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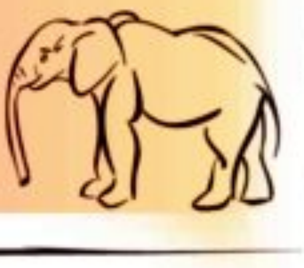


والله ولى التوفيق،،،

لجنة التطوير

Contents

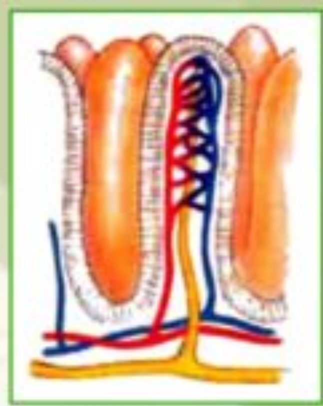
Structure & Function in Living Organisms

Chapter One

Nutrition and Digestion

At the end of this chapter the student should be able to:

- Identify the concept of nutrition.
- Differentiate between heterotrophic and autotrophic nutrition.
- Mention the adaptation of the root hair to its function.
- Explain the steps of photosynthesis.
- Identify the concept of nutrition in Man.
- Understand the process of digestion.
- Explain the process of absorption.
- Explain the role of enzymes.
- Deduce the importance of nutrition.



Nutrition

The concept of nutrition and the need for it:

Nutrition is one of the characteristics of life in living organisms from which the living organism obtains the energy required for all the vital processes of the body. In addition, food constitutes the materials needed for growth and repair of worn-out tissues. The word nutrition is a concept given to the scientific study of food and various modes of nutrition of living organisms.

There are two types of nutrition:

A) Autotrophic Nutrition:

Autorophs are those organisms which can manufacture their food by themselves as the green plants and some types of bacteria can synthesize, inside their cells, the high energy types of food such as sugar, starch, fats and proteins out of simple raw and low energy materials, which are carbon dioxide, water and mineral salts. Green plants obtain these materials from the surrounding habitat. By using these materials together with light energy, they carry out certain chemical reactions which are collectively called photosynthesis.

B) Heterotrophic Nutrition:

Heterotrophs obtain food from bodies of other organisms. They obtain high energy food substances either from green plants or from animals, previously feeding on plants.

Heterotrophs organisms can be classified as follows:

1. Holozoic nutrition: It includes carnivores (which feed on animals' flesh), herbivores (which feed on plants) and omnivores (which feed on both plants and animals).
2. Parasites, as Bilharzia worms and orobanche plant.
3. Saprophytes as fungi and saprophytic bacteria.

Chapter 1

Autotrophic Nutrition

Nutrition in green plants

We have already known that green plants are characterized by autotrophic nutrition. Cells of green plants synthesize high-energy organic food substances such as carbohydrates, fats and proteins from which the plants build their bodies. Plants synthesize these substances by photosynthesis from simple inorganic compounds, namely carbon dioxide, water and mineral salts which are obtained from the environment, in addition to light energy which are derived from the sun

Accordingly, autotrophic nutrition carried out by the green plant includes two important processes, namely the process of absorption of water, salts and carbon dioxide and the process of photosynthesis.

(1) THE PROCESS OF ABSORPTION OF WATER AND SALTS

Higher green plants absorb water and mineral salts from the soil through root hairs present in the root system of the plant. This soil solution is then transported from one cell to another until it finally reaches the ascending vessels.

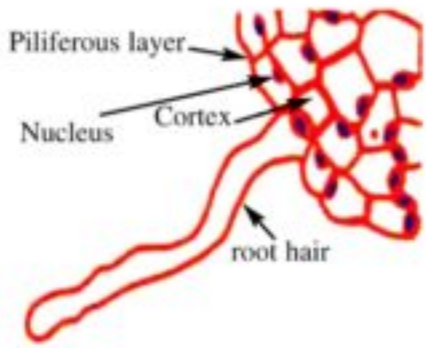


Fig. 1 The Structure of the root hair

* The structure of the root hair: (Figure 1)

A root hair may reach 4 mm long. It is lined internally with a thin layer of cytoplasm which contains the nucleus. There is a large cell vacuole as well. Root hairs do not exist for more than a few days or weeks, since the epidermal cells are lost from time to time and regenerated continuously from the zone of elongation.

Go Further

For more knowledge about this topic you can refer to the Egyptian Knowledge Bank (EKB) through the opposite link

Adaptation of the root hairs to their function:

1. They have thin walls to permit the passage of water and salts through them.
2. Being large in number and protruding to the outside, the root hairs increase the area of the absorbing surface.
3. The solution inside the root-hair vacuole is more concentrated than that of the soil in order to help the water to pass from the soil to the root hair.
4. Root hairs secrete a viscous substance which helps these hairs to find their way easily among soil particles, and to stick to these particles as well. Hence, they eventually help to fix the plant into the soil.

MECHANISM OF WATER ABSORPTION

This mechanism depends on several physical phenomena which you can verify yourself by carrying out some experiments.

1. The phenomenon of diffusion:

Diffusion is the movement of molecules or ions from a highly concentrated medium to a low concentrated one. This is due to the continuous free motion of the molecules of the diffused substance. This can be seen by the diffusion of a drop of ink when it falls into a beaker containing water.

2. The phenomenon of permeability:

Walls and cell membranes differ in their permeability properties. Cellulose walls allow both water and mineral ions to pass through, while walls covered with lignin, suberin or cutin are impermeable to water and salts.

Plasma membranes are semi-permeable. They are better considered as selectively permeable. Plasma membranes are thin, with tiny pores that can control the passage of substances through them. Some substances may be allowed to pass freely through these pores, while others may pass through slowly. A third group of substances are not allowed to pass at all. Such a phenomenon is called selective permeability.

Accordingly, the semi-permeable membrane allows the passage of water, and controls the permeability of many salts but it prevents the permeability of sugars and amino acids because they are large-sized molecules.

3. The phenomenon of osmosis:

It is the passage of water from a medium of high concentration (of water) to another with a low water concentration, through a semi-permeable membrane. The pressure that causes the passage of water through semi-permeable membranes is called "Osmotic Pressure". The osmotic pressure increases by the increase in the concentration of solutes in the solution.

Go Further

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4. The phenomenon of imbibition:

Solid particles especially colloidal ones have the ability to absorb liquids, swell and increase in volume. Walls of plant cells absorb water by this phenomenon which is called imbibition.

Absorption of water by root:

In view of the above mentioned facts, absorption of water by the root can be explained as follows:- root hairs are covered with a thin colloidal layer, therefore they possess a strong affinity for water which surrounds the adjacent soil particles. Accordingly, the outer surface of root hairs will imbibe water from the soil solution. The imbibed water is then withdrawn to the inside of epidermal cells by another force, osmosis, due to the difference between the higher concentration of the sugar solution in the cell sap and the lower concentration of the soil solution. In other words, due to the difference in water concentration which is higher in soil than in the cell sap.

Consequently, water is withdrawn from the soil into the epidermal cells of the root by osmotic forces. As a result, the water concentration in these cells becomes higher than that of the neighbouring cells of the cortex. Absorption and movement of water continues from one cell to another, until it reaches the xylem vessels in the centre of the root.

ABSORPTION OF MINERAL SALTS

Essential nutrients for green plants:

Scientists have managed, through various experiments, to prove that the plant needs certain essential elements (other than carbon, hydrogen and oxygen). It can absorb these elements through the roots. Deficiency of these elements would lead to disturbance in plant growth, which may even stop completely, or may cause no production of flowers or fruits. These elements are divided into 2 groups:

1. Macro-nutrients:

The plant needs these elements in considerable quantities. They are seven: Nitrogen - Phosphorus - Potassium - Calcium- Magnesium - Sulphur and Iron.

2. Micro-nutrients:

These elements are required by the plant in very small quantities, which do not exceed few milligrams/litre. Therefore, they may also be called trace elements. They are Manganese, Zinc, Boron, Aluminium, Chlorine, Copper, Molybdenum and Iodine. It has been proven that these elements help to activate enzymes.

Mechanism of absorption of Minerals:

1. Diffusion:

The ions diffuse from high concentration to low concentration. Solutes are present in a specific ionic form that are available to the plant. These ions behave independently of each other and of water itself. They are present either as positive ions called cations such as K^+ and Ca^{++}, or as negative ions called anions such as $(SO_4)^{--}$, $(NO_3)^-$, Cl^- and $(NO_2)^-$.

These solutes move by diffusion from the soil solution and pass through the wet cellulose walls. Under certain conditions, cations exchange may take place, Na^+ ion for instance, may get out of the cell and is replaced by k^+ ion.

2. Selective permeability:

When ions reach a semi-permeable plasma membrane, some of them are selected and allowed to pass through according to the plant's requirement. Some other ions are not permitted in, (regardless of their sizes, concentrations or charges).

3. Active transport:

Ions accumulate inside the cell against a concentration gradient, i.e. the ion diffuses from the soil solution where the concentration is low to the inside of the cell which is higher in concentration. Therefore, energy is needed to force these ions to move against concentration gradient.

The graph in (Fig. 2) shows the results of an experiment done on "Nitella" alga which lives in swamps. It is clear that the concentration of various ions accumulating in the cell sap of this alga is comparatively higher than their concentration in the water of the swamp. Such case necessitates that the cell must use up some energy to absorb these ions.

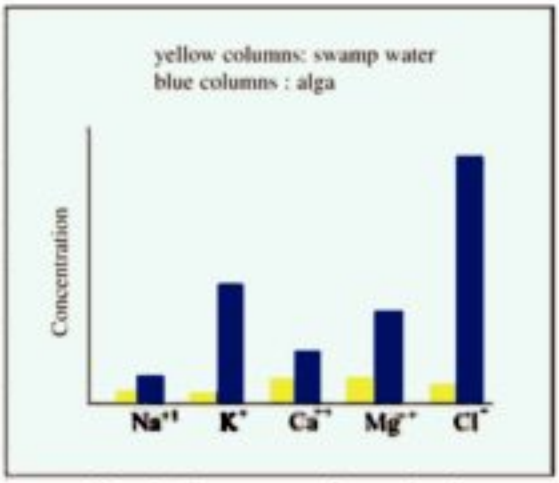

Fig. 2 Concentration of salts accumulated in cells of Nitella alga.

It is also clear from the experiment that the concentration of some ions accumulating in one cell is higher than in another. This proves that the ions are selectively absorbed according to the requirement of the cell.
The passage of any substance through the cell membrane by the help of some chemical energy is therefore called "Active transport".

Second:photosynthesis in green plants

Green leaves are the main centres for photosynthesis, since they contain chloroplasts. Green herbaceous stems may participate, to some extent, in this process as they contain chlorenchymatous tissues with chloroplasts.

Structure of the chloroplast:

In higher plants, the chloroplast appears, under the light microscope, as a homogeneous mass having the shape of a convex lens. However, the study of the chloroplast by the electron microscope has proved that it is enclosed by double thin membrane about 10 nanometres thick. Inside the chloroplast, there is the matrix or "stroma" which is a colourless proteinic substance.

Fig. 3 The green plastid

Embedded in the stroma are disc-shaped grana. Each granum is about 0.5 micron in diameter and about 0.7 micron thick. Grana are arranged along the body of the plastid where they are linked together by thin membranes. Each granum is a pile of 15 or more discs arranged over each other, (Fig. 4).

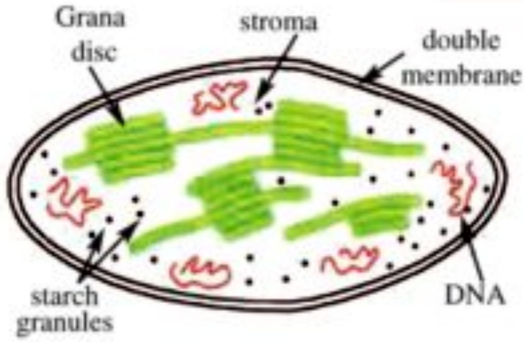

Fig. 4 Diagram of a chloroplast (highly magnified)

Each disc is hollow from the inside, while the margin of some discs extend outside the granum to meet the margin of another disc in a neighbouring granum, Such a structure increases the exposed surface area of the discs greatly. These are responsible for carrying the pigments that absorb light energy.

The chloroplast contains four main pigments which can be separated. These pigments are as follows:

Pigment	Colour	Percentage
Chlorophyll A	Blue-green	about 70%
Chlorophyll B	Yellow-green	
Xanthophyll	Lemon-Yellow	about 25%
Carotene	Orange-Yellow	about 5%

It is clear from the table why green colour dominates the colours of other pigments in the plastid.

The chlorophyll is concerned with absorption of light energy required for photosynthesis. Numerous starch grains are produced inside the chloroplast. These grains are small in size and are the temporary products of photosynthesis. They will soon change back to soluble sugar in order to be translocated, under certain conditions, to other organs of the plant.

The chlorophyll molecule is complex in structure. The molecular formula of chlorophyll A is $C_{55} H_{72} O_5 N_4 Mg$. The magnesium atom occupies the centre of the molecule. It is believed that there is a relationship between the presence of Mg in the chlorophyll molecule, and the ability of chlorophyll to absorb light.

Structure of the plant's leaf

Examination of a T.S. passing through the midrib of a dicotyledonous plant leaf shows clearly how the leaf is adapted in its structure to do the function of photosynthesis and other vital processes.

Referring to (Fig. 5) the leaf consists of three main tissues which are:

1. The epidermis (the upper and lower):

Each of the upper and lower epidermis layers consists of one row of adjacent barrel-shaped parenchyma cells with no chlorophyll. Stomata spread throughout the epidermal layers. The external wall of the epidermis is coated with a layer of cutin.

2. The mesophyll:

It lies between the upper and lower epidermal layers, transversed by veins and consists of two layers:

(a) The palisade layer:

It consists of one row of cells; these cells are cylindrical, elongated and parenchymatous. They are arranged in columnar form, perpendicular to the leaf surface of upper epidermis, they possess many chloroplasts which tend to arrange themselves in that part of the cell which receives the highest light intensity.

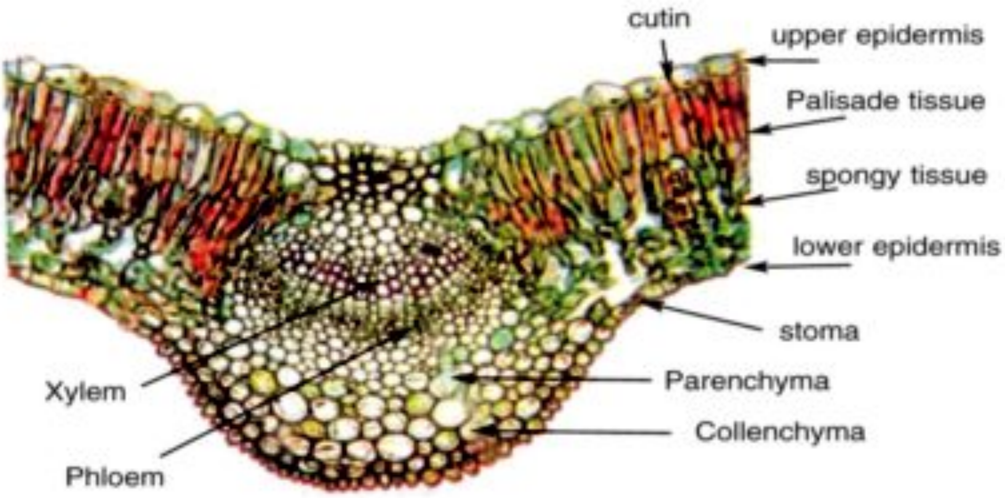

Fig. 5 The structure of the leaf

(b) The spongy layer:

It lies below the palisade tissue in the form of irregular-shaped and -arranged parenchyma cells, in between these cells there are wide intercellular spaces. The cells of this tissue contain a lower number of chloroplasts than the palisade tissue.

3. The vascular tissue:

It consists of numerous vascular bundles which extend through the veins and veinules. The midrib contains the main vascular bundle of the leaf. Inside the vascular bundle, there are several vertical rows of xylem vessels separated from each other by thin-walled cells called xylem parenchyma. The phloem lies toward the lower epidermis; it translocates dissolved organic food from the mesophyll, where it has been manufactured, to other parts of the plant.

Go Further

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Chapter 1

The Mechanism of Photosynthesis

What is the source of oxygen evolved during photosynthesis?

The first person who pointed out that oxygen evolved (produced) in photosynthesis was the American scientist "Van Neil" at Stanford University. He arrived at this discovery by studying photosynthesis in both green and purple bacteria. These bacteria are autotrophic as they contain bacteriochlorophyll (which is simpler in structure than ordinary chlorophyll). They live in swamps and ponds where hydrogen sulphide is abundant. Hydrogen sulphide is the source of hydrogen used by these bacteria to reduce CO_2 in order to build up carbohydrates and Sulphur is released.

"Van Neil" assumed that light decomposed hydrogen sulphide into hydrogen and sulphur. Afterwards, hydrogen was used in certain dark reactions to reduce CO_2 into carbohydrates, as represented by the equation:

$$6\,CO_2 + 12\,H_2S \xrightarrow[\text{Bacterio Chlorophyll}]{\text{light energy}} C_6H_{12}O_6 + 6H_2O + 12S \downarrow$$

Accordingly, Van Neil assumed that light reactions in green plants are similar to those of sulphur bacteria, except that in green plants, it is water which is decomposed by light into hydrogen and oxygen. Hydrogen is then used in the reduction of CO_2 in a series of reactions that do not require light to produce carbohydrates.

Consequently, Van Neil proposed that the release of oxygen comes from water, a case which is similar to sulphur released from hydrogen sulphide by sulphur bacteria.

The general chemical equation which represents the process of photosynthesis in green plants can therefore be represented as follows:

$$6\,CO_2 + 12\,H_2O \xrightarrow[\text{Chlorophyll}]{\text{light energy}} C_6\,H_{12}\,O_6 + 6H_2O + 6O_2 \uparrow$$

In 1941, a group of scientists at California University verified the theory of Van Neil experimentally. They used the green alga called Chlorella and provided it with all conditions favourable for photosynthesis. The water which was used contained the oxygen isotope ^{18}O (instead of ^{16}O). On the other hand, CO_2 contained ordinary oxygen, i.e. ^{16}O. They discovered that the oxygen which evolved during photosynthesis of the alga was the isotope ^{18}O and not ^{16}O. This discovery proved that the source of liberated oxygen is water and not CO_2.

In order to confirm this result, the American scientists repeated the experiment using ordinary water while CO_2 contained ^{18}O. This time ordinary oxygen was released, i.e. ^{16}O coming out from water.

These experiments are represented by the following equations:

First experiment:

$$6\,C\,^{16}O_2 + 12\,H_2\,^{18}O \xrightarrow[\text{Chlorophyll}]{\text{light energy}} C_6\,H_{12}\,^{16}O_6 + 6H_2\,^{16}O + 6\,^{18}O_2$$

Second experiment:

$$6\,C\,{}^{18}O_2 + 12\,H_2\,{}^{16}O \xrightarrow[\text{Chlorophyll}]{\text{light energy}} C_6\,H_{12}\,{}^{18}O_6 + 6H_2\,{}^{18}O + 6\,{}^{16}O_2$$

THE LIGHT AND DARK REACTIONS

In his experiment on the limiting factors of photosynthesis, Blackman concluded that photosynthesis consists of two kinds of reactions; light reactions, in which light acts as the limiting factor of the rate of photosynthesis and the dark reactions (or enzymatic reactions), which are sensitive to temperature and are not affected by light at all. Dark reactions can take place in light and darkness and temperature is the limiting factor of the rate of photosynthesis.

A- The light reactions:

1. When light falls on chlorophyll of the grana inside the chloroplast, some electrons in the atoms of the chlorophyll molecule will gain energy. As a result, these electrons are shifted up from their low-energy levels to higher ones. In this way, the kinetic light energy is stored as potential chemical energy in the chlorophyll. The molecules of chlorophyll, in which some of their electrons have reached this condition, are said to be in an "exited state" (or activated state).

   When the stored energy is released, the electrons fall once more to the lower energy levels. The chlorophyll will return to the stable state, ready for another influence of light to become excited once more.

2. Part of the energy stored in chlorophyll is used in splitting up the water molecule into hydrogen and oxygen ions which were very firmly combined in the water molecule.
3. Another part of the energy of the excited chlorophyll is stored in *ATP molecule (as a result of combination of ADP molecule in the chloroplast with a phosphate group (P) by means of high-energy bond which is marked by a squiggle (~).this progss is called photosynthetic phosphory lation

ADP + P ⟶ ATP

Adenosine - P ~ P + P ⟶ Adenosin - P ~ P ~ P

4. Hydrogen resulting from decomposition of the water molecule combines with a co-enzyme present in the chloroplast

(**) NADP: It is Nicotinamide Adenine Dinucleotide Phosphate which acts as a hydrogen receptor to give $NADPH_2$. In this way, hydrogen will not escape or recombine with oxygen.

5. Oxygen released (as product) due to the decomposition of water.

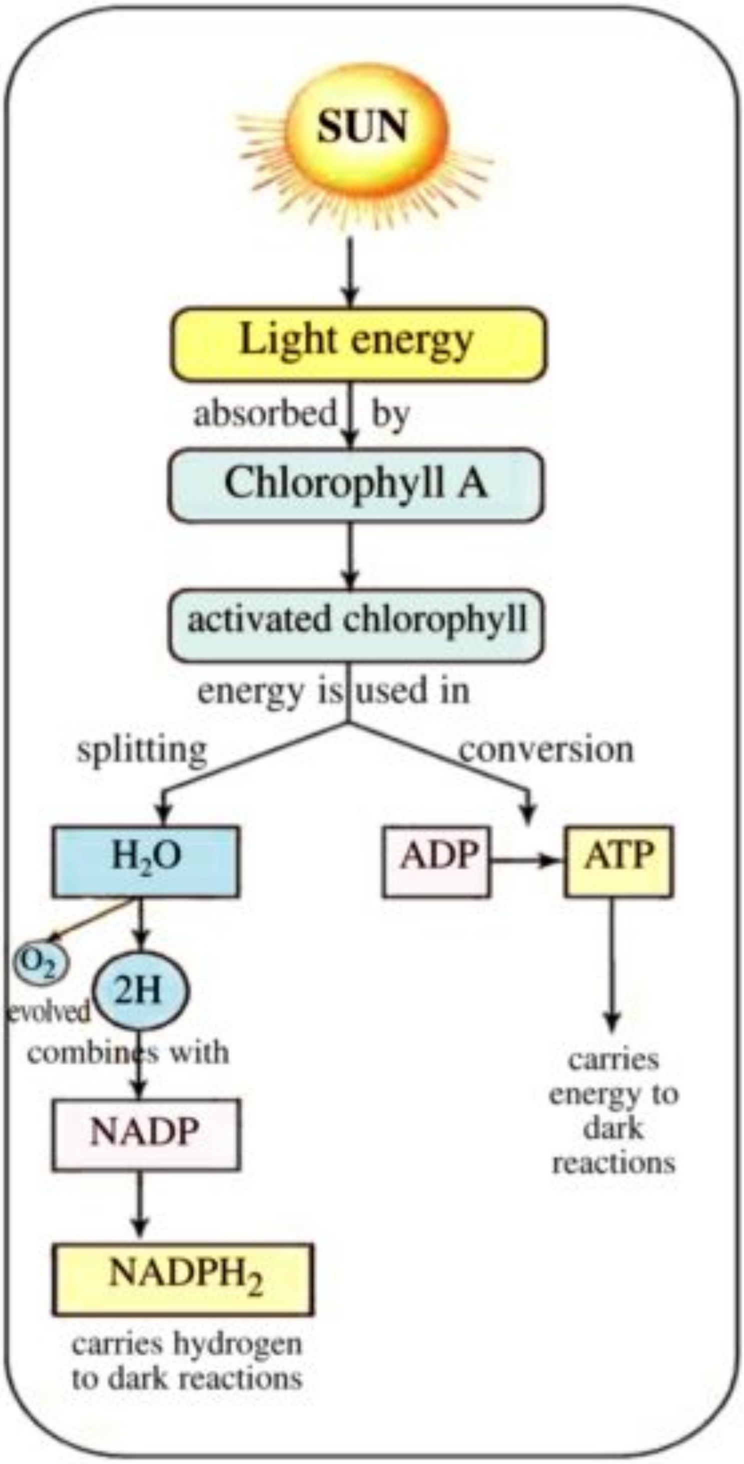

Fig. 6 Summary of light reaction

B- The dark Reactions:

These are a group of reactions which take place in the stroma of the chloroplast outside the grana. In these reactions hydrogen carried on $NADPH_2$ is used to fix CO_2 gas into carbohydrates with the help of energy stored in the ATP molecule.

Melvin Calvin and his associates at California University revealed, in 1949, the nature of the dark reactions by using the newly discovered radioactive isotope of carbon (^{14}C).

They placed the Chlorella alga in the apparatus shown in (Fig. 7) and supplied it with CO_2 gas containing radioactive carbon (^{14}C). A lamp was lighted very briefly in order to allow photosynthesis to take place. Chlorella was then immersed in a beaker containing hot alcohol to kill the protoplasm by stopping its biochemical reactions. They managed to separate the products of photosynthesis by special means and tested for radioactive carbon in these compounds (by using Giger counter).

Results showed that when photosynthesis proceeded with the briefest flash possible, a 3-carbon compound was formed which is PGAL, i.e. Phosphoglyceraldehyde. This is the first stable compound to be produced in photosynthesis. PGAL acts as a sort of crossroads in the metabolic network. From PGAL all other products in plant cells can be produced, such as glucose, starch, proteins and fats. It can also be utilized in cellular respiration as a high-energy compound.

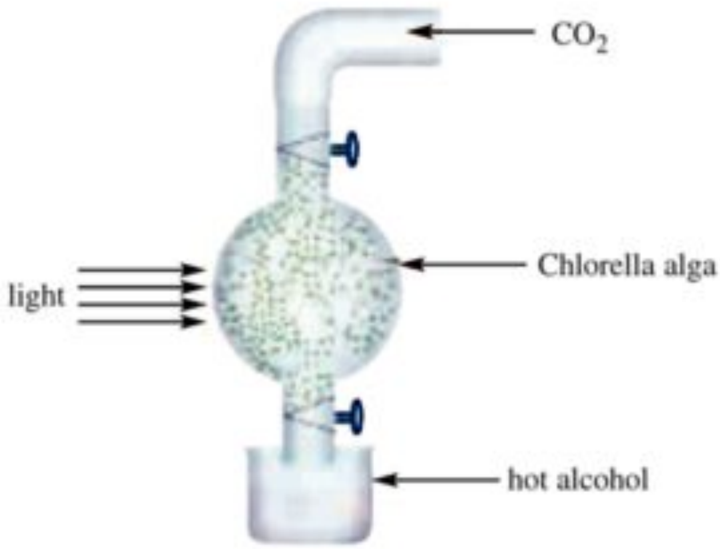

Fig. 7 Calvin experiment

Calvin also pointed out that the synthesis of a hexose sugar is not completed in one step, but throughout several intermediate reactions catalyzed by certain specific enzymes.

