NUTRITION

Nutrition refers to the process of acquiring nutrients and energy from the surrounding which are necessary for metabolic processes.

Metabolic reactions are all enzyme reactions that occur inside living organisms. They are divided into two;

i. **Anabolism,** involves the synthesis or building up of complex molecules (larger units) from simple units.

ii. **Catabolism,** is the process which involves the lysis or breakdown of complex molecules into simple molecules.

Nutrients are the substances which organisms need for their metabolic processes.

Nutrients vary depending on the needs of the organism. Green plants require only inorganic substances like water, carbondioxide and mineral salts. Animals require both inorganic and organic substances.

MODES OF NUTRITION

There are two major forms of nutrition

1. **Heterotrophism (heterotrophic nutrition)**

   This is a mode of nutrition where by an organism obtains food from already manufactured organic compounds.

   Heterotrophic nutrition may be classified as holozoic, saprophytic or parasitic.

   a. **Holozoic nutrition** occurs in free living organisms which have a specialised digestive system (alimentary canal)

   b. **Saprophytic nutrition**, this form of nutrition occurs when organisms feed on dead or decaying organic matter.

   c. **Parasitic nutrition**, feeding of one organism on another to which it causes some harm

2. **Autotrophism (autotrophic nutrition)**

   This is a mode of nutrition in which an organism can synthesise its own food using some external source of energy.

   Photosynthesis occurs in green plants and chemosynthesis occurs in bacteria.

CHEMICALS OF LIFE

Inspite of the diversity of life forms, living organisms use a limited number of substances to carry out life processes and are called chemicals of life. Chemicals of life include proteins, carbohydrates, lipids (fats), vitamins, mineral salts and water.

WATER

The most important substance in all living organisms is water which accounts for the greatest percentage of most organisms. Its roles include:

1. Being part of the protoplasm of living cells
2. Medium for transportation of substances due to its excellent solvent substances
3. Medium in which metabolic reactions take place
4. Maintaining a relatively constant temperature of the body of an organism due to its high heat capacity
5. Offers support in many organisms e.g. those with hydrostatic skeletons and herbaceous plants
6. Control of temperature in animals and plants

CARBOHYDRATES

Carbohydrates are the simplest of the organic molecules in living organisms. Their molecules contain carbon, hydrogen and oxygen only. The ratio of hydrogen (H) and oxygen (O) in a carbohydrate molecule is 2:1 i.e. $C_1 (H_2O)_2$.

All carbohydrates have got a simple basic molecule; the building block, called a **saccharide**. It is from the saccharide that more complex forms of the carbohydrates may be built up.

- If a carbohydrate has molecules which are formed from a single building block, such a carbohydrate is called a **monosaccharide**.
- If a carbohydrate is formed by combination of two simple sugar molecules, then it is called a **disaccharide**.
- When a carbohydrate is formed by a combination of many simple sugar molecules, it is called a **polysaccharide**.

Monosaccharides

These are the simplest forms of carbohydrates with molecules made up of a single sugar molecule.

They are extremely sweet and soluble in water.

Monosaccharides are the form of carbohydrates that organisms can utilise for energy production

They are chemically active and can react with some substances e.g. reducing oxidised copper ions hence they are called **reducing sugars**.

Monosaccharides include *glucose, fructose and galactose*.

Disaccharides

Each disaccharide molecule is made from a combination of two monosaccharide molecules joining together to form a bond, in the process a water molecule is lost i.e. a ***condensation reaction***.

Disaccharides are less soluble and less sweet than monosaccharides

In living organisms, they are not capable of reducing copper ions (non-reducing sugars).

Examples of disaccharides include;

- Sucrose from a combination of glucose and fructose
- Lactose from a combination of glucose and galactose
- Maltose from a combination of glucose and glucose

Note. Maltose is the only disaccharide which can reduce oxidised copper ions

Polysaccharides

A single polysaccharide molecule is formed by a combination of many simple sugar molecules.

They are un-sweet and insoluble in water. They are also used for storage purposes e.g. starch and glycogen.

They are also used as structural molecules e.g. cellulose in cell walls, starch and glycogen in liver and muscle cells

Food sources of carbohydrates

i. Starch from grains and tubers
ii. Sugars from fruits and canes

Deficiency symptoms

An individual who does not consume enough carbohydrates suffers from marasmus

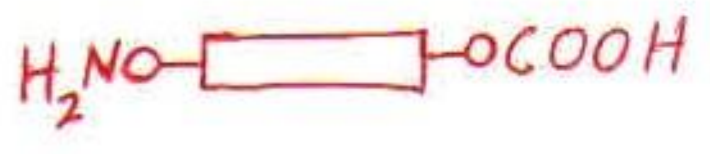
<u>Assignment 1</u>

State the signs and symptoms of marasmus

PROTEINS

These are organic molecules which contain carbon, hydrogen and oxygen together with nitrogen, phosphorus and sulphur.

The building blocks of proteins are amino acids. These are organic molecules which have two ends, one possessing an amino group, while the other possesses a carboxylic acid group.



There are two types of amino acids;

1. **Essential amino acids**. These are amino acids which cannot be made by our bodies and therefore we need them in our diet. There are only 10 essential amino acids.

2. **Non-essential amino acids**. These are amino acids that can be made by our bodies, therefore we may not need them in our diet.

A protein molecule is formed by polymerization (combination) of several amino acids. This process occurs when one acid end of an amino acid joins an amino end of another amino acid in a condensation reaction to form a **peptide bond**. When many amino acids are joined together by such peptide bonds, the resultant molecule is called a **polypeptide**. A number of polypeptide chains join to form a **protein molecule**.

Proteins may be classified as **first class** or **second class proteins**. First class proteins contain all the 10 essential amino acids and they include eggs, milk, soya, meat e.t.c. Second class proteins are those proteins which do not contain all the essential amino acids.

The properties of a given protein depend on the sequence of amino acids in the polypeptide chain which makes up the protein molecule. Because amino acids may be joined in any sequence, there's a great diversity in protein molecule properties and because of that, proteins have got a variety of properties and functions.

Functions

1. Proteins are important for repair and replacement of the worn out or damaged tissues
2. Proteins are important in making enzymes which catalyse all chemical reactions
3. They provide energy when carbohydrates sources in food are not enough or are absent
4. They are used to form structures e.g. collagen, keratin and actin

5. They are used in transport of materials e.g. haemoglobin
6. They are used in blood clotting
7. They are used in the formation of hormones
8. They are used in the formation of antigens

Deficiency symptoms

Children who do not consume enough proteins suffer from kwashiorkor. The child develops a swollen stomach and brown hair.

LIPIDS

These are organic compounds which contain carbon, hydrogen and oxygen like carbohydrates, but the proportion of oxygen to other elements is very low e.g. beef fat $C_{57}H_{116}O_6$.

Lipids consist of both fats and oils which are made from the combination of both **fatty acids** and **glycerol**. Both fats and oils are similar in chemical nature except that fats are solids and oils are liquids at room temperature.

Generally oils are found in plants e.g. nuts, sunflower, peas while fats are found in animals e.g. beef, mutton, pork, e.t.c. Oils can be converted into fats (solids) by the process of **hydrogenation.**

Functions of lipids

1. They provide insulation against heat loss from the body of animals e.g. polar bears
2. They are oxidised to provide energy during respiration
3. They provide protection to vital organs e.g. kidney and heart
4. They are a form of energy storage e.g. mammals store fats and plants store oils as energy reserves.
5. They acts as a solvent and a store for fat soluble vitamins e.g. A, D, E and K.
6. Source of metabolic water to young birds and reptiles still in their eggs
7. Source of metabolic water to desert animals e.g. camel

VITAMINS

These are organic compounds which are essential (vital) for the normal functioning of the body.

They are chemically different and cannot be synthesized by the body except vitamin D. Most vitamins are not stored by the body and therefore they must be regularly supplied in the diet. They are required in small quantities.

Before their chemical nature was found, vitamins were named with letters of the alphabet depending on when they were identified.

Vitamin	Food source	Functions	Deficiency
A **Retinol** (fat soluble)	Liver, egg yolk, green vegetables (butter and margarine)	-normal growth -increased resistance to diseases -normal vision	-sore eyes -reduced night vision -unhealthy skin
B_1 **Thiamine** (water soluble)	-Unpolished cereals -beans, lean meat, egg yolk	-normal functioning of the heart and nervous system -co-enzymes in respiration	-Beriberi, common in rice-eating people -Retarded growth -Paralysis -lack of appetite
B_2 **Riboflavin** (water soluble)	-As for B_1 plus green vegetables -liver and milk	-skin health -cell respiration	-sore mouth -skin disorders
B_3 **Nicotinic acid** (Niacin) water soluble	As for B_1 plus green vegetables and yams	-meat, fish, wheat, eggs, liver, green vegetables -cell respiration	Pellagra Skin diseases Mental disorder
C **Ascorbic acid** (water soluble)	Fresh citrus fruits, green vegetables	Healing of wounds Increased resistance to diseases	Scurvy Teeth disorders Bleeding of gums and other membranes
D **Calciferol** (fat soluble)	Milk, eggs, fish, liver, oil, butter.	Hardening of bones and teeth	Rickets Teeth diseases (Dental carries)
E	Vegetable oil, eggs, liver	Promotes fertility	Sterility in animals

Tocopherol (fat soluble)		Essential in the reproductive processes	
K **Phylloquinone** (Fat soluble)	Unpolished cereals, liver, egg yolk, green vegetables	Essential in blood clotting	Delay in clotting

MINERAL ELEMENTS

These are inorganic substances required in small amounts for the normal functioning of the body. Mineral elements required in relatively large amounts are called **essential elements**. Essential elements include sodium, potassium, calcium, iron and nitrogen.

ELEMENT	SOURCE IN FOOD	FUNCTION
Iron	Liver, green vegetables, yeast and kidney	Formation of haemoglobin *Deficiency causes anaemia
Calcium	Milk, cheese, green vegetables	Formation of bones and teeth Necessary for muscle contraction Necessary for blood clotting *absence causes rickets
Sodium	Table salt and green vegetables	Transmission of nerve impulses Maintenance of tissue fluid Muscle contraction *Deficiency leads to muscle cramp
Phosphorous	Meat, fish, milk, nuts and poultry	Formation of bones and teeth Formation of ATP Synthesis of proteins
Nitrogen	Protein foods, lean meat, eggs and milk.	Synthesis of proteins and other complex chemicals Formation of muscle, skin and nails

Iodine	Cheese, sea fish and ionised table salt	Formation of hormone in the thyroid glands *Absence causes goiter and reduced growth
Chlorine	Table salt	Manufacture of tissue fluid, blood and lymph

FOOD TESTS

These are tests carried out on food samples, in the laboratory, to identify the nutrients present in the food samples.

CARBOHYFRATES

Carbohydrates are tested using three tests: i.e. Starch test, reducing sugars test and non-reducing sugars test. **A positive test** is one where the nutrient under study is found present and **a negative test** is one whereby the nutrient under study is absent.

a. Starch test

Procedure

Add 2cm^3 of test solution to a test tube and add three drops of iodine solution (I_2/KI).

Observation

Either, initial colour of solution turns into a black solution or blue solution

Or, the initial colour of the solution turns into a brown solution

Conclusion

Either, starch present

Or, starch absent

Note:

The test above can be used as a quantitative test to compare the concentration of starch in different solutions. A black solution is more concentrated as compared to a blue solution.

b. Reducing sugars test

Procedure

Add $2cm^3$ of test solution to a test tube and add $2cm^3$ of Benedict's reagent. Shake and heat until the mixture boils.

Observation

Either, the initial colour of the solution turns into a blue solution, green solution, yellow precipitate and orange precipitate.

Or, the initial colour of the solution turns blue and remains blue on boiling

Conclusion

Either, reducing sugars present

Or, reducing sugars absent

Note:

- The sugars are called reducing because they reduce the oxidation state of copper from 2 to 1, hence the change in colour.
- The common reducing sugars include glucose, fructose and the disaccharide maltose.
- The test above can be used as a quantitave test i.e. to determine the concentration of the solution. The closer the colour is to orange, the higher the concentration of reducing sugars in the solution.

c. Non reducing sugars test

Procedure

Add $2cm^3$ of test solution to a test tube followed by $1cm^3$ of dilute hydrochloric acid and boil. Cool the test tube and carefully add $2cm^3$ of sodium hydroxide. Add $2cm^3$ of Benedict's reagent. Shake and heat until the mixture boils.

Observation

Either, the initial colour of the solution turns into a blue solution, green solution, yellow precipitate and orange precipitate.

Or, the initial colour of the solution turns blue and remains blue on boiling

Conclusion

Either, reducing sugars present (non-reducing sugars hydrolysed to reducing sugars)

Or, non-reducing sugars absent

PROTEINS

Two tests are used to determine the presence of proteins in a solution:

a. Biuret's test

Procedure

Add $2cm^3$ of test solution to a test tube and then add $2cm^3$ of sodium hydroxide and mix thoroughly. Add two drops of copper sulphate solution and mix.

Observation

Either, the initial colour of the solution turns into a purple precipitate

Or, the initial colour of the solution turns into a blue precipitate

Conclusion

Either, proteins present

Or, proteins absent

b. Millon's test

Procedure

Add $2cm^3$ of test solution to a test tube and then add $1cm^3$ of Millon's reagent and boil.

Observation

Either, the initial colour of the solution turns into a pink coagulant

Or, the initial colour of the solution remains

Conclusion

Either, proteins present

Or, proteins absent

VITAMIN C

Procedure

Add $2cm^3$ of DCPIP into a test tube, and then add the test solution drop by drop.

Observation

Either, the solution becomes colourless

Or, the initial colour of the solution remains

Conclusion

Either, vitamin C present

Or, vitamin C absent

LIPIDS

Three tests are used to determine the presence of lipids (fats or oils).

a. Emulsion test

Procedure

Add $2cm^3$ of test solution to a test tube containing $2cm^3$ of ethanol. Shake vigorously and then add $2cm^3$ of cold water.

