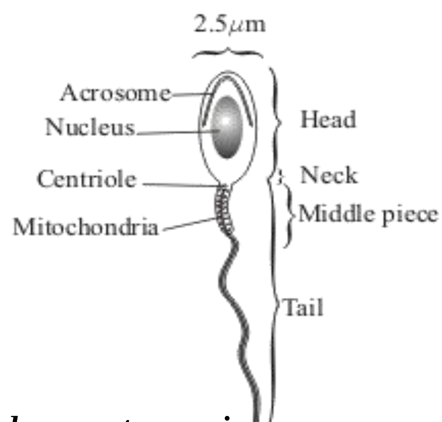
Myometrium - contracts to push foetus out during child birth.

Endometrium - helps to form placenta/ implantation.

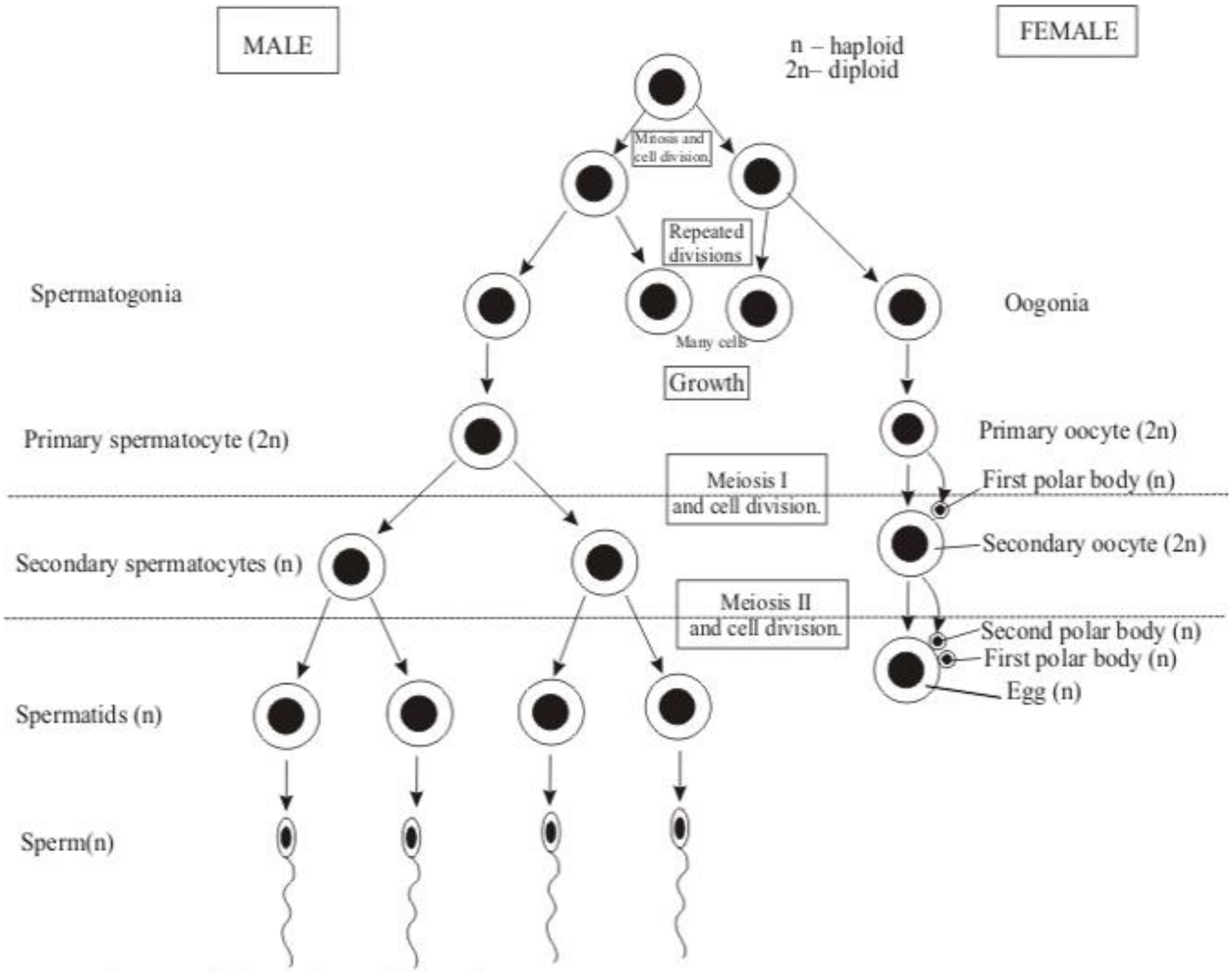


- Testis – produces sperm and male sex hormone – testosterone.
- Scrotum – regulates testis temperature.
- Epididymis – stores sperm.
- Vasdeferens – transfers sperms from epididymis to urethra.
- Cowper's, prostate, seminal vesicle- produces seminal fluid for lubrication during copulation, provides an alkaline medium for sperms to swim and obtain nourishment.
- Penis – transfers sperms to vagina.
- Urethra – common passage for sperm and urine.

Sperm cell



44. Describe the production of the gametes in oogenesis and spermatogenesis.



gametogenesis in male and female.

Differences between spermatogenesis and oogenesis

Spermatogenesis(seminiferous tubule of testis)	Oogenesis (In ovary)
1) Continuous process	1)Cyclic process
2) Begins at puberty	2)Begins in fetus
3) No polar bodies are formed.	3)Polar bodies are formed
4) Meiosis I is immediately followed by meiosis II	4) Meiosis II is completed only after attachment of sperm to secondary oocyte
5)Four spermatozoa are produced from one primary spermatocyte	5) One mature ovum is formed from one primary oocyte.

45. Recall the events in the menstrual cycle; understand the roles of luteinising hormone, follicle – stimulating hormone, oestrogen , progesterone.

1) **FSH**: Initial increase stimulates development of follicles and induces follicle cells to produce oestrogen. (Level then decreases because low levels of oestrogen in blood inhibits FSH secretion.)

Second surge/peak in FSH level is caused by high level of oestrogen. This time FSH triggers ovulation.

2) LH (Leutinizing Hormone): LH level increases due to increase in oestrogen.

<u>Function:</u> Induces ovulation and formation of the corpus luteum.

3) Oetrogen: Initial increase due to development of follicles. Second increase due to secretion from corpus luteum.

