The S.2 Biology Biscuit

S.2 BIOLOGY CLASS NOTES

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A practical approach to theory teaching practices for the Uganda Certificate of Education with revision questions

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THE SOIL

Soil is finely divided material covering the earth crust or surface. It consists of air, water, humus, living organisms, and weathered rocks.

Importance of soil

- It is a medium for plant growth.
- It is a means of water storage, supply and purification.
- It modifies earth's atmosphere.
- Soil is a habitat (home) for many organisms such as earth worms, termites, bacteria fungi and arthropods.
- Soil provides a medium through which man and all other animals dispose of their wastes.
- Soil is an important natural resource which provides construction materials, supports agriculture, craft and art.

SOIL FORMATION

It is formed from parent rocks by the process of weathering. This occurs over several years. The process of weathering takes place in three ways;

1. Physical weathering:

This occurs in the following ways;

i) Alternate heating and cooling of the rocks on exposed mountain sides, causes expansion and contraction which cause the rock to crack and break up.
ii) By water; this is where rivers and streams wear away the rocks over which they flow by rolling pebbles and other hard particles on them.
iii) During sandstorm when wind blows sand against bare rocks
iv) Frosting: frost is weather condition where temperatures fall below 0^0C, water in cracks freezes and expand, causing the rock to break up.

2. Chemical weathering:

This is brought about mainly by the action of water especially rain water on the rocks. As it rains, rain dissolves carbon dioxide in the atmosphere to form weak solution of carbonic acid which when falls on soft rocks for example lime, it dissolves them, this results in the release of mineral elements like calcium, magnesium, Aluminium, etc. which are components of soil.

In hot damp conditions (tropics) the constituency of rocks especially those containing iron, oxidizes very quickly. The oxidized rocks disintegrate to form soil.

3. Biological weathering:

This is brought about by the action and presence of living organisms on rocks. Certain organisms such as lichens are able to grow on bare rock while other small flowering plants are able to grow between the rock fragments. When these die, they form humus which is a component of soil.

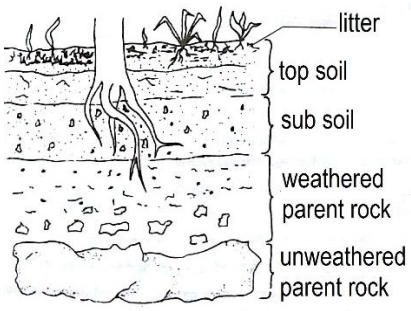
Man contributes to biological weathering through direct splitting of rocks during road and house construction and indirectly through cultivation.

SOIL PROFILE

This is the vertical arrangement of the various soil layers called horizons. It represents the different layers at various stages of soil development.

A soil with distinguished soil layers is known as mature and that without clear profile is immature or young. The profile consists of the following:

i) Top soil
ii) Sub soil
iii) Parent or underlying rock



COMPONENTS OF SOIL

There are basically six components of soil. These are:

i) Inorganic particles,
ii) Humus,
iii) Water,
iv) Air,
v) Mineral salts, and
vi) Soil living organisms

1. INORGANIC PARTICLES

These are produced during the process of weathering. Soil particle vary in size and their sizes are used to classify them. The different soil particles are clay, silt, fine sand, coarse sand and gravel.

Soil particle	Diameter (mm)
Gravel	> 2.0
Coarse	0.2 – 2.0
Fine sand	0.02 – 0.2
Silt	0.002 – 0.02
Clay	< 0.002

Uses of soil particles

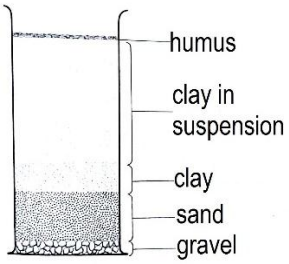
i) They provide a surface for anchoring plant roots hence providing support to the plants.
ii) Soil particles give a rigid frame work to the soil.
iii) They provide mineral elements to the soil which are the absorbed by plants using roots.

Experiment to show the soil texture of topsoil

Apparatus/materials:
Measuring cylinder, Top soil, Stirrer, Beaker

Procedure:
Put water in a measuring cylinder half way. Pour soil (20cm^3) in water and stir thoroughly. Leave the experiment to stand for 3 minutes and observe.

Observation:
When the soil particles settle down, the particles arrange themselves according to their particle size where the heaviest settle at the bottom and the small and lightest at the top as shown above.



Conclusion
Soil is made up of different particles, which have varying sizes and densities.

2. SOIL AIR

Soil air exists between the soil particles. Airspaces in the soil are important for growth of plant roots and health of soil organisms. It is mainly oxygen and nitrogen. (Carbon dioxide is usually in solution as carbonic acid). The depth to which the roots can grow depends on how deep the air can penetrate through the soil

Importance of soil air

- It provides oxygen for respiration of soil organisms and plant roots.
- Oxygen is also needed for the decay that produces humus.
- It also provides nitrogen for fixation by the nitrogen-fixing bacteria in the soil. The nitrogen absorbed is needed in the formation of nitrates and proteins.
- Carbon dioxide in the air increases soil acidity which favours proper growth of some plants.
- Carbon dioxide present in the air dissolves in water to form carbonic acid for weathering.

Experiment to determine the percentage of air in the soil

Apparatus: Measuring cylinders (2), dry soil sample, water, and glass rod.

Method
1. Measure about 50 cm^3 of dry soil in a measuring cylinder and tap the container to level out the soil.
2. Measure 50 cm^3 of water in another measuring cylinder.
3. Add the two together (observe carefully as you pour the water onto the soil)
4. Allow the mixture to stand until no more bubbles appear. Read and record the final level of water plus soil in the measuring cylinder. Calculate the air content in terms of percentage.

Example
Volume of soil = 50cm^3
Volume of water = 50cm^3
Final volume of water + soil after mixing = 85cm^3
Volume of air in soil (100 - 85) = 15cm^3

Percentage of air $= \frac{volume\ of\ air}{volume\ of\ soil\ used}\ x\ 100\%$

Percentage of air $= \frac{15}{50}\ x\ 100\%$

Percentage of air = 30%

Exercise:

While analyzing a soil sample, the following results were obtained

Volume of sand = 200cm^3

Volume of water = 300cm^3

Volume of water and sand after stirring = 450cm^3

The percentage of air in the sand was.

3. WATER

Soil water comes from rain. Also some rise up from the ground water by capillary action to replace water lost by evaporation from the surface. It is found as a thin film surrounding the soil particles.

Importance of soil water

i) It moistens soil and keeps it humid/moist, making it favorable for survival of micro-organisms.
ii) It dissolves mineral salts making them available for plants to take.
iii) It dissolves carbon dioxide produced by living organisms to form carbonic acid which causes chemical weathering of rocks.
iv) It is a raw material for photosynthesis.
v) Water absorbed from the soil allows plant cells to be rigid (turgid), and this is very important for support of the plant, particularly herbaceous plants.

Experiment to determine the percentage of water in a soil sample

Apparatus:

Evaporating dish, fresh soil, weighing scale and oven or Bunsen burner.

Procedure:

a) Weigh a clean evaporating dish and record its weigh. *(Let the weight be X g).*
b) Fill the evaporating dish with soil and record the weight of the soil plus the evaporating dish. *(Let the weight be Yg).*
c) Dry the soil by heating it gently over a Bunsen burner flame for about 30 minutes.
d) Heating and weighing is repeated until a constant mass is achieved. *(Take care not to burn the soil to produce smoke).*
e) Re-weigh the soil and the evaporating dish. *(Let it be Z g).*
f) Then calculate the water content in the soil sample as shown below;

Note:

You should cool in a desiccator before weighing. This ensures that no fresh vapour enters the soil.

Results:

Weight of the evaporating dish =X
Weight of soil + evaporating dish = Y
Weight of soil + evaporating dish after heating = Z
Weight of soil sample = Y-X
Weight of water in the soil sample = Y-Z

Percentage of water $= \frac{amount\ of\ water}{amount\ of\ fresh\ soil}\ x\ 100\%$

Percentage of water $= \frac{Y-Z}{Y-X}\ x\ 100\%$

Exercise:

The results of an experiment to determine percentage of water in a sample of soil are shown below:

Mass of crucible= 15g, Mass of crucible + soil = 30g, Mass of crucible + soil after drying = 25g

The percentage of water in the soil sample is?

4. HUMUS

Humus is decaying plant and animal material-the dead bodies of animals, fallen leaves, dead plants and animal droppings. It is a dark brown, rather sticky material that gives soil its dark colour. For the decay process that form humus to work properly plenty of oxygen is needed.

Importance of humus

i) Because humus is dark-coloured, soil rich in humus absorbs more heat, and this warmth is useful for the germination of seeds and helps to speed up decomposition, making more humus.
ii) It has a high absorptive capacity for water.
iii) It forma\s a sticky coat around soil particles and binds several together to form soil clumps. The clumps structure greatly improves the drainage of the soil.
iv) Humus retains moisture and minerals in the top soil and so, greatly reduces the effects of drying and leaching (washing of minerals).
v) It is a source of nutrients used by plants after it is decomposed.
vi) It improves soil aeration.
vii) It leads to improvement of activities of soil organisms by providing them with food and shelter.
viii) It insulates soil against extreme heat and cold temperatures changes.

Experiment to determine the percentage of humus (organic matter) in the soil

Apparatus: Crucible, soil sample, weighing scale, heat source, wire, tripod stand, pipe clay triangle

Procedure:

a) Weigh a clean empty crucible and record its weight *(W g).*
b) Fill the crucible with soil halfway and record the weight of soil plus crucible on weighing scale *(X g).*
c) Dry the soil by heating it in an oven at ***105^{0}C*** to constant weight *(Y g) - the loss in weight of soil at this temperature is due to the water driven out by evaporation.*
d) Reweigh the soil and crucible and record the weight.
e) Heat the dried soil on a crucible to ***redness*** in an oven, then weigh the soil after cooling and record its weight. Repeat this till a constant weight is achieved *(Z g).*

Results:

Weight of crucible = *W* g
Weight of crucible + fresh soil = *X* g
Constant weight of soil + crucible after heating at 105^{0}C = *Y* g
Constant weight of soil + crucible after heating to redness = *Z* g

Treatment of results:

Weight of fresh soil = *X - W*
Weight of humus = *Y -Z*
Percentage of humus = $\frac{amount\ of\ humus}{amount\ of\ fresh\ soil}\ x\ 100\%$
Percentage of humus = $\frac{Y-Z}{X-W}\ x\ 100\%$

Example

The following experiment was done to find out the percentage of humus in a given soil sample. The soil sample weighing 120g was heated in an oven kept at 100^o C. The dry soil weighed 112g. The soil was then heated slowly to burn away humus. The weight of soil after all humus had burnt was 106g

a) Why was the soil not heated properly at first?
b) What was the weight of humus in the soil?
c) Calculate the percentage of humus in the soil.
d) How many times was water more than humus?

Solution:

a) Because burning the soil strongly will burn the humus containing water.
b) Weight of fresh soil = 120g
Weight of soil after burning humus =106g
Weight of dry soil =112g
Weight of humus =112 – 106 = 6 g

c) *Percentage of humus* $= \frac{amount\ of\ humus}{amount\ of\ fresh\ soil}\ x\ 100\%$

Percentage of humus $= \frac{6}{120}\ x\ 100\%$

$= 5\%$

d) *Weight of water = 120 – 112 = 8 g*

Therefore water is more than humus 2 times (8g – 6g)

Revision questions

1. *A tin of volume 100 cm^3 was completely filled with a certain kind of soil labelled X. the soil was emptied into a measuring cylinder of water raising the level of water from the 600cm^3 mark to the 670cm^3 mark.*
   a) *i) Why did the level not rise to the 700cm^3 mark?*
      ii) What was the percentage of air in soil X? (Show your working).
   b) *The above experiment was repeated with a different kind of soil Y. This time the water level at the end of the experiment was 650cm^3.*
      i) What was the percentage of air in soil Y? (Show your working).
      ii) From the tow experiments, what do you think the soil X and Y were?
      Soil X: ……
      Soil Y: ……
2. *A student carried out two experiments on soil and obtained the following results.*

   Experiment 1

   Volume of soil = 250ml

   Volume of water and soil before stirring = 450ml

   Volume of water and soil after stirring = 375ml

   Experiment 2

   Weight of crucible = 14.5g

   Weight of crucible + soil = 37.0g

   Weight of crucible and dried soil = 32.0g

   Weight of crucible and soil after heating to red hot = 29.5g

   a) *What physical properties of soil was the student studying?*
   b) *Calculate the percentage composition of the physical properties named in (a) above in the soil.*
   c) *What is the importance of these physical properties in the soil?*

Source: Rubahamya, J.B. UCE Biology revision questions for O-Level with answers (2007)

5. MINERAL SALTS

These are chemical elements inform of ions, dissolved in the film of water, surrounding the soil particle.