Observation

Either, the solution turns into a cloudy white emulsion

Or, the solution remains clear

Conclusion

Either, lipids present

Or, lipids absent

b. Sudan III test

Procedure

Add $2cm^3$ of test solution to a test tube add, $2cm^3$ of water and add a few drops of Sudan III reagent and shake.

Observation

Either, a red-stained oil layer separates on the surface of the water which remains uncoloured.

Or, the solution remains clear.

Conclusion

Either, lipids present

Or, lipids absent

c. Grease spot test

Procedure

Rub a drop of the sample onto a piece of paper. Allow time for any water to evaporate.

Observation

Either, a permanent transparent spot is observed

Or, no observable change on the paper

Conclusion

Either, lipids present

Or, lipids absent

ENZYMES

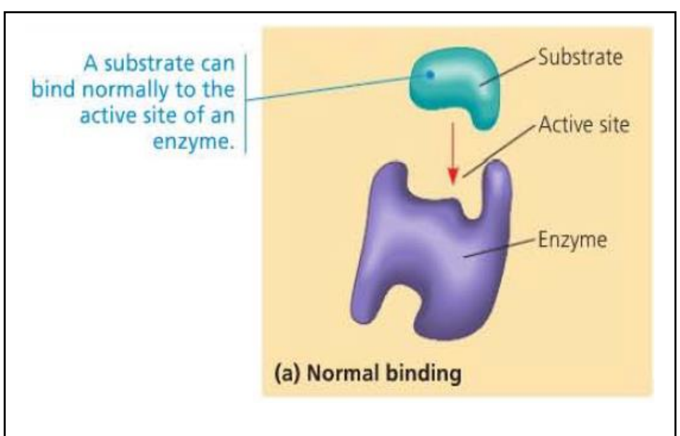
Enzymes are biological catalysts which alter the rate of chemical reactions in the body.

Types

1. Intracellular enzymes. These are found within the cell and act within the cytoplasm of the cell that secretes (produces) them.
2. Extracellular enzymes. These are secreted from the cells and function outside the cell which secretes them

Note:

- The substance acted upon by an enzyme is called a **substrate**
- The results of an enzyme catalysed reaction are called **products.**
- Each enzyme has an **active site** with a specific shape where it binds with a specific substrate just like a key fitting into a padlock thus the **lock and key hypothesis** for enzyme action.



Properties of enzymes

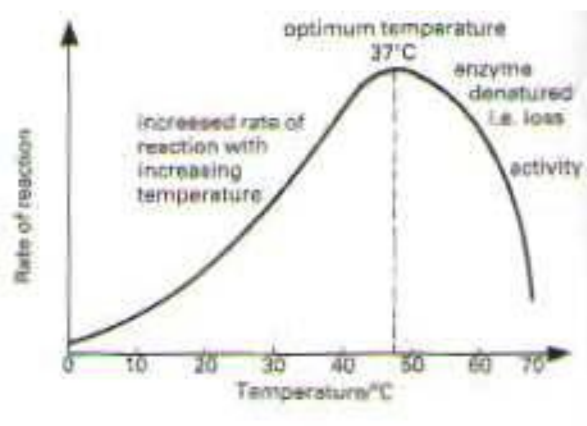
1. They are protein in nature
2. They are specific in action
3. They are heat sensitive
4. They are pH sensitive
5. Their reactions are reversible
6. They are inactivated by some chemicals i.e. inactivators
7. They work in small amounts
8. Some require co-enzymes to act

FACTORS AFFECTING ENZYME ACTIVITY

1. Temperature of the medium

From 10ºC to 37ºC, the rate of enzyme activity increases with increase in temperature. The rate of an enzyme controlled reaction is doubled for every rise of 10ºC. This is because the enzyme and substrate molecules both have more kinetic energy so collide more often.

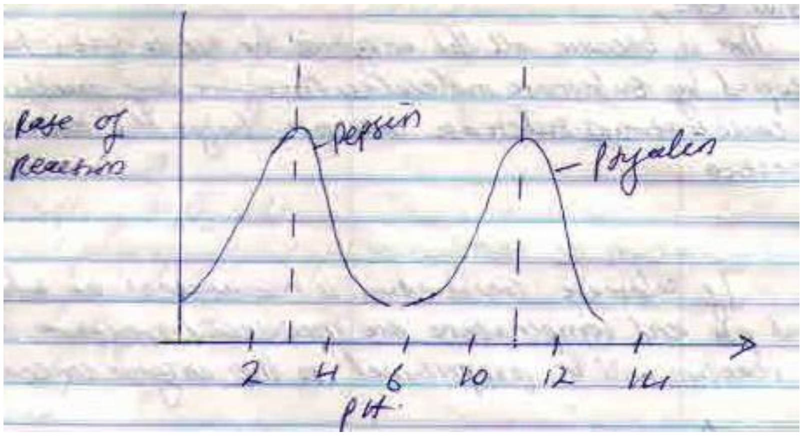
Beyond 37ºC the enzyme structured is disrupted and it becomes **denatured** and the rate of reaction decreases. At or near OºC, the rate of reaction is low because the enzyme becomes *inactivated* and regain its catalytic property if the temperature is increased.

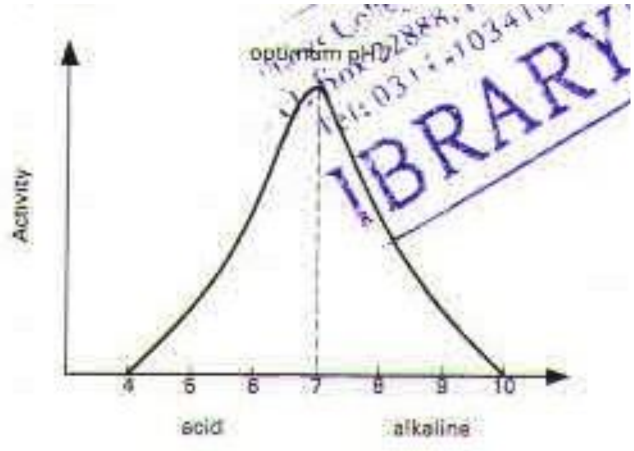


The rate of the reaction is highest at the **optimum temperature**. Optimum temperature is the temperature at which enzymes work effectively and efficiently.

2. pH of the medium

At constant temperature, each enzyme works most effectively over a narrow range of pH. Some enzymes require alkaline medium e.g. ptyalin and lipase while others require acidic media e.g. pepsin and rennin.



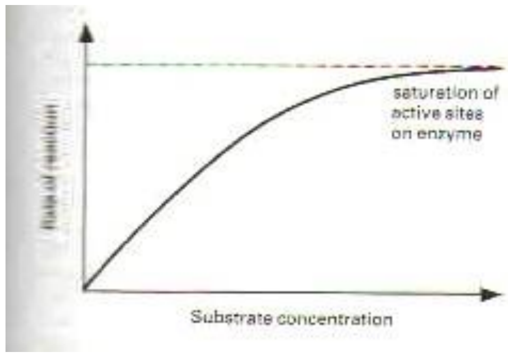


A pH value which is slightly above or below the optimum value leads to a marked decrease in the efficiency of the enzyme.

Enzyme	Optimum pH	Substrate	Products
Pepsin (stomach)	1.5-2.0 acidic	Proteins	Peptides
Ptyalin (mouth)	7.7 slightly alkaline	Starch	Maltose
Catalase (pawpaw, liver, potatoes)	8.0 alkaline	Hydrogen peroxide	Water and oxygen
Lipase (duodenum)	9 alkaline	Fats	Fatty acids and glycerol
Maltase (duodenum)	8.5 alkaline	Maltose	Glucose

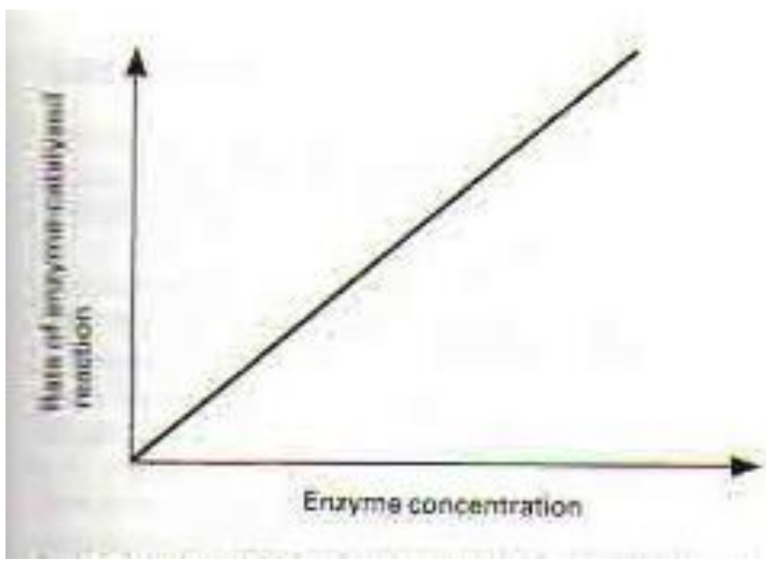
3. Substrate concentration

The rate of an enzyme reaction increases with increasing substrate concentration until an optimum concentration is reached. Beyond the optimum concentration, the rate of the reaction remains constant. This is because all the enzymes' active sites have been occupied by substrate molecules, therefore any further increase in concentration of the substrate does not change the rate of the reaction.



4. Concentration of enzymes

If substrate concentration is maintained at a high level, and pH and temperature are maintained constant, the rate of reaction will be proportional to the enzyme concentration.



EXPERIMENTS ON CATALASE ENZYME

All living tissues contain the enzyme catalase which hydrolyses hydrogen peroxide to oxygen and water. Hydrogen peroxide is a highly active chemical and is continuously formed as a bi-product of reactions in living cells. It is toxic and thus has to be broken-down by cells, once it is formed.

Requirements

- Hydrogen peroxide
- Test tubes
- Beaker of boiling water
- Pieces of different tissues e.g. liver, Irish potatoes

PROCEDURE	**OBSERVATION**	**CONCLUSION**
To $2cm^3$ of hydrogen peroxide in a test tube, drop a cut cube of Irish potato of volume $1cm^3$.		
To $2cm^3$ of hydrogen peroxide in a test tube, drop a crushed cube of Irish potato of volume $1cm^3$		
To $2cm^3$ of hydrogen peroxide in a test tube, drop a boiled cube of Irish potato of volume $1cm^3$		
To $2cm^3$ of hydrogen peroxide in a test tube, add a few strands of hair		
Add $2cm^3$ of dilute HCl and add one piece of Irish potato cube of volume $1cm^3$ and leave for 5 minutes and then add $2cm^3$ of hydrogen peroxide		
On one piece of Irish potato cube of volume $1cm^3$ add $2cm^3$ of NaOH and leave for five minutes and then add 2cm3 of hydrogen peroxide.		
On one piece of Irish potato add $2cm^3$ of water and leave to stand for five minutes then add $2cm^3$ of hydrogen peroxide		

a. Compare the activity of hydrogen peroxide in the first three test tubes and give and explanation n each case.

b. What is the aim of experiments 5, 6 and 7 above?

c. What general conclusion can you draw from the experiment?

BIOSTATISTICS

This is the study of biological concepts presented in a numerical or figure format. Biostatistics is presented in five different ways:

a) Questions asked from numerical data

b) Questions asked from numerical data and a graph is to be plotted

c) Questions asked with the graph plotted

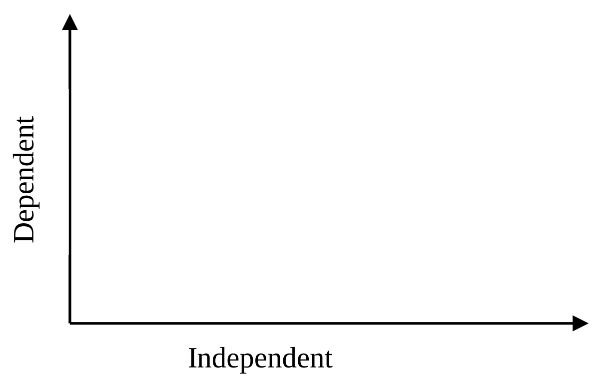
d) Questions asked from an experimental setup with the results presented in a graphical form

e) Questions asked from an experimental set up with the results tabulated

PLOTTING A GRAPH FROM DATA

When plotting a graph, the independent variable **MUST** be indentified and separated from the dependent variable. The independent variable is normally provided in the first column or row and the dependent variable shown in the next column or row.

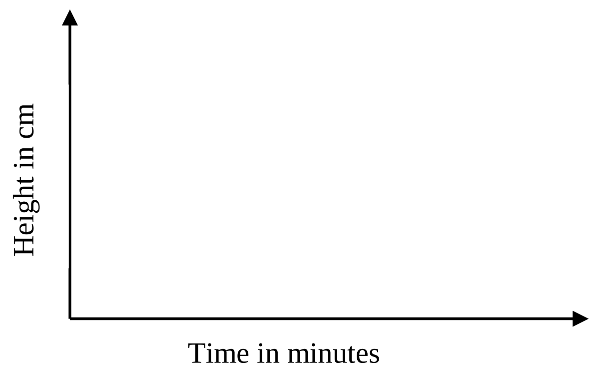
The independent variable is indicated on the X-axis and the dependent variable is indicated on the Y-axis.



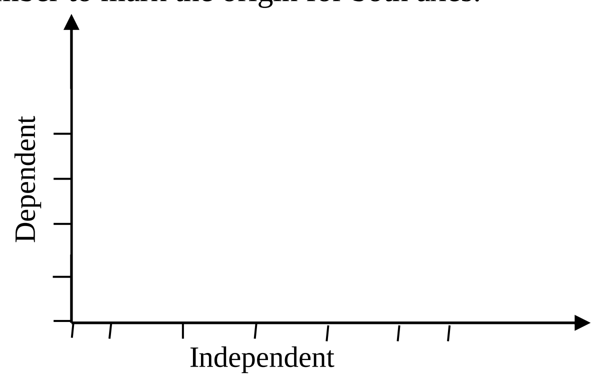
The units on the label must be obtained from those given in the question and written as shown below.