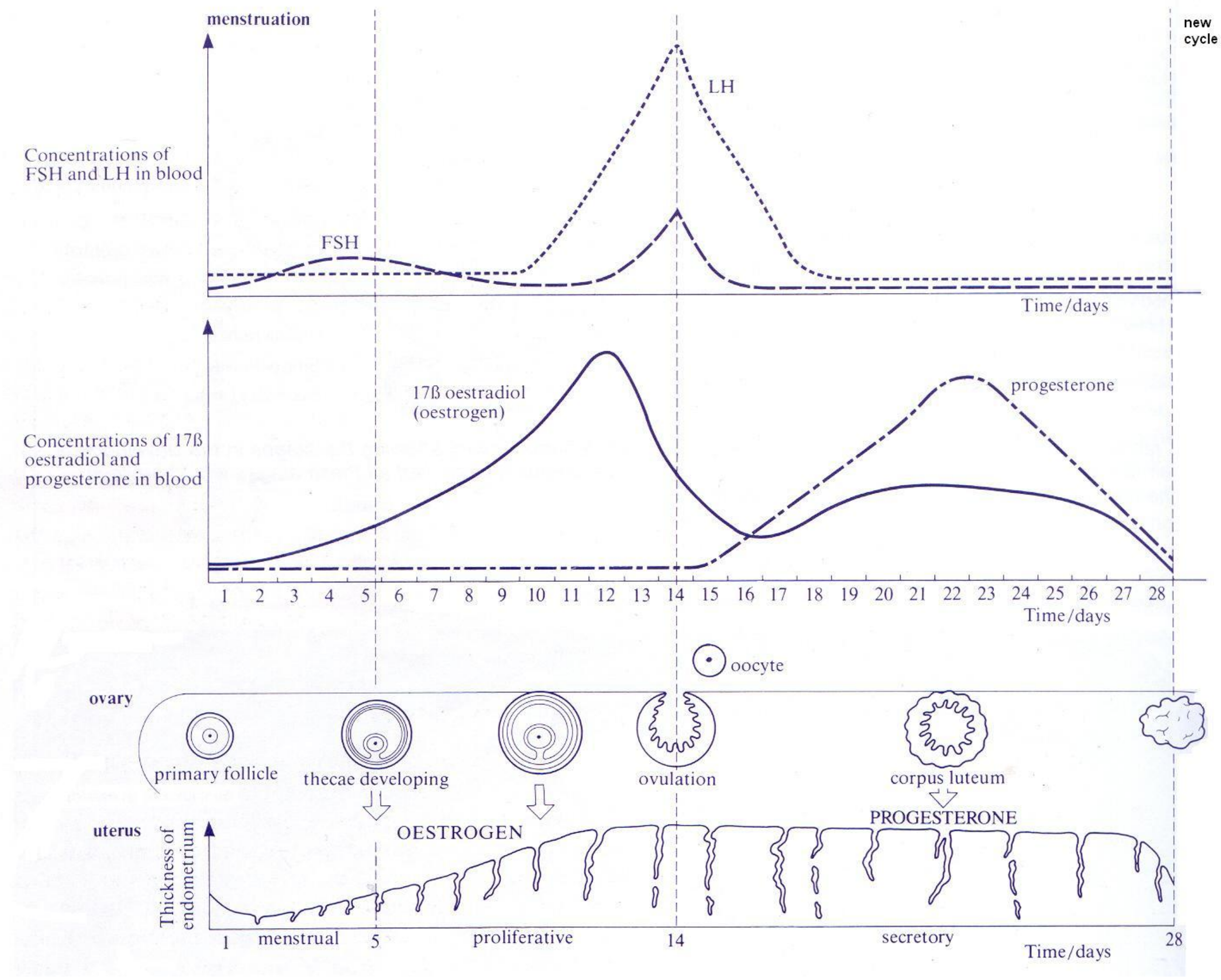
<u>Function:</u> Inhibits FSH secretion at low concentration stimulates FSH and LH secretion at high concentration.

- Repair of endometrial wall.

4) Progestrone: increases as corpus luteum forms as it is secreted by corpus luteum. Decreases when as it is secreted by corpus luteum. Decreases when corpus luteum degenetrates.

- Inhibits LH and FSH.

Function; Maintains thickness of endometrium.