Some of the mineral elements in soil are; Sulphur, phosphorous, nitrogen, silicon, magnesium, iron and Aluminium ions which results from weathering of rocks.

6. SOIL LIVING ORGANISMS

a) Micro organisms

They include bacteria and fungi. They play an important part in maintaining soil fertility through decomposition of plant and animal remains nitrifying bacteria convert nitrogen into nitrates thus making it available to plants.

b) Macro organisms.

They include roots of higher plants, earth worms and soil arthropods. Earth worms are common in moist soils rich in humus. They dislike dry or acidic soils. They tunnel into the soil by force, thus improving the soil aeration and drainage.

Importance of living organisms

i) They improve fertility of the soil through fixing atmospheric nitrogen by nitrogen fixing bacteria and decomposing litter and other wastes into humus carried out by termites and bacteria.
ii) Some living organisms like earth worms burrow in the soil and this improve soil aeration and drainage.
iii) Some living organisms in soil cause diseases to man and his plants.
iv) Wastes from soil living organisms add fertility to the soil.

Experiment to investigate the presence of living organisms in soil

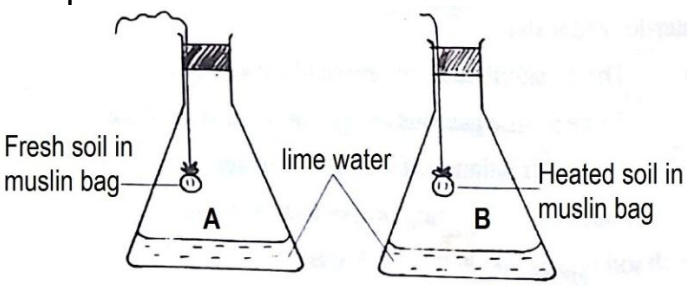
Apparatus

Two conical flasks, Muslin bag, Top soil, two corks and lime water or bicarbonate indicator solution.

Procedure

i) Collect a hand full of fresh top soil and divide it into 2 equal portions.
ii) Sterilize one portion of the soil sample by heating it strongly on a crucible for 30 minutes. Leave it to cool and place it in a muslin bag.
iii) Place the remaining portion of the fresh soil sample in another muslin bag.
iv) Add equal amounts of lime water or bicarbonate indicator in the conical flasks and then suspend the muslin bags with soil in the conical flasks as shown in the set up below.
v) Allow the set up to stand for about 2 days and observe the appearance of lime water or bicarbonate solution.

Set up



Observation

Lime water turns milky or the bicarbonate indicator solution turns yellow in conical flask ***A*** but remains clear in conical flask ***B***.

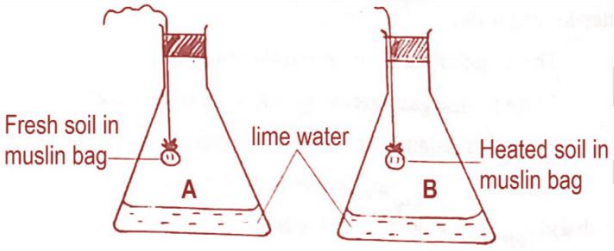
Conclusion

Carbon dioxide was produced in *A* during respiration indicating the presence of living organisms.

Lime water remained clear in *B* because the living organisms were killed by heating the soil.

Revision questions

1. Study the experimental set up below and use it to answer the questions that follow



a) What is:
i) The aim of this experiment?
ii) What is the use of the lime water?
b) Why was the soil in experiment B heated?
c) What results will be obtained in both set ups?
d) What role is played by the soil component being investigated in this experiment?

Source: Rwakasisi, R., Jada C. and Ali G. Fountain revision Biology Questions and Answers for secondary schools (Fountain publishers, 2005)

TYPES OF SOIL

Soil is grouped basing on size and nature of soil particles. On this basis, there are 3 main types of soil namely: Clay soil, Loam soil and Sand soil.

1. **Sandy soils;**
   - Sandy soils contain large space between the particles and these spaces allow water to drain off very quickly.
   - They have a gritty feel when wet and felt between the thumb and figure.
   - They contain only very small quantities of water and they may be deficient in calcium and magnesium
   - They are described as light soils because they are relatively easy to work with.
2. **Clay soil:**
   - They have small fine particles i.e. fine texture.
   - The soil particles in clay are closely parked together leaving very small spaces between them. This causes clay soils to have poor water drainage and also become water logged.
   - They are difficult to work with and therefore described as heavy soils.
   - They have a sticky feel when wet.

   When ***lime is added to clay soil***, the small clay particles aggregate to form larger particles. This helps to improve aeration and drainage, and also reduce the acidity of the soil. This is called ***Flocculation.***

3. **Loam soil:**
   - This is a mixture of sand (about 40%), silt (about 40%), clay (15%) and organic matter (1-4%). It has stable crumb structure and is the best for crop production.

Differences between clay and sand soil

Clay soil	Sand soil
1. Very small air spaces between particles	Large air spaces between particles
2. Rich in dissolved salts	Poorly dissolved salts
3. Has high water retention capacity	Has only very low water retaining capacity
4. Poor drainage i.e. low permeability	Very easy drainage i.e. high permeability
5. Water can rise to high level by capillarity	Water cannot rise to high level by capillarity
6. More than 30% clay and less than 40% sand	More than 70% sand and less than 20% clay

PHYSICAL PROPERTIES OF SOIL

1. **Porosity:**
   - Sandy soil possess large spaces between the soil particles and so more porous.
   - Clay soils possess very small spaces between the soil particles thus less porous.
   - Loam soil is moderately porous.
2. **Air content:**
   - Sand contains a lot of air so it is well aerated. This is because it has large spaces existing between the particles.
   - Clay soil contains little air so it is poorly aerated due to presence of small spaces between the particles.
3. **Drainage of water:**
   - Sand has good water drainage so it allows water to pass through it very quickly.
   - Clay soil has poor drainage of water and this makes clay water logged. This can be improved by adding humus to it.
   - Loam drains water moderately.
4. **Water retention capacity:**
   - This refers to the amount of water soil can hold. Sand soil holds little water so it has a poor water retention capacity. It can be improved by adding humus to it. Humus sticks sand particles together.
   - Clay soil tends to become water logged i.e. it holds a lot of water so has a high water retention capacity.
   - Loam soil holds water moderately but not becoming water logged.

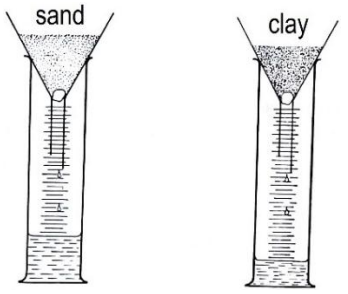
Experiment to compare the drainage and retention of water in sand and clay soils

Apparatus

- filter funnels,
- measuring cylinders,
- filter papers
- Equal volumes of dry sand and dry clay soils,
- Water and
- Beakers

Procedure

i) Measure an equal volume of each soil sample.
ii) Fold filter papers properly and put one in each funnel.
iii) Place clay soil in the filter paper in one funnel and the sand in the other.
iv) Place the funnels with their contents over measuring cylinders, at the same time pour an equal volume of water on each of the soil samples as shown in the diagrams. Observe which soil allows water to drain through quickly.
v) Allow the set up to stand for some time till water stops draining through the soils.



Observation:
Water passes through sand soil faster than clay soil. So much water is collected in the cylinder with sand soil and less water is collected in the cylinder containing clay soil.
Conclusion: Clay soil holds more water than sand soil and sand soils drains water faster than clay.
Explanation: Sand soil has larger air spaces which enable water to drain through more rapidly and on the other hand clay soil retains more water than sand because it has many small particles which can hold more water.

5. Capillarity through different soils:

Capillarity through soil means how well water can rise up in the soil and this depends on the size of air spaces between the soil particles.

Sand soil has the lowest capillarity of water while clay soil has the highest water capillarity and loam soil has medium water capillarity.

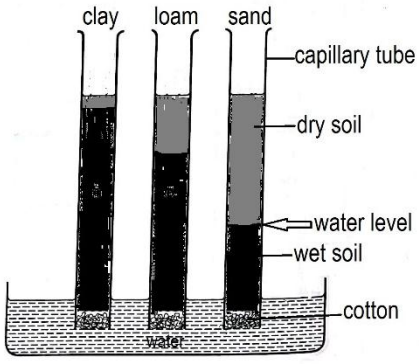
Experiment to demonstrate and compare capillarity through sand, clay and loam soils

Materials: capillary tubes, a glass trough, cotton wool, retort stands, samples of dry sand, clay and loam soils.

Procedure:

i) Put cotton wool at the bottom of the capillary tubes.
ii) Fill one capillary tube with dry sample of sand soil and pack it well ensuring that there are no spaces in the soil.
iii) Repeat this with clay and loam soils.
iv) The capillary tubes are stood vertically with the ends with cotton wool immersed in a glass trough containing enough water. The capillary tubes are supported upright with retort stands and clamps

Set up:



Observation:

Water rises ***faster for a short distance in sand*** soil while ***in clay soil water rises slowly but to higher distances***. In loam soil, water rises moderately to a moderate distance

Conclusion:

Clay soil has the highest capillarity of water.

Sand soil has the lowest capillarity while loam has moderate water capillarity.

Explanation:

Water rises to the greatest height at the nearest stages of the experiment in sand soil because sand has large spaces that enable water to rise more rapidly in the first hours.

Clay soil shows the highest rise of water hence the highest water capillarity because it is composed of tiny soil particles which present the large surface area over which water molecules cling.

Water rises at a slow rate in clay soil because clay has small air spaces between its particles.

Chemical properties of soil

1. Soil colour

This determines the amount of heat that can be trapped in a soil sample. Dark soils retain heat more than light soils.

2. Soil pH

This is the degree of acidity or alkalinity of the soil. Most soils in the tropics are acidic but some are alkaline. Soil pH affects the rate at which mineral salts e.g. nitrogen, phosphorous, iron are absorbed by plant roots. Most plants grow best in slightly acidic or neutral soil.

An experiment to determine the soil pH

Apparatus: Fresh soil sample, Distilled water, Universal solution and Indicator chart.

Procedure:

Place about 3g of soil on petri dish and soak it with universal indicator. Leave it for about 2 minutes.

Tilt the petri dish so that the indicator drains out of the soil and then compare the indicator colour with the indicator chart.

Alternatively: Soak the soil sample with distilled water. Drain off/filter off the water and test it with the universal indicator solution or universal indicator papers.

SOIL EROSION

This is the removal or washing a way of top soil by animals, wind or running water. The extent of soil erosion is dependent upon the intensity with which the rain falls and not the amount of water.

Types of soil erosion

1. **Sheet erosion:** This is where thin uniform layers of soil are eroded over the whole slope.
2. **Rill erosion:** This is where water cuts shallow channels called rills. The channels deepen as volume of water run off increases.

3. **Gully erosion:** This results from rill erosion when the channels deepen and form gullies. Here a lot of soil is carried a way over greater distances. It is enhanced by careless ploughing up and down the slope.
4. **Splash erosion or raindrop erosion:** This occurs when intense raindrops displace soil.
5. **Wind erosion:** In dry conditions, herds of farm animals trample and compact the soil, causing a layer of dust on top. When wind comes, it can blow away the dust.

Causes of soil erosion

1) **Slopes of land:** The deeper the slope the greater the erosion and this is intensified with high amounts of rain. Deeper slopes cause water to flow faster over the soil surface carrying surface soil and weak vegetation cover along with it.
2) **Over stalking:** This is caused by the keeping of many grazing animals on a small area. They finish the grass, i.e. remove the grass cover and open it to water and wind erosion. They trample the soil particles and make them loose, thus making it easy to carry them away.
3) **Over grazing:** feeding grazing animals on the same piece of land for a long time which removes the plant cover to expose the soil surface to agents of erosion.
4) **Deforestation:** this is the cutting down of trees which removes the tree canopy and exposes the soil surface to agents of soil erosion.
5) **Bush burning:** Uncontrolled burning of bushes in dry seasons removes the plant top cover, thus leaving the soil bare and therefore exposing it to agents of soil erosion.
6) **Poor farming methods:** these include ploughing and over-cropping.
   Ploughing: It loosens the soil and destroys its natural structure. Failure to replace humus after successive crops reduces water holding properties like the crump structures which causes the soil to dry up and can easily be blown away. Ploughing up and down a slope accelerates water erosion.
   Over cropping/over cultivation; this is the growing of crops on the same piece of land season after season without rest. Growing or over use of soil depletes fertility, thus plants will not grow which causes loss of plant cover. This leaves the soil bare and so susceptible to erosion.