Go Further

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HETEROTROPHIC NUTRITION

Concept and Importance:

At the heterotrophic nutrition, the living organisms obtain their food in the form of large and complex particles of proteins, carbohydrates and fats, which can not diffuse through the cell membranes. In order to be useful to the living organism, these large molecules must be broken down into molecules of smaller size and simpler structure (amino acids, glucose, fatty acids and glycerol). As these molecules are small and soluble in water, they are easily absorbed by the cells, either by diffusion or by active transport. Cells will then use these simple compounds as a source of energy in the building of new tissues.

Digestion:

Digestion is the conversion of large food molecules, (polymers) into smaller ones (monomers) by means of hydrolysis. This process is catalyzed by enzymatic action.

Enzymes:

The enzyme is a protein substance which has the properties of a catalyst, where it has the ability to activate a particular chemical reaction. The reaction which is catalyzed by a certain enzyme depends on the structure of the reacting molecules as well as the nature of the enzyme. When the reaction is completed, the resulting molecules break away from the enzyme, leaving it in the same form as it was before the reaction.

enzyme + reacting substance $\rightleftharpoons$ unstable intermediate compound

$\longrightarrow$ enzyme + products of reaction

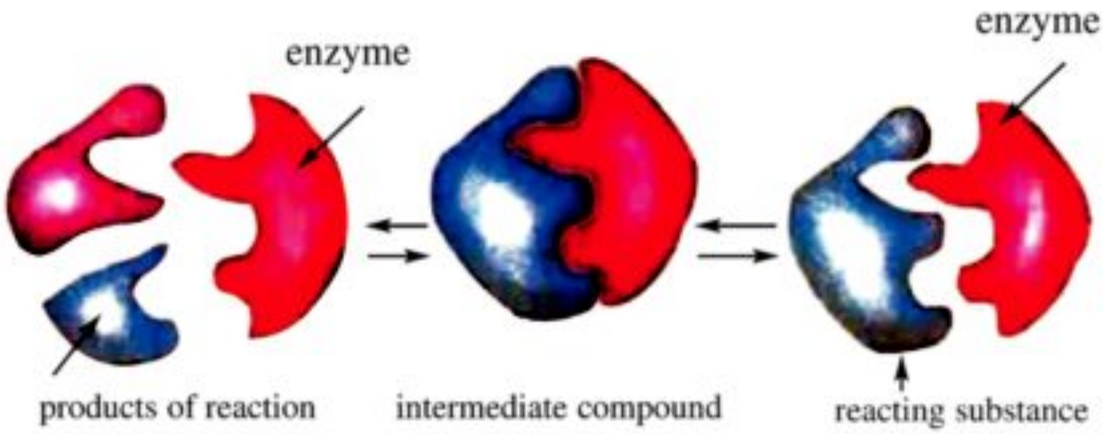


Fig. 8 Mechanism of enzyme action

Most enzymes have a reversible effect. The same enzyme may catalyze the decomposition of a complex molecule into two simpler ones, and may recombine the two small molecules to give rise to the same complex molecule once more. It should be apparent that enzymes only accelerate the rate of the reaction until it reaches a state of equilibrium. Some enzymes are secreted by the cells in an inactive state. Therefore, they need certain substances to be present in order to activate them. Pepsin enzyme, for instance, which is secreted by the stomach as pepsinogen is changed to active pepsin in the presence of HCl in the stomach, the activity of the enzyme depends upon the temperature and the pH of the medium.

Chapter 1

Digestion in Man

The human digestive system is generally built up of alimentary canal extending from the mouth to the anus. This canal starts with the mouth which is followed by the pharynx, oesophagus, stomach, small and large intestine and associated glands including salivary glands, liver, and pancreas.

Buccal Digestion:

The digestive system starts with the mouth which contains the teeth. The teeth are differentiated into incisors, at the front of the jaw for cutting food, then followed by canines to tear food and at the back, there are the premolars and molars for crushing and grinding food.

The tongue helps to manipulate the food in order to be chewed by the teeth, and also serves as an organ of taste. Saliva is secreted by three pairs of salivary glands which open into the mouth cavity through ducts. The saliva contains mucous that soften the food to be easily swallowed.

The saliva also contains the enzyme amylase (or ptyalin) which acts in a weak alkaline medium, pH 7.4 it catalyses the hydrolysis of starch to the disaccharide maltose.

The pharynx is a cavity at the back of the mouth which leads to two tubes: the oesophagus and the trachea which is a part of the respiratory system.

Swallowing is an organized reflex action. When food is pushed from the mouth to the oesophagus; the top of the trachea together with the larynx is elevated causing the epiglottis to close over the glottis (entrance to the air passage).

The oesophagus which is 25 cm long extends from the pharynx downward through the neck and into the chest cavity. It lies parallel to the vertebral column. The oesophagus is lined with glands secreting mucus. Food is carried through the oesophagus to the stomach by a series of rhythmical muscular contractions and relaxations of circular muscles known as peristalsis, (Fig. 9). This movement extends downward along the alimentary canal and sweeps any food contained within the canal. It is also responsible for churning the food and mixing it with the digestive juice.

Fig. 9 Peristaltic action of oesophagus

Gastric Digestion:

The stomach is a dilated muscular sac which lies in the abdominal cavity. It is joined to the lower part of the oesophagus by a region occupied by a constricted circular muscle called the cardiac sphincter. The stomach is connected to the small intestine by a muscular valve of circular smooth muscle called the pyloric sphincter.

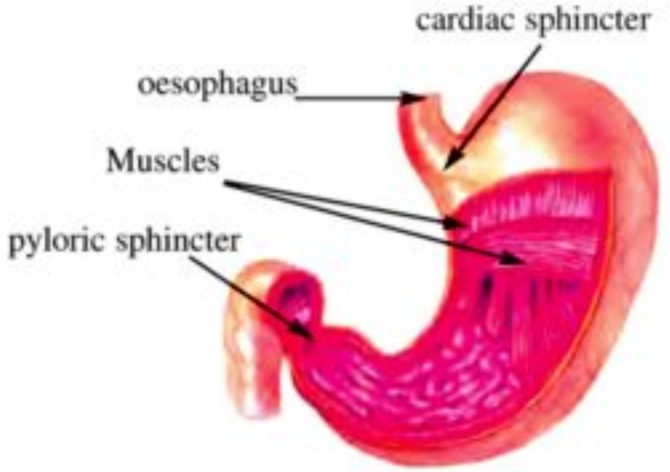


Fig. 10 Stomach

Proteins are the only food substances which are affected by the gastric juice. The gastric juice is colourless acidic liquid. It contains:

1. 90% water.
2. HCl: It creates an acidic medium (1.5 - 2.5 pH) which stops the action of the ptyalin enzyme and kills harmful bacteria that may enter with the food.
3. The enzyme pepsin: It is secreted in an inactive form called pepsinogen. It becomes active by the action of HCl.

$$\underset{\text{(inactive)}}{\text{Pepsinogen}} \xrightarrow{\text{HCl}} \underset{\text{(active)}}{\text{Pepsin}}$$

Protein digestion:

Pepsin catalyzes the hydrolysis of protein by breaking certain peptide linkage in the long chain of the protein to yield smaller fragments called polypeptides.

$$\text{Protein + water} \xrightarrow[\text{HCl}]{\text{pepsin}} \text{Polypeptides}$$

Now, let us ask ourselves, since the stomach is made up of protein, why does it not digest itself?

As an answer to this question, we should appreciate the presence of mucus secretions. These protect the cells against the effect of the digestive enzymes. Moreover, pepsinogen will be activated only when it is mixed with the acid in the cavity of the stomach.

Intestinal Digestion:

The small intestine consists of duodenum and ileum. It is about 8 meters long and about 3.5 cm in diameter at its beginning to 1.25 cm at its end. Coils and loops of the small intestine are connected together by membranous structure called mesentery. The juices that help to digest food in the small intestine are:

1. The Bile:

The bile is secreted from the liver on the food during its passage in the duodenum. It emulsifies fats, i.e. dividing large masses of fats into small globules to facilitate and accelerate the enzymatic action on fats that don't dissolve in water.

2. Pancreatic Juice:

It is secreted from Pancreas on the food in the duodenum.

It includes the following:

a) Sodium bicarbonate to neutralize HCl and renders the medium alkaline (pH = 8).

b) Pancreatic amylase: It catalyzes the hydrolysis of glycogen and starch into maltose.

c) Trypsinogen: It is an inactive enzyme. It becomes active trypsin in the duodenum by the enzyme enterokinase which secreted by the intestinal glands in the lining of the small intestine. Trypsin catalyzes the hydrolysis of protein to polypeptides.

d) Lipase: It catalyzes the hydrolysis of the emulsified fats into fatty acids and glycerol.

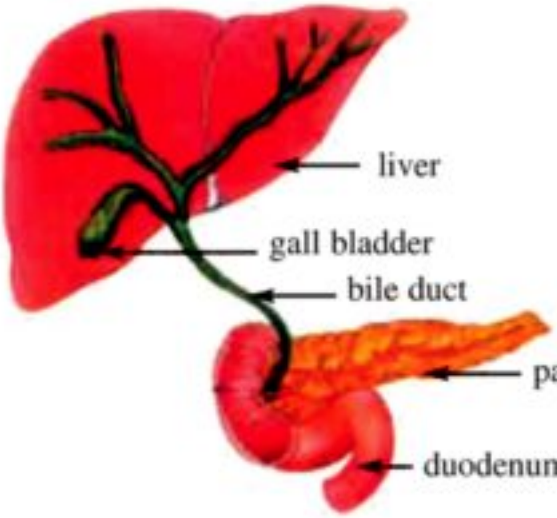


Fig. 11 The liver & Pancreas

3. Intestinal juice:

This juice which is secreted by certain cells in the wall of the small intestine contains a mixture of enzymes. These enzymes complete the action of the previous enzymes and end the action of digestion of all food constituents. These enzymes are:

a) Peptidases: It is a number of enzymes. Each one is concerned with hydrolysis of peptide linkage between certain kinds of amino acids in the polypeptide chains, to give various amino acids.

b) Enzymes which hydrolyse disaccharides to monosaccharides, these are:

- Maltase, which hydrolyze maltose to two molecules of glucose.
- Sucrase, which hydrolyze sucrose (cane sugar) to glucose and fructose.

- Lactase, which hydrolyze lactose (milk sugar) to glucose and galactose.

c) Enterokinase: It acts only as a co-enzyme to activate trypsinogen.

Absorption:

It is the transfer of digested food to the blood or lymph through the mucosa of the ileum. The inner epithelial lining of the ileum is folded to form villi. The surface area, therefore, increases enormously and reaches about 10 m^2, i.e. about 5 times as much as the surface area of the human body surface.

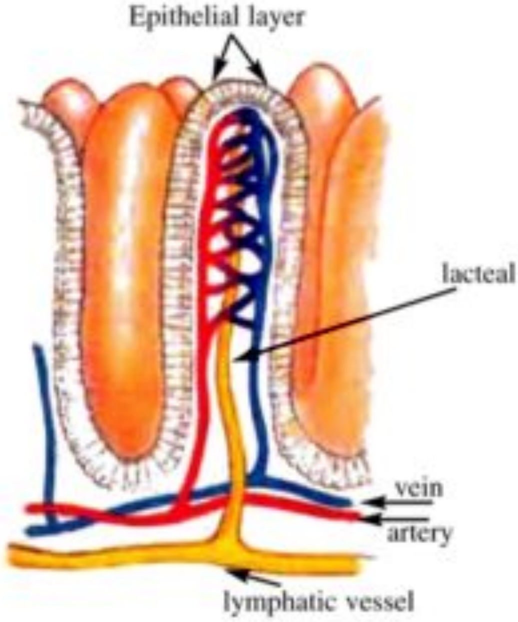


Fig. 12 The structure of villi

Each villus consists of an outer covering of a single layer of epithelial cells which enclose a lacteal surrounded by a network of venous and arterial blood capillaries. The electron microscope has revealed the presence of tiny projections from the epithelial cells of the villi called micro-villi. They increase the area of the absorbing surface.

Products of digestion are transferred to the blood and lymph by absorption through the villi by active transport and membranal diffusion.

a) Blood route:

It starts with the blood capillaries inside villus, where blood carries water, mineral salts, glucose and amino acids together with some water soluble vitamins. These substances are carried to the hepatic portal vein to the liver and then through the hepatic vein to be emptied into the inferior vena cava, then to the heart.

b) Lymphatic route:

Where fatty acids and glycerol pass together through with their contents of vitamins A, D, E and K. However, some of these fatty acids and glycerol may recombine in the epithelial cells of the villi to form fats again.

It may happen that some of the finely emulsified fats are absorbed directly by being engulfed by the epithelial cells. All fats pass into the lacteals inside the villi to lymphatic system which carries them slowly and empties them into the superior vena cava, then to the heart.

Metabolism:

It is the process by which the body can utilize the absorbed food. This process takes place by two ways:

1. Anabolism:

The simple and small-sized food particles can be changed into complex compounds. Glucose can be changed into glycogen and stored in the liver and muscles. Amino acids can be changed into different forms of polypeptides to build up new tissues. Fatty acids and glycerol can be changed into fats and stored mainly under the skin.

2. Catabolism:

The absorbed food, especially the glucose can be oxidized to produce the energy required for the activity of the body.

Large intestine and defecation:

Undigested food passes to the large intestine. One of the most important functions of the large intestine is the absorption of water and salts from the undigested residue to leave semi-solid feaces.

The lining of epithelial wall has many convolutions to help in the absorption. Presence of bacteria in the large intestine is responsible for the bad odour and breakdown of these remains into simple substances. Waste remains are expelled as feaces through the anus by means of strong muscular contractions of the rectum accompanied by relaxation of the two muscles of the anal sphincter situated on both sides of the anus.

The mucosa of large intestine secrets mucus to facilitate the passage of feaces to outside.

Go Further

For more knowledge about this topic you can refer to the Egyptian Knowledge Bank (EKB) through the opposite link

QUESTIONS

1. "Osmosis is an important phenomenon for the absorption of water by roots".

a) What is meant by osmosis? What is its importance for the plant?

b) What is the relation between osmosis and osmotic pressure?

2. Choose the correct answer:

a) Green plants cannot survive in deep oceans because …

- There is no suitable soil to fix the roots.
- The concentration of oxygen is very high.
- The light intensity is very low.
- The concentration of carbon dioxide is very low.

b) One of the following isotopes was useful in revealing the dark reactions of photosynthesis.

(^{14}C - ^{18}O - ^{35}C - ^{12}C)

c) Water passes through the endodermis to the xylem by …

(Imbibition - Capillarity - Osmosis – Permeability)

d) The first stable organic compound produced in photosynthesis is

(ATP - NADP - Glucose - Phosphoglyceraldhyde)

e) The dark reactions take place in the stroma in the presence of …

- Carbon dioxide, water and ATP.
- Carbon dioxide, water and $NADPH_2$.
- Carbon dioxide, $NADPH_2$ and ATP.
- Carbon dioxide and ATP.

f) The action of enzyme is affected by …

1) pH degree only.
2) Temperature only.
3) Type of food molecules.
4) Temperature and pH.

3. "Absorption is the passage of digested food to blood or lymph":

a) At which part of the small intestine absorption occurs?

b) What are the absorbed materials in this part and what is their fate?

c) What happens to the undigested food? How does the body get rid of it?

4. "The absorption of mineral salts by plants takes place by different ways".

a) What are the most important elements for the plants and what are their importance?

b) The passage of these elements through the cell membrane is called "Active Transport". What is meant by active transport? What is its importance?

5. Explain the following:

a) The ability of some plants to fix carbon dioxide in the dark after being exposed to light.

b) Salt ions are translocated from the soil solution to the root cells against the concentration gradient.

c) Gastric juice dose not affect the epithelial cells of the stomach.

CHAPTER 2

Transport in Living Organisms

At the end of this chapter the student should be able to:

- Identify the concept of transport in higher plant.
- Deduce the mechanism of transport from root to leaf.
- Discover the factors responsible for the ascent of sap.
- Recognize the transport of manufactured food from the leaf to other parts of the plant.
- Explain the role of sieve tubes in transport.
- Identify the structure of transport system in man.
- Identify the circulatory system.
- Identify the contents and function of blood.
- Identify the heart beat and pressure.

* Understand the circulation.
* Understand the mechanism of blood clot.
* Identify the lymphatic system.

Chapter 2

The Concept of transport and need for it:

It is clear, from our previous study of nutrition and digestion in living organisms, that each organism ingests what it needs of various substances by different means. For example, the green plant requires an adequate supply of carbon dioxide, water and mineral salts in order to carry out photosynthesis. In primitive plants like algae, these raw materials, together with products of photosynthesis, move from one cell to another by diffusion and active transport. Therefore, there is no need of specialized transport tissues.

In higher plants, gases move by diffusion, while water, mineral salts and soluble products of photosynthesis are transported by means of specialized vascular tissues.

We have found in the case of animals, that they obtain their requirements of energy in the form of food. After digestion of food, the soluble food substances are absorbed, but there still remains the problem of their transport and distribution to various tissues laying far away from the surface of absorption. In small animals like protozoa and Hydra, both gases and food substances move by diffusion. In the case of bigger and more complicated animals, diffusion is insufficient for transportation of food and oxygen to various tissues.

Therefore, the presence of a specialized transport system is essential in these animals.

Transport in higher plants:

We have already studied how the root absorbs water and mineral salts from the soil, and how these substances are translocated across the root tissues, until they reach xylem vessels of the root. They are then carried through the xylem of the stem to the leaves which carry out photosynthesis and, therefore, produce high-energy carbohydrates, fats and proteins. These products are transferred from centres of their manufacture to sites of storage and consumption in various tissues, e.g. roots, stems, fruits and seeds. This organic food passes through the sieve tubes in the phloem of the leaf, the stem and the root.

We have already studied the internal structure of the leaf in relation to the process of nutrition. We should now study the internal structure of the stem as well. The importance of this study will help us to understand the role of the stem in the process of the transport.

If we examine a T.S. in a young stem of a dicotyledonous plant, we find that it consists of the following tissues (Fig. 1):

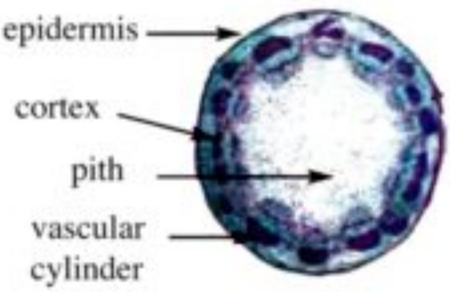
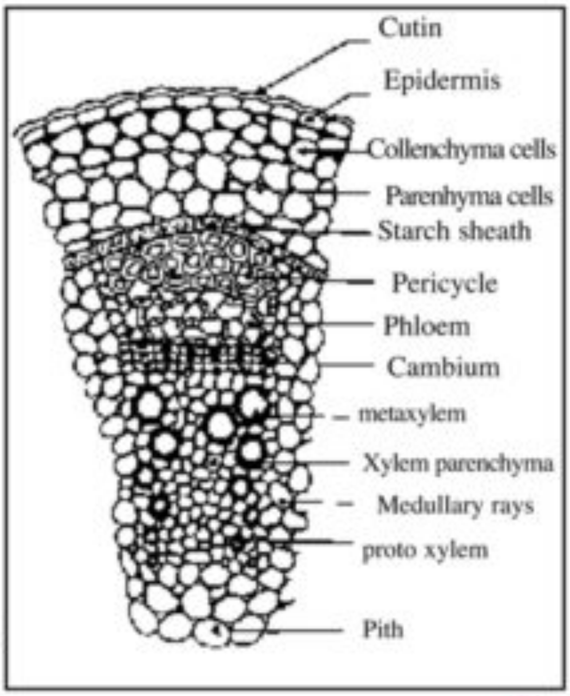


Fig. 1



A detailed T.S. in a dicot stem to show its internal structure

1. Epidermis:

It is one row of adjacent, barrel-shaped parenchyma cells. The outer walls are covered by a cuticle.

2. Cortex:

It consists of several rows of collenchyma cells which have thickened corners by deposition of cellulose. It helps as a mechanical tissue for the support of the stem. Presence of chloroplasts in the collenchyma cells allow them to take part in photosynthesis.

These cells are followed internally by several rows of parenchyma cells with plenty of intercellular spaces for aeration. The innermost row of cells of the cortex is known as starch-sheath for storage of starch grains.

3. Vascular cylinder:

It occupies much of the stem and consists of the following tissues:

a) **Pericycle:** a group of parenchyma cell alternates with the groups of fibres out of vascular bundles. Its function is to make the stem strong and elastic.

b) **Vascular bundles:** which are arranged in a cylinder. Each bundle is triangular in shape with its base directed outwards.

The bundle consists of the following tissues:

1. **Phloem:** It is the outer tissue of the vascular bundle. It consists of sieve tubes, companion cells and phloem parenchyma. The function of the phloem is the transport of organic food substances.
2. **Cambium:** It consists of one or more rows of meristematic cells, lies between the phloem and the xylem. When these cells divide

they give rise externally to secondary phloem and internally to secondary xylem.

3. **Xylem:** It is the internal part of the bundle. The xylem traslocates water and solutes and acts as a support for the stem.

It consists of:

a) Vessels:

The xylem vessels consist of tubes formed from vertical rows of elongated cylindrical cells joined end to end. The transverse walls have been completely dissolved, and so the whole row of the cells has become one tube. At the same time, the cellulose wall has become thickened by lignin which is impermeable to water and solutes. The protoplasmic content has died leaving hollow vessel.

Numerous pits are scattered all over the wall, where the primary wall is left without thickening. These pits permit water to pass from inside the vessel outward. Lignin is laid down on the inner lining of the vessel in the form of strands taking various forms such as annular and spiral (when they appear in longitudinal sections). These forms of thickening help to support the vessel, and prevent the collapse of its wall

b) Tracheids:

These are more or less similar to vessels except that they appear in a T.S., in a pentagonal or hexagonal from. Tracheids are pitted and their ends are not open but pointed and closed. (Fig. 2)

Fig. 2 Xylem

c) Xylem parenchyma:

It consists of one row of cells between xylem vessels. The xylem in the vascular bundles of the stem communicates with the xylem of the root and the leaf, and the phloem communicates with that of the root and the leaf. As a result, a network of vessels spread all over the plant.

d) Pith: It occupies the centre of the stem. It consists of parenchyma cells for the purpose of storage.

e) Medullary rays: They extend between the vascular bundles in the form of parenchyma cells to join the cortex with the pith.

The Mechanism of transport water and mineral salts from the root to the leaf:

The xylem is responsible for the translocation of water and mineral salts from the root to the leaf. (Fig. 3)

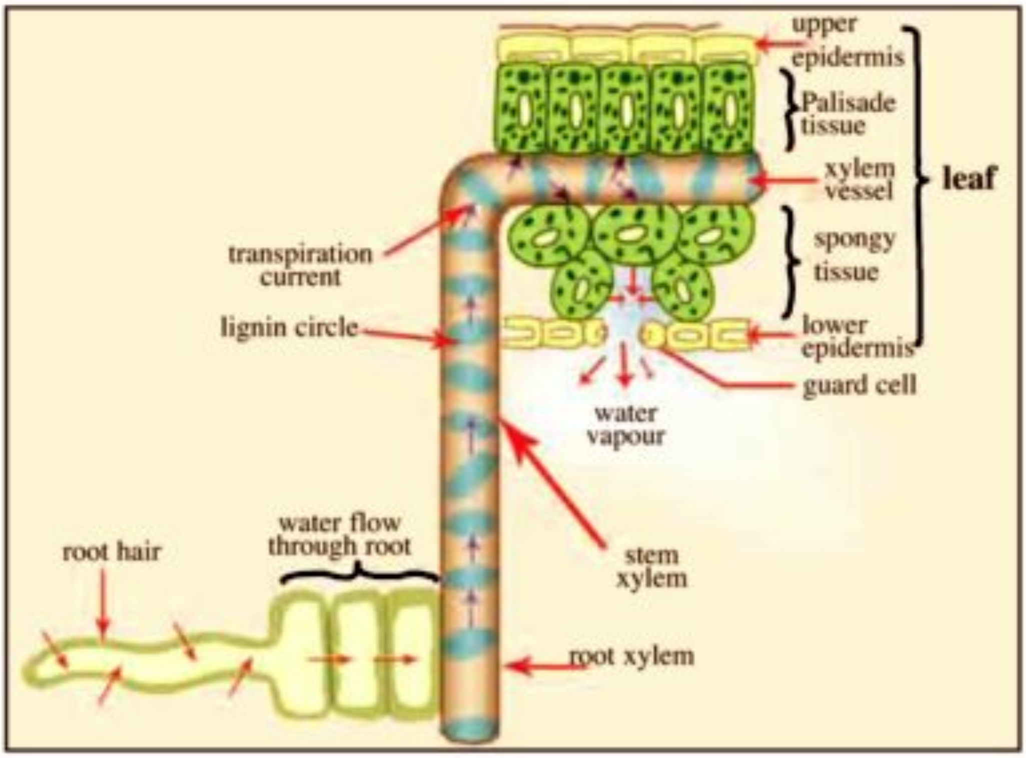


Fig. 3 Transport of water through the xylem vessels

Factors responsible for ascent of sap:

Several theories were put forward to explain the ascent of water in the plant. We are going to discuss some of these:

1. Root pressure theory:

If a plant stem is cut very near to the soil-level, you can see exudation of water from the stump. This phenomenon is known as Exudation, due to the root pressure continuing to force water up the plant. An osmotic pressure mechanism exists in the root tissues leading to continuous and direct root absorption from the soil. We have already studied this in Chapter One.

Water is forced vertically upward through xylem vessels for a short distance to a certain level. At this level, the water stops because the opposing pressure of the water column in xylem vessels has become equal to the root pressure.

Experiments have proved that there is no reasonable explanation of ascent of water to high levels in tall trees by root pressure. The maximum root pressure does not exceed 2 atmospheres. Pinus and other conifers have no root pressure. Moreover, the force of root pressure is affected quickly by external factors.