Time (minutes)	Height (cm)

Time/minutes		
Height/cm		



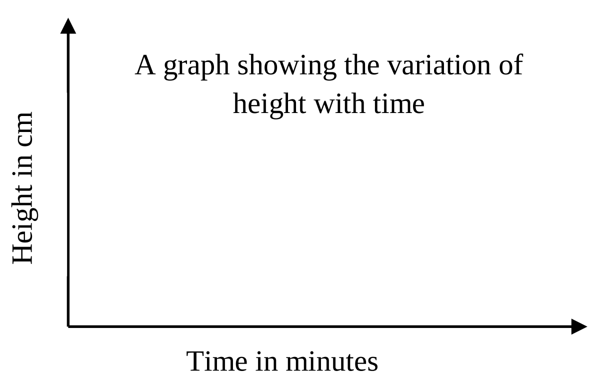
The axis must be labelled along the axis-line and marks made along the axis-line for where the values are to be placed. Remember to mark the origin for both axes.



TITTLE

The title for graphs shall be written as, '*A GRAPH SHOWING THE VARIATION OF Y WITH x'* **OR** *a graph showing the relationship between X and Y*, OR *a graph showing a relationship between Y and X*

For example, a graph showing the variation of temperature with time



PLOTTING

The plot is either  and must be within the limits of the four smallest squares i.e.  or  . After plotting the points are then joined together by free hand.

SCALE

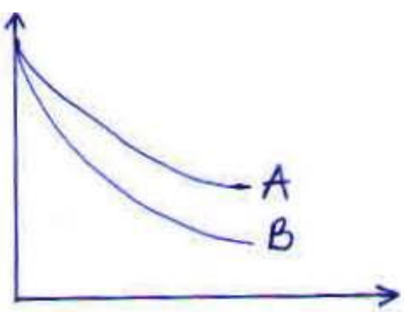
This is normally written in the upper right corner or the upper left corner after plotting the graph. The scale for the (Vertical) Y-axis must be recorded separately from the scale of the (Horizontal) X-axis even if they are the same. The scale MUST be indicated to one centimeter i.e. measure off 1 cm from your plotted graph and record the units it represents.

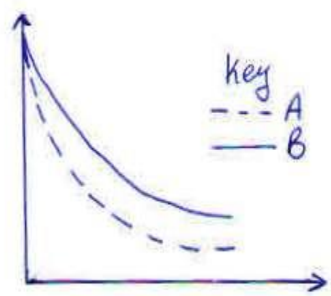
For example: on the Y-axis, 1 cm represents 0.5 hours

On the X-axis, 1 cm represents 10 g

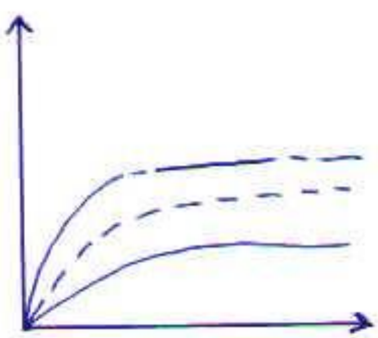
KEY

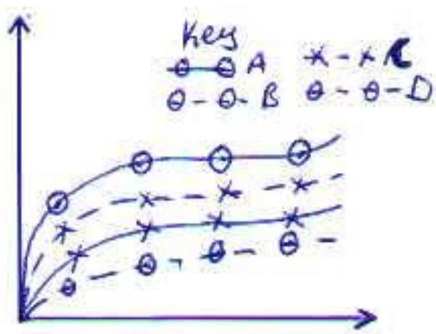
A key is used only when more than one graph has been plotted on the same axis. The key can be indicated separately on the graph paper or it may be done by labeling each individual graph.





When indentifying different graphs on the same axis, vary the plotting style or the type of line used.





DESCRIBING A GRAPH

The following should be done when describing a graph:

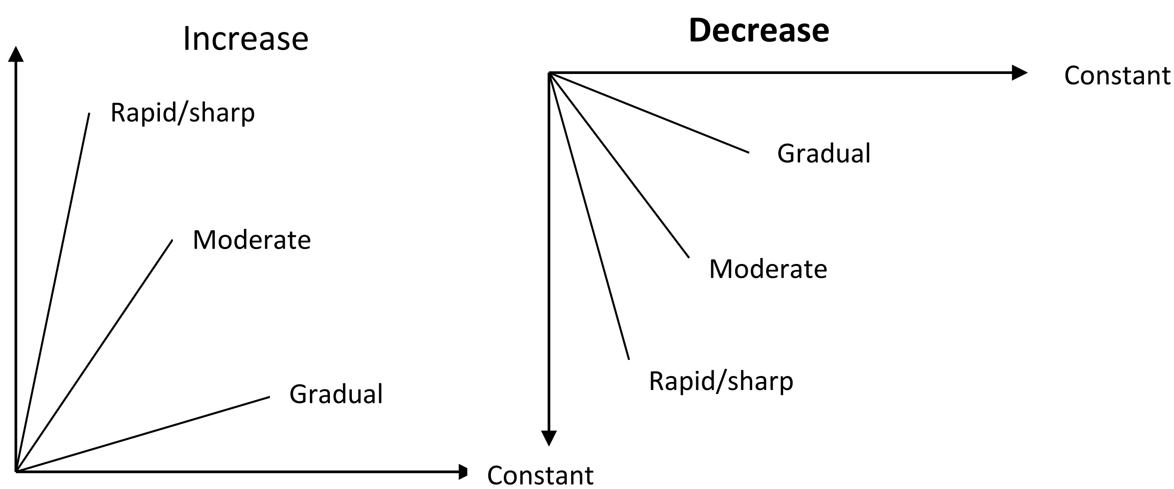
i. Divide or apportion the curves into parts with a **similar gradient**

ii. State the range in the X-axis value for each portion quantitatively i.e. in figures

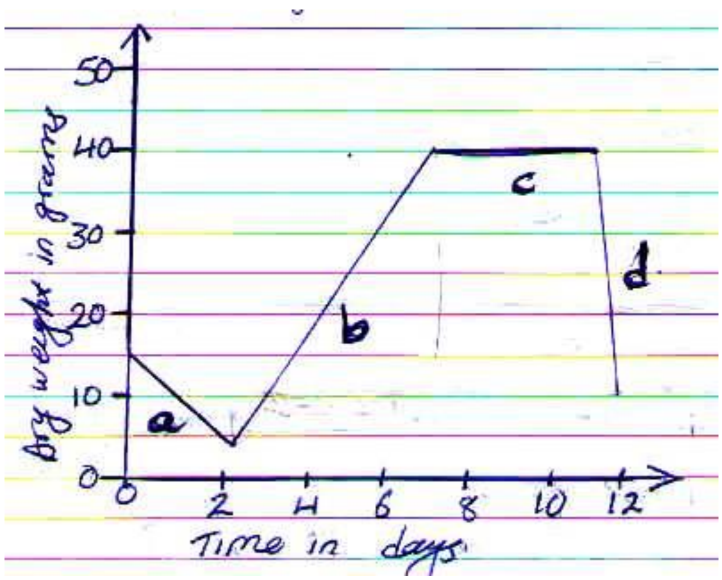
iii. Follow the range above by mentioning the change in the Y-axis variable qualitatively i.e. not in figures.

The terms associated with the qualitative description of graphs include: constant, increase and decrease.

The increase or decrease may be sharp/rapid, gradual or moderate.



Consider the graph below showing the variation in dry weight of a germinating seedling over a period of 14 days.



From 0 to 2 days, the dry weight decreases gradually.

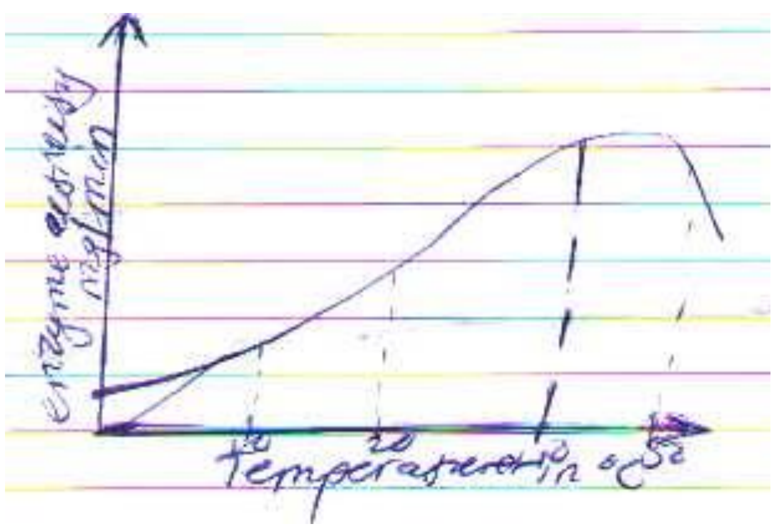
From 2 to 7 days, the dry weight increase sharply.

From 7 to 10 days, the dry weight remains constant.

From 7 to 14 days, the dry weight decreases very sharply.

EXPLAINING A PLOTTED GRAPH

Explaining a graph involves giving reasons, for the described trend. This calls for mastery of biological concepts and interpretation of data using biological knowledge about the variables under study. Consider the graph below;



Account for the trend above? (This question requires the student to describe and then explain)

From 0 to 20°C, the enzyme activity increased gradually. This is because at low temperatures the kinetic energy of the enzyme molecules is low and therefore they work very slowly.

From 20 to 40°C, the enzyme activity increased sharply. This is because as the temperature increases, the kinetic energy of the enzyme molecules also increases and therefore they act very fast thereby increasing the rate of reaction.

From 40 to 50°C, the enzyme activity decreases rapidly. This is because beyond 40°C, the enzymes become denatured, thereby making them ineffective for their work.

EXERCISE

1. The table below shows the change in number of bacterial cells in a period of 300 minutes.

Time in minutes	Number of bacteria
0	1
30	2
60	4
90	8
120	16
150	32
180	64
210	130
240	260
270	510
300	600

a) Draw a graph to represent this information

b) Describe the graph that you have plotted

2. 1 cm^3 of catalase solution was added to an equal volume of hydrogen peroxide solution at different pH values. The time taken to collect 10 cm^3 of oxygen measured. The result were as follows:

pH of solution	5.5	6.0	6.5	7.0	7.5	8.0	8.5	9.0
Time taken to collect the gas (min)	30	20	12	8	5	9	15	25

a) Plot the results on a suitable graph

b) Account for the rate of reaction at pH

i. 5.5

ii. 7.5

iii. 9.0

3. A student carried an experiment using three transparent boxes labelled **X,Y** and **Z,** with each box containing two small holes at the top. In each case, 100 termites were placed in separate boxes.

Box X was transferred to a **dark room**

Box Y was tranferred to a **bright light**

Four big stones were placed in **box Y** and transferred to a **bright light**

Three hens which feed on these termites were introduced into each of these boxes and the change in the number of termites was determined at intervals of 30 secondss for a period of three minutes. The results are shown in the table below;

Time/seconds		**0**	**30**	**60**	**90**	**120**	**150**	**180**
Number of termites	X	100	99	98	97	96	96	96
	Y	100	85	70	59	53	50	47
	Z	100	95	90	85	83	82	81

(a) Using the same axes, draw three graphs to show the changes in the number of termites in each box with time (06 marks)

(b) Describe what happens to the number of termites in each of the boxes

i. X (02 marks)

ii. Y (02 marks)

iii. Z (02 marks)

NUTRITION IN PLANTS

Nutrition in green plants is referred to as **autotrophic nutrition** and this type of autotrophic nutrition in plants is referred to as photosynthesis.

Photosynthesis

This is the process by which green plants use carbon dioxide and water, in the presence of sunlight and chlorophyll to produce a carbohydrate and oxygen.

Raw materials for this process are water and carbondioxide

Conditions for this process are chlorophyll and sunlight

Products for this process are oxygen and carbohydrates

Photosynthesis occurs in all green plants mainly in the **chloroplasts** found within the leaf. The chloroplasts contain **chlorophyll** which traps sun light.

Terrestrial (land) plants obtain carbondioxide from the atmosphere and aquatic (water) plants obtain carbondioxide from water and give off oxygen which is used by the animals.

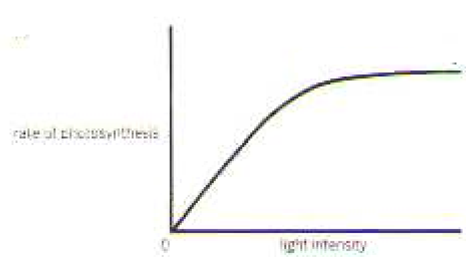
$$\text{Carbondioxide + water} \xrightarrow[\text{Sunlight}]{\text{Chlorophyll}} \text{Carbohydrate + oxygen}$$

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

FACTORS AFFECTING THE RATE OF PHOTOSYNTHESIS

Light

Light is a source of energy for the combination of water and carbondioxide. The rate of photosynthesis increases with increase in light intensity.

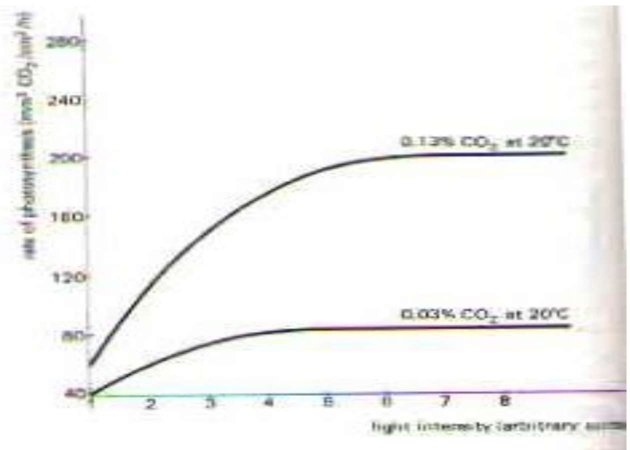


Chlorophyll

This is the pigment that traps solar energy. The higher the amount of chlorophyll in plants, the higher the rate of photosynthesis resulting from increased light trapping.