Methods of reducing (preventing) soil erosion

i) **Contour ploughing:** Ploughing a long contours i.e. across a slope and not up and down. It allows furrows to trap water rather than to channel it a way.
ii) **Strip cropping:** This consists of alternate bands of cultivated and uncultivated soil, following contours. Untilled soil is covered with grass. By alternating the grass and crops each year, the soil is allowed to rebuild its structure while under grass.
iii) **Terracing:** This is cultivation a long contours in horizontal strips supported by stones or walls, so breaking up the step down water rush of the surface run-off. The steeper the slope, the closer the terraces must be.
iv) **Correct crop for soil:** Steep slopes which should not be ploughed are covered with pasture crops, their roots hold the soil
v) **Afforestation:** This is the Planting large areas of land with trees. They act as wind brakes, hold the soil together, and prevent raindrops from hitting the soil directly. They conserve water and control flooding.
vi) **Mulching:** covering of top soil with plant material e.g. banana leaves, maize stems after harvest, cut grass etc. it protects the top soil and conserves the water in the soil. It also adds humus to the soil on decomposition.

Contour ploughing

Terracing

Effects of soil erosion (to farmers)

- Nutrients and soil organisms are carried a way in the top soil.
- The soil left behind is unproductive.
- Fields may be cut into irregular pieces by rill and gully erosion.
- Floods carry a way or submerge and suffocate crops and soil organisms.

SOIL FERTILITY AND CONSERVATION

Soil fertility

Soil fertility refers to the amount of nutrients in the soil that can support the growth of plants. Soil can lose its fertility through the following ways.

i) **Soil erosion**.
ii) **Leaching**; this is the washing down of soluble minerals from topsoil layers to bottom layers where they cannot be accessed by plant roots.
iii) **Soil exhaustion**; this is the depletion/reduction in soil nutrients as a result of monoculture, over cropping, etc.
iv) **Soil compaction**; this is the hardening of soil on the surface due to action of heavy machinery, movement of animals and man on soil, etc. Soil compaction prevents water from penetrating into the soil.

Soil conservation

This is the protection and careful management of soil to maintain its fertility. It includes methods of controlling erosion and others such as:

Intercropping: Here, plants are alternately planted in a systematic or even random manner e.g. coffee, beans, and banana can be intercropped.

Fallowing: Land is left to rest and grow back to bush.

Crop rotation: The farmer carefully rotates his crops season after season, so that the plants make different demands on the soil.

Revision questions

1. *What do you understand by the following terms?*
   - *i) Flocculation*
   - *ii) Soil capillarity*
   - *iii) Leaching*
   - *iv) Soil drainage*
   - *v) Water retention capacity*
   - *vi) Soil erosion*
2. *Under what conditions is sheet erosion likely to occur?*
3. *Describe briefly how tree planting on a steep slope prevents erosion.*
4. *Name three other ways a farmer can use to prevent erosion on a moderate slope.*
5. *Why is it better to water a garden in the evening than in the middle of the day?*
6. *On a certain mountain top the soil is only a few centimeters thick, where as in a forest at the foot of the mountain the soil is about 15metres thick. Suggest reasons for this difference.*
7. *Outline 4 ways in which mulching might be useful in maintain soil fertility.*
8. *Suggest two reasons why it might be necessary to add lime to the soil.*

THE NITROGEN CYCLE

Nitrogen is one of the elements that make up proteins. Nitrogen makes up to 78% of air but it is unreactive so cannot be used by plants and animals in its elemental form. It becomes part of the bodies of organisms in a process called the ***nitrogen cycle***. Nitrogen is in constant circulation between autotrophs, heterotrophs, and the soil in atmosphere.

The changing of nitrogen into more reactive forms is called ***nitrogen fixation***.

Nitrogen fixation takes place during lightening, in the manufacture of artificial fertilizers and in the metabolism of the nitrifying and nitrogen fixing bacteria.

Plants absorb nitrogen as ammonium salts or nitrates.

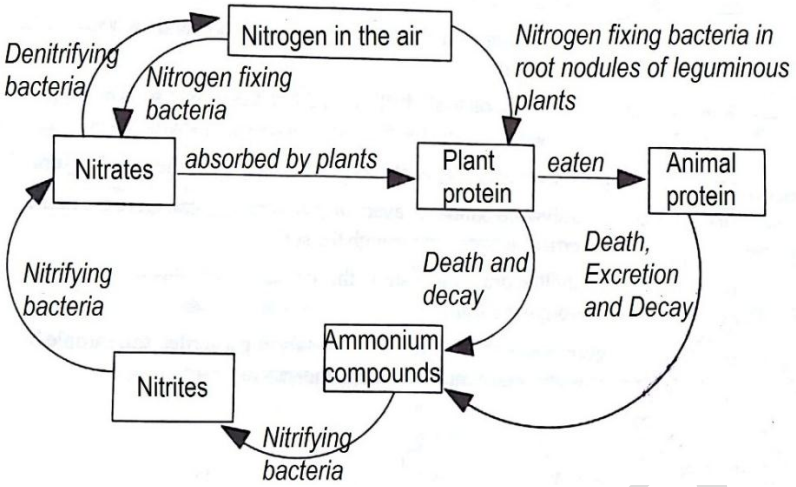
Animals obtain nitrogen they need by eating plants or other animals that have eaten plants.

At death, leaf fall, egestion or excretion (urine) plants and animals are decomposed by the putrefying bacteria into ammonium compounds and then to nitrates by the nitrifying bacteria therefore returning the nitrogen to the soil.

Plants absorb nitrogen inform of nitrates and ammonium salts ***for manufacture or buildup of proteins they require to make new plant parts.***

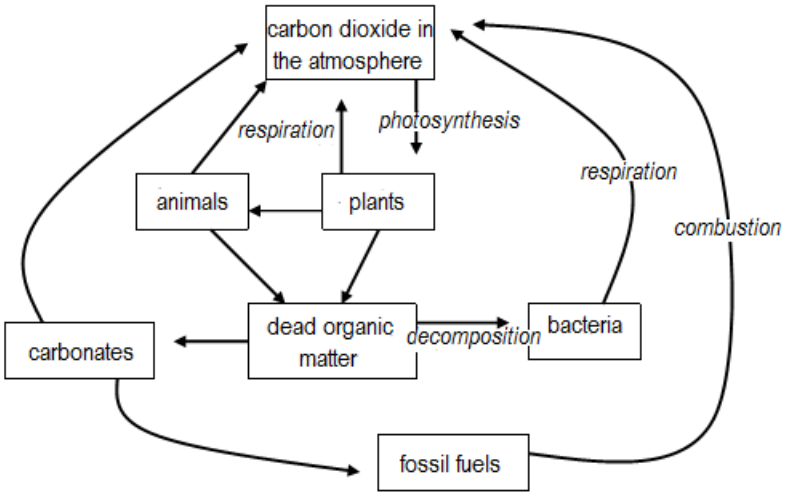
Deficiency of nitrogen in plants causes small sized plants and yellow underdeveloped leaves.

Summary of the nitrogen cycle



THE CARBON CYCLE

Plants get carbon from the atmosphere in the air during the process of photosynthesis. Plants use carbon to make food like starch. Starch is eaten by animals to get energy.



Removal of CO_2 from the atmosphere:

Green plants remove CO_2 from the atmosphere during the process of photosynthesis.

Some of the CO_2 in the atmosphere dissolves in rain water to form carbonic acid. This acid reacts with soil mineral salts to form carbonates.

Addition of CO_2 in the atmosphere:

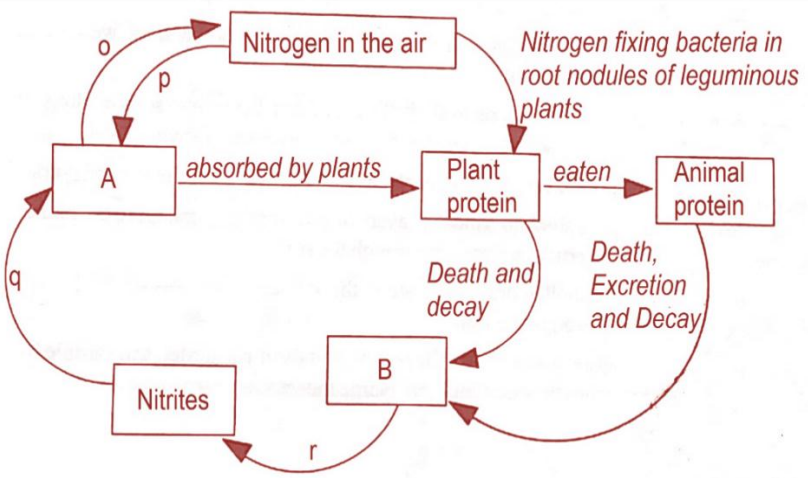
Combustion (burning): When carbon containing fuels e.g. petroleum, coal, natural gas, fire wood are burnt, CO_2 is released into the atmosphere. Formation of such fuels over millions of years is referred to as ***fossilization***.

Respiration in animals and plants.

Decomposition of organic matter by bacteria and fungi. During this process, CO_2 is released into the atmosphere.

Revision questions

The following is a diagram summarizing the nitrogen cycle.



1. *Fill in the boxes A and B*
2. *Name the bacteria responsible for processes o, p, q, r*
3. *List 4 different ways in which nitrogen may be lost from the soil.*
4. *Of what use is nitrogen to a plant?*
5. *What are some of the symptoms in plants growing in nitrogen deficient soils?*

Source: Rwakasisi, R., Jada C. and Ali G. Fountain revision Biology Questions and Answers for secondary schools (Fountain publishers, 2005)

NUTRITION IN LIVING ORGANISMS

Nutrition refers to the process by which living organisms obtain, consume and use food substances to maintain their life processes (metabolic processes). These food substances are called nutrients. The nutrients in green plants are water, mineral salts and carbon dioxide; in animals they are carbohydrates, proteins, lipids, etc.

Modes of nutrition

Nutrition is broadly classified into two groups namely; Heterotrophic nutrition (nourishment on others) and Autotrophic nutrition (self-nourishment).

1. Autotrophic nutrition

This is a mode of nutrition where by an organism is able to synthesize its own food from inorganic nutrients using some external source of energy. Such organisms are called Autotrophs.

Autotrophic nutrition can be divided into two depending on the external source of energy used to drive there processes;

i) Photosynthesis:

This is the type of nutrition where organisms make food with the help of sunlight energy. Examples include; green plants, algae and photosynthetic bacteria.

ii) Chemosynthesis:

This is where organisms make their own food with the help of energy from specific chemical reactions (oxidation of various inorganic compounds). Examples are the *nitrosomonas bacteria* which converts ammonia to nitrite ions and *nitrobacter bacteria* which converts nitrites to nitrate ions in soil.

2. Heterotrophic nutrition

This is the mode of nutrition where by organisms obtain their food by feeding on already manufactured organic (food) compounds. Heterotrophs are incapable of making their own food. They include; all animals, fungi, insectivorous plants and most bacteria.

Heterotrophic nutrition is of 5 major types, which include:

1. Parasitism:

This is an association between two living organisms of different species in which one organism (parasite) obtains food and shelter from the other organism (host) which instead suffers injury and harm. For examples;

- A tape worm in the gut of man.
- A tick sucking blood from a cow.
- A bedbug sucking blood from man.

2. Mutualism:

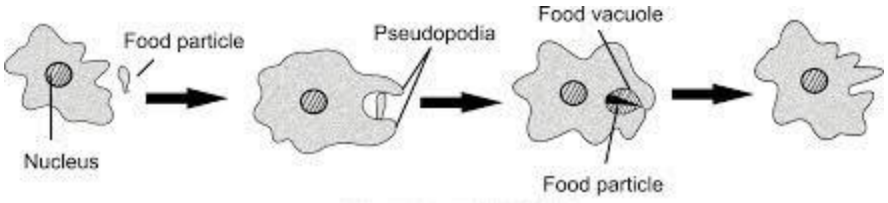
This is a nutritional relationship between two organisms of different species where both organisms benefit. However, only one organism benefits nutritionally.

Examples include;

- Lichens (a fungus and photosynthetic algae). Lichens are found in terrestrial environments that lack soil, such as tree bark or bare rock. The algae in a lichen are protected from drying by the fungus; in return, they provide sugars produced by photosynthesis.
- The nitrogen fixing bacteria in the root nodules of leguminous plants. The bacteria gets shelter inside the root nodule while the plant absorbs the nitrates released by the bacteria.
- Egret white bird removing ticks from a cow.
- The cellulose digesting bacteria in the rumen of ruminant animals.

3. Phagocytosis:

This is the process of nutrition where unicellular organisms engulf solid food particles. For example, **feeding in amoeba:**



Amoeba feeds on microscopic algae and bacteria. It captures the food by developing pseudopodia around the food and it engulfs it. The cytoplasm flows around the food. This one now forms the food vacuole.

Digestive enzymes are produced which break the food particles into soluble food substances. The products are utilized and amoeba moves away from undigested food remains. This is called egestion**.**

4. Saprophytic/saprotrophic nutrition:

Saprotrophic nutrition is a mode of heterotrophic nutrition where an organism feeds on dead decaying matter where by they absorb solutions from this dead decaying matter. Examples include; Mushrooms, mucor and common bread mould.