2. Imbibition theory:

We have already studied this phenomenon. We have also found that the colloidal nature of cellulose and lignin has helped the walls of xylem vessels imbibe water. However, this phenomenon has a very limited effect on the ascent of sap, because experiments have proved that the sap ascends through the cavities of the xylem vessels and not along their walls only.

The importance of this phenomenon is restricted to transport of water along the cell wall until it reaches the walls of vessels and tracheids the root, and from these vessels and tracheids then to all plant parts.

3. Capillarity theory:

Water rises through tiny tubes by capillarity. Since xylem vessels are considered as capillary tubes with a diameter ranging from 0.02 mm to 0.5 mm. Water will rise in these by the phenomenon of capillarity. However, when you realise that the finest capillary tube does not allow the rise of water more than a height of 150 cm., you will appreciate that capillarity is a weak secondary force for the ascent of sap.

4. Transpiration pull - Cohesion - Adhesion theory:

This theory originated principally from the two plant physiology scientists H.H.Dixon and J.Joly in 1895. They proved that these are the principal forces which pull the water upward to very high levels, approximately 100 meters.

This theory states, in brief, that the water column ascends through the xylem vessels depending upon the following forces:

a) **Cohesive force** due to the existence of strong mutual attraction between the molecules of water inside the xylem vessels and tracheids. This explains the existence of a continuous column of water.

b) **Adhesive force** between water molecules and those of the walls of xylem vessels. It helps the water column to be held against the effect of gravity.

c) **Transpiration pull** that attracts the water column upwards due to the continuous process of transpiration in the leaves.

Water has been shown to have a high-pulling force in tubes under the following conditions:

1. It must be a capillary tube.
2. The walls of the tube must possess an adhesive force to attract water.
3. The tubes must be free of any gas or air bubbles to avoid any breaking and therefore descent of the water column.

All these conditions are known to exist in xylem vessels.

And now, can you explain why some seedlings, when transplanted from a nursery to open soil, fail to grow if they remain exposed to the sun for a long time before they are transplanted in the new soil?

Accordingly, the path of the sap during its ascent from the root to the leaves can be illustrated as follows:

Transpiration lessens the water concentration in the air chamber above the stoma in the leaf. Evaporation will therefore, increase from the cells of the mesophyll surrounding the stomata chamber. Such case will lessen the water content of these cells and increase their concentration. This state will create a diffusion pressure gradient for the water, a so-called "pulling force" which attracts water from the surrounding cells. This will continue as far as the xylem elements in the venules and veins, then finally from the midrib of the leaf.

Being subjected to a great force, the water will ascend through the xylem vessels and tracheids of both the stem and the root as they are connected to one another. Transpiration pull of the leaf will not only pull water that has reached the vascular cylinder of the root up, but it will also help in the lateral pull of water from the root hairs. (Fig. 3)

Transport of manufactured food from the leaf to other parts of the plant

The phloem translocates the manufactured food (which consists of high-energy organic substances produced by the leaf during photosynthesis) in all directions, i.e. upwards in order to feed buds, flowers and fruits, and downwards in order to feed the stem and the root system. So, what does the phloem consist of, and how is it adapted to its function?

The Role of sieve-tubes in transport:

The phloem consists of sieve-tubes that appear in a longitudinal section as elongated cells, arranged end to end. They contain cytoplasm without a nucleus. Each sieve-tube has a nucleated companion cell. Vital functions of the sieve tube are organized by the ribosomes and mitochondria present in the companion cell.

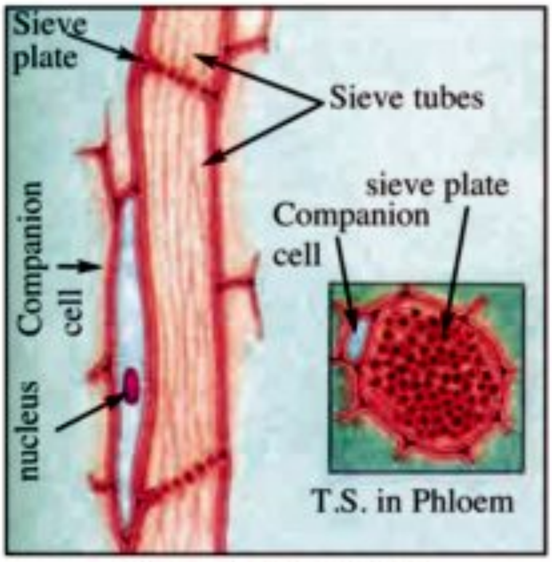


Fig. 4 L.S. in Phloem

The sieve-tubes are separated from each other by cross-walls which are perforated by tiny pores through which cytoplasmic strands extend from one tube to another. Experiments have proved that the role of the sieve-tubes is the transport of ready-made food substances to various parts of the plant. These experiments include the following:

1. The two scientists Rapeden and Bohr in 1945 supplied a green bean leaf with CO_2 (containing radioactive carbon ^{14}C) in order to carry out photosynthesis and to produce carbohydrates. These

carbohydrates, being radioactive, could be traced during their path in the plant. It was discovered that they are translocated upwards as well as downwards in the stem.

2. The scientist Mittler managed, by using the Aphid insect, to describe the contents of sieve tubes in order to identify these contents. This insect penetrates the tissues of the plant until it reaches the sieve tubes, by its piercing mouth parts.

During the process of feeding, the scientist separated the whole body of the insect from its mouth parts. In this way, he managed to collect a sample of the sieve tube's contents. By analyzing this sample, it was shown to consist of the organic substances manufactured in the leaves (sucrose and amino acids). To make sure that this was the phloem content, he sectioned the region of the plant where the proboscis of the insect was inserted. It appeared to be inserted in a sieve-tube by its piercing mouth parts.

Transport of organic substances in the phloem:

In 1961 the scientists Thain and Canny could see long cytoplasmic thereads which contain organic substances inside the sieve tubes, and these lines extend through tiny pores from one tube to another.

They explained the transportation of the organic substances in the phloem on the basis of cytoplasmic streaming, i.e. the cytoplasmic circular movement inside the sieve tubes and companion cells during that, the organic substances translocate from one end to another end then they pass to the neighbouring sieve tubes through the plasmodesmata which pass from tube to another.

They explained that this activity needs more of ATP molecules which exist in the companion cell. This is proved later by experiments which show that the transportation process is delayed with the decrease of temperature or oxygen in cells, thus delaying the movement through the cytoplasm tubes (sieve tubes).

Chapter 2

Human Transport System

The process of transport takes place in the human body through two systems which are closely connected with each other. These systems are:

a) Blood vascular system (or Circulatory system).

b) Lymphatic system.

I - Circulatory system: This system consists of the heart and the blood vessels through which the blood passes. These vessels form a complete circuit, i.e. it is a closed circulatory system.

1. The Heart:

It is a hollow muscular organ which lies nearly in the middle of the chest cavity. It is enclosed in the pericardium that protects the heart and facilitates its action.

The heart is divided into four chambers; the upper two being relatively thin-walled chambers, called atria, which receive blood from the veins. The lower chambers, called ventricles, pump blood through the arteries. The two ventricles have thick muscular walls. The heart is divided longitudinally into two sides by means of muscular walls. Each atrium is connected to its own ventricle through an opening guarded by a valve. Each valve consists of thin flaps, whose free edges are attached by tendons to the ventricle wall; in order to prevent the flaps from turning inside out. Thus, blood is permitted to flow from atrium to ventricle, but not in the reverse direction.

The right valve which is the tricuspid valve is made up of three flaps, while the left one is similar in structure and action, except that it consists of two flaps, and is accordingly called the bicuspid valve (or mitral valve). There are also semi-lunar valves at the connection of the heart with both aorta and pulmonary artery. The heart beats regularly throughout the whole life time.

2. The Blood Vessels:

a) **Arteries:** These are fairly wide vessels which carry blood from the heart to other organs of the body. The wall of an artery is built up essentially of three layers of tissues. The outer layer consists of a coat of connective tissue. The middle layer is relatively thick and consists of involuntary muscles which contract and relax under the control of nerve fibres.

The inner layer (endothelium) consists of one row of tiny epithelial cells provided with by elastic fibres that give the elasticity of the artery.

Arteries are usually buried among the body muscles. They all carry oxygenated blood, except the pulmonary artery which comes out of the right ventricle to the lung.

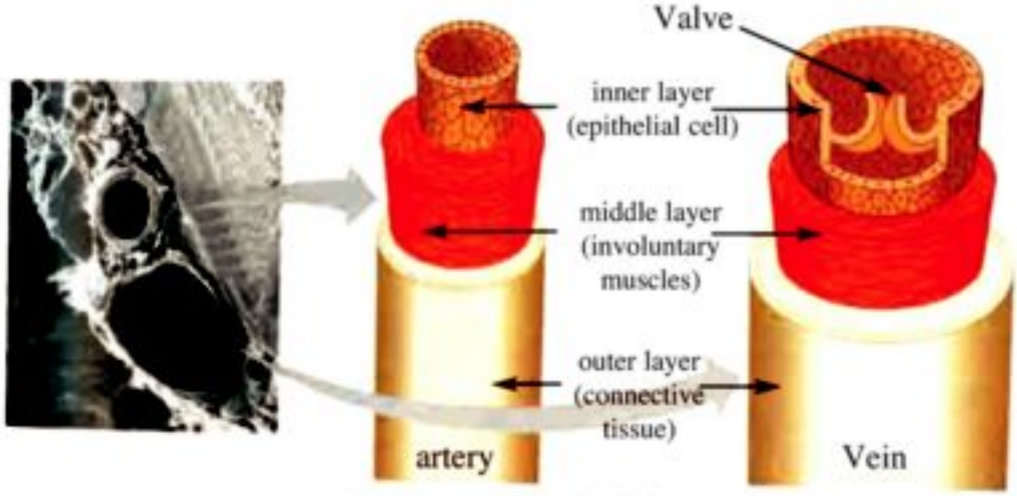


Fig. 5 Artery and Vein

b) The Veins: These are the vessels which carry blood to the heart. The wall of the vein, like the artery, is essentially composed of the same three layers but with certain modifications. There are less elastic fibres and the middle layer is less thick. Accordingly, the wall of the vein is thinner than that of the artery and does not pulsate.

A number of veins possess a system of internal valves along their length to prevent the backflow of blood, and allowing only the passage of blood in the direction of the heart. Sites of these valves can be observed in the arm veins when the arm is tied tightly with a bandage (tourniquet) above the elbow. This was done by William Harvey the English doctor, who discovered the blood circulation in the seventeenth century. After being discovered by the Arab doctor Ibn Al-Nafis in the tenth century.

Veins carry deoxygenated blood except the pulmonary veins which open into the left auricle.

c) The Capillaries: These are tiny, microscopic vessels which connect the arterioles with the venules. This fact was vein artery discovered by the Italian scientist Malpighi towards the end of the seventeenth century, and thus completed the work of Harvey. Capillaries have an average diameter of (7- 10) microns. Their walls, which are very thin, consist of one row of thin epithelial cells with tiny pores between them.

Fig. 6 Blood Capillaries

The wall of the capillary is about 0.001 micron thick, which facilitates quick exchange of substances between the blood and the tissue cells. Capillaries spread in the spaces between cells all over the body tissues supply them with their requirements.

3- Blood:

You already know that blood is a liquid tissue. It contains red blood cells, white blood cells in addition to blood platelets. The tissue fluid is called plasma. The blood is the principal medium in the process of transport. It is a red viscous liquid. The human body contains from 5 to 6 litres of blood on average. It is weakly alkaline (pH=7.4).

The blood contains:

a) Plasma:

It is about 54% of blood volume. It contains 90% water, 1% inorganic salts, such as Ca^{++}, Na^{+}, CL^{-}, $(HCO_3)^{-}$, 7% proteins as albumin, globulin, fibrinogen and 2% of other components as absorbed food (sugar, amino acids), hormones, enzymes, antibodies and wastes (urea).

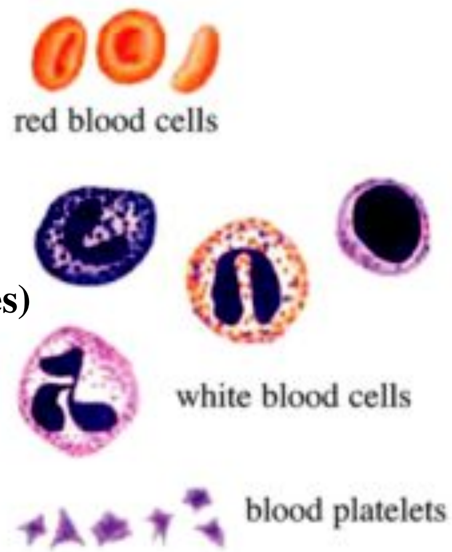


Fig. 7 Blood Components

b) Red blood corpucles (Erythrocytes) (RBCs) :

They are the most abundant blood cells. They are nearly about 4 to 5 million cells/mm^3 in males. and 4 to 4.5 million cells/mm^3 in females. Each is destroyed after

120 days. They circulate about 172,000 circulations.

They are produced in bone marrow of backbones. They are round, biconcave and enucleated. They contain hemoglobin (Protein + iron), which gives the blood its red colour. In the two lungs, the hemoglobin combines with oxygen to form pale red oxyhemoglobin. The oxyhemoglobin carries the oxygen to different parts of the body, where it leaves the oxygen and unite with carbon dioxide to form dark red carbo-amino hemoglobin So, the venous blood is darker than the arterial blood.

RBCs are destroyed in liver, spleen and bone marrow. The proteins in the hemoglobin are used in the formation of the bile.

c) White blood cells (leucocytes) WBCs:

They are about 7000 cells/mm^3 and increase during diseases. They are colourless and nucleated. Some of their kind live for 13-20 days and continuously formed in the bone marrow, spleen and lymphatic system. They are produced in many types, each with a specific function.

The main function of WBCs is the protection of the body against the infectious diseases. They circulate continuously in the blood vessels, attack foreign particles, destroy and engulf them. Some of them produce antibodies.

d) Blood platelets:

They are noncellular very small in size (one-fourth of the RBCs), and live for about 10 days. They are about 250,000 cells/mm^3. They are produced from bone marrow. They play a role in blood clots.

Functions of blood:

1. Transport of digested food substances, together with oxygen, carbon dioxide, waste nitrogenous compounds, hormones and some active or inactive enzymes.
2. Controlling the processes of metabolism and keeping body temperature at 37°C. In addition, it regulates the internal environment (homeostasis) such as osmotic potential.
3. Protection of the body against microbes and pathogenic organisms through white blood cells.
4. Protection of the blood itself against bleeding by formation of clots.

Heart Beats:

The rhythmic heart beats are spontaneous as they originate from the cardiac tissue itself. It has been proven that the heart continues beating regularly even after it has been disconnected from the body and cardiac nerves.

So, what is the source of the regular rhythm of heart beat?

There is a Hess fibre bundle of thin cardiac muscular fibres buried in the right arterial wall near the connection between the right auricle and the large veins. This bundle is called the sino-

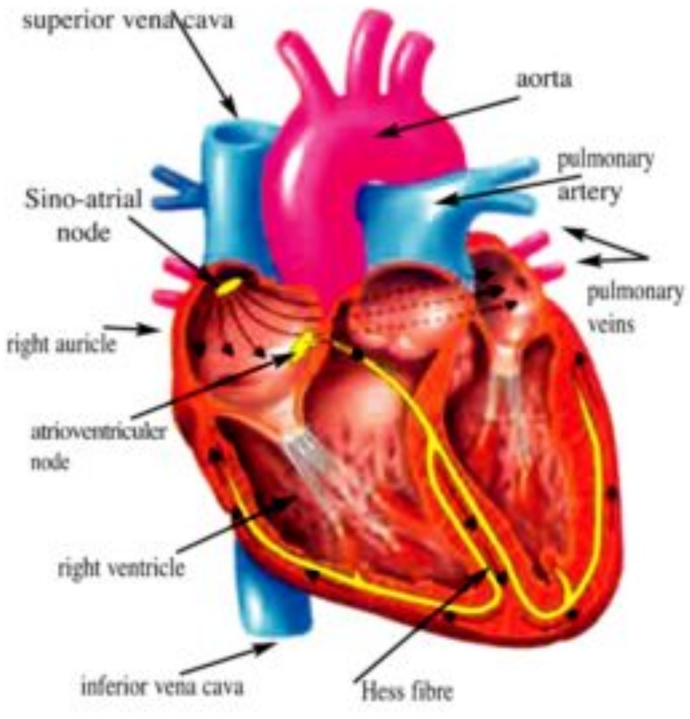


Fig. 8 Heart beats

atrial node which is considered as the pace-maker of the heart.

The sino-atrial node sends impulses over the two atria which are stimulated to contract. When the electrical impulse reaches the atrio-ventricular node (at the junction between atria and ventricles) the impulse will spread rapidly through special fibres from the inter-ventricular septum to the wall of both ventricles, where it stimulates their muscles to contract.

The sino-atrial node, i.e. the pace-maker, beats at a regular rate of 70 beats/minute. It is connected to two nerves, one lowers its rate and the other increases it, so that the number of cardiac beats changes according to the physical and psychological state of the body. For example, the number of heart beats is lowered during sleep and gradually increases after waking up. It is also lowered in states of grief and increases in states of joy. It also increases with sever physical effort.

We can distinguish two sounds in the heart beat, one is long and low-pitched (lubb) and is due to closure of the two valves between the atria and ventricles during ventricular contractions, and the other is shorter and high-pitched (dupp) and is due to the closure of aortic and pulmonary valves during ventricular relaxation. In the normal age of man, the heart beats about 70 beats / minute and pumps 5 liters of blood in each minute which equalizes the whole blood of the body.

Blood Pressure:

The blood is a viscous liquid. It circulates within the arteries and veins smoothly by the process of heart beats. But to pass within the microscopic blood capillaries it needs pressure. The largest blood pressure is measured in the arteries nearer to the heart. The maximum blood pressure is measured as the ventricles contract and the minimum as the ventricles relax.

The blood pressure is measured by means of mercuric instruments, sphygmomanometers. Its readings consist of two numbers, for example 120/80 mm Hg, which is the normal value at youth. The two measurements represent the blood pressure (120) as the ventricles contract (cystolic), and 80 as they relax (diastolic), respectively.

Measurements of blood pressure at other various points along the arteries show progressive decrease. Blood pressure in the venules is very low (about 10 mm Hg). The very low blood pressure in the veins is not sufficient to move blood back to the heart.

When the skeletal muscles near the veins contract, they put pressure on the collapsible walls of the veins and the blood contained in these vessels. Veins, however, have valves that prevent backward flow, and therefore pressure from muscle contraction is sufficient to move blood through veins towards the heart. The blood pressure increases gradually by aging and it must be under medical control to avoid its harmful effects. The sphygmomanometer consists of mercuric tube and scale board. The blood pressure can be measured according to the elevation of mercury inside the tube.

The values of the blood pressure are determined by listening to the heart beats. As the ventricles contract, the doctor can listen to the heart beat, while as the ventricles relax the sound disappear. The blood pressure can be measured when the heart beats and also between one beat and the other. There are some digital instruments to measure the blood pressure, but they are not accurate as mercury instrument.

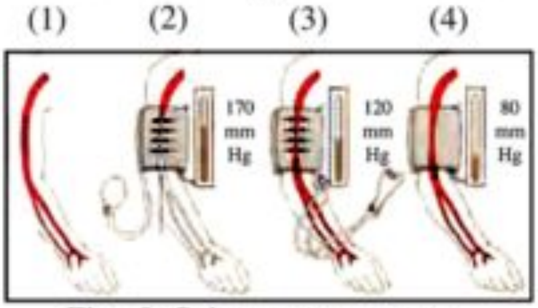


Fig. 9 Sphygmomanometer

Chapter 2

BLOOD CIRCULATON

Blood circulation in Man is divded into three main pathways:

1. Pulmonary circulation: (Fig. 10)

It starts from the right ventricle and ends at the left atrium. When the right ventricle contracts the tricuspid valve closes the opening of the right atrium. The deoxygenated blood will, therefore, rush through the pulmonary artery through the three-flapped semi-lunar valve. This valve prevents the back flow of blood to the ventricle.

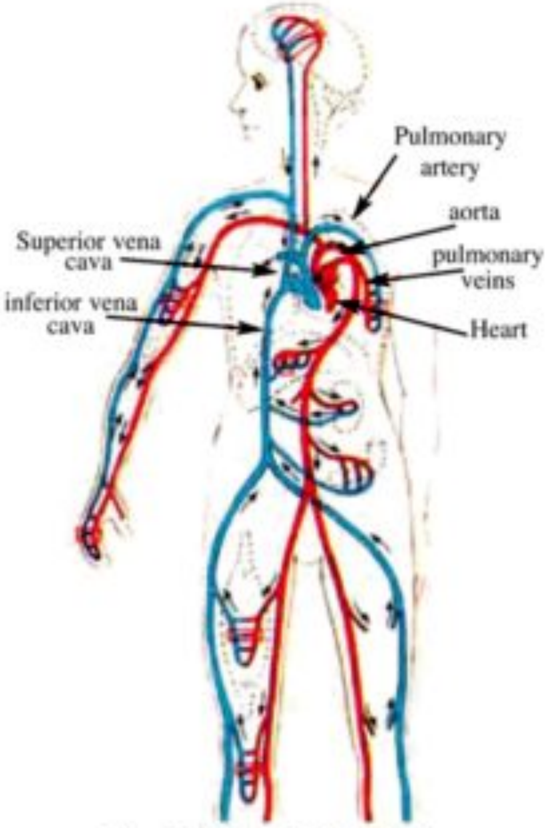


Fig. 10 Blood Circulation

The pulmonary artery gives rise to two branches, each branch goes to a lung where it branches to form several arterioles which terminate in blood capillaries.

Blood capillaries spread around the alveoli, where exchange of gases takes place. Carbon dioxide and water vapour will diffuse from the blood, and oxygen will move towards it, so that blood becomes oxygenated. It returns from the lungs through four pulmonary veins (two veins from each lung) to open into the left atrium. When the left atrium contracts, blood passes to the left ventricle through the bicuspid valve.

2. Systemic Circulation:

It starts from the left ventricle and ends at the right atrium. When the left ventricle contracts after being filled with oxygenated blood, the mitral valve closes. As a result, blood under great pressure rushes from the left ventricle to the aorta through an opening which is controlled by a semi-lunar valve to prevent the back-flow of blood.

The aorta gives rise to several arteries, some of which move upward while others go downward. Arteries then branch to form smaller and smaller arterioles which end by blood capillaries. These capillaries spread through the tissues in between the cells transporting oxygen, water and dissolved food substances to them.

On the other hand, products of catabolism such as carbon dioxide resulting from oxidation of sugar and fat diffuse through the walls of blood capillaries and reach the blood which changes in colour from light red to dark red and is now called deoxygenated blood.

Blood capillaries collect to give rise to larger and larger venules and finally veins, which pour their deoxygenated blood into the superior and inferior vena cava which carry blood to the right atrium. When it is

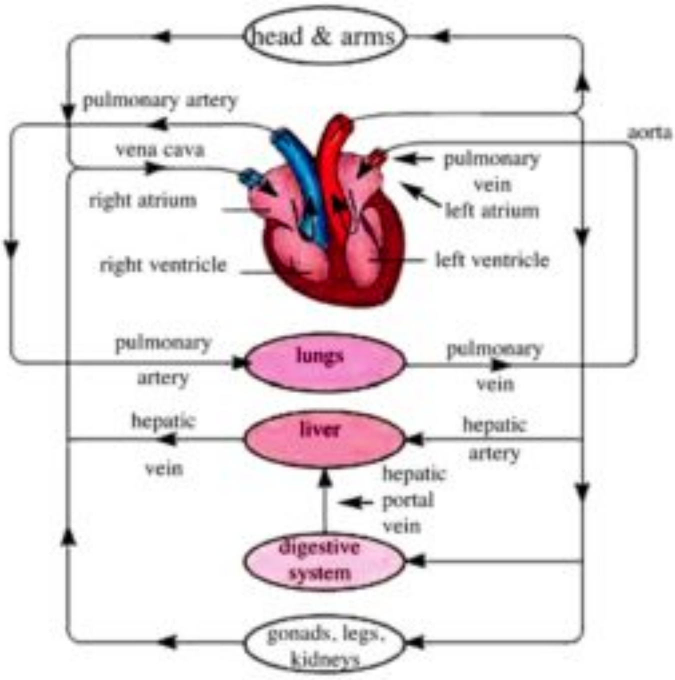


Fig. 11 Diagrammatic representation of the blood circulation

filled with blood, the walls of the right atrium contract and so blood is forced to the right ventricle which becomes filled with deoxygenated blood.

It is worth noting that contraction of the right side of the heart occurs at the same time as contraction of the left side. Therefore, pumping of the deoxygenated blood from the right ventricle, and pumping of oxygenated blood from the left ventricle, both take place at the same time.

3. The Hepatic Portal Circulation:

After being absorbed by the villi of the small intestine, both glucose and amino acids are transported to the blood capillaries inside these villi.

These blood capillaries aggregate into small venules, then large venules and finally they pour their contents into the hepatic portal vein. This also receives veins from the pancreas, the spleen and the stomach.

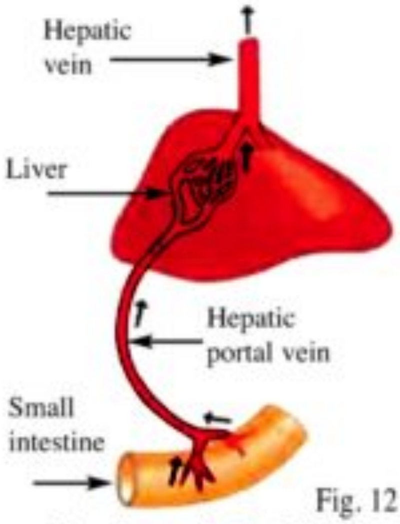


Fig. 12
Hepatic portal circulation

When it first enters the liver, the hepatic portal vein branches into venules which end with minute blood capillaries. Excess food substances which exceed the body needs, filter through the capillary walls cells and pass to the liver where they undergo certain changes. Finally, blood capillaries unite into the hepatic vein which leaves the liver to pour its contents into the upper part of the inferior vena cava, just before it enters the right atrium.

Blood clot:

When a blood vessel is cut, blood soon forms a clot to prevent bleeding before it leads to chock followed by death.