Carbondioxide

The higher the amount of carbondioxide, in the atmosphere, the higher the rate of photosynthesis



Temperature

The rate of photosynthesis increases with increase in temperature up to 40°C beyond which it begins to decrease. Temperature controls the enzyme controlled/catalysed reactions of photosynthesis.

Oxygen

The accumulation of oxygen in the plant cells lowers the rate of photosynthesis

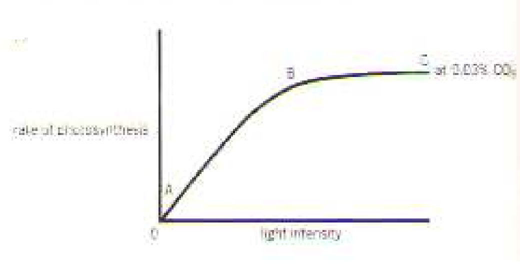
Water

This is a raw material required for photosynthesis to take place. A decrease in the amount of water leads to a reduction in the rate of photosynthesis.

LIMITING FACTORS

If a plant is given plenty of sunlight, carbon dioxide and water, the limit on the rate at which it can photosynthesise is its own ability to absorb these materials, and make them react. However, quite often plants do not have unlimited supplies of these materials, and so their rate of photosynthesis is not as high as it might be. The rate of photosynthesis is governed by the factor in short supply (the limiting factor), if other factors are present in excess.

Sunlight. In the dark, a plant cannot photosynthesise at all. In dim light, it can photosynthesise slowly. As light intensity increases, the rate of photosynthesis will increase until the plant in photosynthesising as fast as it can. At this point, even if the light becomes brighter, the plant cannot photosynthesise any faster. Refer to the graph below;



Over the first part of the curve, between A and B, light is a **limiting factor**. The plant is limited in how fast it can photosynthesise because it does not have enough light.
Between B and C, light is not a liming factor because even if more light is shone on the plant, it still cannot photosynthesise any faster since it already as much light as it can use.

Carbon dioxide. Carbon dioxide can also be a limiting factor. The more carbon dioxide a plant is given, the faster it can photosynthesise up to a point when a maximum is reached.

Temperature. The chemical reactions of photosynthesis will only take place very slowly at low temperatures, so a plant can photosynthesise faster on a warm day than a cold day.

Stomata. The carbon dioxide which a plant uses passes into the leaf through the stomata. If the stomata are closed, then photosynthesis cannot take place. Stomata often close if the weather is very hot and sunny, to prevent too much water being lost. On a really hot day, therefore, photosynthesis may slow down for a time

ADAPTATIONS OF LEAVES TO PHOTOSYNTHESIS

EXTERNAL ADAPTATIONS

1. **Large surface area**

   Leaves of different plants are usually *flat, large and numerous*. The leaves therefore cover a large surface area so as to expose as many chloroplasts as possible to sunlight, to increase on the amount of sunlight absorbed.

2. **Leaf thickness**

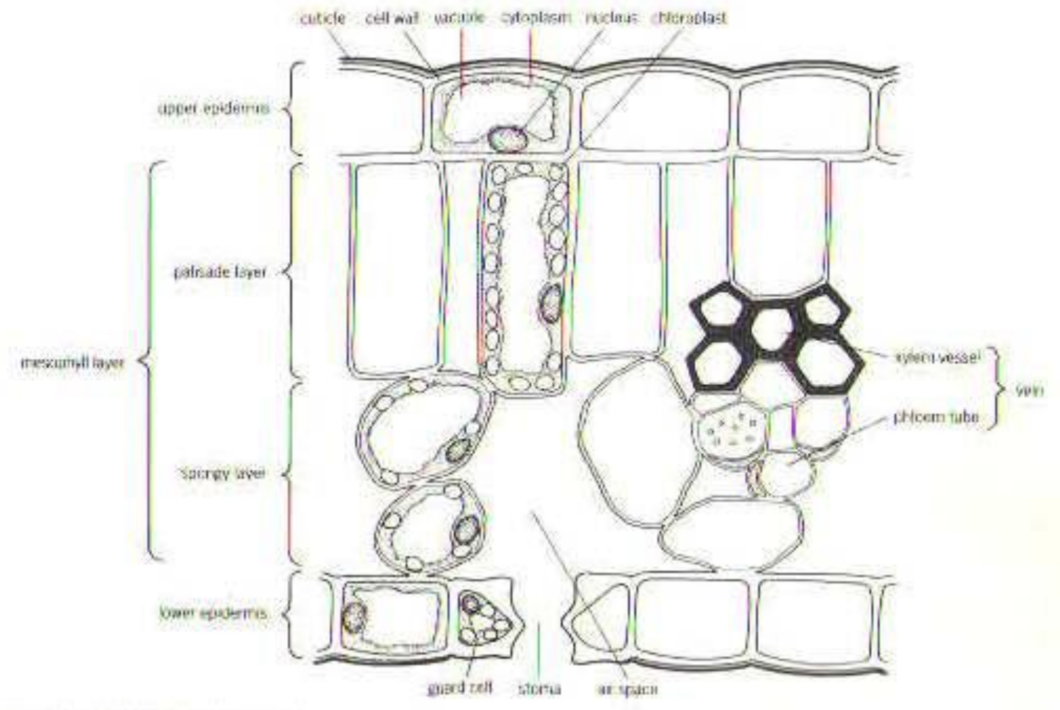
   Leaves are *very thin* to reduce on the diffusion distance of carbondioxide.

3. **Leaf arrangement**

   The leaves are arranged in such a way that they do not shade each other i.e. they have *a leaf mosaic pattern*

INTERNAL ADAPTATIONS

Internal structure of a leaf

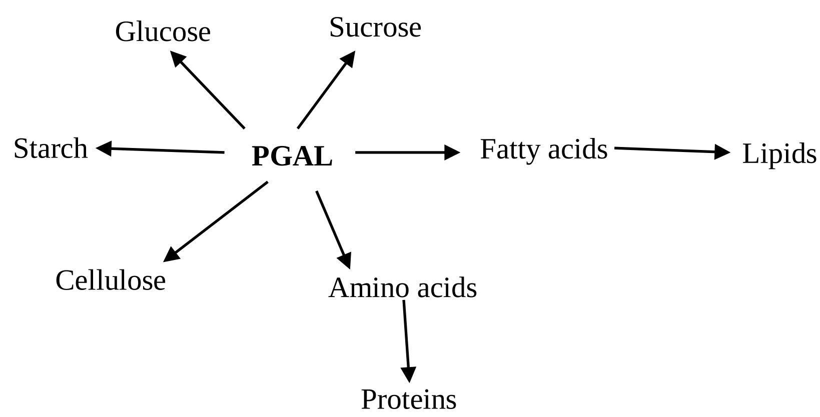


1. Presence of numerous chloroplasts in the mesophyll layer to trap as much light as possible
2. Location of most chloroplasts in the palisade layer in the upper most part which receives most of the light
3. Presence of large air spaces in the spongy mesophyll layer which are loosely packed hence allowing free circulation of air in the leaf
4. Presence of xylem and phloem i.e. vascular bundle, xylem distributes water with mineral salts to all cells whereas the phloem distributes manufactured food to all parts of the plant.
5. The leaf epidermis is transparent which allows light penetration.
6. The leaf cuticle is water proof to avoid desiccation of the photosynthesising cells
7. Presence of stomata which allow exchange of carbondioxide and oxygen between the leaf and the surrounding
8. The leaf is thin to reduce the diffusion distance for carbondioxide and oxygen

PHOTOSYNTHETIC PRODUCTS

The process of photosynthesis usually results into formation of 6-carbon sugars which may be used during respiration to produce energy or which may be polymerised to form disaccharides or polysaccharides for storage or for structural purposes.

Prior to the formation of the 6-carbon sugar molecules during photosynthesis, an unstable 3-carbon compound (PGAL) is formed and it's from this compound that photosynthesis may result into the formation of the various compounds as shown below



The synthesis of complex organic compounds may occur in other plant parts other than the leaves where photosynthesis takes place. This is enabled by the fact that sugar synthesised in the leaf can be translocated to other plant parts where is changed to PGAL from which other organic molecules can be synthesised.

PGAL contains carbon, hydrogen and oxygen which are required for the synthesis of carbohydrates and fats but it lacks nitrogen which is essential in the formation of proteins. This nitrogen enters the plant roots in form of the nitrate ions, but for it to be used in plant amino acid synthesis, it as to be in the form of ammonia. The ammonia is formed when a nitrate undergoes a series of reduction reactions

$$NO_3 \longrightarrow NO_2 \longrightarrow NH_3OH \longrightarrow NH_3$$

The first amino acid produced is always glutamic acid and it is from this that other amino acids are formed.

EXPERIMENTS ON PHOTOSYNTHESIS

Destarching a plant

Since light is one of the conditions for photosynthesis, one has to take away the plant from light for it to be destarched i.e. stored starch takes 48 hours to get used up in a plant.

EXPERIMENT TO TEST A LEAF FOR STARCH/EXPERIMENT TO SHOW THAT STARCH IS FORMED DURING PHOTOSYNTHESIS

Apparatus and materials

- Leaf
- Ethanol
- Heat source
- Test tube
- Beaker
- Dropper
- Tripod stand
- Iodine solution

Procedure

i. Take a leaf from a plant that has been exposed to sunlight for two hours and obtain four leaf discs.

ii. Dip the leaf discs into boiling water for ten minutes. [This kills the living substance (protoplasm) and makes the leaf discs permeable to water].

iii. Half fill a test tube with ethanol and then place in it the leaf discs whose protoplasm has been killed

iv. The test tube is then placed in a water bath maintained at 100°C. (The ethanol will boil and dissolve out the green matter hence the leaf remains colourless)

v. The leaf discs are then placed into a petri dish containing water, to dissolve out the ethanol.

vi. Place the softened leaf discs into a petri dish and cover with iodine solution for 10 minutes.

vii. Repeat the experiment with a leaf from a shoot of a similar plant which has been kept in the dark for two days.

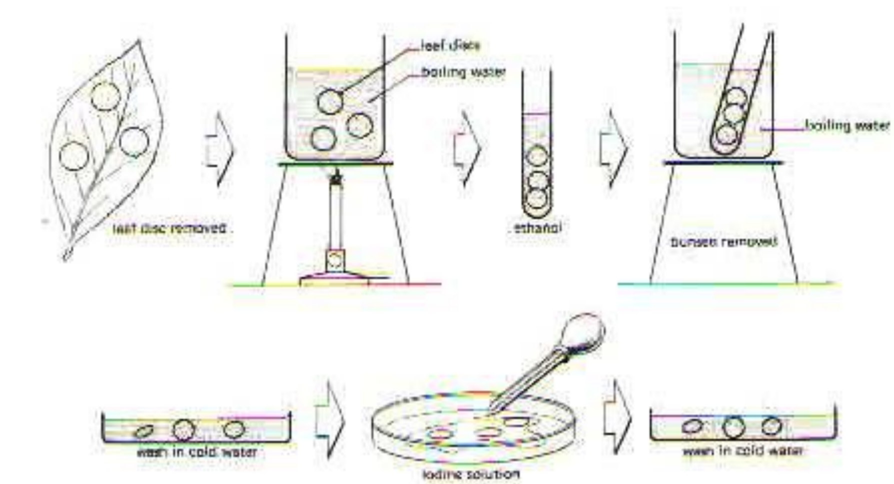


fig 1.11 A flow sequence for decolourising a leaf followed by the starch test

Observation

The leaf discs from a shoot exposed to light turned from colourless to blue when iodine solution was added.

The leaf discs from a shoot which had been destarched turned from colourless to brown when iodine solution was added.

Conclusion

Starch is formed during photosynthesis

EXPERIMENT TO SHOW THAT CARBONDIOXIDE IS NECESSARY FOR PHOTOSYNTHESIS

Apparatus and materials

- Soda lime/ potassium hydroxide
- Watered destarched plant
- Source of heat
- Conical flasks with one hole corks
- Iodine
- Alcohol
- Water
- Sodium hydrogen carbonate (sodium bicarbonate)
- Black polyethene bag

Procedure

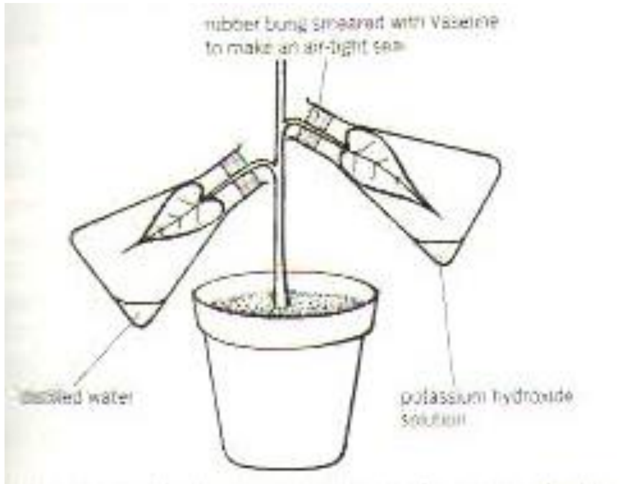
i. Two leaves, which are still attached to a plant, are destarched by enclosing them in a black polythene bag for 2 days.

ii. One leaf, still attached to the plant is enclosed in a conical flask containing soda lime (whose function is to absorb carbondioxide)

iii. Another leaf, on the same plant, is enclosed in a conical flask containing sodium bicarbonate (whose function is to release carbondioxide)

iv. The plant is the transferred to the light and left to stand for 5 hours.

v. At the end of the experiment, the two leaves are tested for the presence of starch.



Observation

The leaf in the flask containing soda lime turns brown with iodine while that in the flask containing sodium bicarbonate turns blue.

Conclusion

Carbondioxide is necessary for photosynthesis

EXPERIMENT TO SHOW THAT OXYGEN IS PRODUCED DURING PHOTOSYNTHESIS

Oxygen is one the products of photosynthesis. A water plant displayed under the sun produces oxygen which is an indicator that photosynthesis is taking place.