5. Holozoic nutrition;

This is the mode of nutrition where by food nutrients are taken into the body and broken down into smaller soluble molecules which can be absorbed and assimilated (utilized) by the body.

Animals which undergo holozoic nutrition can be classified into three groups;

Herbivores; These live entirely on plant vegetation.

Carnivores; These feed on flesh only e.g. lion, cat, dog.

Omnivores; These feed on both plants and animals e.g. man and a pig.

FOOD

Food is any substance which can be digested and absorbed by the body to maintain the body's life processes (Metabolic process).

Food is required by organisms for:

i) Growth so as to build new cells.
ii) Respiration to produce energy
iii) Repair of worn out cells or tissues
iv) Protection of the body against diseases e.g. vitamins, proteins.

Classes of food

There are three classes of food, namely:-

a) Energy giving foods (fats and oils).
b) Body building foods (growth foods) e.g. proteins.
c) Protective foods, these protect the body against infections and diseases e.g. vitamins and minerals.

TYPES OF FOOD (NUTRIENT COMPOUNDS)

There are mainly six different nutrient compounds namely:-Carbohydrates, Proteins, Vitamins, Mineral salts, lipids (fats and oils) and Roughages.

CARBOHYDRATES

These are made up of carbon, hydrogen and oxygen. Carbohydrates are grouped into 3 categories; disaccharides, monosaccharides and polysaccharides depending on number of sugar molecules they are composed of.

1) Monosaccharides

Monosaccharides (mono=one, saccharide= sugar) are substances consisting of one molecule of sugar. They are also known as simple sugars.

Properties of monosaccharides

- ✓ They have a sweet taste
- ✓ They dissolve in water
- ✓ They form crystals
- ✓ Can pass through a selectively permeable membrane.
- ✓ They change the colour of benedict's solution from blue to orange when boiled with the solution because they reduce the copper (II) sulphate in benedicts solution to copper (I) oxide, thus they are known as ***reducing sugars.***

Monosaccharides include the following:

i) Glucose (present in grapes)
ii) Fructose (present in many edible fruits)
iii) Galactose (present in milk)

2) Disaccharides

Disaccharides (di=two, saccharide= sugars) are carbohydrates molecules made up two simple sugars joined together. When the two monosaccharides combine, it results in the loss of one molecule of water and this reaction is called a ***condensation reaction***.

Glucose + Glucose = **maltose** + water
Glucose + Galactose = **lactose** + water
Glucose + Fructose = **sucrose** + water

The disaccharides have the following properties:

i) They are sweeter than monosaccharides
ii) They can be crystallized
iii) They are soluble in water
iv) Can be broken down into simple sugars by dilute mineral acids and enzymes

Examples of disaccharides include:

i) Sucrose (present in sugar cane)
ii) Maltose (present in germinating seeds)
iii) Lactose (present in milk)

3) Polysaccharides

Polysaccharides (poly = many, saccharide = sugar) are complex carbohydrates made up of many units of simple sugars.

Properties of polysaccharides include:

- ✓ Are not sweet
- ✓ Do not dissolve in water
- ✓ Cannot be crystallized
- ✓ Do not change the colour of Benedict's solution

Examples are: Starch**,** Glycogen and Cellulose.

Functions of carbohydrates

i) They provide energy in the body when oxidized during respiration.
ii) They are the cheap sources of energy for living things

iii) They act as food reserves which are stored within organisms e.g. many plants store food as starch and animals as glycogen.
iv) They are important components of body structures e.g. cellulose is a component cell walls, chitin forms exoskeleton of arthropods, and heparin is anticoagulant in mammalian blood.
v) They are important for commercial values as they provide raw materials for manufacture of various products such as cellulose provides raw materials for manufacture of paper and textiles.

Deficiency of carbohydrates results in a deficiency disease called marasmus.

Symptoms of marasmus

i) High appetite.
ii) Dehydration of the body
iii) Growth retardation
iv) Wastage of muscles
v) Misery and shrunken appearance

FOOD TESTS ON CARBOHYDRATES

1. Test for reducing sugars

The reagent used is Benedict's solution (blue). Boiling is required.

Procedure	Observation	Conclusion
To 1 cm^3 of food solution, add 1 cm^3 of Benedict's solution and ***boil***.	Colourless or turbid solution turned to a ***blue solution***, then to a ***green solution***, to a ***yellow precipitate***, to ***orange precipitate*** and finally to a ***brown precipitate***.	*Reducing sugars* ***present.***
	Colourless or turbid solution turned to a blue solution which persisted.	Reducing sugars ***absent.***

Examples of reducing sugars include all monosaccharides and some disaccharides:

i) Glucose (present in grapes)
ii) Fructose (present in many edible fruits)
iii) Galactose (present in milk)
iv) Maltose (present in germinating seeds) **and**
v) Lactose (present in milk)

conclusions are based on the final colour of the solution after boiling:

Blue ***solution: no*** *reducing sugars*
Green ***solution: little*** *reducing sugars present*
Yellow ***precipitate: moderate*** *reducing sugars present*
Orange ***precipitate: much*** *reducing sugars present*
Brown ***precipitate: too much*** *reducing sugars present*

2. Test for non-reducing sugars

procedure	Observation	conclusion
To 1 cm^3 of food solution add 1 cm^3 of dilute hydrochloric acid and ***boil***, cool under water then add 1 cm^3 of sodium hydroxide solution, followed by 1 cm^3 of Benedict's solution and ***boil***.	Colourless or turbid solution turned to a ***blue solution***, then to a ***green solution***, ***yellow precipitate,*** then to an ***orange precipitate*** and to finally a ***brown precipitate***.	***Too much Non-reducing sugars present*** after being broken down to reducing sugars.
	Colourless or turbid solution turned to a blue solution which persisted.	Non-reducing sugars ***absent.***

Note:

i) When boiled with dilute HCl, the non- reducing sugars breaks down into the reducing sugars.
ii) Sodium hydroxide solution or sodium hydrogen carbonate powder is added to neutralize the acid so that Benedict's solution can work.

An example of non-reducing sugars is sucrose (present in sugar cane)**.**

3. Test for starch:

The reagent used is iodine which is a brown or yellow solution.

Procedure	Observation	Conclusion
To 1 cm^3 of food solution, add 3 drops of iodine solution.	Turbid solution turned to a ***blue-black solution.***	*Starch* ***present.***
	Colourless or turbid solution turned to a ***brown solution***.	Starch ***absent.***

PROTEINS

These are food nutrients containing carbon, hydrogen, oxygen and nitrogen and sometimes Sulphur or phosphorus. The smallest and basic building unit of proteins are called Amino acids. The amino acid molecule can condense to form dipeptide; further condensation gives rise to polypeptide molecule (protein).

The **amino acids** can be differentiated into essential and non-essential amino acids. There are a total of twenty (20) amino acids present thus allowing the formation of a variety of proteins.

Types of amino acids

i) Essential amino acids: These are amino acids which cannot be synthesized in the body. This means they can only be got from the diet.

ii) Non-essential amino acids: These are amino acids that can be synthesized by the body so they are not essential in the diet.

Sources of proteins: Food substances rich in proteins are eggs, lean meat, beans, Soya, milk and its products, fish and groundnuts.

Properties of proteins

i) Most dissolve in water to form colloidal or sticky suspensions.
ii) They are denatured by high temperatures-there structure is completely changed.
iii) They have both acidic and alkaline properties

The main functions of proteins

i) Body building which brings about growth i.e. from structures like in cell membrane, certain as in horns, fingernails, hooves etc.
ii) Repair and regenerate tissues that are damaged or worn out.
iii) Synthesis of body chemicals like enzymes, hormones, hemoglobin etc.
iv) Provision of energy in times of starvation.

Note: Protein deficiency results in poor health especially in children where it causes ***kwashiorkor.***

Symptoms of kwashiorkor

i) Loss of appetite
ii) Diarrhea
iii) The hair becomes soft and can easily be plucked out accompanied by loss of its colour.
iv) Growth retardation
v) Pot belly i.e. swollen lower abdomen
vi) Swollen legs and joints i.e. Oedema.
vii) Wasted muscles

TEST FOR PROTEINS

The reagents used are sodium hydroxide and copper (II) sulphate solution. This test is known as the ***Biuret*** test

The Biuret test:

Procedure	Observation	Conclusion
To 1 cm^3 of food solution, add 1 cm^3 of sodium hydroxide solution, then add 3 drops of Copper II sulphate solution and shake.	Turbid solution turned to a colourless solution then to a ***violet*** or ***purple solution***.	Proteins ***present***.
	Turbid or colourless solution turned to a blue solution.	Proteins ***absent.***

LIPIDS (FATS AND OILS)

Lipids also contain carbon, hydrogen and oxygen but with higher proportions of hydrogen and less oxygen than carbohydrates. Because of this, they are able to yield more energy than carbohydrates or proteins weight for weight when oxidized. Lipids are made up **fatty acids and glycerol.**

Fats differ from oils in that they are solids at room temperature whereas oils are liquids at room temperature (25^0C). Fats are mainly found in animal tissues while oils are obtained from plant tissues. Examples of fats include; kimbo, cow boy, tamu, margarine, etc. Examples of oils include; fortune buto, sun seed cooking oil, ufuta cooking oil, etc.

Food sources are, Ground nuts**,** Eggs**,** Sun flower**,** Palm oil**,** Castor oil, etc.

Properties of lipids

i) They make a permanent translucent mark or spot on papers.
ii) They also don't dissolve in water

Functions of lipids

i) Energy production during respiration
ii) Insulate the body to prevent excessive heat loss.
iii) Prevent water loss and entry in cells and tissues
iv) They are also constituents of waxy cuticle of animals and plants and the cell membrane.
v) In some areas of animals they act as shock absorbers
vi) They can be used as a source of water in desert animals such as camels- when stored fat is broken down in the body, much water is produced.

TESTS FOR LIPIDS

They are tested for using the emulsion test or the grease spot (translucent spot) test.

a) The emulsion test:

The reagents used are ethanol and water.

Procedure	Observation	Deduction
To 1 cm^3 of food solution, add 1 cm^3 of ethanol and shake. Then add 5 drops of water and shake.	A turbid solution turns to a ***cream emulsion***	Lipids ***present***.
	Turbid or colourless solution remains a turbid or colourless solution.	Lipids ***absent***.

b) Translucent spot test:

Procedure	Observation	Conclusion
Add 2 drops of test solution on a piece of filter paper, allow to dry and observe under light.	A ***translucent spot*** is left on the paper.	Lipids ***present***
	No translucent spot formed on the paper.	Lipids ***absent***.

VITAMINS

These are organic compounds required in small amounts in the diet for the normal functioning of the body. They are designated with alphabetical letters and are classified into two: Water soluble vitamins and Fat soluble vitamins.

Water soluble vitamins are those which dissolve in water. They include vitamins B and C.

Fat soluble vitamins dissolve in fats but not in water. They include vitamins A, D, E, and K.

A table showing vitamins and their deficiency diseases

Vitamin	Common food source	Functions	Symptom of deficiency
A Retinol	Liver, red pepper, vegetables like carrots.	• Needed to form visual pigments. • Maintains normal skin.	• Poor night vision. • Dry skin.
B_1 Thiamin	Yeast, beans, bread, liver and rice husks	• Tissue respiration. • Keeps the heart and nerves healthy.	• Nervous disorder called **beriberi.** • Mental disturbances. • Heart failure
B_2 Riboflavin	Yeast, liver and dairy products.	Tissue respiration.	Soreness of the tongue and corners of the mouth.
B_3 Niacin/ Nicotinic acid	Cereal grains, bread, liver and yeast	Tissue respiration	• Skin cuts known as **pellagra**. • Diarrhea.
B_{12} Cobalamine	Meat, eggs, dairy foods.	Formation of red blood cells	Anemia
C Ascorbic acid	Most juicy fruits (orange, lemon, tomato, passion fruits, mango...)	Formation of connective tissue especially collagen fibres.	**Scurvy**- a disease characterized by poor blood flow especially in thighs and legs plus bleeding gums
D Calciferol	Liver, fish oil, dairy products and action of sunlight on the skin.	• Building strong bones and teeth • Promotes absorption of calcium and phosphorus in the gut	Weak bones (**rickets**) and teeth.
E Tocopherol	Liver, green vegetables	• Anti-oxidant to prevent excess energy production. • Promotes fertility in animals like rats	• Sterility (infertility) in some animals like rats. • Anemia
K-Phylloquinone	Green vegetables.	Normal clotting of blood	Prolonged bleeding.

Test for vitamin C:

The reagent used is **DCPIP** (Dichloro Phenol Indole Phenol). It is a deep blue solution.

Procedure	Observation	Conclusion
To 1 cm^3 of DCPIP solution in the test tube, add the food solution drop wise.	The blue DCPIP solution is decolorized or turned to a colourless solution.	Vitamin C present
	The blue DCPIP solution remained blue.	Vitamin C absent

Note: boiling foods that contain vitamin C reduces the vitamin C content in them that's why fruits and vegetables have to be eaten when still fresh and uncooked. The sources of vitamin C are fresh fruits e.g. oranges, mangoes, lemon, tomatoes, etc.