The mechanism of blood clotting:

It is initiated by a blood vessel cut and involves a sequence of steps:

1. When blood becomes exposed to air or to friction with a rough surface such as damaged vessels and cells, the blood platelets form, together with the destroyed cells, a protein substance called thromboplastin.

Fig. 13 Blood Clot

2. In presence of calcium ions (Ca^{++}) and blood clotting factors in the plasma, thromboplastin activates the conversion of prothrombin to thrombin (prothrombin formation occurs in the liver with the help of vitamin K and is passed directly into the blood).
3. Thrombin, being an active enzyme, catalyzes the conversion of fibrinogen (soluble protein in plasma) into an insoluble protein which is fibrin.
4. Fibrin precipitates as a network of microscopic interlacing fibres and the blood cells aggregate forming a clot which blocks the hole in the damaged blood vessel. In this way bleeding stops. (Fig. 13)

Why doesn't blood clot inside blood vessels?

Blood never clots inside blood vessels as long as it runs in a normal fashion, and does not slow down. Blood platelets should also slide easily and smoothly inside the blood vessels in order not to be broken. Prevention of clotting inside blood vessels is, also, due to the presence of heparin (secreted by the liver) which prevents the conversion of prothrombin to thrombin.

The mechanism of blood clotting is illustrated by the following simplified representation:

1. Blood platelets + destroyed cells $\xrightarrow[\text{in the blood}]{\text{Factors of clotting}}$ Thromboplastin
2. Prothrombin $\xrightarrow[\text{+factors of clotting + } Ca^{++}]{\text{thromboplastin}}$ Thrombin
3. Fibrinogen $\xrightarrow{\text{thrombin}}$ Fibrin

Lymphatic system:

The lymphatic system is considered as the immune system of the body due to its ability for defence and the production of antibodies that give the body its immunity.

The lymphatic system (Fig.14) consists of large number of lymphatic capillaries. They take up blood fluid comes from the blood capillaries, which is

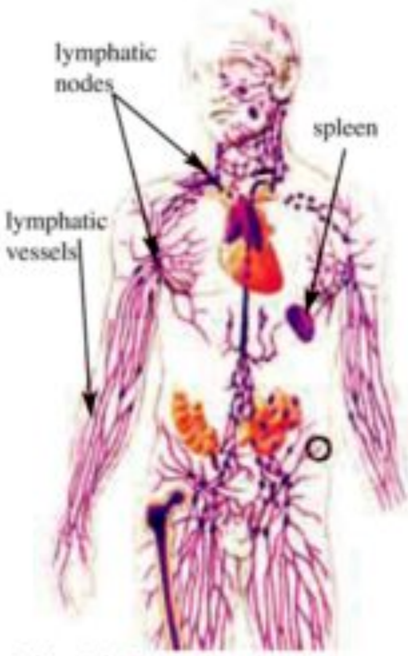


Fig. 14 Lymphatic system

called the lymph. The lymph contains nearly most of the plasma constituents and leucocytes. The lymphatic capillaries empty the lymph into the circulatory system along the superior vena cava.

The lymph passes across the lymph nodes which are found at certain points along the lymph capillaries. Lymphocytes are packed into the space of lymph nodes which trap microbes by white blood cells (W.B.Cs) which they produce. The spleen is considered one of the most important lymphatic organs in the body.

Practical Activities

- Examination of a transverse section of the stem of a dicotyledonous plant (Helianthus).
- Demonstrations to show transport in higher plants (The role of the xylem in the transport of water).
- Dissection the heart of a sheep to identify its parts.

Transverse section in dicot stem (Helianthus):

Materials:

1. Transverse section in Helianthus stem (prepared slide).
2. Light Microscope .

Instructions:

1. By the low power of the microscope, examine the prepared section to detect the main tissues: epidermis, cortex, vascular cylinder, number of vascular bundles, arrangement of pericycle, phloem, xylem, pith and medullary rays. Draw a fully labelled diagram of the section.
2. By the high power of the microscope, examine the previous tissues, taking in consideration the following:

a) Epidermis: What is the shape of the cells? Does it have cutin, external hairs, stomata and intercellular spaces?

b) Cortex: What is the number of its layers? Are they all similar in shape and type? What are the sizes of these layers? Are there any intercellular spaces? What is the shape of the last layer? Does it have starch grains?

c) Pericycle: What is the type of its cells and the thickness of its wall?

d) Phloem: What is the type of its cells?

e) Cambium: What is the type of its cells? How many rows are there?

f) Xylem: What is the type of its cells? What is the position of metaxylem and protoxylem in relation to pith?

g) Medullary rays: Where is it and what is the type of its cells? Does it have any spaces?

h) Pith: What is the type of its cells? How many layers are there? Draw a detailed section with labels.

Questions

1. What would happen to the following heart beats:

a) During sleep.

b) After waking.

c) During joy.

d) During exerting a weak effort.

e) During grief.

2. Write short notes on:

a) Cambium

b) Sinoatrial node

c) White blood cells.

3. Mention the place and function of the following:

a) Tracheids

b) Pith

c) Pericardium membrane

d) Cuitn

e) Haemoglobin

f) Atrio-ventricular node.

4. In higher plants there are tissues responsible for transportation.

a) Mention the name of these cells.

b) What are the substances transported by these cells.

c) Detect the direction of these transports.

5. The bean plant absorbs water and minerals by the roots and obtains CO_2 through stomata.

a) Detect the place of CO_2 diffusion.

b) Detect the pathway of water, minerals and CO_2 untill the plant consumes them.

c) What are the final compounds produced?

6. Explain how the blood clot is formed in man.

7. Give reasons for:

a) Some seedlings, when transplanted from a nursery to open soil, fail to grow if they exposed to the sun for a long time.

b) The Doctor hears two different sounds for heart beats.

c) Blood does not clot inside blood vessels

d) Number of heart beats change according to the physical and psychological state of man.

e) Blood pressure is measured by two numbers.

f) Presance of lymphatic nodes on certain distances along lymphatic vessels.

8. Choose the correct answer for each statement, from the answers underneath.

a) Transport of water from roots to leaves occurs according to the following order:

- Root hair - Phloem - Cortex - Mesophyll - Upper epidermis.
- Cortex - root hair - phloem - spongy tissue - Lower epidermis.
- Root hair - Cortex - Xylem - Mesophyll - Stomata.
- Epidermis - Cortex - Xylem -Palisade layer - stomata.

b) A person suffers from inflammation of the Appendix, his blood shows an increase in the number of:

- Enzymes.
- Leucocytes (white blood cell).
- Blood platelets.
- Erythrocytes (red blood corpuscles).

c) Water reachs to the top of high trees according to the phenomenon of imbibition - capillarity - adhesive, cohesive and transpiration pull - root pressure.

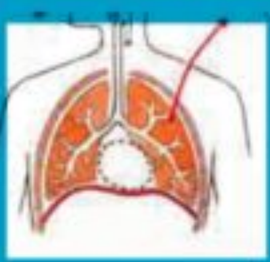
d) The back flow stops in veins by valves - muscles - heart beats - lymphatic vessels.

e) From plasma protein that has a role in blood cloting.

globulin - fibrinogen - albumen - heparin.

f) The blood that reaches brain cells leaves the heart from.

Right atrium - left atrium - Right ventricle - left ventricle.



CHAPTER THREE

Respiration in Living Organisms

At the end of this chapter the student should be able to:

- Identify the concept of cellular respiration.
- Understand the steps of glycolysis and its importance.
- Identify the steps of aerobic respiration and where it takes place.
- Distinguish between aerobic and anaerobic respiration.
- State the importance of cellular respiration.
- Link between photosynthesis and respiration in plants.

Chapter 3

The concept of respiration and its importance to living organisms:-

We have already seen that green plants absorb energy from sun light and change it into chemical energy. They store this energy after converting it into chemical energy by photosynthesis as high energy compounds. The most important of which are carbohydrates, particularly glucose. Respiration process occurs by taking in the oxygen directly as in unicellular organisms or by a respiratory system in the case of multicellular organism and carbon dioxide is produced as a final product of respiration. In this process, we should not confuse between gas exchange and cellular respiration. In the latter, the cell breaks down food molecules in order to release the energy which is used by the cell to perform its vital functions and activities.

The cellular respiration:

Glucose as well as other carbohydrates are considered as a form of stored energy, also it is a form of energy by which energy transfers from one cell to another and from one living organism to another.

Cellular respiration is the process by which energy is extracted from chemincal in the food molecules manufactured by plants or eaten by animals.

The glucose molecule is considered as an excellent example to study the steps of breaking down the food molecules, as it is used commonly by the majority of living organisms to produce energy more than any molecule of available food.

Any energy required by a cell needs ATP which is considered like small currency. It can be easily spent and exchanged. It is actually considered as the universal currency of energy in the cell.

In order to understand how ATP performs its functions we have to study its structure. The molecule is built up of three sub-units which are: "adenine" which is a nitrogenous base (i.e. it has the properties of a base) and a 5 carbon-pentose sugar called "ribose". The two are joined to a chain of 3 phosphate groups linked together by bonds.

In cellular reactions only one of these bonds usually breaks down, i.e. only one phosphate group is removed by hydrolysis of an ATP molecule which becomes adenosine diphosphate "ADP" and an amount of energy (which is about 7-12 k cal / mole) is released.

The process of cellular respiration starts with a glucose molecule, and can be summarized by the following equation, which indicates the amount of energy released from one mole of glucose.

$$C_6H_{12}O_6 + 6O_2 \xrightarrow[\text{respiratian}]{\text{cellular}} 6CO_2 + 6H_2O + 38\ ATP$$

Oxidation of glucose molecule takes place in three major stages:

a) Glycolysis.

b) Krebs cycle.

c) Electron transport.

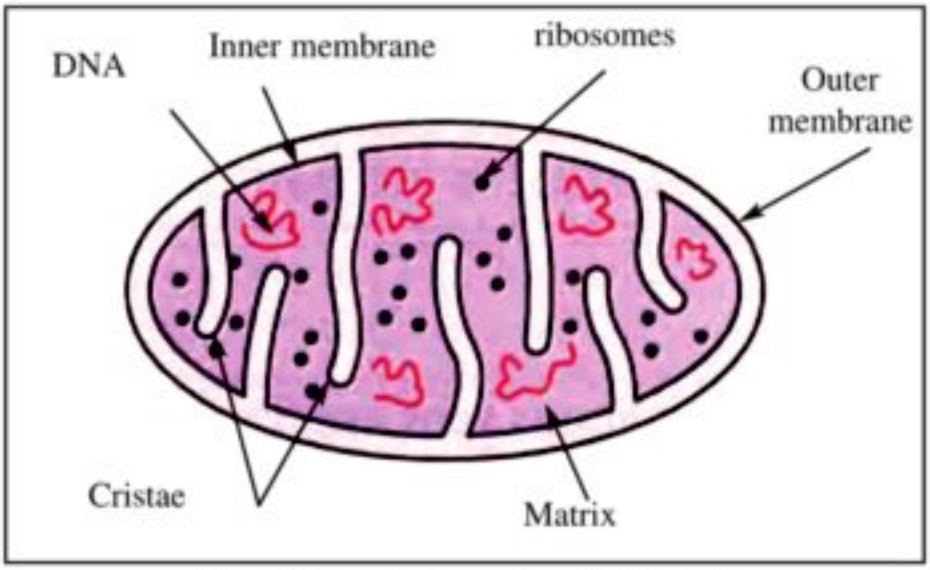


Fig. 1 The structure of a mitochondrion

Glycolysis occurs in the cytosole of the cell, while the two steps of Krebs cycle and electron transport occur inside the mitochondria, where respiratory enzymes, water, phosphate groups, co-enzymes, and electron carrier molecules or cytochromes (carried electrons at different levels) are situated.

In the breaking down of glucose and Krebs cycle, hydrogen atoms are removed from the carbon skeleton of glucose molecule to pass to the co-enzymes which act as hydrogen carriers. The most important of them are NAD^+ which is reduced into NADH and FAD which is reduced into $FADH_2$.

$$NAD^+ + H_2 \xrightarrow{\text{Reduction}} NADH + H^+$$

$$FAD + H_2 \xrightarrow{\text{Reduction}} FAD\,H_2$$

A) Glycolysis:

Glycolysis takes place in both aerobic and anaerobic respiration to produce energy in which one molecule of glucose breaks down forming two molecules of pyruvic acid (3-carbon) passing through a group of reactions through which glucose is converted into glucose 6-phosphate then fructose -6-phosphate then fructose 1-6 diphosphate which forms two molecules of PGAL (phosphoglyceraldehyde) to be oxidized into two pyruvic molecules and reduce two molecules of NAD^+ into NADH and two molecules of ATP are produced in the cytosole of the cell. All of these reactions occurr in the absence or lack of oxygen. Therefore, these reactions are called anaerobic respiration.

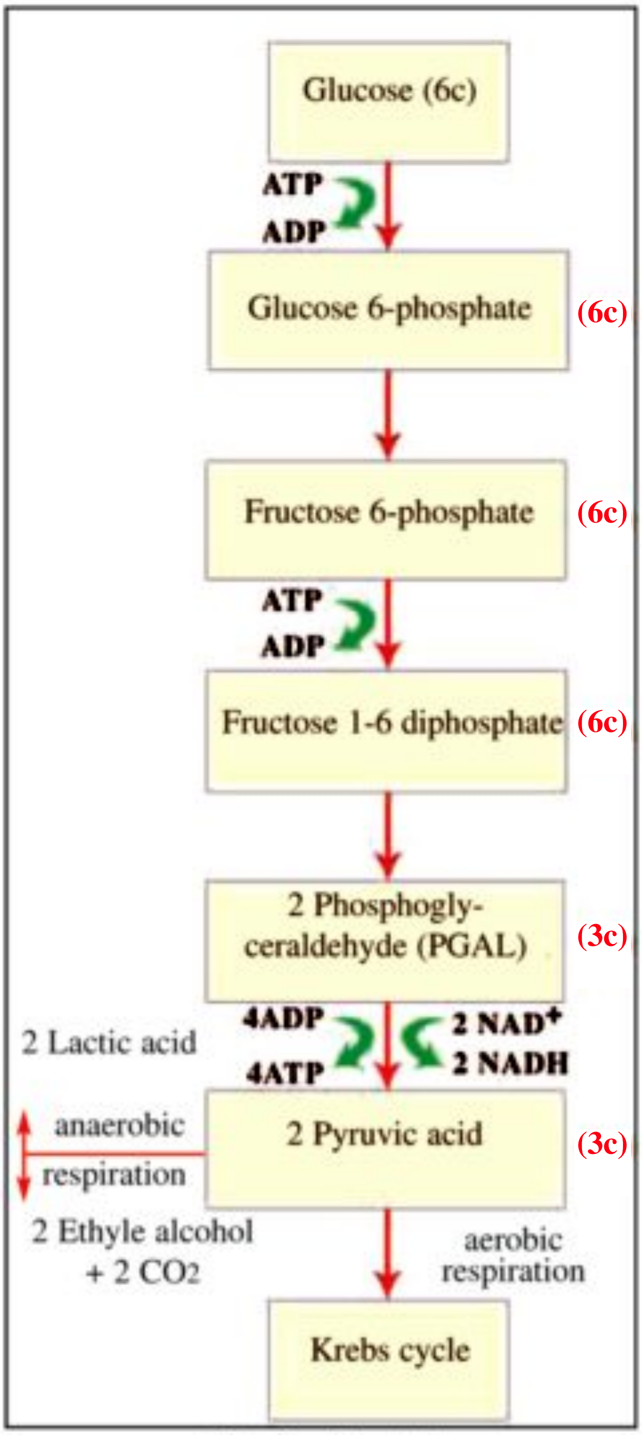


Fig. 2 Glycolysis

$$C_6H_{12}O_6 \xrightarrow[\text{Respiratory enzymes}]{\text{Anaerobic respiation}} 2\,C_3H_4O_3 + 2\,ATP$$

The energy resulted is not enough to perform all vital activities of living organisms, therefore, in the presence of oxygen, pyruvic acid passes into the mitochondria to produce more energy. This takes place in two stages, Krebs cycle and electron transport.

B) Krebs cycle:

The first describer of this cycle was Sir Hans Krebs in 1937. He won Noble prize in 1963.

Go Further

For more knowledge about this topic you can refer to the Egyptian Knowledge Bank (EKB) through the opposite link

Krebs cycle takes place in two stages:

1. Each molecule of pyruvic acid is oxidized in the presence of co-enzyme (A) into acetyl co-A, in this reaction two molecules of NADH and two molecules of CO_2 are produced. Also acetyl groups from breaking down fat molecules or protein molecules can combine with co-A enzyme to join to Krebs cycle.
2. Each molecule of acetyl co-A joins Krebs cycle where its co-A splits off to repeat its role, at the same time acetyl group (2C) combines with a compound (4C) oxaloacetic acid to form a compound (6C) citric acid which passes through three intermediate compounds. It starts by ketoglutaric acid then succinic acid then malic acid and at the end of the reactions citric acid is formed again, therefore, Krebs cycle is called the citric acid cycle.

3. Two moleules of CO_2 are released and one ATP molecule with three NADH molecules, one $FADH_2$ molecule are produced in each cycle (Krebs cycle is repeated twice, once for each molecule of acetyl group).

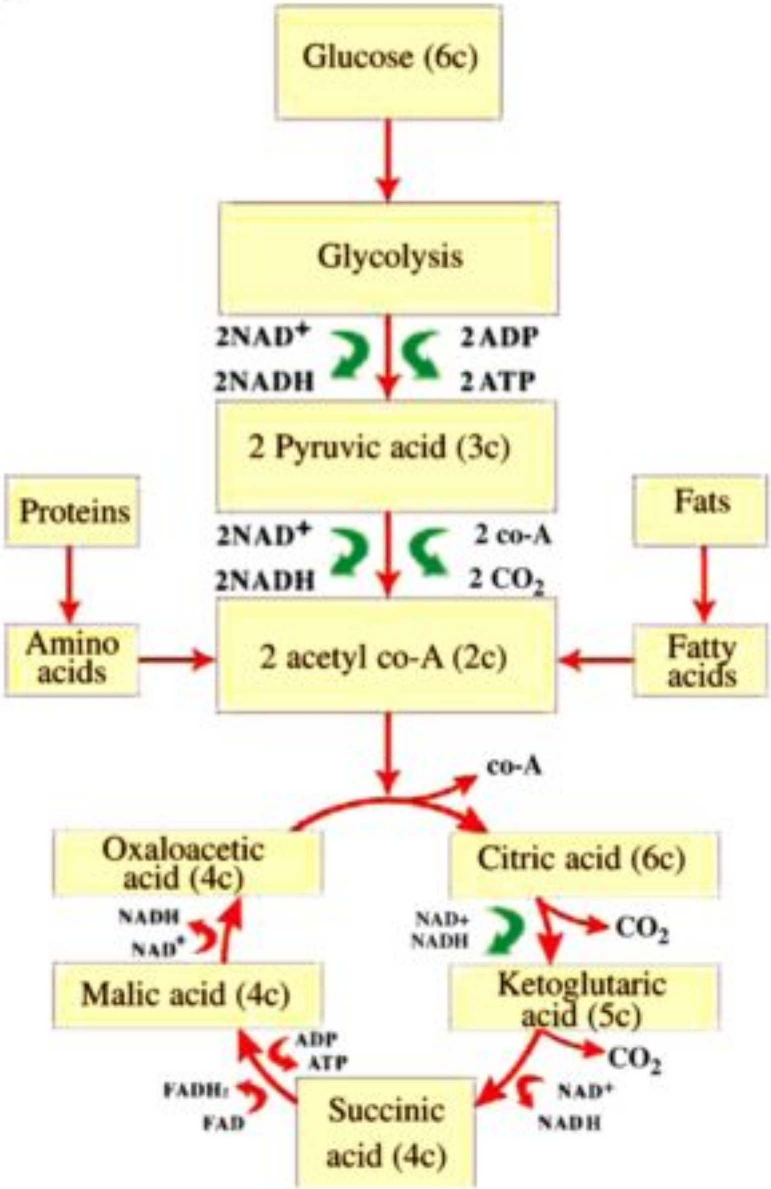


Fig. 3 Krebs cycle

It is clear that Krebs cycle does not need oxygen, since all electrons and protons are removed during oxidation of carbon atoms and received by NAD+ and FAD molecules.

C) Electron transport chain:

1. At the terminal stage of aerobic respiration and by the end of Krebs cycle, hydrogen and high energy electrons carried by NAD^+ and FAD are transported over certain sequences of co- enzymes called cytochromes (electron carriers) present inside the inner membrane of mitochondria. They carry electrons at different energy levels. These high energy electrons are passed from one molecule of cytochromes to another, and during that energy is released to form ATP from ADP plus a phosphate group. This process is called oxidative phosphorylation.

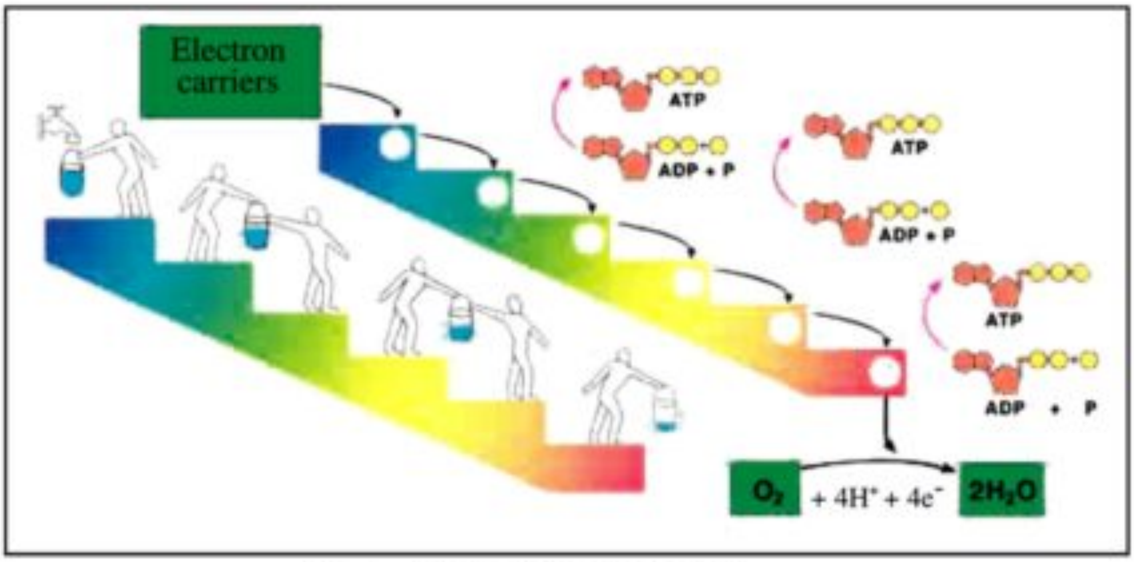


Fig. 4 Electron transport chain

2. Oxygen is considered the last receptor in the electron transport chain where the two electrons combine with two H^+ and one oxygen atom to form water. $2e^- + 2H^+ + 1/2\ O_2 \longrightarrow H_2O$

(In electron transport chain each NADH molecule produces 3 molecules of ATP while each $FADH_2$ molecule produces two molecules of ATP.)

3. Accordingly, in aerobic respiration each molecule of glucose produces 38 ATP, two of them are produced in the cytoplasm of the cell during glycolysis and 36 molecules are produced inside the mitochondria.

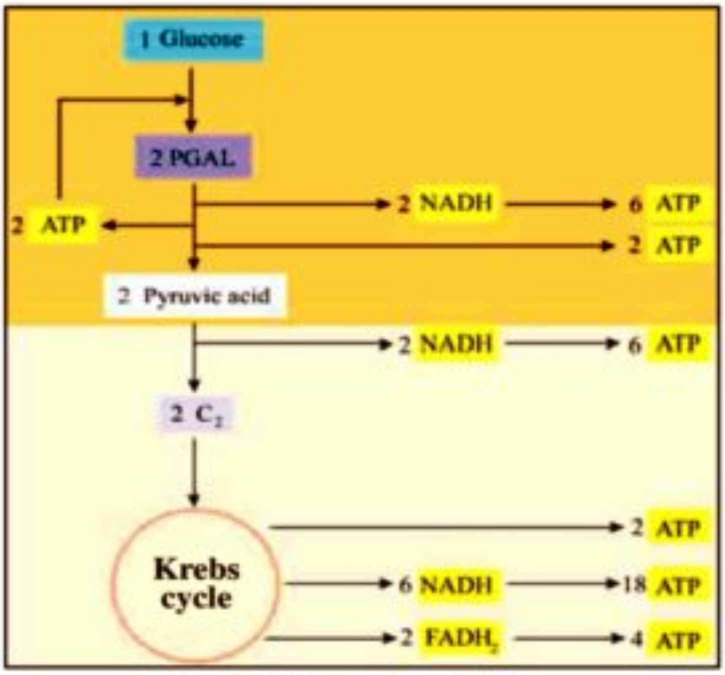


Fig. 5 Calculation of ATP

Go Further

For more knowledge about this topic you can refer to the Egyptian Knowledge Bank (EKB) through the opposite link

Anaerobic respiration:

When oxygen is missing or in low quantity, living organisms as bacteria and fungi respire by another kind of respiration called anaerobic respiration. Also plant and animal cells may respire anaerobically when oxygen is not available, and this is known as fermentation, this kind of respiration does not need oxygen but it takes place in the presence of special enzymes.