Apparatus and materials

- Test tube
- Beaker
- Water
- Retort stand
- Glowing split
- Water plant
- Funnel
- Wooden supports
- Sodium hydrogen carbonate solution

Procedure

i. Place water into a beaker and add sodium hydrogen carbonate

ii. Insert a water plant into the beaker

iii. Place a filter funnel upside down over the water plant.

iv. The funnel is raised above the bottom of the beaker by placing it on wooden supports

v. A test tube is filled with water and inserted over the funnel

vi. The apparatus is then transferred to sunlight for three hours

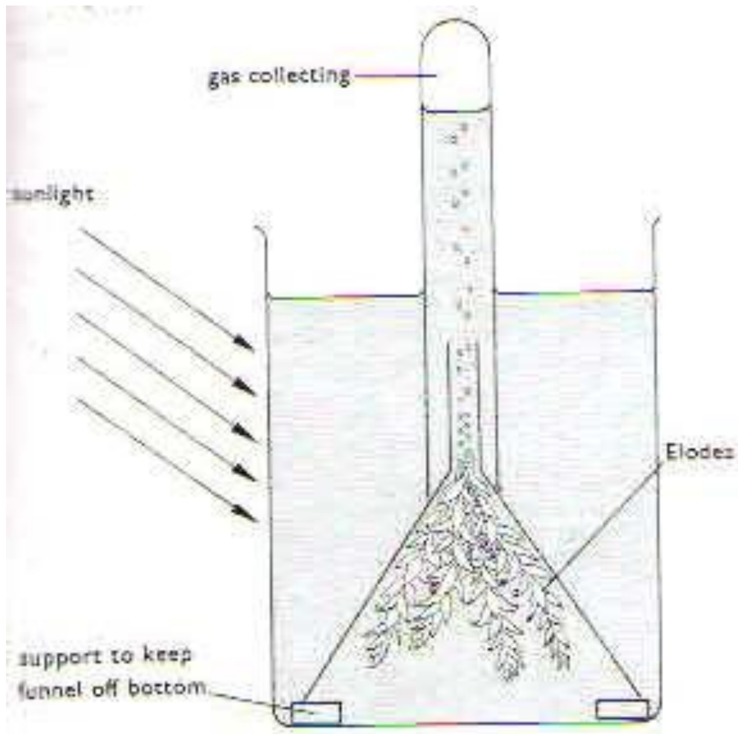


Fig. 10.6 To show that oxygen is set free

Observations

a. A colourless gas is observed at the top of the test tube

b. On testing the gas, it relights a glowing split

Conclusion

Oxygen is produced during photosynthesis

EXPERIMENT TO SHOW THAT LIGHT IS NECESSARY FOR PHOTOSYNTHESIS

Apparatus and materials

- Aluminum foil
- Destarched plant
- Beaker
- Alcohol

- Iodine solution
- Source of heat
- Test tubes

Procedure

i. A strip of aluminum foil is attached on part of a destarched leaf still attached to the parent plant, covering both sides of the leaf

ii. After 5 hours of exposure to light, the leaf is detached from the plant and tested for starch.

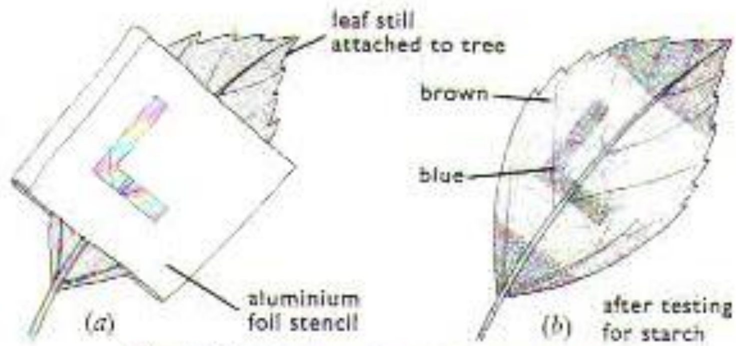


Fig. 10.4 To show that light is necessary

Note: the uncovered part of the leaf is used as a control

Observation

a. The part covered with aluminium foil turns born with iodine

b. The uncovered part of the leaf turns black with iodine

Conclusion

Light is necessary for photosynthesis

EXPERIMENT TO SHOW THAT CHLOROPHYLL IS NECESSARY FOR PHOTOSYNTHESIS

Apparatus and materials

- Beaker
- Test tube
- Iodine
- Source of heat
- Alcohol
- Plant with variegated leaves

Note: a variegated leaf is one which has chlorophyll in some parts and not others i.e. it has green and non-green parts. The parts of the leaf that are not green are used as the control experiment.

Procedure

i. After a period of destarching a plant, the plant is exposed to light for atleast one hour

ii. The leaf is then removed and tested for starch

Observation

The parts of the leaf that were green turned blue with iodine while those that were not green turned into brown with iodine

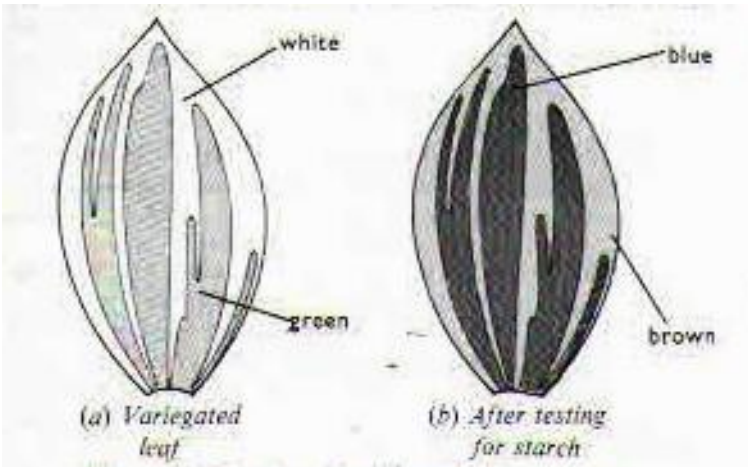


Fig. 10.3 To show that chlorophyll is necessary

Explanation

The results show that green parts of the leaf contain starch while the non-green parts do not. This is because the non green parts lack chlorophyll.

Conclusion

Chlorophyll is necessary for photosynthesis

MINERAL NUTRITION IN PLANTS

Apart from nitrogen, plants need to take up other mineral elements for proper metabolism. These elements are grouped into two categories; the **major elements** and the **minor elements**.

The **major elements** are those which plants need in bulk (large amounts) and lack of any of them results into serious malfunctioning of plant metabolism. For example: potassium, nitrogen, phosphorus, magnesium, sulphur and iron. The major elements may also be called **macro elements**.

The minor elements are those elements that the plant requires in very small amounts. For example: manganese, zinc, boron, silicon, copper, aluminum, e.t.c. The minor elements may also be called **micro elements**.

Mineral elements their functions and effects of deficiency

Major element	**Function in plants**	**Effect of deficiency**
Nitrogen	-formation of plant proteins -part of chlorophyll	-yellowing of leaves called ***chlorosis*** -poor root growth -small sized plants
Potassium	-enzyme activator -protein synthesis, especially cell membrane formation	-chlorosis of margins and tips of leaves -stunted growth -premature death
Calcium	-enzyme activator -part of cell wall -development of root and stem apex	-poor root growth
Phosphorus	-formation of high energy phosphate compounds i.e. ATP -part of nucleic acid	-small plants -leaves dull and dark green -premature leaf fall -stunted growth
Magnesium	-enzyme activator -part of the chlorophyll molecule	-leaves turn yellow -veins remain green
Sulphur	Protein formation	Chlorosis
Iron	Chlorophyll formation	Chlorosis
Minor elements		
Manganese	Activator of some enzymes	Chlorosis between the veins
Zinc	Activator of enzymes	-stunted growth -interval chlorosis of older leaves

Boron	-influences calcium uptake -pollen germination -part of the cell membrane	-poor translocation -deaths of root and stem tips
Aluminium	Essential in cell division	Upset to cell division
Silicon	Cell wall formation in grasses	Decrease in weight
Copper	Essential in metabolic pathways in respiration and photosynthesis	Inhibition of respiration and photosynthesis

To investigate the effect of deficiency of a given mineral nutrient, scientists use **culture solutions** to observe differences in plant growth. A **complete culture solution** contains all the mineral elements dissolved in water while an **incomplete culture solution** lacks one or more mineral elements. Incomplete culture solutions are used to investigate deficiency by intentionally leaving out the mineral nutrient under investigation.

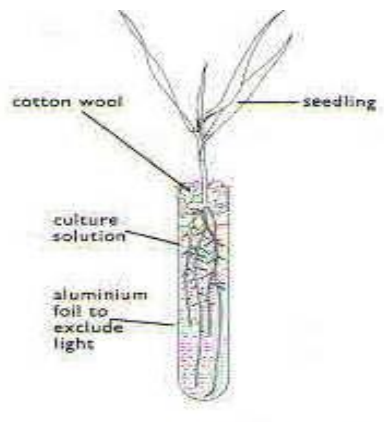


Fig. 10.10 To set up a water culture

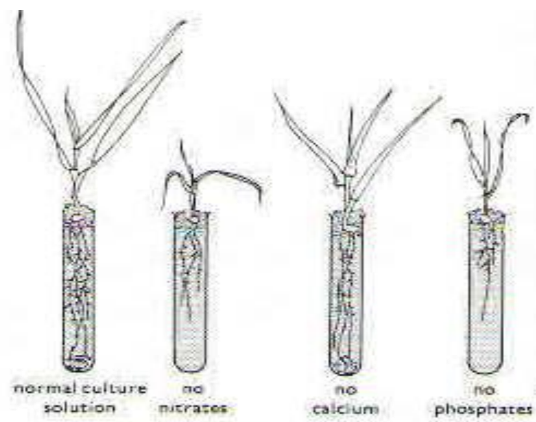


Fig. 10.11 Result of water culture experiment

NUTRITION IN NON-GREEN PLANTS

Non-green plants lack chlorophyll and therefore cannot carry out photosynthesis. They exhibit a type of nutrition called **saprophytic nutrition.**

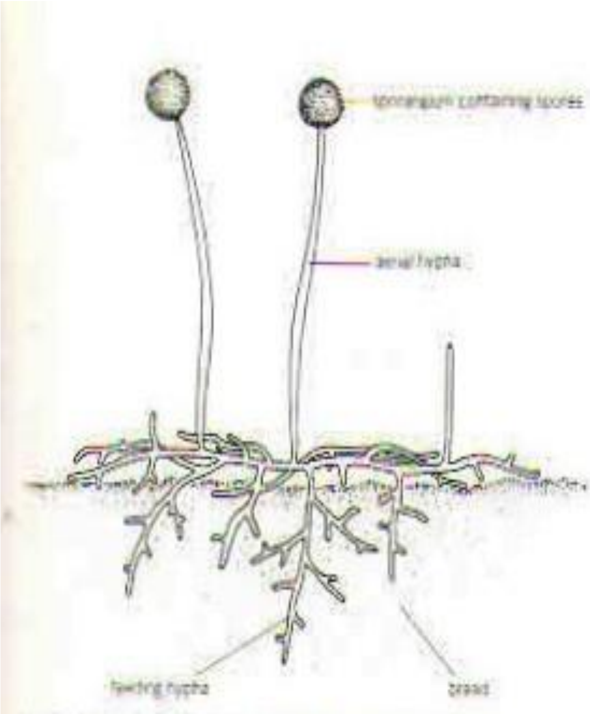
Saprophytes obtain nutrients by first digesting complex organic molecules outside their bodies and they later absorb the soluble simple organic molecules e.g. simple sugars and amino acids

Rhizopus and ***mucor*** (common bread mould) are examples of saprophytes.

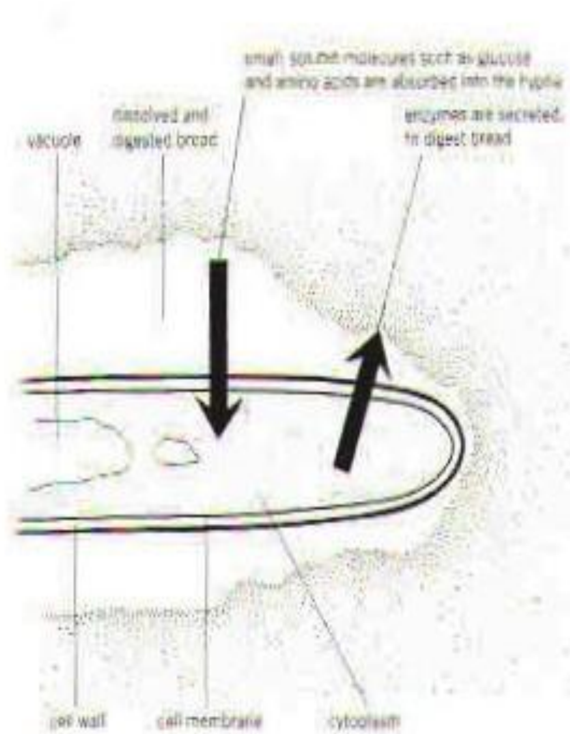
Spores of the moulds fall onto appropriate food sources and germinate into tubular structures called **hyphae**, which have root like projections that grow into the substrate. These projections secrete enzymes which digest the organic compounds around them, breaking them into the simplest molecules i.e. simple sugars, amino acids, fatty acids e.t.c.

After the organic compounds have been digested, the products of digestion are absorbed into the hyphae and metabolised for the growth of the fungus.

The mass of the hyphae is called a mycelium and these fungi are propagated by spores produced inside the sporangia which are found on vertical-growing hyphae called sporongiophore.



2.36 Mucor. The network of hyphae is called a mycelium.



2.37 The tip of a hypha growing through bread

Saprophytic nutrition is characterised by external digestion and absorption of digested nutrients.