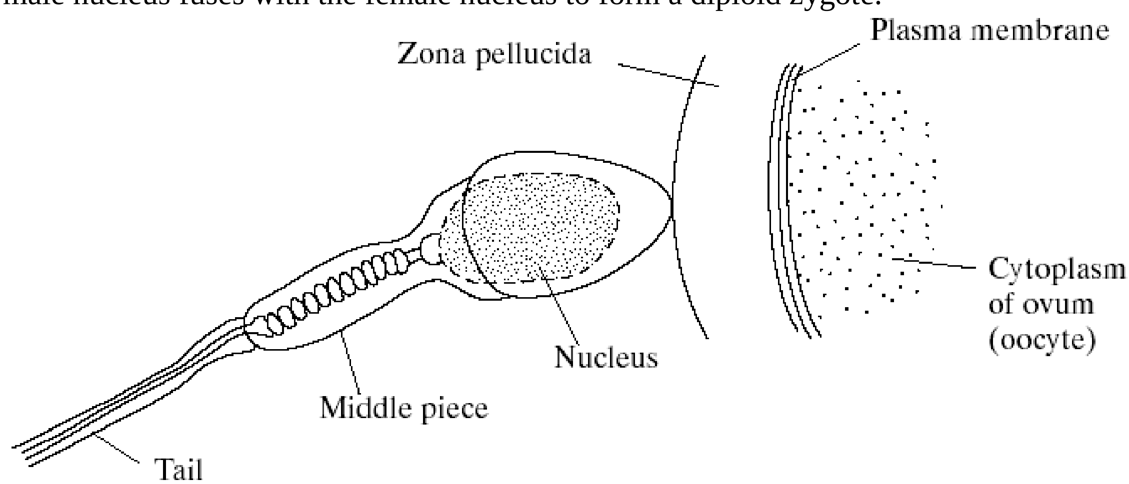


46. Describe the transfer of male gametes leading to fertilization.

The semen is deposited at the cervix during copulation. The sperms then use their flagella to swim through the cervix and up through the uterus to the oviducts. The alkaline semen provides an alkaline medium for the sperms to swim. It also contains hormones called prostaglandins which stimulate contraction of the uterus and oviducts to assist movement of the sperms. Out of the few millions of sperms, only a few hundred reach the oviduct and come into contact with the secondary oocyte, If ovulation has occurred recently. The secondary oocyte can remain viable for 24 hours; the sperms can remain viable up to 2 days.

- The secondary oocyte is surrounded by follicle cells and a clear membrane called the zona pellucida. Proteases from the Acrosomes of many sperms hydrolyse a pathway through the follicle cells and zone pellucida.
- Eventually one sperm succeeds in passing through the outer layer and penetrating/fusing with the cell surface membrane of the secondary oocyte. Immediately the cortical granules (lysosomes) rupture and release enzymes into the secondary oocyte, which causes the zona pellucida to thicken and prevent entry of other sperms.
- The sperm nucleus then enters the secondary oocyte. At the same instant the secondary oocyte completes its second meiotic division to form a mature ovum and another polar body.

The male nucleus fuses with the female nucleus to form a diploid zygote.