Anaerobic respiration starts the same way as aerobic respiration by the decomposition of a glucose molecule into two molecules of pyruvic acid with two molecules of NADH and a small quantity of energy as 2 ATP released. Pyruvic acid is converted according to the type of cell in which it was formed, in case of animal cells, especially the muscle fibres, when the muscles exert vigorous efforts or exercises they consume most of the oxygen in their cells and tend to convert pyruvic acid into lactic acid after its reduction by combining with hydrogen on NADH

$$C_6 H_{12} O_6 \xrightarrow{\text{Acidic fermentation}} 2C_3 H_6 O_3 + 2\ ATP$$

This is known as muscular fatigue, (if oxygen is available, lactic acid is converted into pyruvic acid again and then into acetyl co-A). In the case of bacteria pyruvic acid is converted into lactic acid. In the case of yeast or in some plant cells pyruvic acid is reduced into ethyl alcohol and carbon dioxide. This process is called alcoholic fermentation and is used in the industry of some products.

$$C_6 H_{12} O_6 \xrightarrow[\text{fermentation}]{\text{Alcoholic}} 2C_2\ H_5 OH + 2\ CO_2 + 2\ ATP$$

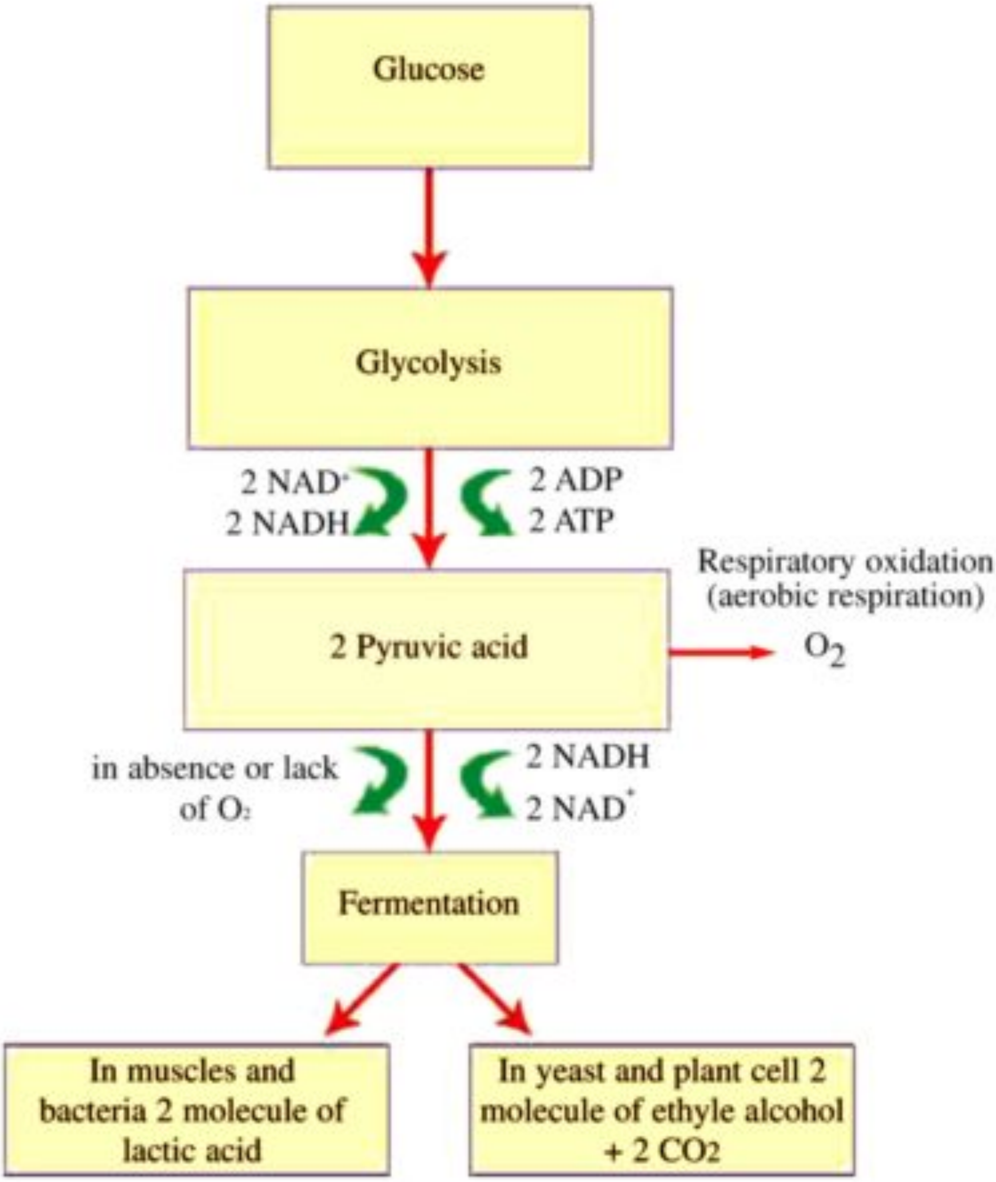


Fig. 6 Diagram of anaerobic respiration

Respiration in Man

The respiratory system in man:

The air enters the body through the nose or the mouth. It is preferable, from the hygienic point of view, for air to enter through the nose, because this passage is warm (as it is lined with numerous blood capillaries) and moist (as it secretes mucus). It also serves as a filter (because it contains hair which act as a filter).

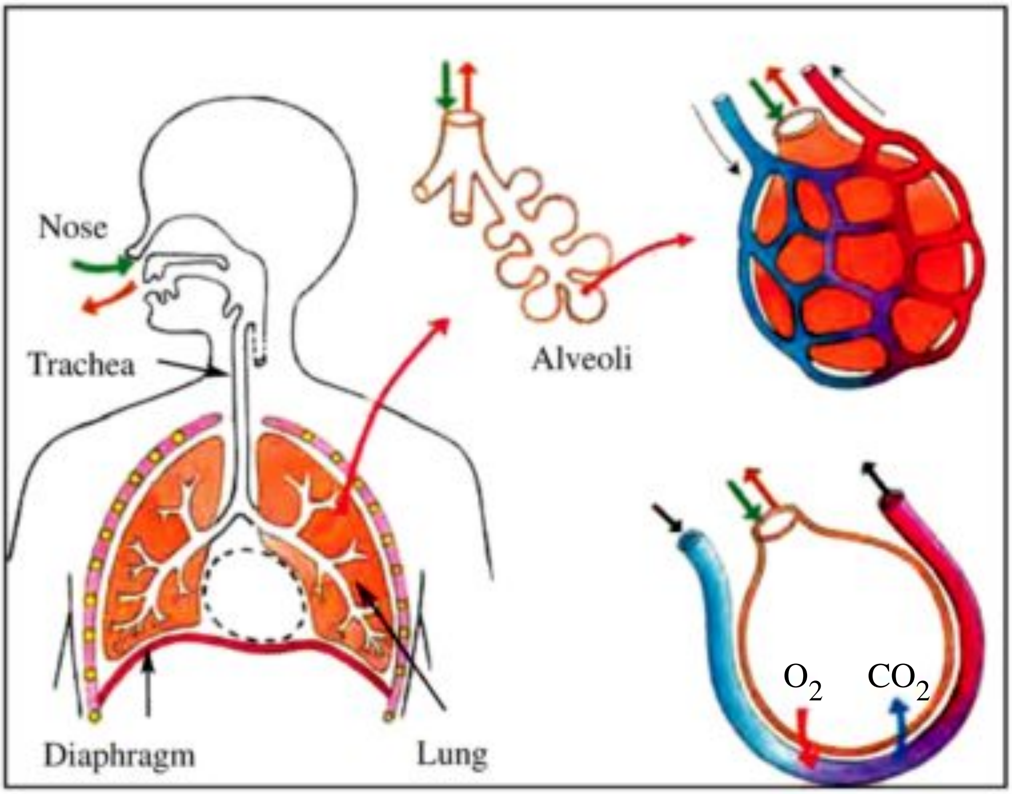


Fig. 7 Respiratory system

Air then passes through the pharynx which is common passageway for both air and food. It enters the trachea through the larynx (which is also known as the voice box). The trachea wall contains a series of cartilage 3/4 rings which prevent the trachea from collapsing, thus maintaining an open passageway for air. The inner surface of the trachea is lined with cilia which beat upwards tending to create air and mucus currents. This impedes the entry of small foreign bodies, and moves them to the pharynx, where they may be swallowed. The trachea is divided at its lower end into two bronchi which divide and subdivide into progressively smaller and smaller bronchioles. Each bronchiole finally opens into one of the many alveoli (air sacs) of which there are about 600 millions per lung.

The thin alveolar walls are considered the actual respiratory surface, as they are surrounded with a large network of blood capillaries. Blood receives oxygen from the alveolar air and carries it to the rest of the body. It gives out CO_2 to the alveoli in return so that it may get rid of it. The whole group of alveoli and bronchioles connected to them, together with the huge network of capillaries, constitute the lung. Each animal including man possesses two lungs, a right lung and a left one.

The respiratory system in man plays an important role in the excretion of water. The expirated air contains water vapour. Man usually loses daily about 500 cm^3 of water through his lungs out of the 2500 cm^3 of water that he loses daily. This is due to the evaporation of water that moistens the alveoli membranes. This water is necessary for dissolving oxygen and carbon dioxide so that the exchange of gases between the air of the alveoli and the surrounding blood in the capillaries occurs.

Respiration in plant

The green plant absorbs light energy from the sun and transforms it into chemical energy through photosynthesis process to store as high energy complex organic molecules (glucose). Whenever the plant needs energy to carry out one of its vital activities, it releases this energy slowly in a chain of reactions which includes breaking down of carbon bonds of the organic substances. This is the process of respiration in plants. If oxygen is present, aerobic respiration occurs, but if oxygen is absent it is called anaerobic respiration. In fact, in most plants each living cell is in direct contact with the external environment and therefore gaseous exchange is easy to occur. In this case oxygen gas diffuses inside while CO_2 is released outside the cell.

In the case of vascular plants oxygen reaches the cells through various passageways. When the stomata of the leaf open, air enters to the air chambers and then diffuses through the intercellular spaces spreading to various parts of the plant. Eventually, the gas diffuses through the cell membranes and dissolves in the water of the cell. In addition, some of the oxygen is carried to the phloem passageway, dissolved in water, and finally reaches the tissues of the stem, the stem and the root.

Oxygen may also enters the plant through the roots, soluble in water of the soil solution when it is absorbed by root hairs or imbibed by cell walls. If the stem of the plant is green, the stomata which spread on its surface will act as an entrance for air.

Similarly, the lenticels or any cracks in the bark of woody stems may act the same.

As regards for CO_2 resulting from respiration of the plant, it is expelled to the external environment by direct diffusion from plant cells which are exposed directly to the external environment. For deep seated cells, gaseous exchange occurs by mutual diffusion of CO_2 to xylem vessels or phloem tissue which passes CO_2 in return to stomata then to the external atmosphere.

- We shouldn't forget the relation between photosynthesis and respiration in plant, what takes place in plastids is reversed in mitochondria to liberate the energy by respiration. The next figure shows this relation in the form of a cycle occurring between photosynthesis and cellular respiration.

Fig. 8

Cycle of cellular respiration and photosynthesis

An experiment to prove the respiration in plants :

1. Take a green potted plant and place it on a glass plate together with a small beaker containing clear lime water. Invert a glass bell-jar over the two then cover the jar with a black piece of cloth.
2. Prepare a similar apparatus, with a pot empty of any cultivated plant.
3. Put some clear lime water in a small beaker and leave it exposed to atmospheric air.

Leave the three for sometime. What do you observe?

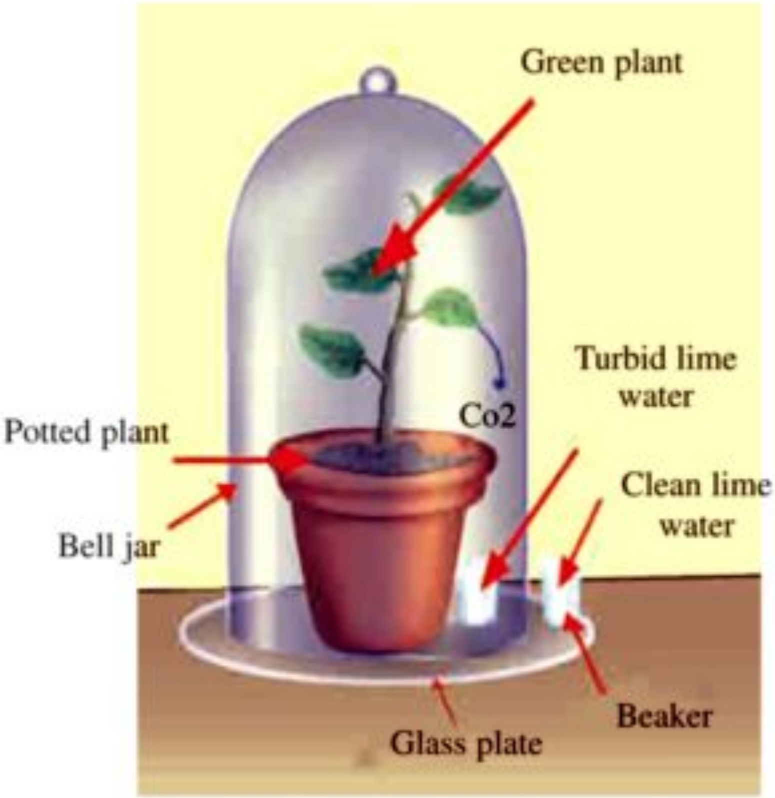


Fig. 9 Respiration of green plant

Observation:

Lime - water becomes turbid in (1) only.

What do you conclude?

Interpretation:

In (1), the green plant in the pot has respired and produced CO_2 (which causes the turbidity of lime water in the beaker). The bell-jar was covered with a black piece of cloth in order to keep light away from the green plant and to stop the process of photosynthesis (which uses up CO_2 inside the bell-jar which has been released due to respiration). In (2) and (3), the lime water showed no turbidity due to the small percentage of CO_2 whether in the air of bell-jar or in atmospheric air.

Experiment to illustrate the process of alcoholic fermentation

1- Put a sugary solution (or molasses dilated with double of its volume water) in a conical flask. Add piece of yeast and mix it thoroughly.

2. Close the flask with a stopper of rubber through which a delivery tube passes.

3. Dip the free end of the tube into a beaker containing lime water.

4. Leave the apparatus in a worm place for several hours. (Fig. 10)

What do you observe?

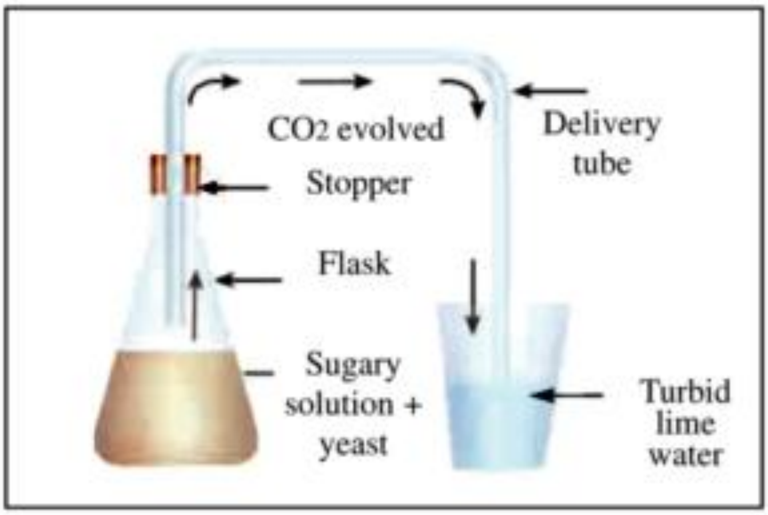


Fig. 10 Alcoholic fermentation

Observation:

Gas bubbles are seen on the surface of the solution in the flask. Lime water has become turbid, too.

What do you conclude?

Conclusion:

Turbidity of lime-water is a proof that CO_2 has been evolved, as a result of respiration of yeast. We should mention another kind of fermentation called acid fermentation carried out by several kinds of bacteria. It produces an acid instead of alcohol. Many milk products such as cheese, butter and yoghurt are manufactured by this kind of fermentation.

Seeds of Angiosperms, too, have the power to respire anaerobically if they are kept under anaerobic conditions.

Questions

1. Choose the correct answer :

1. Electron transport chain allows the electron to ....

a) Transfer from grana to stroma.

b) Transfer from Sun energy to chlorophyll.

c) Transfer into carotene.

d) Release energy.

2. Krebs cycle is started by combining acetyl group with fourth carbon compound to form ....

a) Citric acid.

b) Acetic acid.

c) Adenine.

d) Malic acid.

3. Muscle fibres which perform vigorous exercise form a great percentage of ....

a) Pyruvic acid.

b) Lactic acid.

c) Citric acid.

d) Acetic acid.

4. In cellular aerobic respiration, oxidation of glucose occurs through ....

a) Combining glucose with oxygen.

b) Glucose losing oxygen.

c) Combining glucose with hydrogen.

d) Glucose losing electrons.

5. CO_2 is released as a result of ....

a) Glycolysis.

b) Fermentation of lactic acid.

c) Alcoholic fermentation.

d) Dehydration of glycogen.

6. Pyruvic acid is oxidised to ....

a) PGAL.

b) CO2 and Ethanol.

c) Fractose 1-6 Diphosphate.

d) Malic acid.

7. Electron transport chain is described as ....

a) Molecular carrier which change by enzyme changing.

b) Oxidative phosphorylation cycle.

c) Sequences of oxidation and reduction.

d) Exothermic reaction.

2. Explain each of the following:

1. 38 molecules of ATP are produced from the complete oxidation of one glucose molecule.
2. Cellular respiration differs from burning process.
3. Formation of intermediate compound in Krebs cycle.
4. Photosynthesis linked by respiration in plant.

3. a) Explain with drawing an experiment to prove alcoholic fermentation.

b) Electron transport chain is considered as the basic last step in releasing ATP molecules.

1. What does electron transport mean?
2. What is the role of co-enzymes in releasing ATP?
3. What is the relation between oxygen and electron transport chain?

4. "Glycolysis is called fermentation process in the absence of O_2"

Explain this phrase with illustrating the meaning of glycolysis and its results in animal and plant cell.

5. How is protein used as a source of energy?

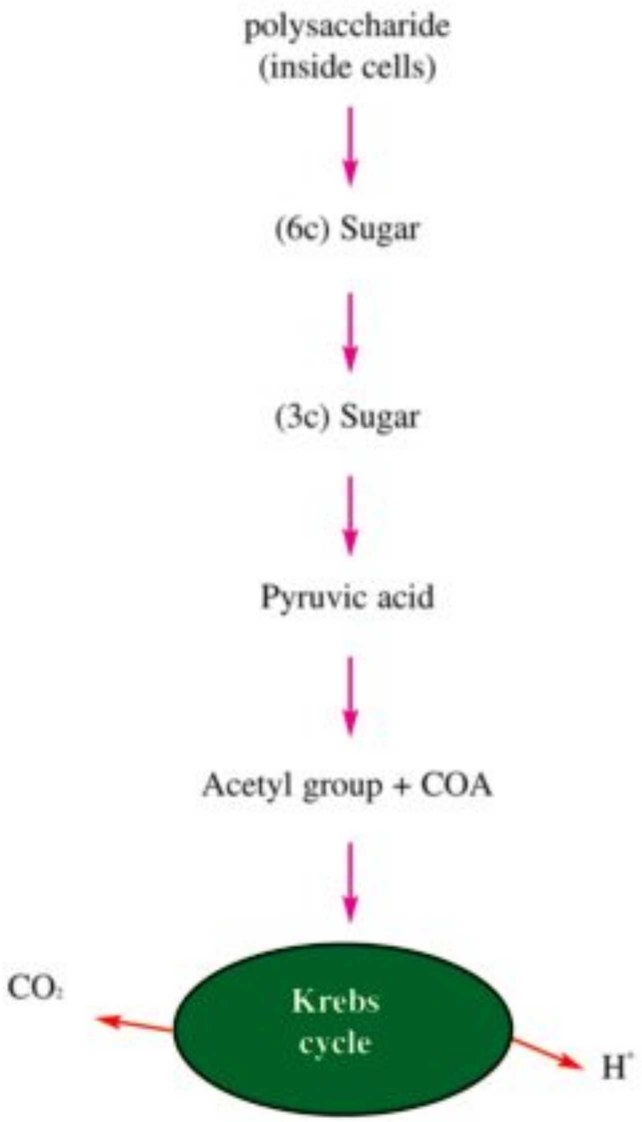
6. The opposite diagram shows what occurs inside a living cell.

Answer the following questions after studying the resulting compounds.

a) State the two types of stored sugar inside plant and animal cells.

b) What is the name of the process by which (6C) sugar is converted to pyruvic? Where does it take place?

c) What would happen to the resulted Hydrogen ions?

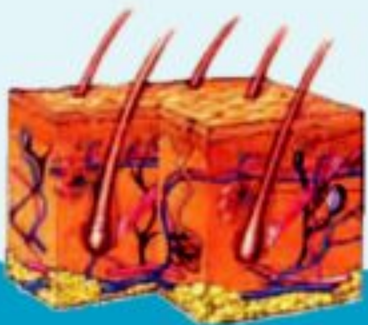


CHAPTER FOUR

Excretion in Living Organisms

At the end of this chapter the student should be able to:

- Know the concept of excretion.
- Know the mechanism of excretion.
- Know the structure of the excretory system in man.
- Know the role of the artificial kidney.
- Know the role of liver.
- Know the role of excretion in plants.



The concept and importance of excretion:

All biological processes that occur in the bodies of all living organisms are carried out through chemical reactions that leave some waste products. The living organism must get rid of these waste products as soon as they are formed, otherwise they will cause many problems and infections. The process by which the living organisms get rid of these waste products is called excretion.

First: Excretion in animals:

The process of excretion refers only to the materials that leave the body through the plasma membranes. The undigested food that goes out of the animal body in the form of faeces is not considered as excretion. The same thing applies to the nitrogen in the air which enters the lungs in inspiration and leaves them in expiration .

The important waste products that are produced and excreted from the animal body include CO_2 and water that are produced from degeneration of organic molecules and the nitrogenous waste products (ammonia, urea and uric acid) which result from protein degradation.

The organs that carry out excretion in the higher animals are the skin, the lungs, the liver and the kidneys. In addition, the excretion organs in animals regulate the body content of minerals. Some of the spices that have volatile content leave the body through the lungs and the rest is excreted through the kidneys. The poisonous materials are transformed into non-poisonous forms in the body or into non-soluble form by the liver or the kidney.

The following table represents the important waste products of the human body and the ways of their excretion.

The excreted material	The excretion organ
Carbon dioxide	lungs
Water	kidneys - skin - lungs
Nitrogenous waste products	kidneys - skin (small percentage)
Salts	kidneys - skin
Spices	kidneys - lungs (volatile substances)

Excretion In Man:

1- The Skin: It is considered an excretion organ in man. It is the biggest organ in the body as it covers the whole body and the limbs from the outside.

Skin structure:

The skin consists of two main layers, an outer epidermis and an inner dermis. Under this is a layer of fat.

Go Further

For more knowledge about this topic you can refer to the Egyptian Knowledge Bank (EKB) through the opposite link

1. The epidermis:

It consists of several layers of epithelial cells. At the surface, the cells are dead, full of a horny substance, called keratin and always are subjected to friction, e.g. when wiping your face or body with a towel or rubbing your hands. This layer is worn away and continually replaced from beneath. At the base of its inner layer, there are pigment cells which secrete granules responsible for the colour of the skin (melanin).

2. Dermis:

It is next to the epidermis, consisting of connective tissues. It contains blood capillaries, nerve endings, lymphatics, sweat glands, fat glands, fatty cells and hair follicles.

The sweat gland is a coiled tube that reaches the skin surface through a pore.

This sweat is continually being produced on the surface of the skin, so decreasing the body temperature.

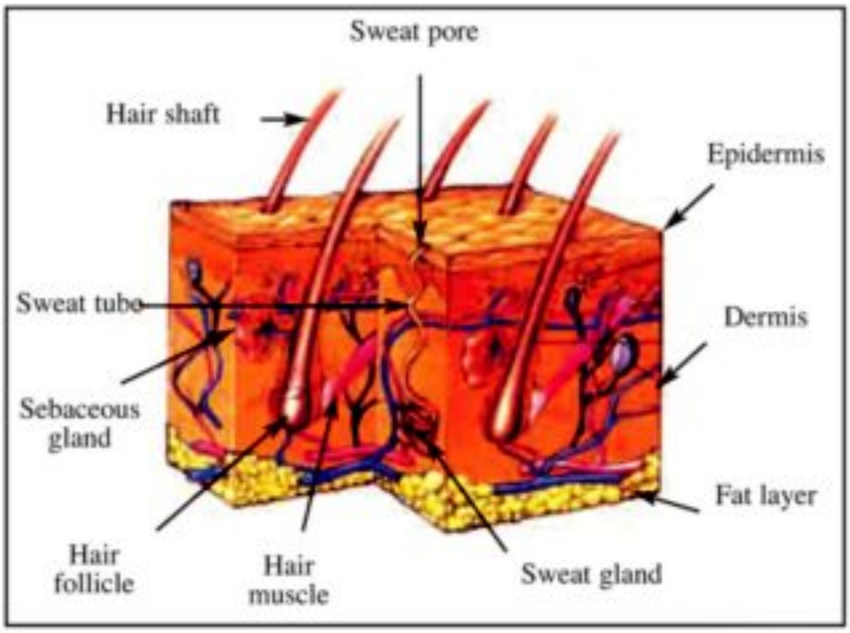


Fig. 1 Structure of skin

Remaining wastes cause the skin to be sticky. It is important to remove these wastes continually by washing; otherwise sweat pores become blocked resulting in a foul odour.

The hair is made of a hair follicle, surrounded by many blood capillaries. At its free end, there is a sebaceous (fat) gland, which produces an oily secretion. This oil secretion facilitates the exit of the hair from the skin, keeping it soft and pliable. The hair follicle is supplied with an erector muscle.

The sensory nerve endings respond to touch, pain and temperature.

Go Further

For more knowledge about this topic you can refer to the Egyptian Knowledge Bank (EKB) through the opposite link

2- The kidney:

Each vertebrate animal has two kidneys. In lower vertebrates, the kidneys are long, thin organs which extend from the two sides of the vertebral column. In higher vertebrates, such as mammals, the kidneys are more firm and are situated behind the peritoneum (membranes lining the abdominal cavity). A tube, the ureter, runs from each kidney to the base of the bladder, through which urine is collected and passed to the outside through the urethra.

Kidney structure:

The two kidneys are situated in the upper part of the abdominal cavity, one at each side of the vertebral column. The length of each kidney is about 12 cm long and about 7 cm wide. Its thickness is about 3 cm. The kidney is bean-shaped. Its outer part is convex, while the inner one is concave. On the inner side of each kidney, the renal artery comes from the aorta, and the renal vein leads to the posterior vena cava. (Fig. 2)

Internally, the kidney is differentiated into two regions, an outer narrow cortex and an inner broad medulla. The functional unit of the kidney is the nephron.