An experiment to determine the amount of vitamin C (ascorbic acid) in a food solution

Materials/apparatus:

DCPIP, two fresh fruits e.g. a ripe guava and a tomato, water, test tubes and a dropper.

Procedure:

- Chop and crush the fruits separately and add an equal volume of water to each fruit. Filter off 1cm^3 of solution from each fruit and put into test tubes and label them *A* and *B*.
- Put 1cm^3 of 0.1% DCPIP in each of the two test tubes and label them A_1 and B_1.
- Add drops of fruit *solution A* into DCPIP solution in the test tube A_1. Keep adding without shaking while counting the number of drops until the colour disappears. Repeat for fruit *solution B* into the test tube B_1. Record the number of drops added for the DCPIP to become decolorized.

Observation:

The color of DCPIP is decolorized as the fruit solution is added drop wise.

Conclusion:

The less the number of drops used to decolorize the DCPIP, the higher the concentration of vitamin C in that fruit.

Revision questions

The table below gives the results of an experiment to determine the amounts of ascorbic acid in solutions D and E.

Substance	*DCPIP*	*Number of drops*
0.1% ascorbic	*0.1%*	*24*
x*% *D	*0.1%*	*40*
2.8% E	*0.1%*	*3*

a) What is the percentage of ascorbic acid in solution D? Show your working.

b) What is the relationship between ascorbic acid concentration and the number of drops used?

c) You are given two fresh fruits. Describe briefly how you find out which one has more vitamin C.

Source: Rwakasisi, R., Jada C. and Ali G. Fountain revision Biology Questions and Answers for secondary schools (Fountain publishers, 2005)

MINERAL ELEMENTS AND SALTS

These are inorganic food constituents required in small amounts but whose deficiency affects the normal functioning of the body leading to deficiency diseases.

Mineral salts can be divided into;

Essential mineral elements (macro elements): These are mineral elements required in relatively large amounts. They are sodium, potassium, phosphorous, calcium, iron, etc.

Non-essential or Trace mineral elements (micro- elements): These are mineral elements required in relatively very small amounts. However, their presence in the diet is of at most importance. They are Zinc, Molybdenum, cobalt, Manganese, etc.

A table showing some elements and their deficiency diseases

MINERAL ELEMENT	SOURCE	IMPORTANCE	DEFFICIENCY
Fe (Iron)	Meat, liver, kidney, green vegetables.	It is a constituent of Haemoglobin.	• **Anemia (**Reduced red blood cell account). • Reduction in oxygen transportation rate.
Ca (Calcium)	Vegetables, fish, milk, eggs.	• Hardening of bones and teeth. • Blood clotting	• Rickets in children • Soft bones and poor skeletal growth. • Delay in blood clotting
PO_4^{3-} (Phosphate)	Dairy foods, eggs, meat, vegetables.	Component of ATP, nucleic acids, bones and teeth.	• Tiredness • Weak bones and teeth.
I (Iodine)	Iodized salts and sea foods	It is a constituent of the growth hormone	• **Goiter:** Swelling of the Thyroid gland. • Muscle cramp (sharp pains in muscles).
F (Fluorine)	Drinking water	Strong bones and teeth.	Improves resistance to tooth decay
K (Potassium)	Fish, beef, liver, mushrooms	Transmission of nerve impulses along neurons.	Muscular cramp
Na (sodium)	Common salt (NaCl) and cheese		

ROUGHAGES (DIETARY FIBRES)

They are indigestible materials in food and consist mostly of cellulose, pectin and lignin.
The major sources of roughages include: vegetables, such as cabbages, dodo, fruits, etc.

Functions of roughages

- ✓ They stimulate muscular movements called peristalsis which move food (propel) through the alimentary canal.
- ✓ Some delay food in the intestines whereas others enable food pass through the intestines very fast.
- ✓ The deficiency or lack of roughages causes constipation.

Importance of water in the diet

- ✓ It's a universal solvent in which absorbed foods, wastes and hormones are transported around the body in blood.
- ✓ It participates in many metabolic reactions or processes as a raw material e.g. respiration, photosynthesis, gaseous exchange and removal of wastes.
- ✓ Plays a role in temperature regulation i.e. cooling the body on hot days through sweating and plants through transpiration.
- ✓ It acts as a Lubricant e.g. salvia lubricates the mouth, tears lubricate eyes, synovial fluids lubricate the joints.

Balanced Diet:

A balanced diet is a meal containing all food nutrients in their right proportions. If a person depends on a poor diet (unbalanced diet) i.e. containing inappropriate quantities of nutrients, then the person suffers from Mal nutrition.

Mal-Nutrition:

This simply refers to an unhealthy state of the body resulting from a long term deficiency or excess of one or more of the essential nutrients.
Malnutrition is normally detected by the onset of some deficiency diseases like kwashiorkor, marasmus, obesity, etc.

ENZYMES

Enzymes are organic compounds protein in nature that speed up the rate of biochemical reactions in the body of an organism and remains unchanged at the end of the reaction.

Importance of enzymes

- They *speed up the rate of the reaction without changing the product formed and the nature of reaction*.
- *They also control metabolic processes hence promoting normal body functions.*

Nomenclature/naming of enzymes

Enzymes are named by adding a suffix "ase" to their substrates. A substrate is a substance, which the enzyme acts upon, or simply it is the raw material for the enzyme.

Examples of enzymes and their substrates

Enzyme	Peptidase	lipase	Maltase	Sucrose	Lactase	Cellulase
Substrate	Peptides	Lipids	Maltose	Sucrose	Lactose	Cellulose

Some enzymes however retained their names they had before this convention. Such enzymes include pepsin and trypsin.
Sometimes the enzymes digesting carbohydrates are generally called carbohydrases and those digesting proteins as proteases.

Properties of enzymes

1) They are all protein in nature.
2) They are specific in their action i.e. they catalyze specific food i.e. Maltase on Maltose.
3) They speed up the rate of chemical reactions (they are catalysts).
4) They are effective even in small amounts.
5) They remain unchanged at the end of the reaction.

6) They are denatured by high temperatures since they are protein in nature and are inactivated by low temperatures.
7) They are inactivated by inhibitor chemicals (poisons e.g. cyanide).
8) They work at a specific PH. (either acidic or alkaline).
9) Their reactions are reversible.
10) Their activity can be enhanced by enzyme activators e.g. chloride ions activate amylase.

Factors affecting enzyme activities

i) Temperature
ii) Concentration of the substrate
iii) PH of the medium
iv) Presence of activators
v) Presence of inhibitors
vi) Concentration of the enzyme

1) Concentration of substrate:

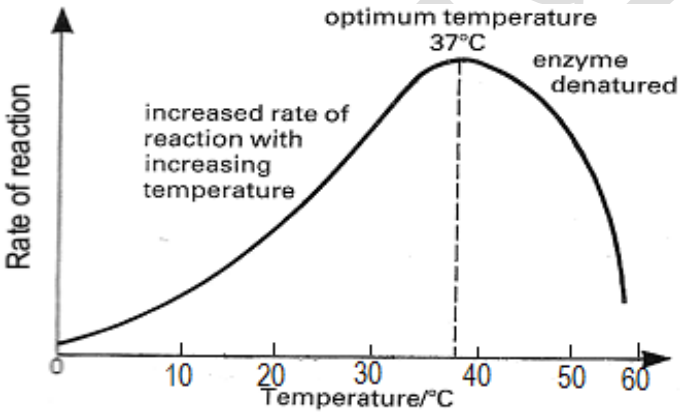
A substrate is a substance (food) acted upon by the enzyme to form simpler products.

The rate of enzyme reaction increases with increase in substrate concentration and enzymes work slower when the substrate concentration is low. However, further increase in substrate concentration will not increase enzyme reaction rate since all its active sites are fully saturated with food.

2) Temperature:

Very low temperatures ***inactivate enzymes***. The rate of enzyme activity increases with increasing temperatures. Very high temperatures ***denature enzymes*** (completely destroys the enzyme structure). Most enzymes work best at optimum temperatures of (approximately 37^{0}C). *An **optimum temperature** is one that promotes maximum enzyme activity*.

A graph showing the variation of enzyme activity with temperature



Interpretation and explanation:

At very low temperatures, the rate of enzyme reaction is very slow because the enzyme is inactive at such low temperatures.

As the temperatures increase, the rate of reaction also ***increases gradually*** and ***then rapidly*** until it ***attains a peak*** at optimum temperature where the enzyme activity is at its maximum. Increase in the rate of reaction is due to increased kinetic energy of the substrate and the enzyme molecules.

Further increase in temperature beyond the optimum rapidly decreases the rate of reaction because very high temperatures ***denature*** the enzyme i.e. completely destroy the protein structure of the enzyme.

3) Enzyme concentration:

As the concentration of the enzymes increases, the rate of reaction also increases until all the substrates are being acted upon when the rate finally becomes constant.

4) The pH of the medium.

Enzyme reactivity is reduced or stopped completely if placed in a medium whose pH is different from that in which it works best (optimum pH).

PH varies slightly above or below an enzyme's optimum pH resulting in a marked fall in the enzyme efficiency. E.g. pepsin enzyme in the human stomach has a maximum activity with in acidic pH of 1.5 and 2.5 while the enzymes in the duodenum e.g. trypsin work at maximum with in alkaline pH of 8.5 to 9.5.

5) Presence of enzyme inhibitors

Enzyme activities decrease in presence of enzyme inhibitors and increase in their absence.

6) Presence of activators

Enzyme activators increase with presence of enzyme activators and decrease with absence of enzyme activators.

CATALASE ENZYME

Catalase enzyme is an enzyme that catalyzes the breakdown of hydrogen peroxide to water and oxygen gas.

$$2H_2O_2 \xrightarrow{\text{catalase enzyme}} O_2 + 2H_2O$$

The enzyme is found in living tissues like liver, meat and Irish potatoes.

Hydrogen peroxide is toxic and can poison cells, yet it constantly forms in living cells as a metabolic waste. Therefore it is important that catalase enzyme speeds up its breakdown to avoid cells from being poisoned.

When hydrogen peroxide is broken down, the oxygen gas released is observed as colourless bubbles or froth at the top of the solution. If a glowing splint is brought close, it relights which confirms that the gas is oxygen.

The more metabolically active the tissue, the more catalase it contains and therefore the more rapid the bubbling when dropped in hydrogen peroxide. Accordingly the liver contains a higher concentration of catalase than most of the other tissues and gives very rapid frothing/bubbling.

An experiment to show the breakdown of hydrogen peroxide by catalase enzyme

Apparatus/materials: fresh Irish potato or raw pawpaw, hydrogen peroxide solution and water

Procedure:

- Peel the Irish potato and cut out four equal cubes each measuring 0.5cm x 0.5cm x 05cm.
- Label four test tubes as 1, 2, 3 and 4. Add $3cm^3$ of hydrogen peroxide to test tubes 1, 2 and 3 and add $3cm^3$ of water to test tube 4.
- Carry out tests on the cubes and record your observations and deductions as shown in the table below.

Tests	Observation	Deductions
To **test tube 1**, add one whole cube	Slow bubbling/effervescence	The enzyme in the irish potato tissue caused a slow breakdown of hydrogen peroxide.
To **test tube 2**, add one cube after cutting it up into 16 equal parts.	Rapid bubbling/effervescence	The enzyme in the irish potato tissue caused a rapid breakdown of hydrogen peroxide.
Boil one whole cube for 10 minutes, drop it in cold water and after, place it in **test tube 3**.	No bubbling	No breakdown of hydrogen peroxide.
To **test tube 4**, add one whole cube.	No bubbling	No breakdown of water.

Note:

- *All the tissues (Irish potatoes) must be dropped into the four test tubes at the same time.*
- *After heating, ensure that the specimen cools totally before dropping it in hydrogen peroxide since the heat itself breaks down/decomposes hydrogen peroxide.*

Explanation:

1) **Test tube 1:** the slow bubbling is due to a small surface area of catalase enzyme exposed to hydrogen peroxide.
2) **Test tube 2**: the rapid bubbling is due to increased enzyme surface area exposed to hydrogen peroxide caused by cutting the tissue into small pieces.

3) **Test tube 3**: there was no bubbling because boiling denatured catalase enzyme hence it did not take part in the reaction.
4) **Test tube 4**: no bubbling because catalase enzyme does not breakdown water.

Therefore:

- Increased surface area (enzyme concentration) increases rate of reaction **(test tubes 1 and 2).**
- Heating denatures enzymes **(test tube 3**).
- Enzymes are specific in nature **(test tubes 4).**

Precautions to note in catalase experiments:

- All the cubes must be dropped into the test tubes at the same time.
- When boiling the tissue, heat for about 5 minutes.
- After boiling, ensure that the specimen cools totally before dropping it in hydrogen peroxide because the heat itself causes decomposition of hydrogen peroxide.