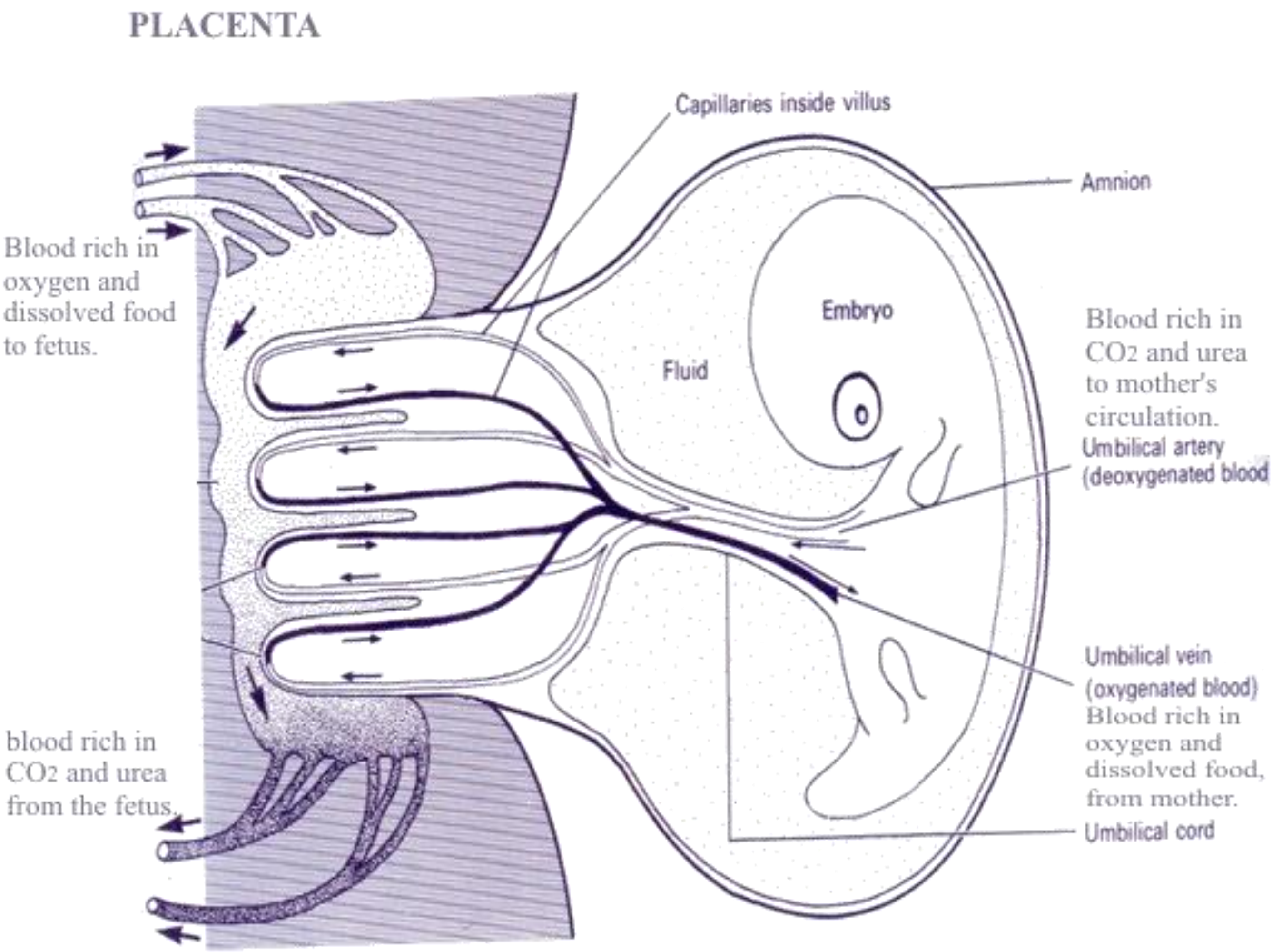


47. Describe implantation; understand the functions of the placenta in relation to the development of the embryo.

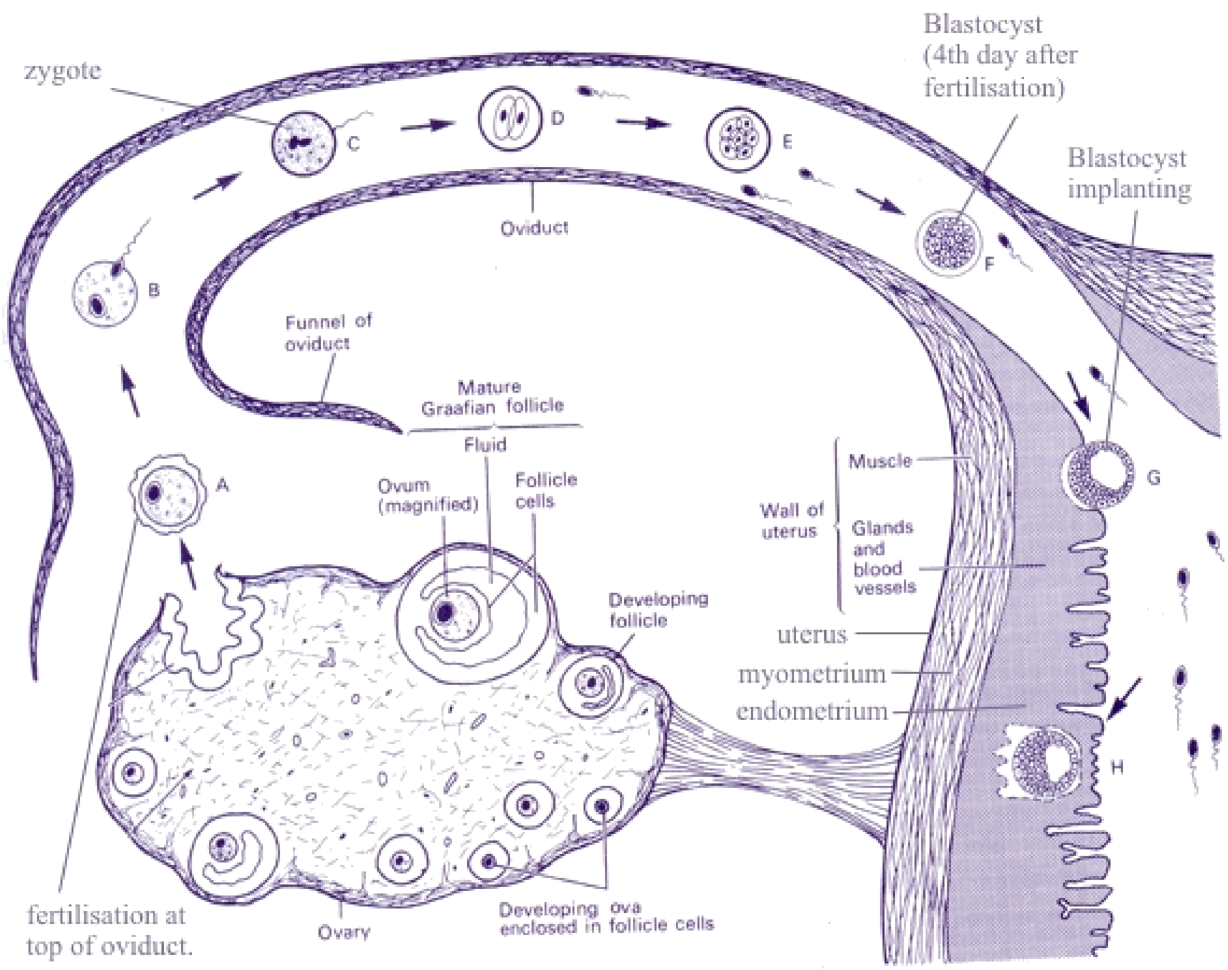
- The zygote then divides and redivides by mitosis to form a ball of cells called blasttocyst. The outer layer of cells of the blasttocyst is called trophoblast, which is able to penetrate and get embedded into the endometrium. This is called implantation.
- The trophoblast develops into two membranes_ The chorion and amnion.The chorion form many chorionic villi which secrete Human chorionic Gonadotrophin (HCG) to prevent degeneration of the corpus luteum (to maintain pregnancy).It later forms placenta.
- The placenta is an organ formed from the tissues of the mother and the foetus. The chorionic villi project into blood filled spaces within the endometrium of mother's uterus. This increases the surface area for diffusion, but at the same time prevents maternal and fetal blood from mixing.

The main functions of placenta include;

_ Transport of oxygen and food (Glucose, amino acids, vitamins, etc) from maternal blood to fetal blood.
_ Excretion of carbon dioxide and Nitrogenous wastes from fetal blood to maternal blood.
_ Placenta produces progesterone to maintain the thickness of endometrium during pregnancy, also prevents ovulation and menstruation from occurring.
_ Acts as a filter to prevent toxins and disease causing microbes getting into fetal blood. However, HIV rubella, alcohol and nicotine can cross placenta.
_ Some antibodies of mother can cross the placenta, providing passive immunity to the fetus.



IMPLANTATION



48. Understand birth and lactation, and the roles of oxytocin and prolactin.

Forty weeks after conception, the fetus lies with its head near the cervix. The level of progesterone falls dramatically. This makes the myometrium more sensitive to oxytocin released by the posterior pituitary gland. Together with prostaglandins secreted by placenta, oxytocin stimulates the smooth muscles of myometrium to contract. The pressure on the uterine wall and cervix stimulate more oxytocin to be released (positive feedback).The contractions eventually push the fetus through the cervix and vagina. The placenta and umbilical cord are then expelled as the after birth.

_ Lactation is the production of milk from breasts. Each mammary gland is composed mainly of fat and a number of lactiferous glands, which secrete milk. Progestrone and oestrogen from placenta stimulate the development of these glands during pregnancy.

_ Prolactin causes these glands to secrete milk, which is then stored in lactiferous ducts, so the hormone prolactin stimulates milk production in breasts.

_ Oxytocin stimulates the release of milk in response to sucking.