Each kidney consists of about one million nephrons Each nephron starts in the cortex with a cup shaped, thin, double-walled Bowman's capsule. (Fig. 3)

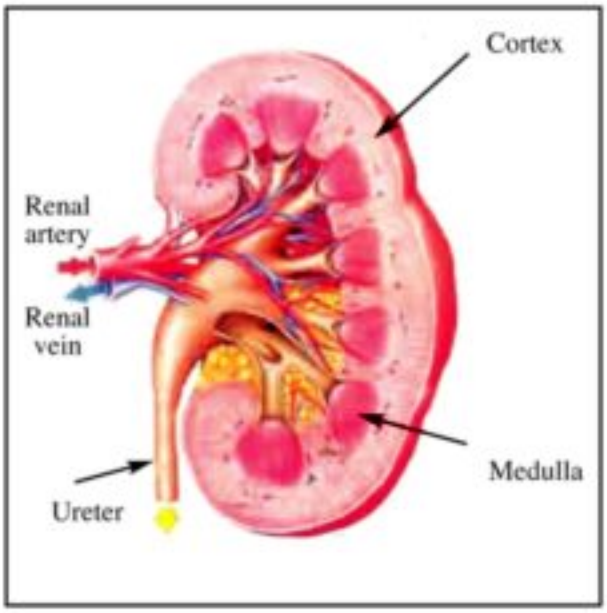


Fig. 2 Section of the kidney

The capsule leads to the first coiled tubule in the cortex then to the loop of Henle in the medulla which is U-shaped, then to the second coiled tubule in the cortex before joining the collecting duct. This duct opens in the concave cavity of the kidney called the pelvis. A ureter emerges from each kidney, which passes the urine into a small muscular sac called the

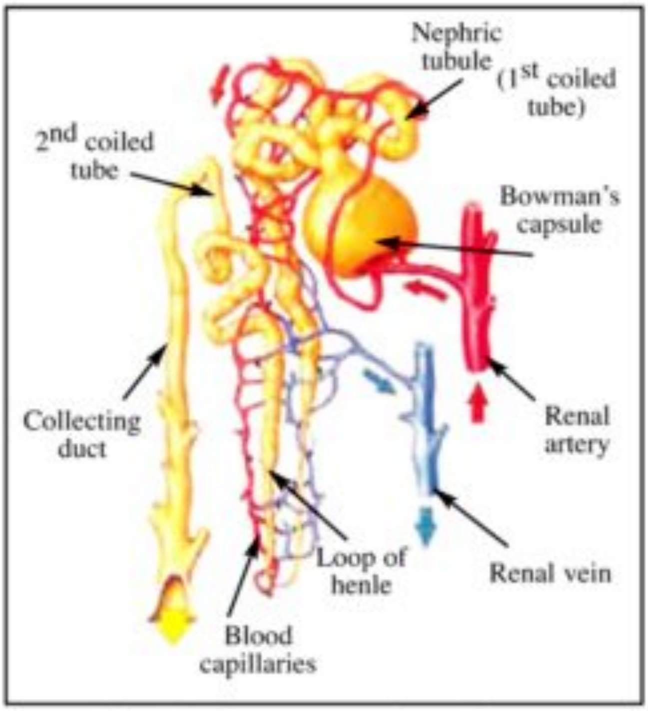


Fig. 3 Structure of nephron

urinary bladder. The ureter opens at the back of the bladder in an inclined position. A sphincter muscle closes the outlet of the bladder till urine accumulates, then the bladder contracts expelling the urine through a duct called the urethra.

Urine extraction:

The renal arteries come from the aorta, each entering a kidney at its concave surface. The renal artery divides into a great many arterioles and capillaries at the cup-shaped nephron. Plasma (blood fluid) filters out of the blood to collect in the nephron. The filtered fluid conatins water, wastes, salts and glucose, but blood cells and large protein molecules remain in the blood.

What happens if all the contents of this fluid are excreted outside the body?

In this case the body will lose much of its required water and essential substances and the individual has to drink, daily, 170 litres of water to compensate its loss. Therefore, re-absorption of required water, glucose and mineral substances, back into the blood, must takes place.

The remaining liquid contains nitrogenous wastes (urea), some inorganic salts and excess water which forms the urine. Excess substances, such as small amounts of glucose and vitamins may be also present.

Re-absorption takes place in the nephron tubule. Urine then passes down the collecting duct to the pelvis of the kidney where it collects and continues down the ureter to the bladder to be stored. When the bladder contracts, urine is expelled through the urethra. Kidneys, ureters, urinary bladder and urethra are collectively known as "the urinary system". (Fig. 4)

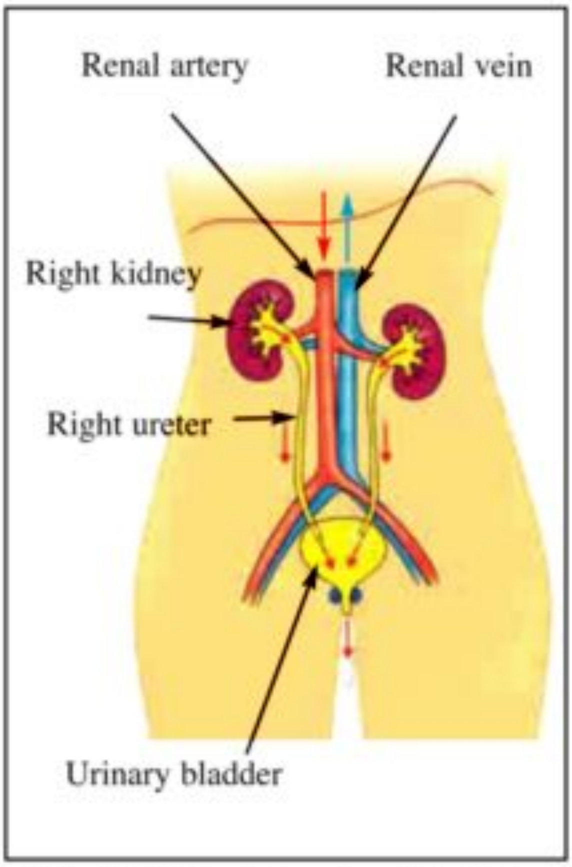


Fig. 4 Urinary system in Man

The individual can live with one kidney. In this case, this kidney grows and becomes slightly bigger to perform the function of two kidneys. No one can live without a kidney; nor can he live if the kidneys stop functioning. Accumulation of poisonous wastes in the blood leads to death.

The human body contains about 5.6 litres of blood. 1.2 - 1.3 litre of blood passes through the kidney per minute. The total amount of blood which passes daily through the kidney is about 1600 litres (i.e. approximately 1/4 of the blood volume pumped by the heart). This means that a very high percentage of blood always passes through the kidney. Of the total blood volume, three litres of plasma pass through the kidney to be examined about 560 times per day.

3- The Liver:

In addation to the function of liver in digestion and metabolism, liver has a role in the excretion process where it breaks down poisonous substances which are absorbed by the small intestine to purify the blood and also separates the amino group from excess amino acids (deamination) to change them to urea and expel them through kidneys outside the body .

Go Further

For more knowledge about this topic you can refer to the Egyptian Knowledge Bank (EKB) through the opposite link

The Artificial Kidney:

Kidney failure takes place due to some diseases. The kidney stops functioning and this leads to the accumulation of harmful wastes in the blood.

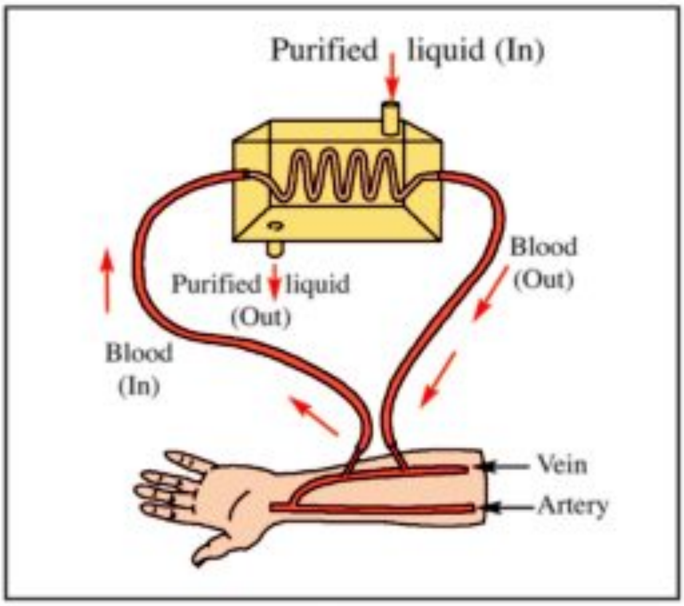


Fig. 5 Artificial kidney

In treating cases of kidney failure, a tube is inserted into an artery in the patient's arm and the blood is channelled through semipermeable tube immersed in a bath containing all the normal blood chemicals except urea and other metabolic wastes. Since the concentration of harmful metabolic wastes is higher in the blood than in the bath, they pass through the wall of the tubes into the bath and purified blood is returned to the body. A patient receives artificial kidney treatment for several hours each day, 2-3 times a week.

Excretion in plants

Excretion in plants does not cause any serious problem, since the rate of catabolism is much lower than that in animals of equal weights. As a result, accumulation of metabolic wastes in the plant cells will be very slow.

Also green plants re-use the catabolic wastes. For example, carbon dioxide and water, which result from respiration, will be again utilized in photosynthesis.

The plant also utilizes the nitrogenous wastes in the synthesis of the required proteins. Since the metabolism of plants is based mainly on carbohydrates rather than proteins, this reduces their excretory needs, as the wastes of carbohydrate metabolism are less toxic than those resulting from protein metabolism.

The metabolic wastes such as organic salts and acids are stored in the form of insoluble crystals in the cells of terrestrial plants, mainly in the cytoplasm or in the vacuoles. Since these crystals are insoluble they will cause no harm to the cells.

Many plants get rid of carbon dioxide and some mineral salts through their roots. Plants, which live in soils rich in calcium, can get rid of the excess amounts of these elements by its accumulation in leaves which are finally shed.

Carbon dioxide which results from respiration and oxygen obtained from photosynthesis are excreted through the stomata by diffusion. Excess water is cast, mainly through transpiration or guttation, where drops of water can be seen at the leaf tips of some plants like potatoes and tomatoes. This occurs in the early morning in spring. There is a special system for guttation which consists of one or many loose cells, opening by a water stoma called a hydathode which is open constantly day and night. Guttation water contains other substances which can therefore be deposited, when water evaporates rapidly. (Fig. 6)

Fig. 6 Guttation

Great quantities of water are absorbed from the soil, mainly through the roots. Water is then transferred through the conductive tissues to the stems and leaves. At the same time the plant loses most of this water in a continuous manner. Water passes, in the form of vapour, through the moist cell walls of the mesophyll tissue, and evaporates into the intercellular spaces, where it diffuses out into the atmosphere through the stomata.

The same process occurs in other cells that overlook other intercellular spaces in different plant tissues. Small quantities of water pass through the cuticle or through lenticels (openings that exist in the cork layer of the tree's stem). Loss of water therefore takes place over the total surface of the plant, exposed to air. The loss of water in the form of water vapour is called transpiration. More than 90% of the total is lost through the stomata and is called stomatal transpiration. Water vapour which passes out directly through the epidermis covered with cuticle in the vegetative organs is called cuticular transpiration. It does not exceed 5% of the total amount of the lost water. Stems of woody plants lose small quantities of water vapour through the lenticels by lenticular transpiration.

Stomata occur in plant leaves rather than in any other vegetative organ so most of the transpired water is lost through the leaves.

Experiment to illustrate transpiration in plants:

Take a potted leafy plant. Cover the soil surface and the surface of the pot with paraffin. Place the potted plant on a glass sheet under a dry bell-jar and wait for some time, (Fig. 7)

What do you observe?

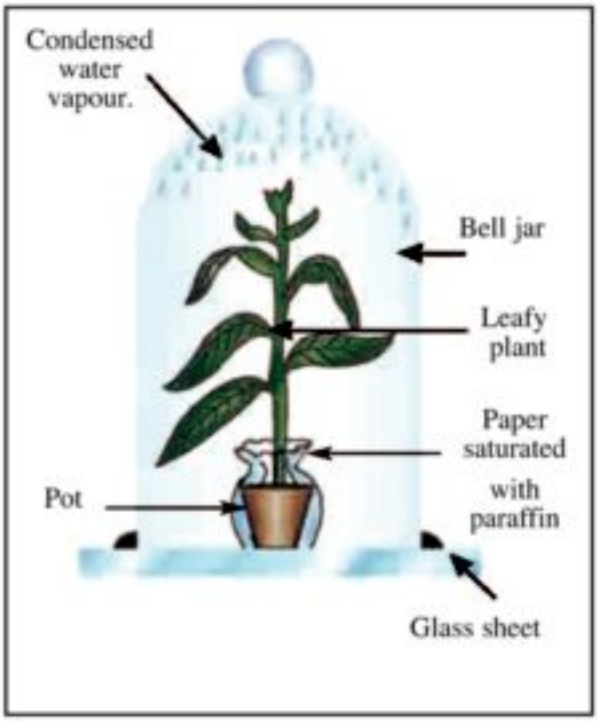


Fig. 7 Transpiration in green plant

Observation:

Tiny droplets of water appear on the inside of the bell-jar, accumulate, they become bigger in size and run downwards on the wall of the bell-jar.

Conclusion:

Air inside the bell-jar receives water vapour from the plant which condenses. If you add the condensed liquid to anhydrous white copper sulphate, it becomes blue, confirming that the liquid is water. We can conclude that water passes from the exposed parts of the plant to the surrounding air.

Importance of transpiration for the plant:

1. Decrease of the plant temperature.
2. Ascent of water and salts from the soil.

1. Decrease of plant temperature:

A large amount of energy absorbed by the leaves is in the form of heat or is converted into heat inside the leaf tissues. This may cause a rise in the leaf temperature, especially on sunny, warm days. This rise in temperature harms the protoplasm and could lead to its death if transpiration did not decrease the plants' temperature through water loss.

2. Ascent of water and salts from the soil:

The root cells contain cell sap with a concentration (of soluble organic and inorganic substances) higher than that of the soil solution. As a result, the soil water enters the root cells by osmosis. The osmotic pressure is sufficient to move water from the root hairs to the inner root tissues till it reaches the xylem vessels and tracheids. Water rises upwards through the xylem vessel of the stem, through vessels of the leaf (veins) and at the end it reaches the mesophyll cell sap, hence decreasing the ability of these cells to pull up more water.

There are intercellular spaces full of air between the mesophyll cells, to which water vapour passes. As a result of the continuous loss of water from the mesophyll cells, their concentration increases, and so the ability to pull water upwards increases. This explains the so-called transpiration cycle and its role in the ascent of water.

Osmotic pressure is only enough to move water through the plant stem for a short distance by what is known as root pressure.

In some trees, water has to move through their vessels to a height reaching up to 125 meters, and therefore, a new theory was sought to explain the force which pushes water to such heights. This new theory is known as the adhesion and cohesion theory. (see fig (3) page 47).

Experiment to show that water ascends through the xylem:

a) Fill a test tube with eosin solution. Carefully detach a small flowering plant (potted plant) with its roots. Immerse the plant roots in the eosin solution and close using a cotton wool plug at the opening of the tube. Keep the tube in a vertical position for few hours. (Fig. 8), What do you observe?

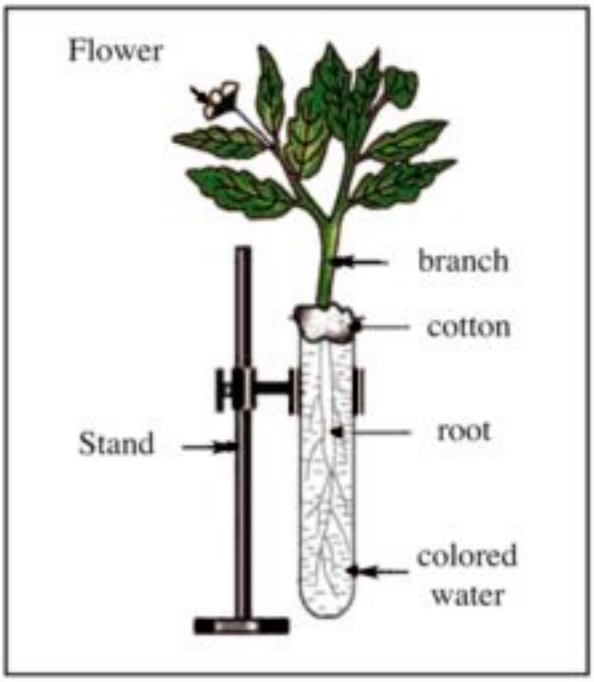


Fig. 8 Ascent of water in xylem vessels

Observation:

The leaf petioles change to pink, as well as the veins of the leaves and petals.

b) Cut a thin, transverse section of the plant stem and examine under the microscope. (after placing it on a slide) What do you observe?

Observation:

Xylem tissue only is stained by eosin.

Conclusion:

Pink coloration of petioles and petal veins indicates that eosin solution reaches these organs. This experiment shows:

1. Water is absorbed by roots.
2. Water ascends through xylem tissue of the stem to the leaves.

Experiment to show the ascent of water by transpiration:

a) Fill a small beaker with mercury. Fill a narrow tube with water and invert it in the beaker, so that its lower end becomes immersed in the mercury.

b) Cut a leafy twig of a potted plant under water. Insert the lower tip of the twig in a cork plug through a hole. Fix the cork plug tightly with the twig in the upper opening of the tube and close it firmly with vaseline. Mark the mercury level in the tube. Leave the apparatus in open air for a while. What do you observe?

Observation:

Mercury rises in the tube.

Conclusion:

The rise of mercury is due to transpiration pull, where the leafy twig loses water by evaporation, so water from the tube must rise to replace it. As a result, mercury rises up in the tube. This indicates that water loss by transpiration generates a pull to raise water upwards. (Fig. 9)

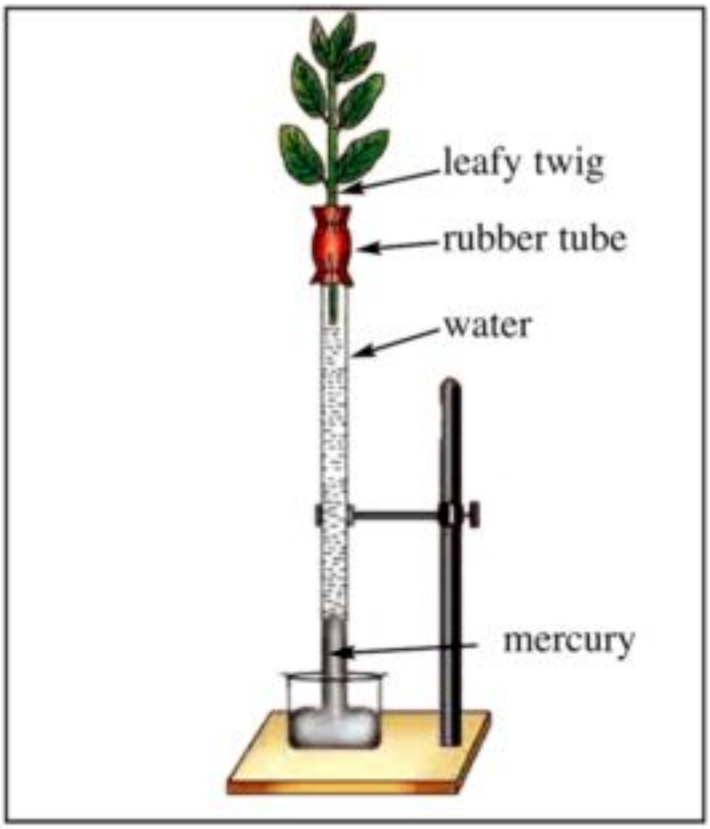


Fig. 9 Transpiration Pull

Practical Activities

a) Zoology: studying a section in human skin to know its structure.

b) Examination and dissection for a kidney of a mammalian animal to know the internal structure of its kidney.

c) An experiment to show transpiration using the potometer.

Questions

1. Mention the scientific concept:

a) A biological process to get rid of the harmful metabolic products.

b) A functional unit in the kidney that extract urine.

c) The excretion of water at the leaf tips of some plants in the early morning.

2. Choose the correct answer:

a) Which of the following controls the excretion of urine outside the body:

(urinary bladder - ureter - urethra - kidney - sphincter muscle around the opening of the urinary bladder)

b) The urea is extracted from:

(skin- kidney - liver - lung)

c) The average blood volume passing into the renal artery is:

(one litre/min - 2 L/min- 2 L/hr – 3 L/ min).

d) In warm weather, the amount of sweat increases. The blood vessels in the skin:

(dilate - shrink - contract - relax)

e) From the functions of the epidermal skin:

(absorption of air - excretion of gases - production of sweat - prevent the penetration of bacteria)

f) The urea is extracted by (urinary bladder - the cortex of the kidney - malpighian corpuscle - nephron)

g) The average number of the human nephrons in the two kidneys.

(Million - 3 millions - 2 millions - 5 millions)

h) Swollen tubule surrounded by double membranes is called:

(Bowman's capsule - Henle's loop – Malpighian corpuscle - ureter)

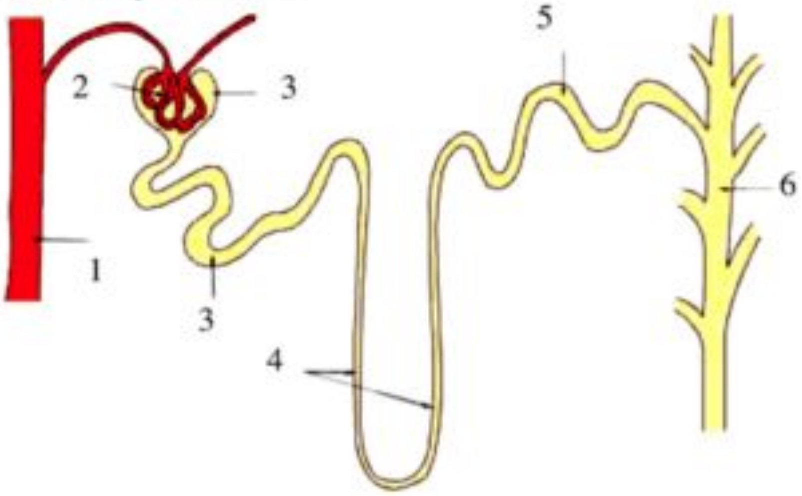
3. From the figure:

a) Mention the labelled numbers.

b) Explain how can the component pass from 2 to 3.

c) Mention two components that pass through 2 and do not pass through 3. Mention the reason.

d) The liquid passing through 3 contains glucose, water and urea. What will happen to these components as they pass through the rest of the nephron? Name the fluid which passes from the kidney to the urinary bladder.



4. Compare between the kidney in lower and higher vertebrates.

5. Give reasons for:

a) Defecation is not excretion.

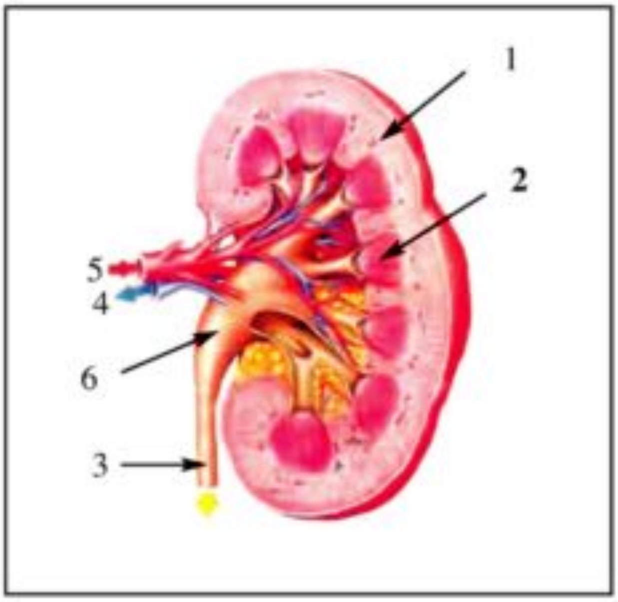
b) The sweat is also produced in winter.

6. From the figure:

a) Mention the name and characteristics of the labels 1-6.

b) The daily amount of the extracted urine depends upon many factors. Mention two.

c) The body extracts urea by catabolism. What does the urea consist of? Which organs extract urea?



d) The kidney receives one liquid and two liquids leave it, name these liquids.

7. Write briefly on : Hydathode cuticle transpiration - stomatal transpiration - lenticular transpiration.

8. Explain an experiment to show the ascent of water in the plant by transpiration pull

CHAPTER FIVE

SENSITIVITY (IRRITABILITY) in Living Organisms

At the end of this chapter the student should be able to:

- Know the concept of sensitivity in living organism.
- Explain the concept of nervous & hormonal coordination
- Explain the transmission across synaptic area or along nerve fiber.
- Explain the reflex action.
- Inqiure the skills of drawing the nerve cell.
- Examine the nerve cell by microscope.
- Link between the structure and the function of nervous system.
- Know the response of some plants to touch and darkness.
- Know the concept of tropism in plants.
- Know the role of auxins in phototropism, geotropism and hydrotropism of stem and root.

Sensitivity is one of the functions shown by a living organism to maintain its life. Sensitivity in animals is more obvious than in plants. It reaches its highest efficiency and accuracy in man.

I. Sensitivity in plants:

1) Response to touch and darkness:

If you touch a Mimosa leaflet, its petiole soon droops as if it has wilted. Other neighbouring leaflets soon follow, till the effect is seen in all the leaflets.

In day time, the leaflets are held in a horizontal position. At night, the leaflets hang downwards and fold their upper surfaces, i.e. undergo sleep movements.

These movements can be explained according to cell turgidity. Mimosa leaves are compound, pinnate; each has a primary rachis which carries at its end four secondary rachis. Each secondary rachis carries two rows of leaflets. At the base of each primary and secondary rachis, is a swollen structure called a pulvinus.