Revision question

An experiment was carried out to investigate the effect of temperature on the rate of an enzyme catalyzed reaction by salivary amylase. The pH was maintained slightly alkaline. The results are shown in the table below.

Temperature/ ^0C	***5***	***10***	***20***	***25***	***30***	***35***	***38***	***45***	***50***
Rate of reaction	***0.3***	***0.5***	***1.25***	***2.0***	***3.5***	***4.8***	***4.8***	***2.5***	***0.8***

a) Plot these figures as a graph on a graph paper.
b) What is the optimum temperature for this enzyme? Give a reason for your answer.
c) At what temperature was the rate of reaction 1.4?
d) Describe the shape of the graph.
e) Explain the shape of the graph between
i) 5^0C and 35^0C
ii) 38^0C and 50^0C

MAMMALIAN TEETH

Mammals have different types and shapes of teeth and they are thus termed **Heterodonts.** Those which have teeth of the same size and shapes are termed as **Homodonts**.

In mammals teeth consist of an exposed portion known as **a crown** and a portion that is firmly fixed or anchored in a jaw bone called a **root.**

Types of teeth in mammals

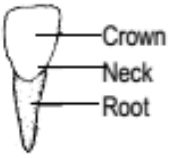
There are 4 types of teeth in mammals and these include;

1. Incisors

These are the front teeth in both the upper and lower jaws in man. The crowns have sharp flat edges and have only one root.

Incisors are used for cutting food.

A drawing of an Incisor tooth



Adaptations:

- *Have sharp chisel-sharped edge for cutting food.*
- *Have one long root for anchoring the tooth firmly into the jaw.*

2. Canines

These are found next to the incisors and they are normally long and pointed.
They are poorly developed in herbivores and very prominent in carnivores.
They have a sharp and pointed crown edge and only one root.
They are used for tearing flesh.

A drawing of a canine tooth

Adaptations:

- *Have a sharp pointed crown edge for tearing flesh.*
- *Have a long root for anchoring the tooth firmly into the jaw*

3. Premolars

These lie behind the canines on both jaws.
These have flat broad surfaces which are used for grinding food.
Premolars possess two or more **cusps** and **ridges** on the tooth's ***working surface*** and have only two roots.
Premolars are used for crushing and chewing food.

A drawing of a premolar tooth

Adaptations:

- *Have broad top surfaces to provide large surface area over which food is crushed/chewed.*
- *Have two long roots for anchoring/supporting the teeth firmly into the jaw.*

4. Molars

They are absent in young mammals.
These have wider crowns with more ridges and cusps compared to premolars.
They may have three or more roots.
Molars are used for grinding and crushing food.

A drawing of a molar tooth

Adaptations:

- *Have broader top surfaces to increase surface area over which food is crushed/chewed.*
- *Have deep cusps and ridges which make the top surface rough for crushing and grinding food.*
- *Have three roots for stronger support in the jaw.*

Note:

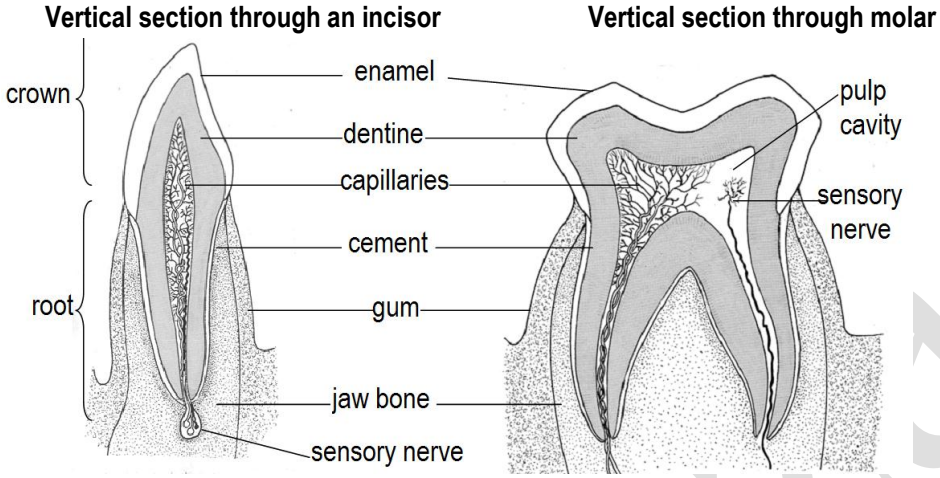
- ❖ Elephant tusks are **incisors.**
- ❖ Carnivores have two modified larger molar teeth called the **carnassial teeth** which are adopted for cracking bones and removing meat from bones.

Revision questions

The figures below show three types of teeth. Use them to answer the questions that follow.

a) Name each tooth.
b) How are the teeth shown above adapted to their functions?
c) Mention three structural differences between a molar tooth and a canine tooth.
d) Draw and label the working surface of a molar tooth.

Internal structure of mammalian tooth



Functions of the parts of the tooth

i) **Crown:** It is used for breaking down food into small particles during chewing, grinding and cutting.
ii) **Neck:** This is the junction between the crown and the root.
iii) **Root:** This is the region which lies embedded in the jaw bone. It cannot be seen and it anchors / fixes firmly the root into the jaw bone.
iv) **Enamel**; this strengthens the tooth to enable it grind and cut. It protects the dentine and pulp cavity. It is the hardest material in the body. It is white in colour and made up of ***calcium phosphate salts.***
i) **Dentine**; this strengthens the tooth.
ii) **Pulp cavity**; this contains nerves that provide sensitivity to the tooth and blood vessels that transport food and oxygen to the tooth.
iii) **Gum**; this is fibrous which fixes or anchors the teeth firmly in the jaw. It is also called the gingiva.
iv) **Cement**; this is a thin layer of bone-like material that fixes the tooth in the jawbone.

Dental formula

This is a formula indicating the number of each type of teeth in half upper jaw and half the lower jaw. The dental formula gives evidence that the dentition of an animal is closely related to its diet. The number of teeth in the upper jaw is written above that of the lower jaw. The different types of teeth are represented by letters i.e.
Incisors-**I,** Canines**-C,** Molars **M,** Premolars-**PM**

The dental formula of an adult human is written as: $\mathbf{I}\frac{2}{2}$; $\mathbf{C}\frac{1}{1}$; $\mathbf{PM}\frac{2}{2}$, $\mathbf{M}\ \frac{3}{3}$ = 32

This means that man has 2 incisors on each half on the top and lower jaws, one canine on each half of the top, lower jaws, and 2 premolars on each half of the top and lower jaws and 3 molars on each half.
Therefore man has 8 teeth on each half on the jaws which adds up a total of 32 teeth.

Dental formulae of some animals

Mammal	Dental formulae	Total number of teeth
Man		32
Dog	$\mathbf{I}\ \frac{3}{3};\ \mathbf{C}\ \frac{1}{1};\ \mathbf{PM}\ \frac{4}{4},\ \mathbf{M}\ \frac{2}{3}$	42
Rat	$\mathbf{I}\ \frac{1}{1};\ \mathbf{C}\ \frac{0}{0};\ \mathbf{PM}\ \frac{0}{0},\ \mathbf{M}\ \frac{3}{3}$	16
Cow	$\mathbf{I}\ \frac{0}{3};\ \mathbf{C}\ \frac{0}{1};\ \mathbf{PM}\ \frac{3}{3},\ \mathbf{M}\ \frac{3}{3}$	32

Dental care in man

Although hard, teeth are delicate and need proper care if their life is to be sustained.

Common problems that may arise if teeth are not cared for include:-

i) Tooth decay or dental caries.

This is caused by lodging (when food gets stuck) of food particles especially sugars between the teeth. This food is then attacked by micro-organisms (bacteria) which ferment this food producing an acid which reacts chemically with the enamel and removes calcium from it making it soft. During chewing, the soft part of the enamel begins wearing away forming a hole which gets larger and larger as more food gets stuck in the now bigger hole and fermentation process continues. Tooth ache commences into the dentine, the pulp cavity with nerves and blood vessels get affected and a lot of pain is felt.

ii) Periodontal diseases.

These are diseases which make the gum soft and flabby so that they do not support the tooth well.

Sometimes these diseases may lead to bleeding of the gum and passing out of pus. The 2 periodontal diseases known are; Pyorrhea and Gingivitis.

They are characterized by reddening of the gums, bleeding and presence of pus in the gums.

Prevention of dental decay and proper care of teeth

- Visit a dentist regularly for checkup.
- Proper cleaning of teeth (brushing after meals).
- Avoid sweet sugary foods like sweets which encourage bacterial growth.
- Avoid opening bottles using teeth.
- Avoid eating very hot and very cold foods especially at a go since they result into alternate expansion and contraction since it leads to cracking or chipping of the enamel.
- Eating foods rich in calcium, phosphates and vitamins A, D, and C.
- Exercising your teeth by eating hard fibrous foods like sugar canes, carrots, etc. This stimulates the flow of saliva which neutralizes acids formed by bacterial fermentation.

Carnivore dentition

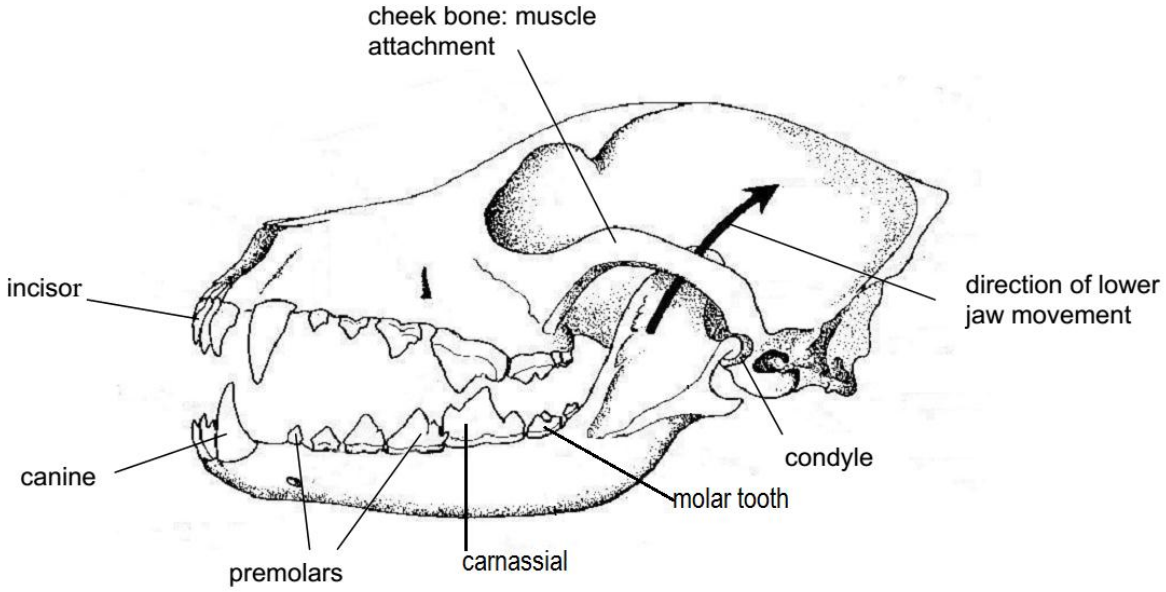
Carnivorous animals such as dogs, cats and lions are adapted for feeding on other animals. Their teeth are adapted for capturing and killing other animals and tearing their flesh. Their incisors are chisel shaped and enable them to grip and strip off pieces of flesh from bones.

Their canines are long, curved and pointed used for piercing the prey and preventing it from escaping.

The upper fourth premolar and the first lower molar are large and powerful. They are called ***carnassial teeth***. They overlap like blades of scissors and are used for tearing and slicing flesh.

The other premolars and molars have jagged edges that fit perfectly together making them ideal for cracking bones.