Importance of saprophytism

i. It brings about decay which can result into damaging of food and other materials e.g. timber

ii. Some saprophytes, e.g. penicillin, produce antibodies which are used in treating bacterial diseases

iii. Some saprophytes, e.g. yeast, are used in industries in the production of bread, cakes and beer.

iv. Yeast can be used to convert proteins to vitamin B_1

v. Some saprophytes are eaten as food e.g. the edible mushrooms

NUTRITION IN ANIMALS

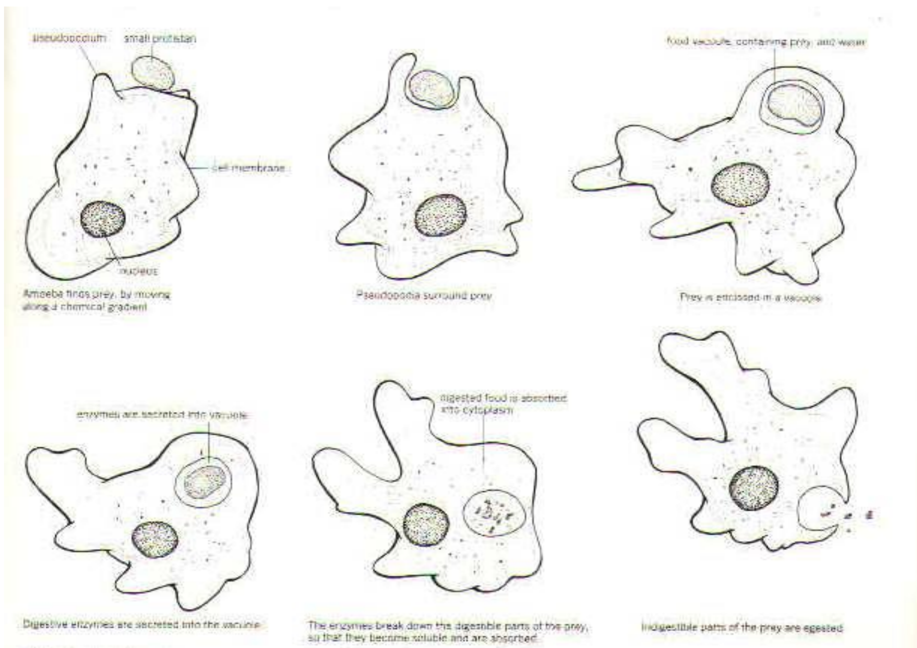
The food for most animals is solid and therefore it must be broken down into smaller pieces for the nutrients to be accessed and utilised by the animal for its metabolism

NUTRITION IN AMOEBA

Amoeba feeds by engulfing food with pseudopodia. A **food vacuole** is eventually formed around the food. The food vacuole is taken into the cytoplasm with in which digestive enzymes are secreted onto the food. The products of digestion diffuse into the cytoplasm while the indigestible contents are taken to cell surface and eliminated by the food vacuole opening through the membrane to the outside.

Since amoeba takes food into the cell, the process is called **phagocytosis** and since digestion occurs within cell, the process is called **intracellular digestion**.

Illustration



NUTRITION IN TOADS

A toad is an **insectivorous animal**. It has a wide mouth with a long tongue which is hinged at the front of the mouth. To catch insects, the toad opens up its mouth and dashes out its long tongue to trap the insects. After bringing insects into its mouth, it uses its eyeballs to squeeze its prey and place it into the oesophagus. It should be noted that amphibian mouths are toothless.

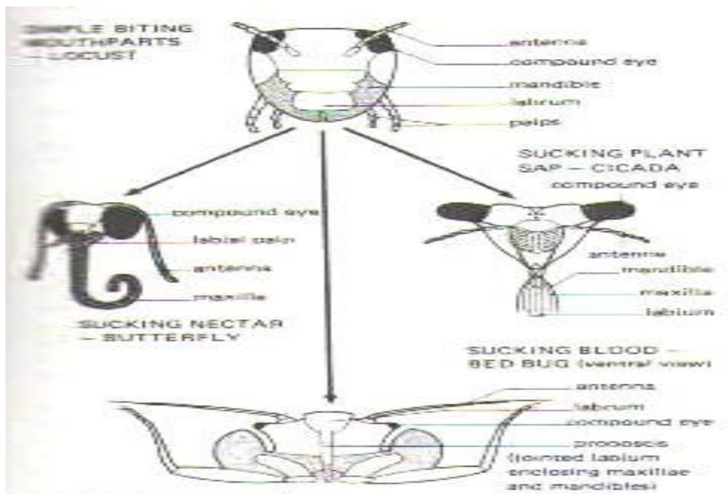
NUTRITION IN INSECTS

Insects have got a variety of feeding methods and because of this; insects' mouth parts are variously modified to suit each insect's diet. Some insects have mouth parts which are adapted to:

1. **Cutting and chewing mouth parts** e.g. grass hoppers, locusts, cockroaches e.t.c. These insects have mandibles with which they tear off solid food, chew and digest.

2. **Sucking mouth parts** e.g. houseflies, bees and butterfly. These insects use a proboscis which is also equipped with sucking parts for ingesting liquid food.

3. **Piercing and sucking mouth parts** e.g. mosquitoes. They use their mouth parts for ingesting liquid food got from bodies of other animals.

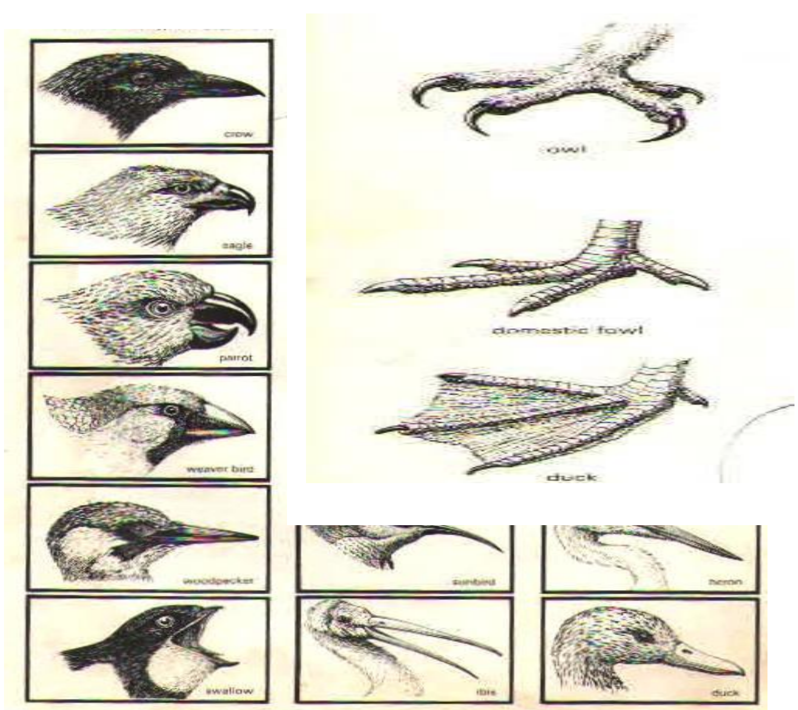


ig 1.33 Insect mouth parts

NUTRITION IN BIRDS

All birds have mouths which are in form of a beak (bill). The beak is a horny structure which projects infront of the head and bears nostrils, while lacking teeth. There's a great diversity of beak structure since birds have a variety of diets. Each bird's beak (and feet) is adapted to its diet.

Illustration



In birds, the food is taken in by the beak, and then it moves to the ***crop*** where it is stored for some time to enable the bird to do other activities. Food then moves to the ***gizzard*** where mechanical digestion takes place (grounding of food). Food then moves to the ***ileum*** where it is absorbed into the blood. The residue is ejected out through the cloaca.

Beak ⟶ Crop ⟶ Gizzard ⟶ Ileum ⟶ Cloaca

HETEROTROPHIC NUTRITION

This is the form of nutrition by which organisms depend on an organic source of carbon.

Heterotrophic nutrition involves the following processes:

a. **Ingestion**, this is the introduction of food into the body of an animal, usually through the mouth

b. **Digestion**, this is the breakdown of large complex food molecules into simple, soluble particles. Digestion is of two types:

    - ***Mechanical digestion***, which involves the use of teeth or movement of muscles to break down food into smaller particles without changing its chemical composition
    - ***Chemical digestion,*** this is the use of enzymes to break down complex food particles into smaller molecules.

c. **Absorption**, this is the taking in of soluble molecules from the region of digestion into the tissues of the organisms

d. **Assimilation**, using absorbed nutrients for a particular purposes

e. **Egestion**, this is the removal of undigested food and indigestible materials from the body through the anus. This is usually in form of faeces.

Heterotrophic nutrition includes holozoic, saptrotrophic and parasitic nutrition.

HOLOZOIC NUTRITION

This is the type of nutrition that occurs in free-living animals which have a digestive tract, the alimentary canal.

TEETH

Teeth are bony structures found in the mouth. They are fixed in sockets in the jaw bones.

External structure

Each tooth consists of a crown, a neck and a root. The crown is the part of the tooth which appears out of the gum and it is used for breaking down the food into smaller pieces. The neck is the region where the tooth comes out of the gum and the root is that part of the tooth which is found in the socket of the jaw bone.

Internal structure

a) An incisor tooth

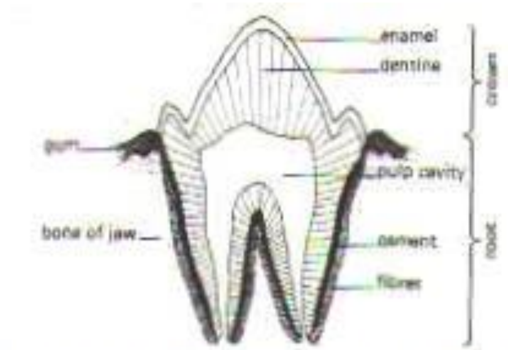


fig 1.39 A vertical section of a premolar tooth of a carnivore

b) A molar tooth

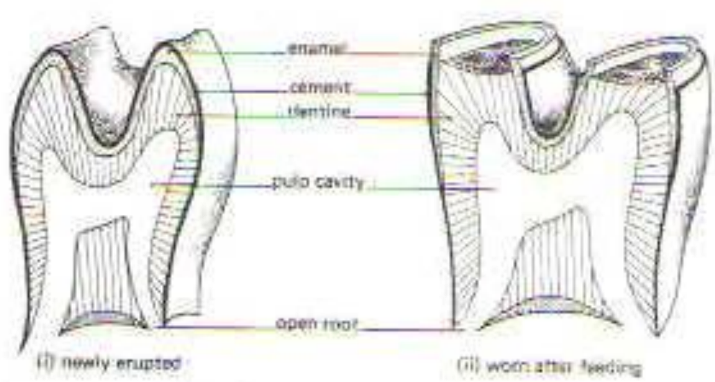


fig 1.40 A half section of a premolar tooth of a herbivore

Functions of the parts

a. Enamel.

This is the hardest natural substance and it contains salts like calcium phosphate.

- It protects the inner parts from damage
- It strengthens the tooth

b. Dentine

This is the main constituent material of the tooth and it is structurally similar to bone.

- It protects inner parts from damage
- It replaces worn out enamels
- Its strengthens the teeth

c. **Pulp cavity**

This is a hollow cavity into which blood capillaries and sensory nerve endings are located.

d. **Blood capillaries**

They supply blood rich in nutrients and oxygen to the tooth and take away waste products of metabolism and carbondioxide.

e. **Nerve endings**

They detect changes in temperature and pain

f. **Cement**

This is a thin layer which is bone-like and it covers the tooth in the root region.

- It holds the tooth firmly in the jaw bone

g. **Gum**

This is a fibrous tissue and it makes the teeth firm in the jaw bone

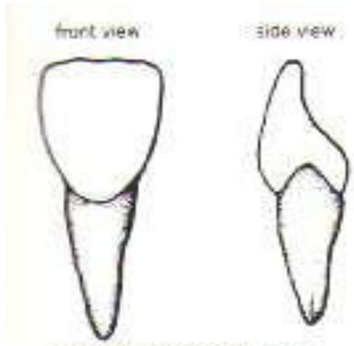
Types of teeth

Mammals, including human beings, have different types of teeth and therefore are called ***heterodonts***. Organisms with the same type of teeth are called ***homodonts*** and they include reptiles and amphibians.

Adult human beings have got four types of teeth namely: incisors, canines, premolars and molars.

Incisors

- They have a wedge shaped (flat sharp edge) crown
- They are mostly found in the front of the jaw
- They have one root



incisors are chisel shaped for biting off pieces of food.

– Their main function is to cut food into pieces small enough to be taken into the mouth.

Canines

- They have a sharp pointed crown
- They have one root

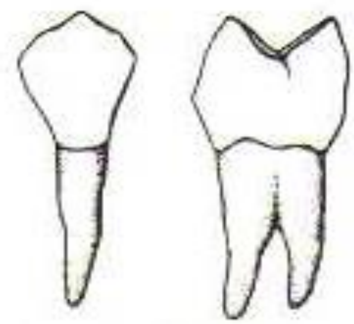

Canines are very similar to incisors in humans.

– Their function is to tear fresh

Premolars

They are the cheek teeth

- They have a wide crown with two cusps i.e. projections on the surface of the tooth
- They have two roots



Premolars have wide surfaces for grinding food.

- Their main function is to chew or grind food

Molars

- They have a wider crown than the premolars
- They have two or three crowns

Molars, like premolars are used for grinding food.

- They also perform the same function of grinding food.

NOTE: molars are absent from the first set of teeth (milk teeth), because of that, they are not replaceable.

Human beings have two sets of teeth in their life time. The first set (milk teeth) consists of incisors, canines and 2 cheek teeth on each side of the jaw. From five years, this set is replaced by a set of permanent teeth which consist of 2 incisors, 1 canine, 2 premolars and 3 molars on each side of the jaw. The last molar on each jaw normally appears after 18 years and because of this, it is sometimes called the **wisdom tooth**.