Go Further

For more knowledge about this topic you can refer to the Egyptian Knowledge Bank (EKB) through the opposite link

When the leaflet is touched or at night, the primary rachis hang downwards, the secondary ones become depressed and so the upper surfaces of the opposing leaflets become folded together. The swollen structures (pulvinus) act as joints in these movements where the lower surfaces shrink when being touched. This leads to water diffusing to the neighbouring tissues and hence the leaflets droop. When the stimulus is removed, the cells regain their turgidity and the leaflets open once more. It is found that the cell walls of the lower half


Leaves before touching


Leaves after touching

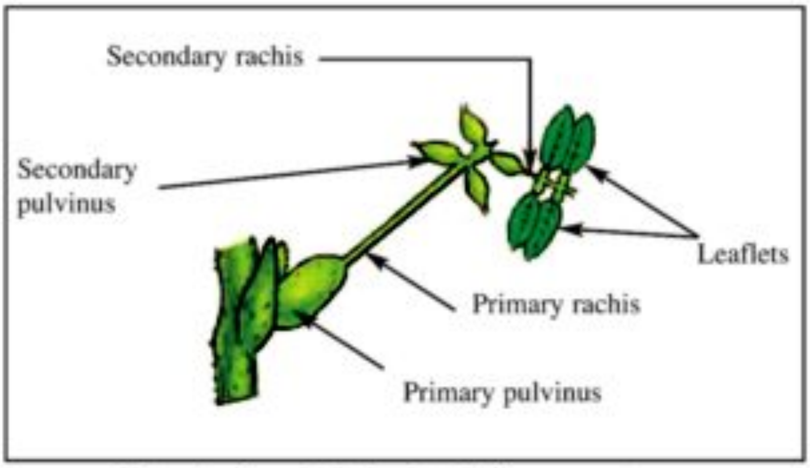


Fig. 1 Sensitivity in Mimosa stem

pulvinus are more sensitive than those of the upper half. They play the main role in this movement. (Fig. 1)

2) Tropism:

Irritability (sensitivity) and movement in plants are seen in tropisms. It is known that the growth of roots and stems depends on many factors such as light, humidity and gravity. When these factors are exerted on the sides of the stem or roots in an unequal form, curvature results. This curvature is known as a tropism.

Types of tropisms:

A - Positive and negative phototropism:

Experiment:

Place a straight seedling on a cork disc floating on the surface of a beaker half-filled with water. Put the beaker in a light-proof box. At one side leave a small circular hole to admit light. Leave it for a few days. You will observe that the stem will be inclined towards the source of light, while the roots grow away from it (Fig. 2).
Tropism is due to the unequal growth of the two sides in both the root and stem. The side of the stem which is away from light grows more rapidly, while in case of the roots the opposite occurs.

What causes this unequal growth? Why does curvature in the root differ from that of the stem?

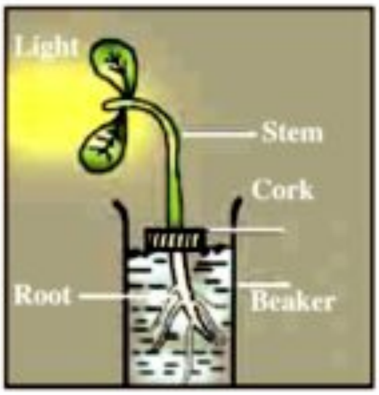


Fig. 2

Stem is positive phototropic and root is negative phototropic

Scientists explained this phenomena, Bosyen Johnson found that oat (Avena) coleoptile, (Fig. 3), loses its ability to bend towards light, if the tip is cut off (1-2 mm of the tip), but this ability is restored if the decapitated tip is returned or fixed again to the tip with gelatine (Fig. 4).

If the tip is separated from the remaining coleoptile with a mica sheet, there will be no curvature.

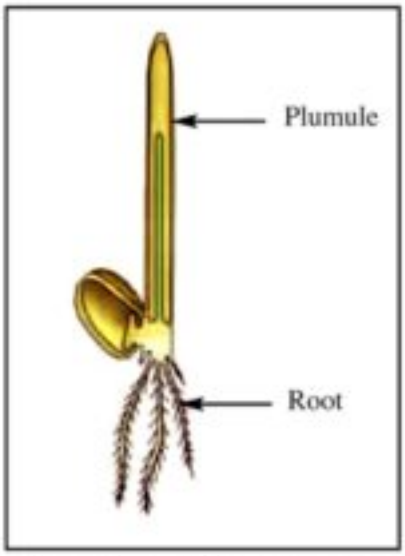
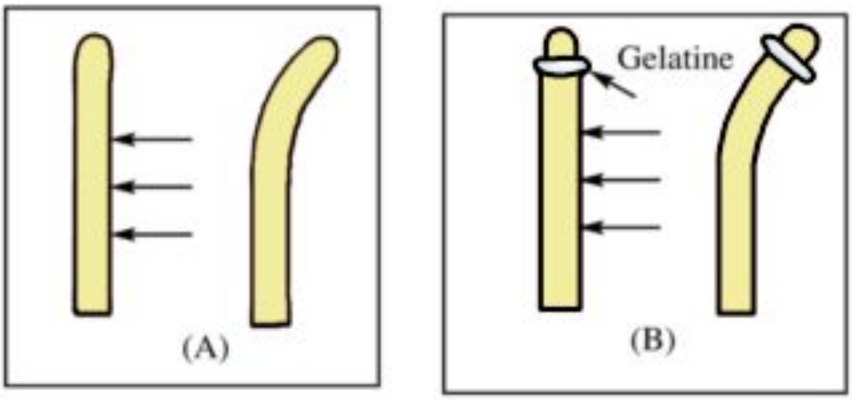


Fig. 3 Coleoptile of Oat plant

This indicates that the tip of the coleoptile synthesizes chemical substances that diffuse through gelatine and affects the growth. It cannot pass through the mica sheet. These chemicals are termed auxins, and the main one is known to be indole-acetic acid (IAA). Curvature towards light is the result of the unequal growth of the two sides which is due to the unequal concentration of auxins on the two sides of the coleoptile.



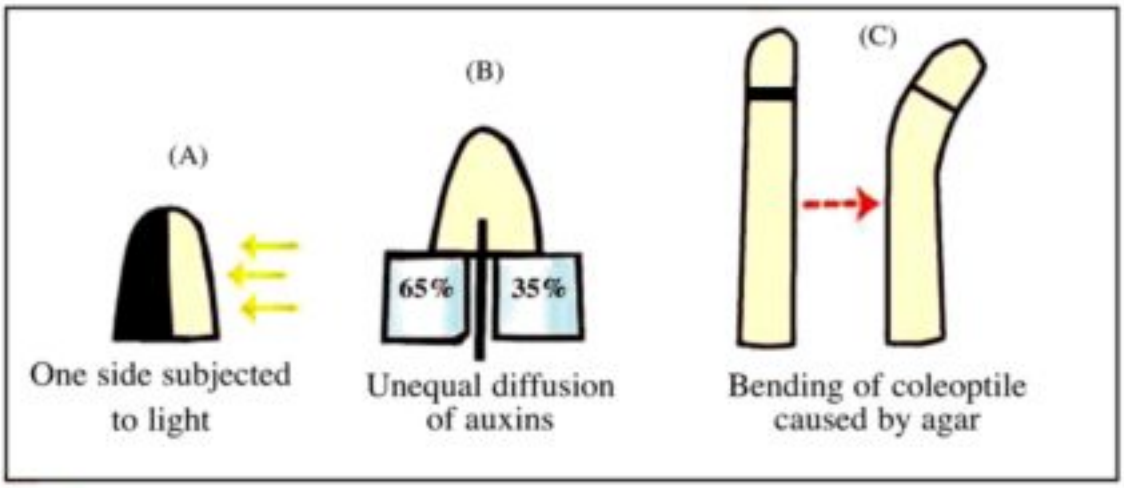
Bending of coleoptile towards light

Ability of bending is restored again

Fig. 4

Many experiments were done to prove the validity of this conclusion. One of them was performed by "Went". (Fig. 5)

"Went" exposed an oat coleoptile to unidirectional illumination



/ent´s experiment

(Fig. 5a) then he cut off the tip and placed it on two blocks of agar separated by a metallic sheet. He measured the concentration of auxins in each block and found that a great amount of auxins accumulated in the side, away from light. (Fig. 5b)

This means that auxins move from the side facing light to the far (dark) side. These blocks of agar will produce curvature if placed on decapitated coleoptiles which are not subjected to light. (Fig. 5c)

This means that if a coleoptile tip is exposed to light, auxins move away from light to the non-illuminated side. This leads to the elongation of cells on that side thus curvature towards light occurs. The stem is known to be positive phototropic.

In the root, accumulation of auxins on the dark side produces an opposite effect. Elongation is inhibited in the dark side, while the illuminated side continues to grow. The root curvature bends away from light, and the root is known to be negative phototropic.

The difference in the behaviour of the root and the stem can be explained in view of the fact that the concentration of auxins required for the elongation of root cells is less than that required for the elongation of stem cells. As a result, the increase in auxins concentration will inhibit cell-elongation in roots, whereas it activates elongation of stem cells.

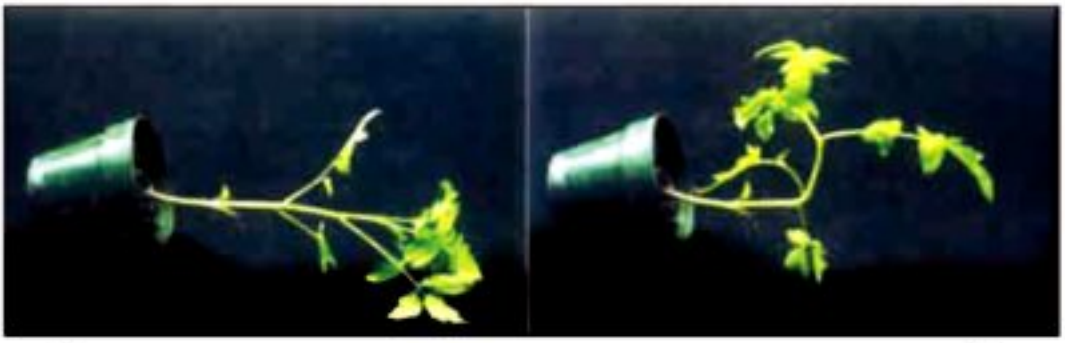
B - Geotropism:

Geotropism is the response of plant parts to the external stimulus of gravity where they move away or towards the stimulus. The root grows vertically downwards while the stem grows upwards. It was believed that roots grow downwards in order to avoid light and seek nutrients, but this is incorrect. When you hang a pot with a plant upside down for a certain time the root grows downwards away from the soil and towards gravity. While the stem grows upwards away from gravity.

Experiment:

A number of seeds are germinated in a soil moistened with water. The plumules grow vertically upwards, while the radicles grow downwards.

One seedling is placed on its side so that the radicle and the plumule are horizontal (Fig. 6a). Leave it for several days. You will observe the growth of the plumule upwards and the growth of the radicle downwards (Fig. 6 b). This means that stems are negative geotropic, while the roots are positive geotropic. (Fig. 6)



(A) (B)

Fig. 6 Effect of geotropism

Curvature is due to the variation in growth of the two sides of the organ as a result of the unequal distribution of auxins.

When the plant grows in its natural vertical position, auxins will be equally distributed in the tips of both roots and stems. As a result, the stem grows vertically upwards, while the root grows downwards. In the horizontal position, auxins accumulate in the lower side of both the root and the stem. Auxins activate the cells of the lower side of the stem, which elongate more than those of the upper side, and so the tip of the stem curves upwards, against gravity. On the contrary, accumulation of auxins on the lower side of the root inhibits activity, and so cells of the upper side elongate more than the lower side and the root bends downwards.

C- Hydrotropism:

Experiments:

1. Germinate a number of seeds in two glass troughs containing two equal amounts of dry soil. Spray water at regular intervals in the first trough, but only at the sides in the second trough. Leave the two troughs for several days. Roots in the first trough will be observed to grow straight down, while roots in the second trough grow towards the water at the sides of the trough. (Fig. 7)

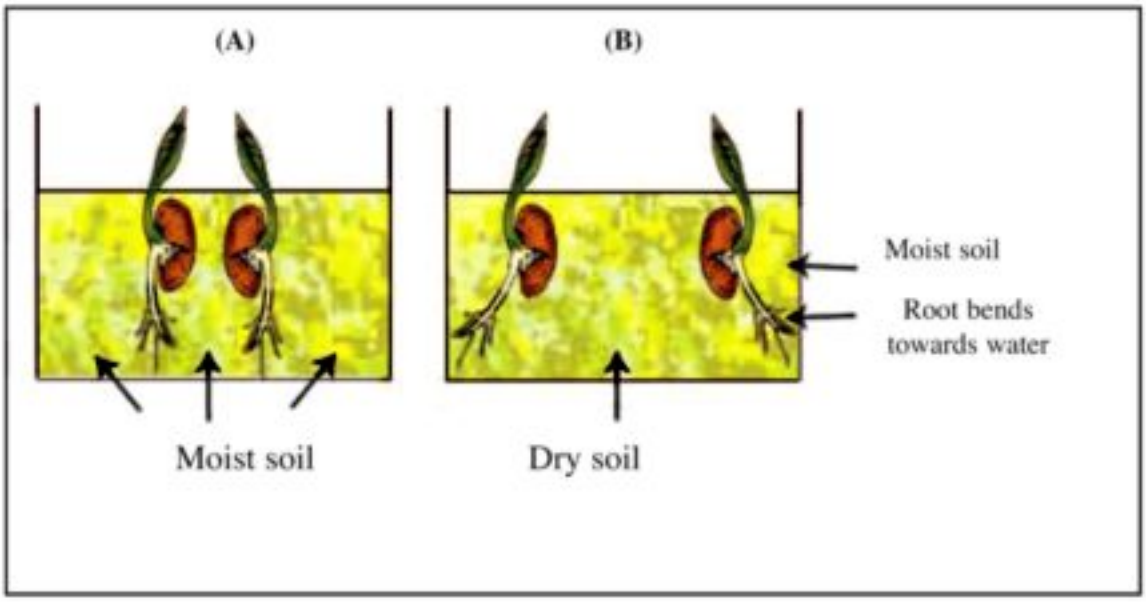


Fig. 7 Hydrotropism

In the fist trough, the roots grow vertically due to equal distribution of water in the soil around the roots, while curvature of roots in the second trough is due to the presence of water at the sides and its absence in the middle. As a result, auxins accumulates in the side facing water and inhibits the elongation, while the cells on the far side continue their normal growth which leads to curvature of the root towards water. The root is positive hydrotropic.

The nervous system and sensation in Man

Nervous system:

In addition to the control of all functions of human body systems, the nervous system receives information in the form of external and internal stimuli through receptor systems and then gives the proper response. It keeps the human body in a continuous direct communication with his external and internal environment. This helps, with the endocrine glands to keep the internal condition of the body in an ideal, constant and balanced state (homeostasis). The nervous system is highly developed in vertebrates, especially in man.

The nervous system is divided into:

1. **Central nervous system:** (C.N.S) Includes the brain and spinal cord.
2. **Peripheral nervous system:** Includes the cranial nerves and the spinal nerves.
3. **Autonomic nervous system**: Includes the nerves that control the involuntary muscles and the glands.

This system is subdivided into:

1. **Sympathetic nervous system:** The nerve fibres of this system originate from the thoracic and lumbar regions (segments) of the spinal cord.
2. **Parasympathetic nervous system:** The nerve fibres of this system originate from the brain and the sacral region of the spinal cord.

The unit of structure of the nervous system is the nerve cell (neuron).

The Nerve Cell:

The nerve cell is small in size and cannot be recognized by the naked eye (Fig. 8). It consists of :

A) Cell body:

It contains rounded nucleus surrounded by cytoplasm known as neuroplasm. The neuroplasm contains neurofilaments and Nissil granules (which are unique for nerve cells). Nissil granules are considered as a stored food for the cell. All cell organelles as mitochondria and Golgi bodies are present except the centrioles (that's why neurons cannot divide).

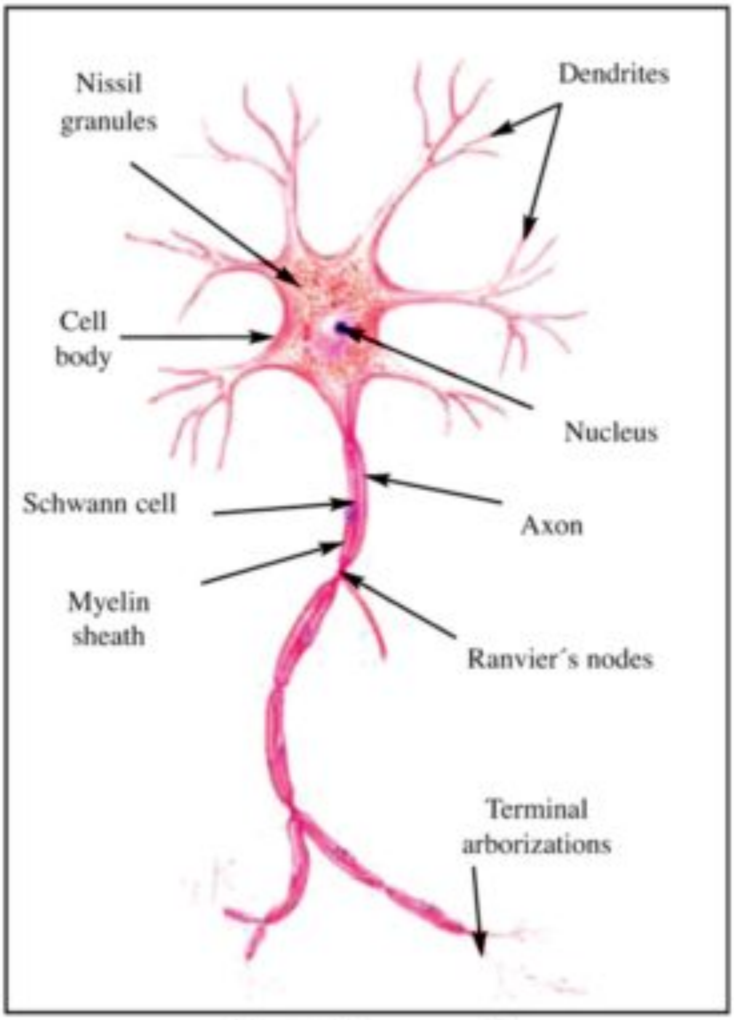


Fig. 8 Nerve cell

B) Cell processes:

1- Dendrites: Many short processes which increase the surface area available to receive nerve impulses and through which all nerve impulses enter to the cell.

2- Axon: It is a long cytoplasmic extension of the cell (may reach more than a metre in length) and usually known as the nerve fibre. In some cells the axon is surrounded by a sheath of lipid called myelin sheath secreted by special cells called Schwann cells. The outer cover of the axon "nerve fibre" is the neurolemma. The myelin sheath is not continuous around the axon but is interrupted at certain points by nodes of Raniver.

The conduction of nerve impulses in myelinated axons (covered by myelin sheath) are much more rapid than in nonmyelinated nerve fibres (axons) because the myelin sheath is an insulator.

Normally, the nerve impulse is propagated and conducted through the nerve cell in one direction only, from the dendrite to the nerve cell body to the axon, then to another next neuron "nerve cells" through a synapse. The axon ends in a group of branches called terminal arborizations.

Go Further

For more knowledge about this topic you can refer to the Egyptian Knowledge Bank (EKB) through the opposite link

Types of Nerve cells:

According to the function, nerve cells are classified into three types:

A- Sensory neurons: Convey (transmit) impulses from receptors to the central nervous system.

B- Motor neurons: Convey impulses from the central nervous system to the effector organ as muscles and glands.

C- Connector (intermediate) neurons:Relay impulses from sensory to motor neurons.

Neuroglia:

Another type of cells in the nervous system, (Fig. 9), have the ability to divide and perform the following functions:

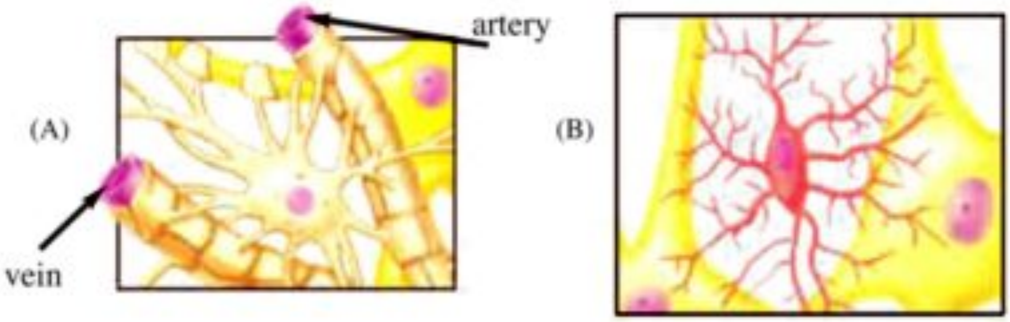


Fig. 9 Neuroglia

1. Act as a connective tissue to support neurons.
2. Act as insulators between neurons.
3. Nutrition of neurons.
4. Have a role in repair of injured parts of some neurons.

Structure of the Nerve:

The nerve (Fig. 10) consists of a group of nerve bundles, each of which is surrounded by a connective tissue sheath. The whole nerve is surrounded by another connective tissue called epineurium which contains blood vessels. Each nerve bundle is formed of a group of nerve fibres (axons) and connected by supporting neuroglia cells (glial cells).

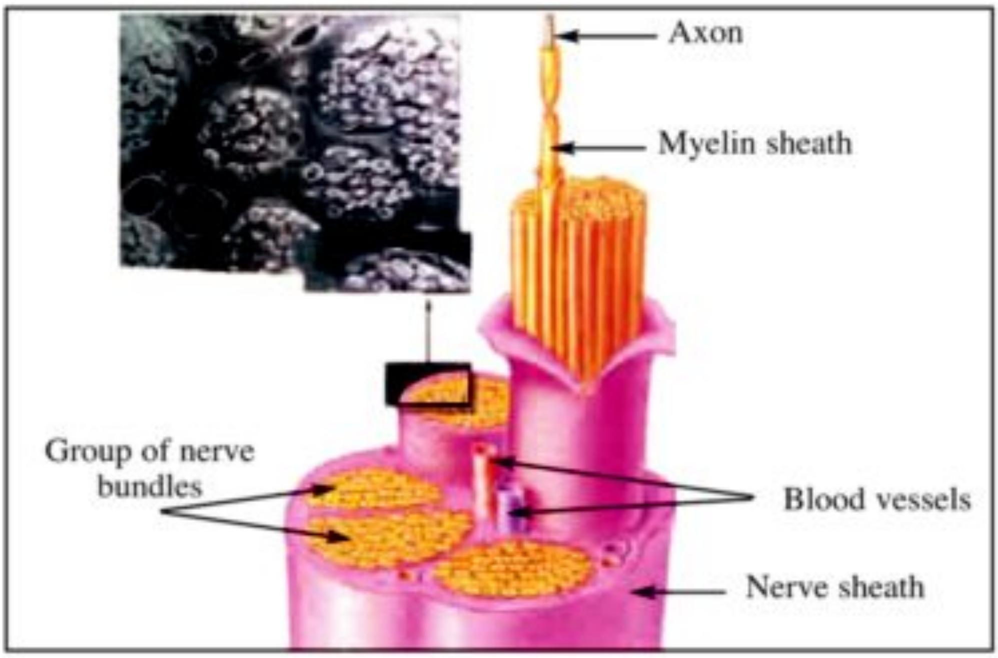


Fig. 10 Structure of a Nerve

The Nerve Impulse:

The nerve impulse is the message transmitted through the nerves from sense organs (receptors) to the central nervous system and from the latter to the effector (responding) organs. What is the nature of the nerve impulse?

The nerve impulse is an electrical phenomenon with a chemical nature (electrochemical phenomenon).

To understand the nature of the nerve impulse and its transmission, we have to study the nerve cells "neuron" during four different conditions:

Chapter 5

1. The nerve cell at rest.
2. Changes in the nerve cells on stimulation.
3. Propagation of the nerve impulse.
4. The return of the nerve cell to its original state.

a) The nerve cell at rest:

It is called the resting potemtial.

At rest, there is a difference in distribution and concentration of ions outside and inside the nerve cell, as follows:

- The concentration of sodium ions (Na^+) outside the cell is 10 to 15 times higher than inside.

- The concentration of potassium ions (k^+) inside the cell is 30 times higher than outside.

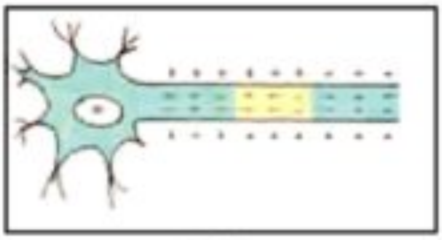


Fig. 11
Porlarized membrane
Propagation of nerve impulse along nerve fiber

- The concentration of negative ions as chloride ($C1^-$) and protein ions are higher inside the cell.

- The amount of negative ions inside the cell exceeds the positive ions.

- This unequal distribution of ions results in the presence of an electrical potential difference between outside and inside the cell surface equals - 70 millivolt (mV). It is called resting potenial.

- The membrane of the nerve cell during this resting condition is said to be polarized (Fig. 11). This state of polarization is a result of:

1. The selective permeability of the resting membrane: The membrane of the nerve cell is 40 times permeable for potassium ions (which diffuse from inside to outside) than for sodium ions (which diffuse from outside to inside). This results in accumulation of excess positive charges on the outer surface of the membrane.
2. Accumulation of high molecular weight protein ions in addition to chloride ions which are negatively charged on the inner side of the membrane.
3. Sodium- potassium pump which plays a role in maintaining this ionic distribution.

Therefore, at rest there is accumulation of positive potassium ions outside and negative protein and chloride ions inside the membrane. (Fig. 12)

b) Changes in the nerve cell on stimulation:

The nerve cell is stimulated only when the stimulus is sufficient (strong enough).

There are changes in the permeability of the membrane in which the inflow of the positively charged sodium ions exceeds the outflow of potassium ions through special channels in the membrane leading to accumulation of excess positive charges inside the membrane, i.e. reverse the original polarity and the membrane potential becomes + 40 mV. This new state is called depolarization.

C) Propagation of nerve impulse through the nerve fibres:

The depolarized (stimulated) point acts as a stimulus for the neighbouring points which when stimulated undergo the same previously mentioned changes as the first one and the process is repeated along the nerve fibre.

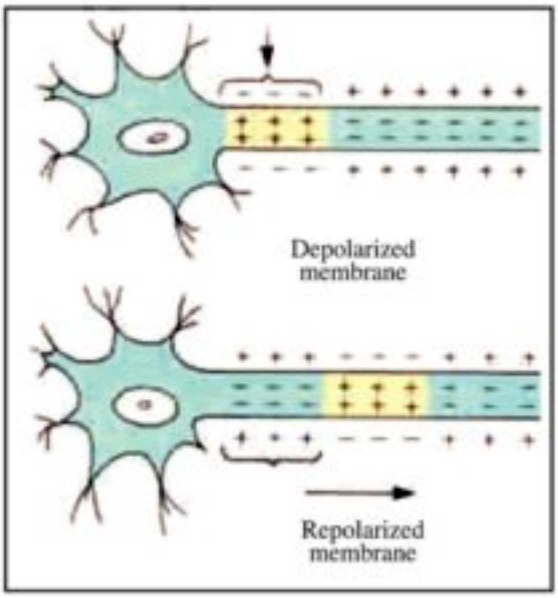


Fig. 12

D) How the nerve cell returns to its original state: (Repolarization)

1. After the end of depolarization the membrane becomes again permeable to potassium ions and impermeable to sodium ions.
2. Continuous outflow of potassium ions leads again to accumulation of excess positive ions outside the membrane and the membrane is said to be repolarized, i.e. returns to the resting state again (-70 mV).