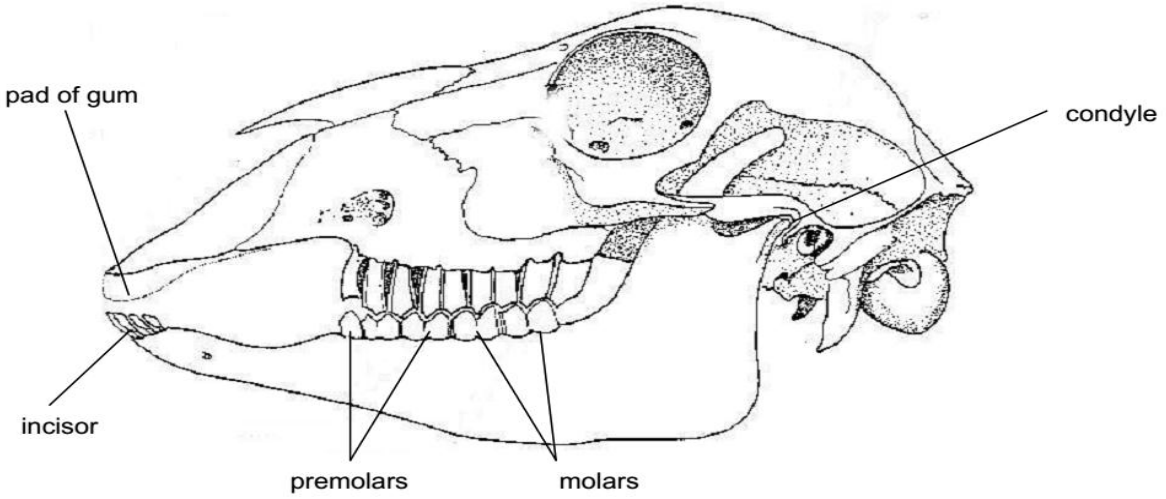
Diagram showing dentition in the carnivore e.g. a dog



Herbivore dentition

Herbivorous animals e.g. cows, goats and elephants eat plant foods such as grass, leaves and small stems. Their teeth are adapted for crushing and grinding vegetables. Their incisors and canines are chisel shaped and only found in the lower jaw. In the upper jaw, the incisors and canines are replaced by a thick horny pad. Grass and other vegetables are gripped between the incisors and canines on the lower jaw and the horny pad. Between the front teeth and the cheek teeth is a large gap called ***diastema***. It provides space for the tongue to manipulate vegetation in such a way that the material being chewed is kept away from that which is freshly gathered.

Dentition of a sheep



DIGESTION IN HUMAN BEINGS

Digestion is the process by which complex food substances are broken down into simpler soluble compounds that can be absorbed and assimilated (utilized) by the body. Digestion can be divided into; physical (mechanical) digestion and chemical digestion.

Physical digestion: This is the breakdown of food due to the mechanical action of teeth, muscular contractions and bile juice.

Chemical digestion: This is the breakdown of food catalyzed by enzymes.

Steps involved in digestion of food

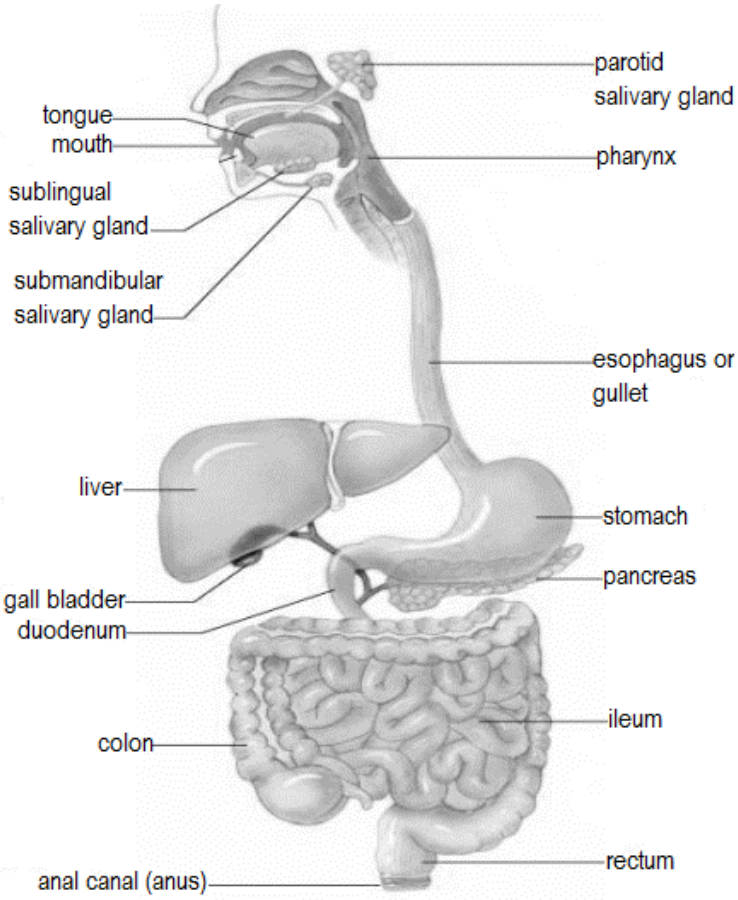
Ingestion → Digestion → Egestion

Ingestion: This is the taking in of food into the body.

Egestion: This is the process by which insoluble undigested compounds of food are discharged or expelled from the body as faeces.

Digestion takes place in the **alimentary canal.**

The human digestive system and the alimentary canal



Digestion in the mouth

Digestion in the mouth is both physical and chemical.

Physical digestion: Physical digestion in the mouth is carried out by the action of teeth or is the act of Mastication or chewing.

Mastication is important in that;

i) Increase the surface area of food for efficient Enzyme action.
ii) It helps to mix the food with saliva and in so doing; it softens the food, mixes it with the enzymes and lubricates it with the mucus in the saliva.
iii) With the help of the tongue, the food is rolled into a Bolus (a small ball) for easy swallowing and movement in the gut.(alimentary canal)
iv) Chewing stimulates enzyme secretion because the secretion of saliva is a reflex action stimulated by the presence of food in the mouth.

NOTE: The secretion of saliva can also be stimulated by sight, smell and thought of food.

Chemical digestion in the mouth

Chemical digestion is catalyzed by the enzyme salivary amylase (ptyalin).

Saliva is an alkaline watery solution (high PH) and it provides the optimal PH for the action of amylase.

Salivary amylase only catalyzes digestion of starch to a disaccharide called Maltose. *(This explains why when you chew a piece of bread (starch) for long it eventually tastes sweet- disaccharides are sweet)*

Cooked starch $\xrightarrow[\text{(Ptyalin)}]{\text{Salivary amylase}}$ Maltose.

The act of swallowing:

Food is rolled into a Bolus which is then transferred into the Oesophagus (gullet).

During the act of swallowing, breathing momentarily stops and the epiglottis closes the entrance into the trachea preventing food from entering into the trachea.

At the same time, the soft palate also closes the entrance into the nose cavity preventing the food from escaping or passing through the nose.

Once the bolus is in the oesophagus, the food moves by a wave of muscular contractions called ***Peristalsis.***

Practical example on the effect of saliva on starch

You are provided with a starch solution. Rinse your mouth with water and collect about 2cm^3 of saliva in a test tube. Carry out the following tests on the starch solution.

Method/procedure	Observation	Conclusion and explanation
i) To 1 cm^3 of the starch solution, add 3 drops of iodine solution.	***The solution turns to a blue-black solution.***	***Starch is present***
ii) To 1 cm^3 of the starch solution, add Benedict's solution and boil.	***The solution turns to a blue solution.***	***Reducing sugars are absent***
iii) To 1 cm^3 of fresh starch solution, add 1 cm^3 of ***boiled saliva*** and shake to mix. Incubate in a water bath at 35-40^{0}C for 15 minutes. Then after add 5 drops of iodine solution.	***The solution turns to a blue-black solution.***	***Starch is still present. This is because, boiling the saliva denatures the enzyme salivary amylase in it hence does not catalyze the breakdown of starch even after incubation.***
iv) To 1 cm^3 of the starch solution, add 1 cm^3 of saliva and shake to mix. Incubate in a water bath at 35-40^{0}C for 15 minutes. Then after, divide the solution into two equal portions. To the first portion add 5 drops of iodine solution.	***The solution turns to a brown solution.***	***Starch was absent because Salivary amylase in saliva catalyzes its breakdown.***
To the second portion, add 1cm^3 of Benedict's solution and boil.	***The solution turns to a blue solution, then to a green solution and finally to a yellow/orange precipitate.***	***Reducing sugars were present because the salivary amylase in saliva catalyzed the breakdown of starch to maltose-a reducing sugar.***

Digestion in the stomach

Most of the digestion in the stomach is chemical. Food is allowed into the stomach from the oesophagus by a ring of muscle called the ***Cardiac Sphincter.***

In the stomach, there is only protein digestion.

Gastric juice is secreted and it contains two enzymes, (**pepsin** and **rennin**), hydrochloric acid, mucus and water.

Pepsin catalyzes the breakdown of proteins to peptides.

Pepsin is initially secreted in an inactive form called Pepsinogen which is activated into active pepsin by hydrochloric acid. This is the safe guard mechanism because if pepsin was stored in its active form, it would destroy the gut walls or stomach walls since they are protein in nature (self-digestion).

Pepsin works at low PH i.e. acidic conditions provided by the presence of Hydrochloric acid (HCl).

Rennin coagulates milk protein in baby mammals from soluble milk protein caseinogen to an insoluble curd, casein which is then acted upon by pepsin breaking it down to polypeptide.

Caseinogen (soluble protein) $\xrightarrow{\text{Rennin}}$ *Casein (insoluble protein)*

Proteins $\xrightarrow{\text{pepsin}}$ *peptides*

Functions of HCl in the stomach

i) It kills some bacteria in ingested food.
ii) It activates pepsin and rennin and provides ideal medium for their activity.
iii) It stops the action of salivary amylase and ensures protein digestion only.
iv) It prevents fermentation of food in the stomach by bacteria.

Mucus:

Mucus forms a barrier between stomach walls and Gastric juice thus protecting the stomach walls from self-digestion by pepsin and the action of hydrochloric acid which can give rise to stomach ulcers.

Digestion in the duodenum

The chyme from the stomach enters the duodenum in small quantities at a time regulated by the ***pyloric sphincter.*** There are access organs which provide secretions. They secret bile from the gall bladder and pancreatic juice from the pancreas

Functions of bile

i) It contains high percentage of water and adds it to the food coming from the stomach called chyme.
ii) It's alkaline and neutralizes the HCl of the chyme to stop the action of the stomach enzymes and allow enzymes in the pancreatic juice to begin working.
iii) It reduces the surface tension of fats and breaks them into minute droplets i.e. emulsifies fat.

The arrival of food in the duodenum stimulates the production of a hormone called ***secretin*** which stimulates the release of bile from the gall bladder and hydrogen carbonate ions from the pancreas and another hormone called ***cholecystokinin*** which stimulates the pancreas to release its enzymes. The secretions are alkaline thus stopping the action of pepsin and provides an ideal medium for enzymes in pancreatic juice to work. Pancreatic juice contains a number of enzymes which are called the *pancreatic enzymes.*

Pancreatic enzyme	Food acted upon	Products
Trypsin	Proteins	Peptides and Amino acids
Pancreatic amylase	Starch	Maltose
Pancreatic lipase	Lipids	Fatty acids and glycerol

Trypsin is also secreted in an **inactive** form, **trypsinogen** to prevent it from digesting the duodenum walls.

Both trypsin and pancreatic amylase catalyzes the breakdown of proteins and starch that were not broken down in the stomach and mouth respectively.

Digestion in the ileum

This is where final digestion takes place. Food moves down from the duodenum into the ileum by peristalsis. The presence of food in the ileum stimulates the secretion of the ***intestinal juice, succus entericus by the walls of the ileum***. Succus entericus contains several enzymes which complete the process of digestion forming a milky fluid substance called ***chyle*** (food after final digestion is called **chyle**) ready to be absorbed through the ileum lining.

Enzymes	Food and Upon	Products
Sucrase	Sucrose	Glucose and fructose
Maltase	Maltose	Glucose and glucose
Lactase	Lactose	Glucose and Galactose
Peptidase	peptides	Amino acids
Lipase	Lipids	Fatty acids and glycerol

Digestion in the large intestines/colon

In the colon, water and mineral salts are absorbed. The undigested and indigestible food substances pass down into the large intestines which are eventually removed from the body as faeces through the anus. ***There is no digestion in the large intestine.***

Accumulation of hard particles like stones, small sticks in the appendix results into a condition known as **appendicitis.** The appendix is thus removed surgically by a simple operation.

Summary of the process of digestion of starch

In the mouth; The food is thoroughly chewed by teeth, breaking it into smaller particles. During this chewing, food is mixed with saliva to make it soft and easy to swallow. Saliva contains salivary amylase which catalyzes the breakdown of cooked starch in food into maltose under neutral or slightly alkaline conditions.

Food is then pushed down the Oesophagus by a process called peristalsis.

In the stomach; no digestion of starch occurs because of acidic conditions due to presence of hydrochloric acid which provide unfavourable pH for activity of salivary amylase.

In the duodenum; the pancreatic juice contains pancreatic amylase which speeds up the breakdown of undigested cooked starch to maltose.

In the ileum, intestinal juice contains maltase which speed up the breakdown of maltose to glucose molecules which are soluble hence easily absorbed by the body. This marks the end of the digestion of starch.

Summary of digestion of proteins

In the mouth; Protein food is chewed by the teeth and swallowed into the stomach.

In the stomach; gastric juice is produced which contain pepsin that catalyzes the digestion of proteins to peptides.

In the duodenum; presence of food stimulates pancreas to secrete pancreatic juice containing trypsin which digests undigested proteins from the stomach to peptides.