DENTITION

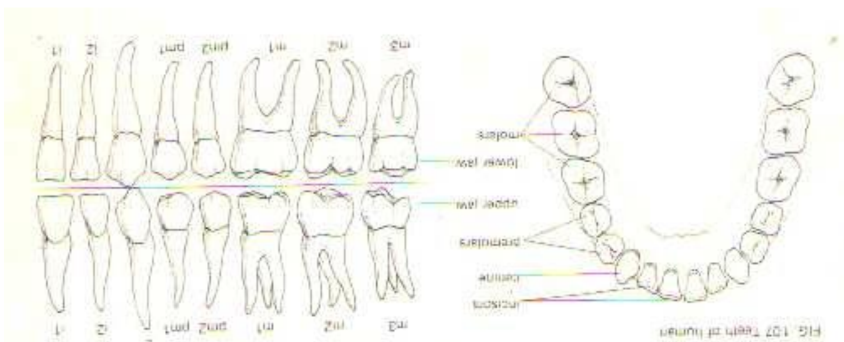
This refers to the total number, shape and specialisation of the different types of teeth in a mammal's mouth.

Different animals have got different numbers of each type of teeth which are arranged differently depending on the type of food onto which the organism feeds.

Dental formula

This is a formula describing the number and position of teeth in the jaw of the mammal.

Only one half of each jaw is included in the formula and the four types of teeth can be indicated by their initial letters e.g. I=incisors, C=canines, Pm = premolars and m= molars



Examples of dental formulae

Man (omnivore): $I\frac{2}{2}, C\frac{1}{1}, Pm\frac{2}{2}, m\frac{3}{3}$

Total number of teeth = 2+2+1+1+2+2+3+3=16x2=32

Goat (ruminant): $I\frac{0}{3}, C\frac{0}{1}, Pm\frac{3}{2}, m\frac{3}{3}$

Dog (carnivore): $I\frac{3}{3}, C\frac{1}{1}, Pm\frac{4}{4}, m\frac{2}{3}$

Rat (gnawer): $I\frac{1}{1}, C\frac{0}{0}, Pm\frac{0}{0}, m\frac{3}{3}$

Cow (herbivore): $I\frac{0}{4}, C\frac{0}{0}, Pm\frac{3}{3}, m\frac{3}{3}$

Assignment: State ways in which teeth should be cared for

1. By brushing every after a meal
2. By not eating too many sweet foods
3. By eating food rich in calcium e.g. meat, eggs, fish e.t.c

4. By not using sharp objects to remove the remains of food in teeth
5. By eating or chewing hard foods to exercise the teeth
6. Visit the dentist, atleast twice a year
7. Avoid eating very hot food or very cold food

ALIMENTARY CANAL OF MAN

The human alimentary canal is meant to enable man extract useful substances (nutrients) from the food he /she eats. In order to do this, the food has to be ***digested***, ***absorbed*** and thereafter ***assimilated***. The non useful components of the food eaten have to be expelled from the alimentary canal in the process of ***egestion***.

The alimentary canal has organs joined to it which enable it to carry out the above processes efficiently. These organs include the salivary glands, the liver, the gall bladder and the pancreas. All these organs secrete digestive juices that pass through ducts into the canal.

The alimentary canal consists of the mouth, stomach, duodenum, ileum and large intestines.

Structure of the alimentary canal in man

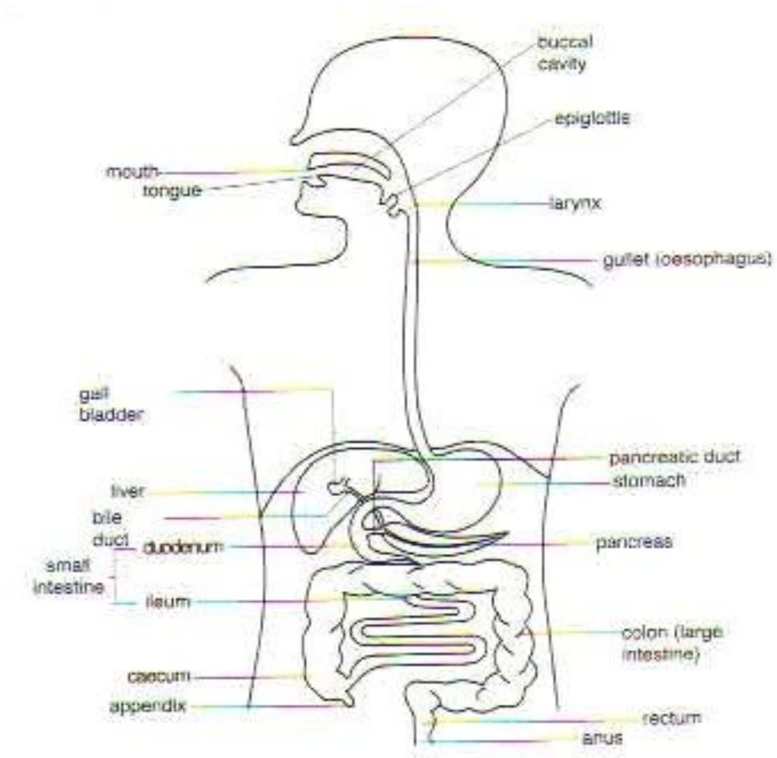


Fig. 4.15:Human digestive system

DIGESTION IN MAN

The human digestive system starts with the mouth where food is ingested. The process of digestion starts in the mouth where the teeth are used to break up large food particles in the processes of ***mechanical digestion*** during the process of chewing or mastication.

Importances of chewing

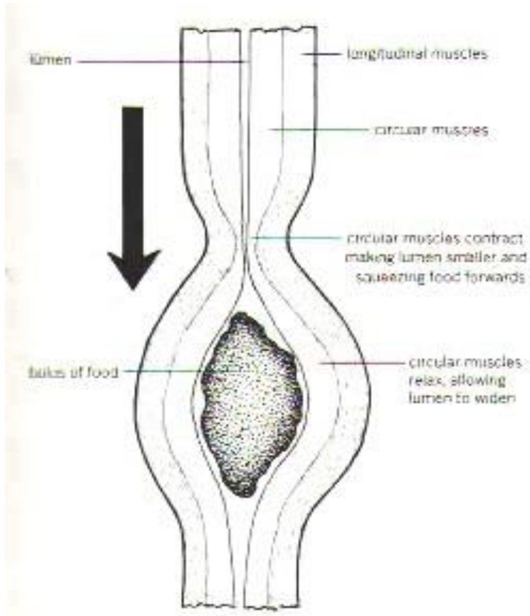
1. The food particles are broken down into smaller particles thereby exposing a large surface area for the action of enzymes
2. The size of the food particles reduces for easy swallowing
3. Chewing mixes food with saliva which softens the food and lubricates it for smooth movement in the alimentary canal.
4. Saliva also contains an enzyme called ***salivary amylase*** or ***ptyalin*** which starts digesting ***starch***, hydrolyzing it to ***maltose***.
5. Chewing activates enzyme production in the stomach

SWALLOWING

After the food has been chewed, the tongue is used to form the food into a ball-like structure called a ***bolus*** which is then pushed to the back of the mouth before being pushed to the oesophagus. The process of swallowing takes place in a coordinated way so as to prevent the entrance of food into the trachea/ pharynx which opens into the back of the mouth.

When food enters into the oesophagus, it is propelled along the alimentary canal by muscular contractions of muscles in the walls of the alimentary canal. ***The process whereby food is driven along the alimentary canal by wave-like motions due to muscle contraction and relaxation is called peristalsis***. This process occurs by alternate contraction and relaxation of the longitudinal and circular muscle walls of the alimentary canal.

Illustration



Peristalsis

DIGESTION IN THE STOMACH

Peristaltic movements propel the bolus from oesophagus to the stomach. The bolus enters the stomach through the ***cardiac sphincter***. This sphincter prevents food from returning to the mouth once it has entered into the stomach even if an individual is turned upside down after a heavy meal.

The stomach is like a ***sac where food is stored*** for some time to enable the human being to do other activities apart from eating. In the stomach, the food undergoes further ***mechanical digestion*** due to the churning movements brought about by the rhythmic contraction of the stomach wall muscles.

The stomach wall produces ***gastric juice*** which contains several secretions. These secretions include:

1. ***Water***, which moistens the food and creates an environment where enzymes can act
2. ***Hydrochloric acid***, which serves several functions:
    - It provides an optimum pH for the action of pepsin and renin enzymes.
    - It activates pepsinogen to pepsin enzyme
    - It kills bacteria that could have come along with the food
    - It stops the action of salivary amylase enzyme
3. ***Renin***, it brings about the coagulation of milk by converting the milk protein ***carcinogen*** into carcein.
4. ***Pepsin***, this enzyme catalyses the reaction of hydrolysis of **proteins (carcein)** to ***polypeptides***

NOTE: pepsin and renin are secreted in an inactive form i.e. pepsinogen and prorennin. This is done in order to prevent them from digesting the walls of the stomach, which are also made up of proteins.

DIGESTION IN THE DUODENUM

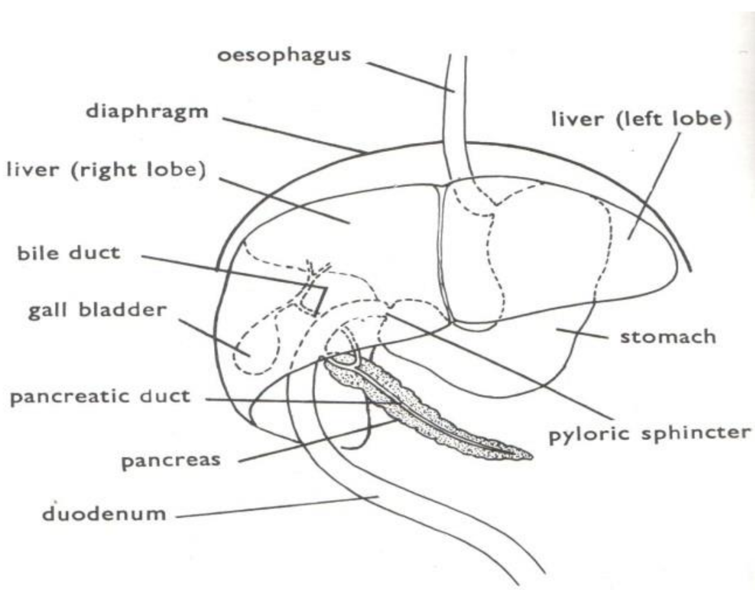
After food in the stomach has undergone mechanical and chemical digestion, it is in a semi-solid state called ***chyme***. At the end of the stomach, towards the duodenum, there's another sphincter muscle called the ***pyloric sphincter***, which regularly opens to release a little amount of chyme into the duodenum.

The duodenum has got an opening from the union of the bile and pancreatic ducts which pours its contents into the duodenum. The pancreas produces the **pancreatic juice** which contains three enzymes, and the enzymes are:

1. ***Pancreatic amylase***, catalyses the hydrolysis of starch to maltose
2. ***Trypsin,*** catalyses the conversion of proteins into peptides and amino acids
3. ***Lipase,*** catalyses the conversion of lipids into fatty acids and glycerol

Bile is produced in the liver and stored in the gall bladder. It contains a number of salts which have a number of functions:

1. They neutralise acidic chyme to an alkaline pH
2. They emulsify fats
3. They remove excretory products like cholesterol
4. They react with fat soluble vitamins and cholesterol to make them water soluble and hence easier to remove



NOTE:

- The release of pancreatic juice from the pancreas and bile from the gall bladder is stimulated by ***secretin hormone*** which is secreted by the walls of the duodenum.
- **Emulsification** refers to the breakdown of fats into small droplets by reducing their surface tension which increase the surface area for the action of lipase enzyme to maximumly hydrolyse them into fatty acids and glycerol.

DIGESTION IN THE SMALL INTESTINES

From the duodenum, the partially digested food, now called ***chyle***, is propelled along to the next region of the small intestines called the ***jejunum***. This region does not have external ducts opening into it, but its walls contain glands which secrete mucus as well as intestinal juice which is called **saccus entericus**. Intestinal juice contains several enzymes which include:

1. ***Maltase***, catalyses the breakdown of ***maltose*** to ***glucose***
2. ***Sucrase***, catalyses the breakdown of sucrose to ***glucose*** and ***fructose***
3. ***Lactase***, catalyses the breakdown of lactose to **glucose** and ***galactose.***

The enzymes breakdown the carbohydrates into monosaccharide sugars namely; glucose, fructose and galactose which completes the digestion of carbohydrates.

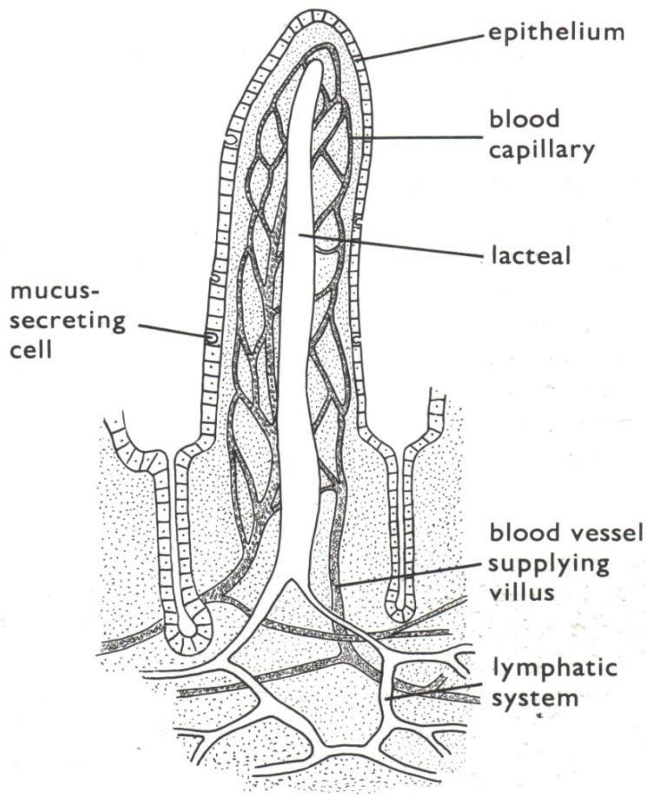
Intestinal juice also contains ***lipase enzyme*** which completes the hydrolysis of lipids, producing ***fatty acids*** and ***glycerol***

Intestinal juice also contains enzymes which are called ***erepsin*** or ***peptidase***, which complete the digestion of proteins by breaking up ***peptones*** and ***peptides*** into ***amino acids***.