The response of the nerve cell to the stimulus is called action potential which includes a state of depolarization followed by repolarization (110 mV).

The nerve impulse is the propagation of the action potential along the nerve cell (fibre).

3. For 0.001 to 0.003 second following stimulation, the nerve cell will not respond to any stimulus what ever its strength. This period is called the refractory period. During the refractory period the membrane of the nerve cell regains its physiological properties to be ready to respond to new stimulus and to transmit another nerve impulse.

Properties of the nerve impuls:

1. The speed of propagation of the nerve impulse along a nerve fibre depends on its diameter where it reaches 140 meters/second in thick (myelinated) nerve fibres, while the speed is 12 meters/second in thin (non myelinated) nerve fibres.
2. Stimulation of the nerve "and muscle" obeys the all or none law which means that the nerve responds maximumly or does not respond at all; in other words the sufficient stimulus produces a maximum response (generation of nerve impulse) and any increase in the strength of the stimulus will not increase the response. Weak stimuli are insufficient to produce an action potential (nerve impulse).

The synapse:

The synapse is defined as the site between the terminal branches (arborizations) of the axon of one neuron and the dendrites of the next. (Fig.13)

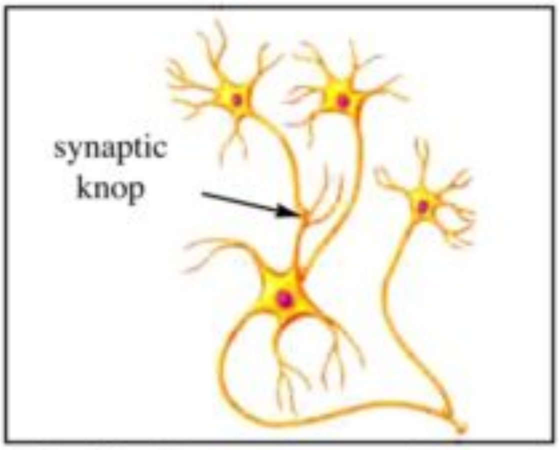


Fig. 13 Synapse between Neurons

Types of synapses:

a) Synapse between two neurons.

b) Synapse between a neuron and a muscle fibre.

c) Synapse between a neuron and gland cells.

Structure of the synapse:

The ultrastructure of the synapse (Fig. 16) reveals that the terminal branches of the axon end with swellings called buttons which are very close to the dendrite of the next neuron. In between, there is a very narrow space called the synaptic cleft.

This cleft separates a presynaptic membrane (axon) from a postsynaptic membrane (dendrite). The synaptic button contains a small vesicles (sacs) called synaptic vesicles, filled with chemical transmitters as acetylcholine and noradrenaline which play an important role in synaptic transmission of the nerve impulse from one neuron to the next.

Mechanism of transmitting a nerve impulse across a synapse:

1. Arrival of a nerve impulse to the buttons leads to entrance of calcium ions by the action of a calcium pump in the cell membrane. The inflow of calcium ions leads to rupture of the synaptic vesicles and the release of the chemical transmitters.
2. The chemical transmitters cross the synaptic cleft and reach the membrane of the dendrites of the next neurons. (Fig.14)

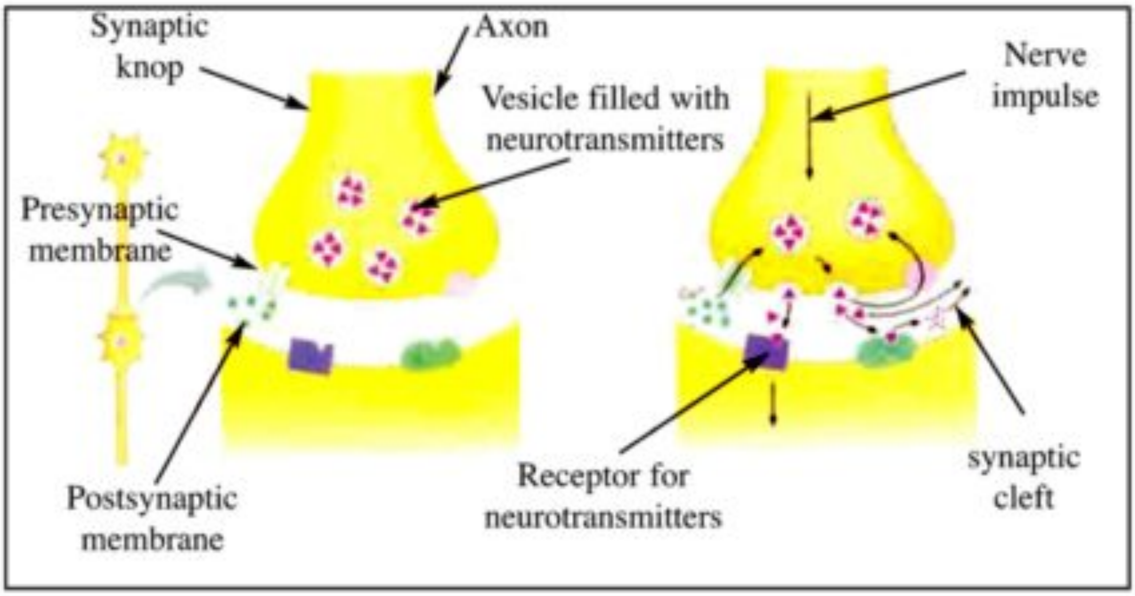


Fig. 14 Synaptic transmission of nerve impulse

3. Binding of the chemical transmitters to special receptors on the membrane of the dendrites leads to stimulation of theses points and changes the permeability of the membrane to sodium and potassium ions. These results in depolarization and reduction of an action potential (nerve impulse) as previously mentioned. This nerve impulse is propagated through the cell body then to the axon of the neuron then to a next synapse and so on.

4. After performing its function, acetylcholine (chemical transmitter) is destroyed under the effect of an enzyme called cholinesterase to terminate its action. After that, the postsynaptic membrane (dendrite) returns to the resting state again.

Chapter 5

The central nervous system (C.N.S):

As previously mentioned the central nervous system is divided into brain and spinal cord.

A) The brain:

The brain constitutes the major part of the central nervous system and its weight is about 350 grams at birth and reaches 1400 grams in an adult man. The brain occupies a bony space called the brain case or the skull (cranium).

The brain is surrounded by three membranes called the meningies (Fig. 15) responsible for the protection and nutrition of the brain cells. These membranes are:

1. The dura mater which lines the skull.
2. The pia mater which is in direct contact and adheres to the brain.
3. The arachnoid which is in between the other two membranes and contains a transparent fluid to protect the brain from mechanical trauma.

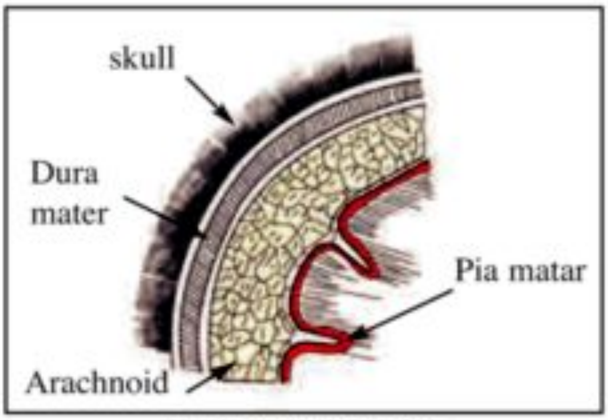


Fig. 15 Meningies

The brain (Fig. 18) consists of three main parts:

a) Fore brain: It includes brain cortex, thalamus and hypothalamus.

b) Midbrain.

c) Hindbrain: It includes

cerebellum, pons Varolii and medulla oblongata. 12 pairs of cranial nerves originate from the brain.

The structure and function of each part of the Brain:

A) Forebrain: It consists of:

1. Two cerebral hemispheres and cerebral cortex:

Two big lobes separated by a big fissure and attached to each other through a big bundle of nerve fibres. Each lobe is called cerebral hemisphere.

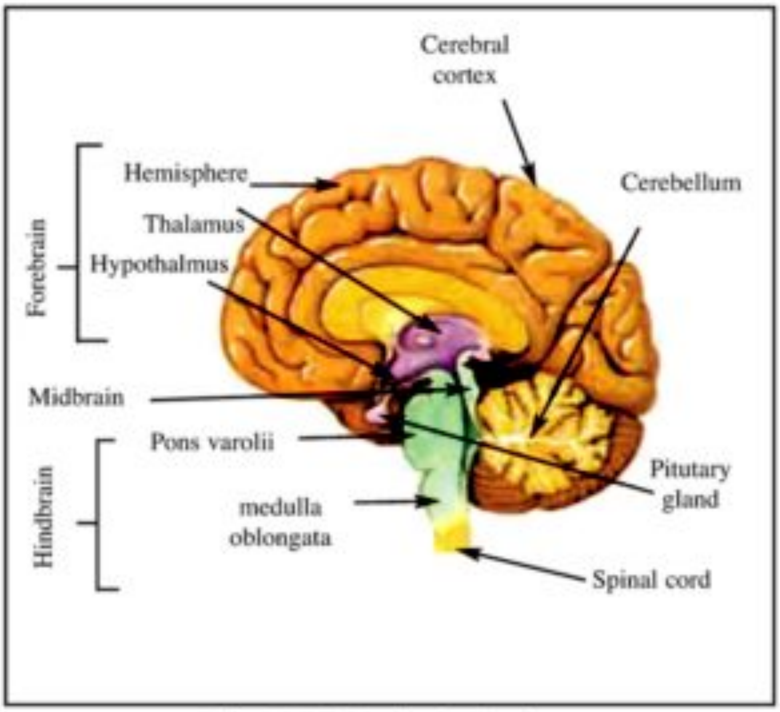


Fig. 16 Section in brain

The cortex of each lobe (cerebral cortex) is characterized by the presence of depressions of different depths called fissures and grooves and in between there are folds.

Each cerebral hemisphere is divided into many lobes. These lobes are:

1. Frontal lobe.
2. Parietal lobe.
3. Temporal lobe.
4. Occipital lobe.

In addition, there is a 5th lobe covered by the frontal and parietal lobes.

Functions of cerebral cortex:

a) The frontal lobe contains centres of voluntary movements (motor centres), centre of memory and speech.

b) The parietal lobe controls many sensory functions and contains centres of sensation of heat, cold, pressure and touch (somatic sensations from the skin).

c) The occipital lobe contains centres of vision. (Fig. 17)

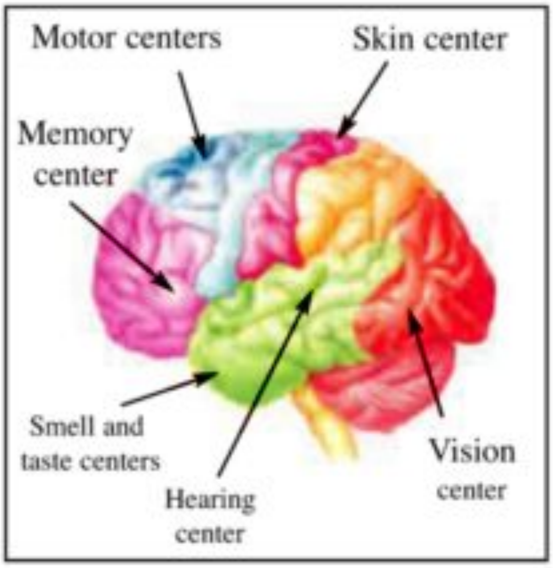


Fig. 17 Brain centers

d) The temporal lobe contains centres of smell and also centres of hearing

2. Thalamus:

It is an important centre for coordination of different sensations (except the smell) that reach the cortex .

3. Hypothalamus:

It controls different reflexe actions and contains centres of hunger, satiety, thirst and body temperature regulation, in addition to centre of sleep.

B) Midbrain: The smallest part of the brain and represents a connection between the forebrain and the hindbrain and contains centres of keeping the body balance and centres related to hearing and vision. In addition, it regulates many reflexes as those related to hearing.

C) Hindbrain: It consists of:

1. Cerebellum: It is situated in the posterior region and consists of three lobes. The main function is to keep balance of the body in association with the inner ear and muscles.
2. Pons Varolii and medulla oblongata perform the following functions:
   a) Transmission of nerve impulses between the spinal cord and different brain regions.
   b) The medulla oblongata contains vital centres as those of respiration, swallowing, vomiting, cough, sneezing and blood vessels.

c) The spinal cord: The spinal cord exists inside a canal in the vertebral column called the neural canal. It extends from the medulla oblongata in the form of a cylindrical cord about 45 cm. long.

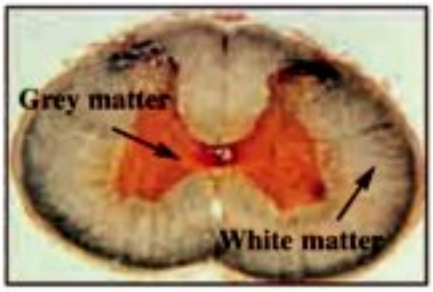


Fig.18 Section in spinal cord

The spinal cord is hollow, containing a central canal and covered by meninges (3 membranes) as those surrounding the brain (dura mater, pia mater and arachnoid). Along the midline there are two fissures (dorsal and ventral) which divide the spinal cord (incompletely) into two halves. The spinal cord consists of 2 layers; outer white matter formed of nerve fibres and inner grey matter formed of nerve cells with their dendrites and neuroglia. Grey matter is H-shaped with two dorsal horns and two ventral horns. (Fig.18)

Functions of spinal cord:

The grey matter is the main centre of reflex action as it contains thousands of reflex arcs. The white matter transmits impulses from different parts to the brain and vice versa.

Spinal Nerves:

There are 31 pairs of successive spinal nerves that originate from both sides of the spinal cord as follows:

1. Eight pairs of cervical nerves.
2. Twelve pairs of thoracic nerves.
3 Five pairs of lumbar nerves.
4. Five pairs of sacral nerves.
5. One pair of coccigeal nerves.

Each spinal nerve originates from the spinal cord by two roots (dorsal and ventral). The dorsal root carries sensory nerve fibres that transmit impulses from the receptors to the spinal cord and then to the brain. The ventral root carries motor nerve fibres that transmit impulses to the responding (effector) organs as muscles and glands.

Peripheral Nervous system:

This system consists of a network of nerves distributed all over the body connecting the central nervous system to all parts of the body. These nerves are of two types:

1. Cranial nerves: 12 pairs connected to the brain. Some cranial nerves are purely sensory containing sensory fibres only and carry impulses from receptors to the brain, others are purely motor containing motor fibres only and carry impulses from the brain to the effector organs. Some cranial nerves are mixed with both motor and sensory fibres.
2. Spinal nerves: 31 pairs connected to the spinal cord and these are mixed nerves with both sensory and motor fibres.

The reflex action (reflex arc):

The reflex action (Fig.19) is the unit of nervous activity. The majority of the nervous functions can be analysed to a group of reflex actions.

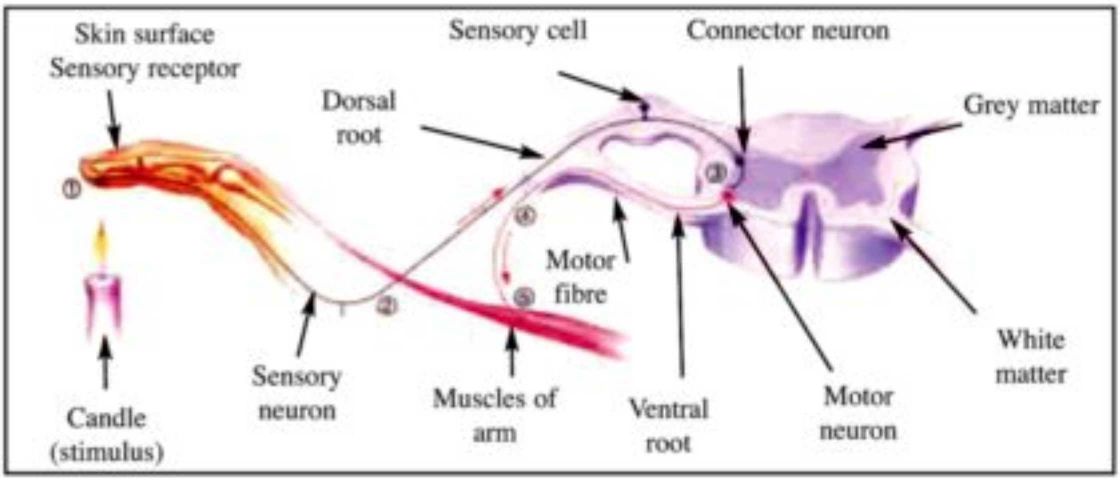


Fig. 19 Reflex action

The reflex action consists of at least two nerve cells (neurons), one sensory (afferent) and the other is motor (efferent). The majority of reflex actions consist of 5 elements:

1. Receptor (sense organ).
2. Afferent (sensory) neuron.
3. Connector (intermediate) neuron.
4. Efferent (motor) neuron.
5. Effector (responding) organ.

If the effector organ is a voluntary (skeletal) muscle the reflex is called voluntary (somatic) reflex and if the effector organ is an involuntary muscle, a gland or heart the reflex is called involuntary (autonomic) reflex.

Autonomic Nervous system:

This system regulates the different involuntary activities as contraction of cardiac muscle and smooth (involuntary) muscles in addition to secretion of glands.

The autonomic nervous system (Fig.20) includes two divisions:

The sympathetic nervous system:

The nerve fibres of this system arise from the thoracic and lumbar regions of the spinal cord. This system is important as an emergency system which enables the body to confront emergency situations.

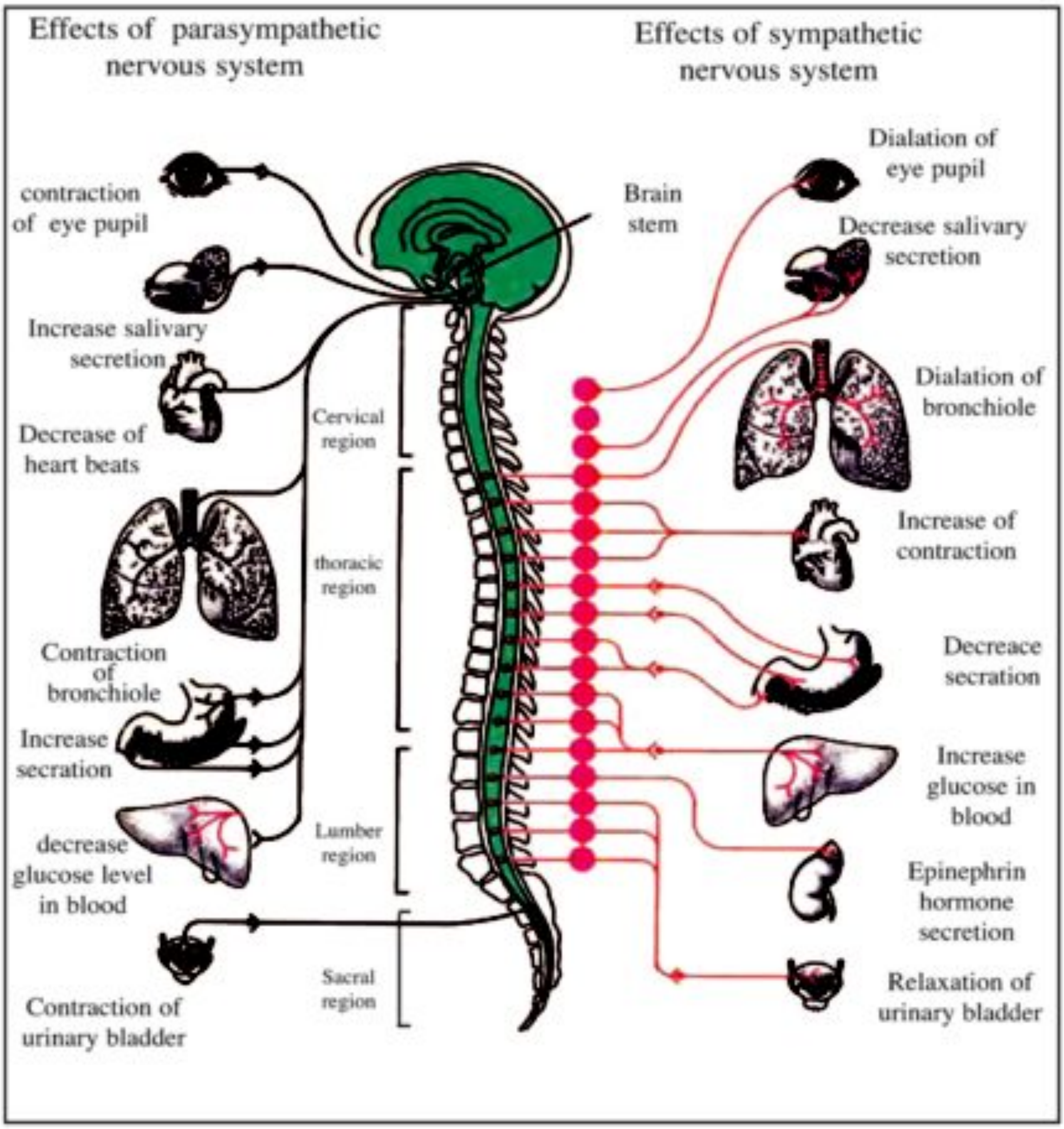


Fig. 20

Effects of autonomic nervous system on some parts of the body

The parasympathetic nervous system:

The nerve fibres of this system arise from brain stem and the sacral region of the spinal cord.

Most of the internal parts of the body receive nerve fibres related to both sympathetic and parasympathetic systems and in most cases the effect of one system antagonize the effect of the other.

The following table summarizes the effects of the sympathetic and parasympathetic systems on some parts of the body.

Go Further

For more knowledge about this topic you can refer to the Egyptian Knowledge Bank (EKB) through the opposite link

Effector organ	Effect of sympathetic N.S	Effect of parasympathetic N.S
Heart	Increases heart rate and force of contraction	Decreases heart rate and force of contraction
Blood vessels	Vasoconstriction of blood vessels of skin, viscera, salivary glands, brain, external genetalia and lungs	Vasodialation of blood vessels of salivary glands and external genetalia
Alimentary canal	Relaxation of the wall of stomach, intestine and colon	Contraction
Respirstory system	Dilatation (relaxation) of bronchioles and decreases secretion	Constriction (contraction) of bronchioles and increases secretions
Urinary bladder	Relaxation of the wall of urinary bladder	Contraction of the wall of urinary bladder
1.Salivary glands	Stimulates little secretion of saliva	Stimulates large secretion of saliva
2. Gastic (of stomach)	Inhibits secrtion	Stimulates secrtion
3. liver	Break down of glycogen and increases glucose level in blood	Decrease glucose level in blood
4. Pancreas	Inhibits secretion of enzymes	Stimulates secretion of enzymes
5. Adrenal medulla	stimulate the secretion of the hormone adrenaline (epinephrine) which increases blood pressure, increases heart rate and increases the glucose level of the blood " sugar"	No parasympathetic fibres connection

Questions

1- Choose the correct answer:

1. The vital function that helps the living organism to adapt with its environment is:

a) Respiration.

b) Transport.

c) Movement.

d) Sensation.

2. The nerve fibre represents:

a) A dendrite of a neuron.

b) An axon of a neuron.

c) A dendrite or an axon of a neuron.

d) A neuron.

3. The nerve represents:

a) A dendrite of a neuron.

b) Non myelinated axons.

c) A group of myelinated axons.

d) A collection of neurons forming the nerve cord.

4. All the following glands are affected by the parasympathetic n.s. except:

a) Pancreas.

b) Adrenal medulla.

c) Gastric and salivary.

d) Liver.

5. Myelinated axons (nerve fibres) conduct nerve impulses faster than non myelinated axon.

a) This is true because myelin is an insulator.

b) This is true because myelin is a conductor.

c) This is false as myelin is only for nutrition.

d) This is false as myelin only secrets spinal fluid.

6. All The follwing show the refractory period except ?

a) Is the time needed to pump sodium to outside actively.

b) About 0.001 - 0.003 second.

c) The membrane responds to stimuli during this period.

d) The membrane regains its physiological properties.

7. Some of the following membranes surround the brain but the one that protects the brain from trauma is:

a) Pia mater. b) Dura mater.

c) Arachnoid. d) Perineurium.

Chapter 5

2 - Give reason for:

1. The reflex action does not involve the brain.
2. Transmission of a nerve impulse across the synapse.
3. The root is positive geotropism and negative phototropism
4. Presence of Nissil granules in the nerve cell.
5. A lesion or injury in the nervous centres can be healed although the neurons cannot divide or replace the damage.

3. Draw a labelled diagram of the nerve cell (neuron)

4. Mimosa plant has two types of movement. Mention them and explain.

5. Explain the role of Auxins in the follwing :

1- phototropism for both root and stem.

2- Hydrotropism for root.

6. Explain the transmission of a nerve impulse.

a) Through a nerve fibre.

b) Across a synapse.

7. What happens in the following cases and give reasons:

a) Growth of seedling in horizontal position.

b) Cut the cleoptile of a plant.

c) Injury of cerebellum.

c) Damage of medulla oblongata.

8. What is meant by:

refractory period - nodes of Ranvier - myelin - synaptic vesicle - mixed nerve - membranes of the brain (meningies).

9. Explain with experiments:

1- Hydrotropism for root.

2- Went experiment.

3- B. Jensen experiments.

10. Write what you know about spinal nerves.

11. What are the effects of the autonomic nervous system on each of the following organs:

heart - blood vessels - alimentary canal - urinary bladder – eye

تم الطبع بالشروق الحديثة ـ القاهرة
بالمواصفات الفنية الآتية

عدد الصفحات بدون الغلاف : ١٤٨ صفحة

عدد الملازم بدون الغلاف : ٩,٢٥ ملزمة

المقـــاس : ٥٧ ١/٨ × ٨٢ سم

نـــوع الـــورق : لا يقل الداخلى عن ٨٠ جرام والغلاف ٢٠٠ جرام

ألـــوان الطبـــع : ٤ لون للداخلى والغلاف

رقـــم الكتـــاب :