From jejunum, food flows to the next region of the alimentary canal, which is the ileum where final products of digestion are absorbed. The absorption is made possible by this region having millions of projections called ***villi*** lining the inside of the ileum wall.

Villi greatly increase the surface area through which digested food substances are absorbed from the gut into the blood stream. The surface area is further increased by the presence of ***microvilli*** on the cells that line the outside of the villi. Inside each villus, there's a ***dense network of blood capillaries*** into which the digested food, soluble in water, is absorbed and carried away. Each villus also contains a blind-ended vessel called a ***lacteal*** into which fatty acids and glycerol are absorbed and converted into fats again before being transported and joining the lymphatic system

Structure of the villus



After the digested soluble nutrients have been absorbed the rest of the food (undigested and indigestible) continue to join the large intestines in the region of the caecum. From the caecum, the food continues along the colon where it remains for about 24 hours during which time most of the water and salts are absorbed from it. The indigestible material consists of mainly plant fibres, cellulose, dead cells which have been dislodged from the lining of the gut, mucus and water with the dissolved salts.

From the colon, the semi-solid residue is lubricated by mucus and is temporarily stored in the rectum from where it is periodically ejected out of the gut as faeces or faecal matter, during the process of egestion.

NOTE: in human beings, the caecum and appendix do not play any important role and for that matter, these organs are referred to as ***vestigial organs***.

Adaptations of the ileum to absorption of food

1. It is long, wide and folded to provide a large surface area for maximum absorption of the soluble food substances into the blood stream.
2. It has numerous finger-like projections called villi which offer a large surface area for maximum absorption of soluble food substances into the blood stream.
3. Its epithelium has tiny projections on the cells called microvilli which further increase the surface area for efficient food absorption.

4. It has a thin epithelium which reduces the diffusion distance for the soluble food substances into the blood stream in order to allow a high rate of diffusion.

5. It has a permeable epithelium which allows movement of soluble food substances across it into the blood stream with minimum resistance.

6. Each villus has a dense network of blood capillaries which offer a large surface for the absorption of food materials and also allows the absorbed food materials to be rapidly carried away from the absorption area which maintains a steep diffusion gradient for more materials to be absorbed.

7. Each villus contains a lacteal, a branch of the lymphatic system in which fatty acids diffuse as well as glycerol, and become transported away from the gut.

8. Its cells have numerous mitochondria to produce sufficient energy for transport of food from the ileum to the blood.

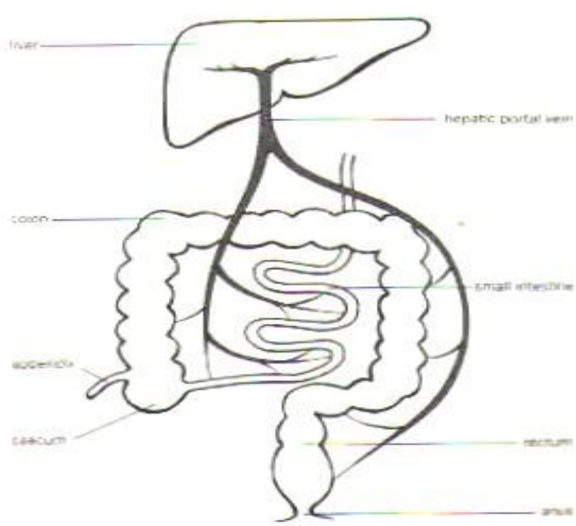
9. It is line with a lot of mucus to prevent self digestion.

ASSIMILATION OF FOOD

After food has been absorbed in the ileum, the monosaccharides and amino acids enter the blood capillaries. Blood capillaries unite to form the ***hepatic portal vein***.

The hepatic portal vein conveys its blood, rich in monosaccharides and amino acids, to the liver where they undergo different types of metabolisms.

The fatty acids and glycerol are absorbed, converted back into fat droplets and taken into the ***lacteal*** of the villi. The lacteal joins the lymphatic system in which they are transported before joining the blood circulatory system.



2.26 The hepatic portal vein

Functions of the liver

1. Assimilation and metabolism of carbohydrates

2. Assimilation and metabolism of proteins where there's transamination and deamination
3. Assimilation of lipids
4. Production of heat
5. Production of bile
6. Manufacture of plasma proteins
7. Storage of iron and other minerals
8. Storage of vitamins
9. Storage of blood
10. Elimination of sex hormones
11. Removal of poisonous substances from the body i.e. detoxification
12. Formation of red blood cells in the foetus

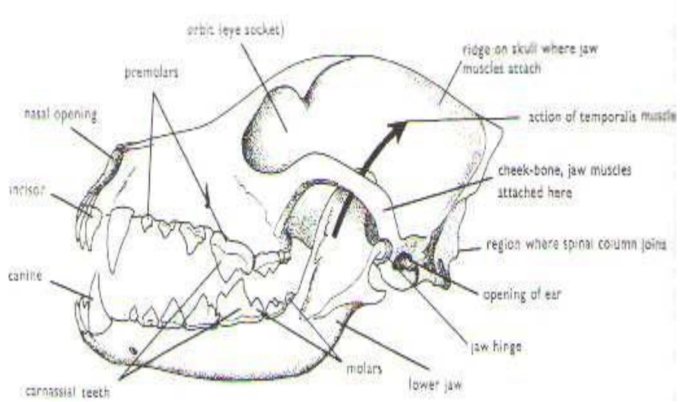
NOTE: excess proteins are not stored in the body

NUTRITION IN CARNIVORES

The diet of carnivores consist of almost only digestible food substances, and for that matter, it is relatively short hence food does not stay in for a long time. Small pieces of fresh cut by the incisors are pushed into the stomach where pepsin starts the digestion for proteins. As food goes along the alimentary canal, carbohydrates and fats are also digested and their products are absorbed in the ileum.

The remaining indigestible material, usually hairs (fur) are then passed on to the colon and are eventually egested through the anus.

Diagram showing the skull of a carnivore



The carnassial teeth are useful in crashing bones.

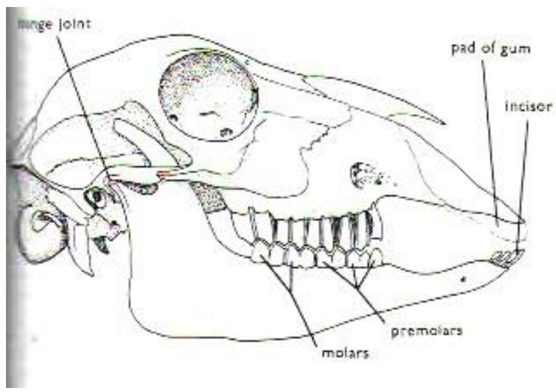
NUTRITION IN HERBIVORES

Animals which feed on vegetation fall under two categories namely: non-ruminants i.e. those that do not chew cud and the ruminant herbivores i.e. those that chew cud.

Non-ruminant herbivores

The animals cut vegetation with their incisors, manipulate it through the diastema to the cheek teeth where they grind it before swallowing it into the oesophagus and hence to the stomach. The grinding flashes open some of the plant cells to release their contents which then undergo chemical digestion in the stomach, duodenum and ileum. The soluble digested nutrients are absorbed in the ileum where the villi are located.

Diagram showing the skull of a herbivore



The diastema allows free movement of the tongue.

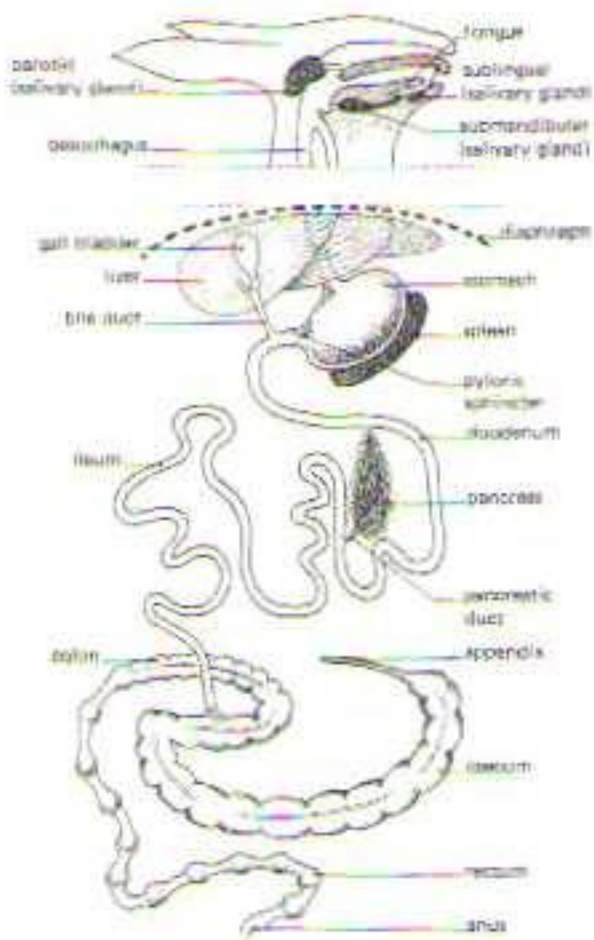
Since animals are unable to produce ***cellulase***, most nutrients remain locked up within the unbroken cells. For the animal to obtain these nutrients; such cells have to be broken open. Non ruminant herbivores overcome this problem by having ***a large caecum containing cellulose digesting bacteria***. Food from the ileum is directed and stored for some time to enable the bacteria to digest the cellulose cell walls and release the cellular contents.

Since digested food can only be digested in the ileum and the caecum is beyond the ileum, the only way the animal is able to obtain such nutrients is by passing out the contents of the caecum and ingesting them again in order for the process of digestion and absorption of soluble nutrients to be completed. This phenomenon is known as ***coprophagy*** and is exhibited by rabbits which pass out pellets of two types:

a. the hard faecal pellets which they do not eat

b. the large soft green pellets which they eat as soon as they pass them out

Digestive system of the rabbit



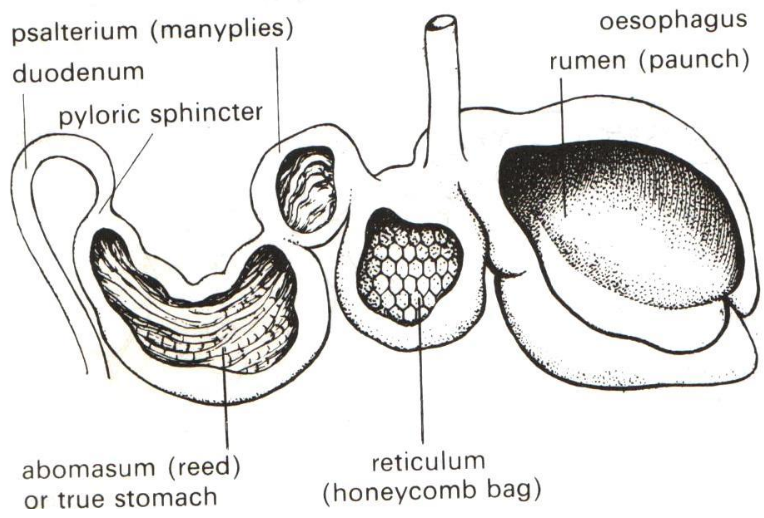
Ruminant herbivores

These animals cut vegetation with incisors, manipulate it through the diastema and pass it through the oesophagus into a large holding chamber of the stomach called a ***rumen***. Within the rumen, there are numerous ***bacteria*** which break down ***cellulose into fatty acids***. The food is softened and fermented.

After the food has stayed in the rumen for some time and when the animal is not actively grazing, the contents of the rumen are drawn back into the mouth (**regurgitation**) to undergo a second round of chewing.

From the mouth, the food is swallowed into another chamber of the stomach called the ***reticulum***. In the reticulum, cellulose digesting bacteria continue their action and the finely ground food is separated from the hard food.

From the reticulum, the food proceeds to the next chamber called ***psalterium or omasum*** eventually reaching the final chamber of the stomach called the **abomasum**. In the psalterium, food is further ground into fine material and the abomasum is the true stomach where the digestive enzymes begin acting.



From the stomach, the gut contents proceed to the small intestines where digestion is completed and absorption of soluble nutrients takes place. The indigestible materials continue through the colon, rectum, and is finally egested through the anus.

The caecum and appendix of ruminant herbivores are relatively small as compared to those of non-ruminant herbivores because the ruminants do not need to store food in the caecum.

Comparison between ruminants and non-ruminants

Similarities

In both the,

1. young ones have a single stomach where digestion takes place
2. final digestion of proteins and carbohydrates occurs in the small intestines
3. large intestines carry out absorption of water

Differences

Ruminants	***Non- ruminants***
They chew cud	They don't chew cud
They have a four chambered	The stomach has one chamber
Ptyalin is absent in the saliva	Ptyalin in present in the saliva
Can digest cellulose with the help of cellulose digesting bacteria which produce cellulase enzyme	Cannot digest cellulose

PARASITIC NUTRITION

A parasite is an organism which lives on or in the body of another organism called a ***host*** from which it obtains food.

Parasitism is an association in which an organism (the parasite) lives on or in the body of another organism (the host).

The parasite obtains benefits such as food and shelter from the host while the host suffers harm as a result of the association.

Types of parasites

These are basically two types:

1. ***Ectoparasites*** which live outside the body of the host e.g. ticks, houseflies and mosquitoes
2. ***Endoparasites*** which live inside the body of the host. They live in areas such as:
    - Body cavities (gut) e.g. *Taenia solium* (tape worm), *Ascaris Lumbricoides* (Round worm)
    - Body fluids between cells e.g. trypanasoma (intercellular)
    - Inside cells e.g. plasmodium (intracellular)
    - The witch weed (plant parasite) depends entirely on the plant hence causing fatal destruction

Advantages of parasitism

1. A tapeworm has got plentiful supply of food while the host is still alive
2. Parasites obtain shelter from the host and this protects them from predators and from extreme conditions
3. Parasites don’t compete with other organisms for food and shelter

Disadvantages of parasitism

1. In case the host dies, the parasite also dies
2. Some parasites have become completely dependent on one type of host, and cannot survive without it

END