In the ileum; intestinal juice is produced containing peptidase which catalyzes the breakdown of peptides to amino acids which are later absorbed through the ileum walls.

ABSORPTION OF THE SOLUBLE PRODUCTS OF DIGESTION

Absorption is the process by which soluble products of digestion diffuse through the cellular lining of the villi into the blood stream.

The villi are located in the ileum (small intestine) and thus absorption takes place in the small intestine. Some nutrients like minerals and vitamins also enter the villi by active transport.

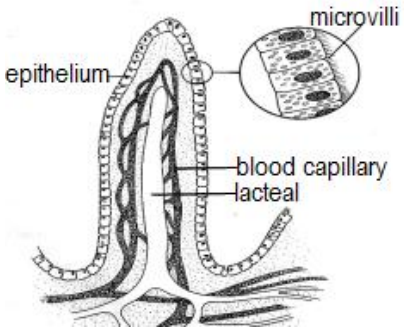
The ileum shows various adaptions to suit the process of absorption which includes:

i) It is highly coiled/folded and consequently long thus providing a large surface area for digestion and absorption of food. (It is six (6) meters long).
ii) Has a thin layer of cells to reduce the diffusion distance over which soluble food passes through.
iii) They are highly supplied with blood capillaries and lacteals which transport away absorbed food thus maintaining a diffusion gradient.

iv) Have finger-like projections called the villi which increase the surface area for absorption of soluble food.

v) The villi also have hair like extensions called the micro villi which ***further*** increase the surface area for absorption of soluble food products. The villi are the actual sites for absorption of soluble food products.

The villus



Fatty acids and glycerol are absorbed into the lacteal of the villi. These lacteal later join up to form the lymphatic system carrying these food materials and distributing them to all parts of the body.

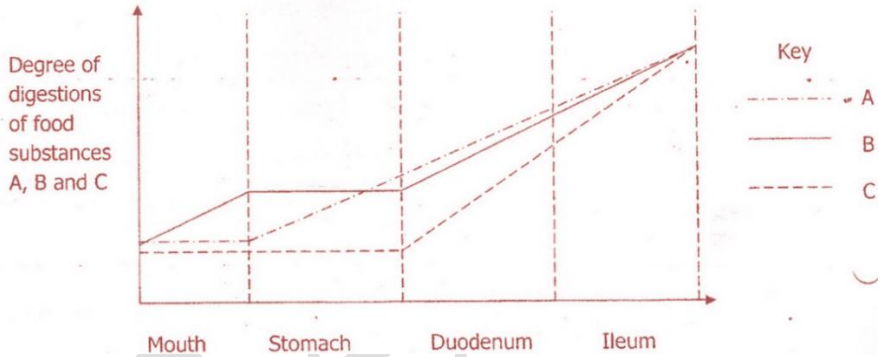
Glucose, Amino acids and Fructose pass into the blood capillaries of the villus which join up to form the Hepatic portal vein which transport these nutrients to the liver.

Assimilation

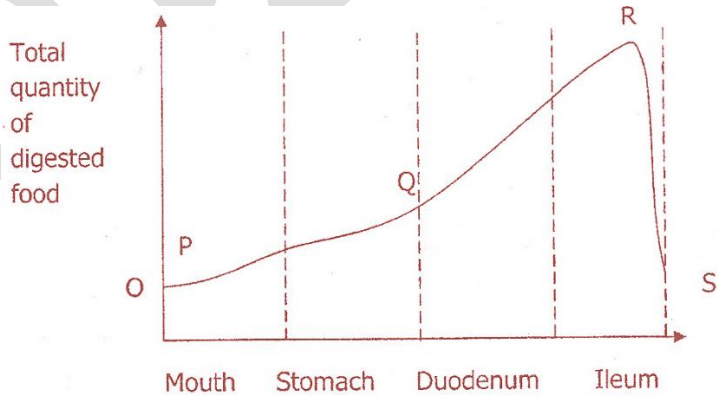
Assimilation is the incorporation/utilization of the products of digestion into the body's metabolism for life processes e.g. respiration, growth and repair and digestion.

Revision questions

1. *The figure below shows the degree of digestion of three different classes of food substances along the human alimentary canal from the mouth to the ileum.*



The figure below shows the changes in the total quantity of digested food along the human alimentary canal from the mouth to the ileum.



(a) Suggest the type of class of food A, B, and C, giving reasons for your answers in each case.

(b) Describe the changes in the total quantity of food digested from; P to Q, Q to R and R to S

(c) Give a reason to explain the changes described in (b) above.

Source: Unknown

ASSIMILATION OF THE ABSORBED PRODUCTS OF DIGESTION BY THE BODY

Assimilation is the incorporation/utilization of the products of digestion into the body's metabolism for life processes e.g. respiration, growth and repair and digestion. Once absorbed into the blood capillaries and taken to the liver, they are used by the body in the following ways:

1) Carbohydrates: (Glucose)

Glucose is mainly broken down in the process of respiration to provide energy for the body's metabolic process.

Excess glucose is stored as **Glycogen** (animal starch); however, the liver has the ability to re-covert back the glycogen to Glucose in periods of starvation.

2) Proteins (amino acids)

Amino acids are used in the synthesis of new proteins especially regulators like enzymes, and hormones.

Some Amino acids are used in body growth and repair and in absence of Glucose and Fats, Amino acids can instead be used in the process of respiration to produce energy.

Excess Amino acids are not stored in the liver, they are instead **deaminated** by the liver (removal of the Amino group) to form urea which is then passed on to the kidneys and excreted in urine.

Deamination is the removal of the amino group from Amino acids to form urea (which is a toxic waste product).

3) Lipids (Fatty acids & Glycerol)

Fatty acids and glycerol in the absence of Glucose can be oxidized to release energy. Fats produce much more energy compared to glucose considering the same amount by mass.

Fats are used for body insulation i.e. they prevent heat loss from the body which is an important temperature regulatory mechanism. Lipids are used in the formation of structures like the cell membrane.

Excess fats and Glycerol are stored under the skin in the **adipose tissue.**

THE LIVER

This is the largest organ in the body. It carries out several functions within the body. The liver is the body's metabolic center as it receives all nutrient supplies from the blood through the ***hepatic portal vein*** from the intestines.

Functions of the Liver

i) ***Metabolism of carbohydrates.*** The liver converts excess glucose absorbed from the intestine into glycogen. Once the glycogen store is full, excess carbohydrate will be converted to fat by the liver.

ii) ***Metabolism of lipids.*** Lipids entering the liver may either be broken down or modified for transport to storage areas elsewhere in the body.

iii) ***Metabolism of proteins.*** Proteins are not stored by the body and so the excess amino acids are deaminated in the liver.

iv) ***Production of heat.*** Since there are many metabolic reactions occurring in the liver, there is a lot of heat generated and this heat can be used to compensate any fall in body temperature.

v) ***Manufacture of plasma proteins.*** The liver is responsible for the manufacture of proteins found in the blood like Albumin, Globulin and fibrinogen which are important in body process like clotting of blood (stopping bleeding).

vi) ***Production of bile.*** The liver produces bile which is important in the process of digestion i.e. in the emulsification of lipids.

vii) ***Storage of minerals.*** The liver stores minerals like iron, potassium, copper and zinc.

viii) ***Storage of vitamins.*** The liver stores vitamins which can later be released if deficient in the diet.

ix) ***Formation and breakdown of red blood cells***. Red blood cells in the fetus are produced by the liver but in adults, they are made in the bone marrow. The adult liver however continuous to break down the expired red blood cells at the end of their 120-day life span.

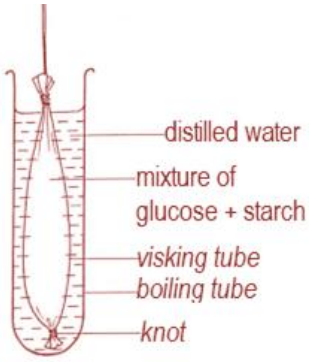
x) ***Storage of blood.*** Blood vessels in the liver can expand and contract such that the amount of blood in the liver can vary from $300cm^3$ – $1500cm^3$, an increase of five times thus the liver can be a blood reservoir.

xi) ***Detoxification.*** The liver convert toxic substances to harmless substances by altering their chemical structure and later sends them to the excretory organs for expulsion e.g. it converts Ammonia to urea which is then expelled by the kidneys. It also contains ***catalase enzyme*** which catalyzes the breakdown of hydrogen peroxide to water and oxygen. Hydrogen peroxide is a toxic waste product of metabolism produced by the liver cells.

xii) ***Break down of hormones.*** The liver break down all hormones like testosterone and insulin.

Revision questions

1. *The diagram below shows an experiment which is intended to show what happens in the human gut. After being set up, glucose, but not starch passes out of the bag into the surrounding water.*
   a) How could you show that glucose has leaked out, but starch has not?
   b) How would you explain this result?
   c) To what extent is this similar to what happens in the human gut?



2. *Explain each of the following*
   i) If you chew a piece of bread for long enough, it eventually begins to taste sweet.
   ii) When you swallow a piece of food, the food normally does not go up into the nose cavity.

(Source: Roberts, M., Biology (Nelson science)

3. *The enzyme lipase acts on fats producing fatty acids. The indicator cresol red changes to yellow when acidic. $3cm^3$ of milk were placed in each of the test tubes and then other substances were added, as shown in the table below. In each case, the indicator was red at the start of the experiment.*

	Test tube 1	***Test tube 2***	***Test tube 3***	***Test tube 4***
Temperature	*37^0C*	*37^0C*	*37^0C*	*4^0C*
Material present	*$3cm^3$ of milk + $1cm^3$ lipase extract + $0.5cm^3$ bile salts.*	*$3cm^3$ of milk + $1cm^3$ boiled lipase extract + $0.5cm^3$ bile salts.*	*$3cm^3$ of milk + $1cm^3$ lipase extract + $0.5cm^3$ distilled water.*	*$3cm^3$ of milk + $1cm^3$ lipase extract + $0.5cm^3$ bile salts.*
Time taken for indicator to change from red to yellow	*4 minutes*	*No change*	*9 minutes*	*27 minutes*

   a) Explain the difference in time for the colour to change in test tube 1 and 4?
   b) Why was there no colour change in tube 2?
   c) Where are bile salts and lipase produced in the body?
   d) State two ways in which fat is used by the body.

Source: Rwakasisi, R., Jada C. and Ali G. Fountain revision Biology Questions and Answers for secondary schools (Fountain publishers, 2005)

DIGESTION IN HERBIVORES

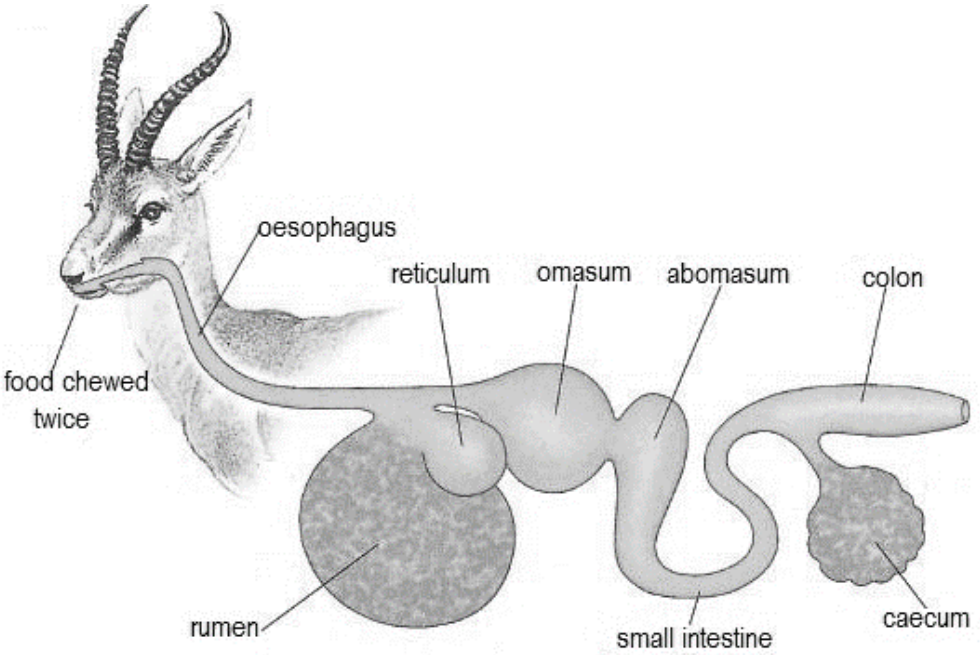
Animals that depend on plant materials (herbivores) like leaves, wood, grass are faced with a problem of digesting the cellulose that make up the plant walls. It is necessary to break down cellulose into glucose and also break through the cellulose to release the inside cell nutrients which are required by the herbivores.

These herbivores cannot secret the **enzyme cellulase which catalyzes the digestion of cellulose to glucose.** Some micro-organisms live in the guts of these herbivores in a harmless beneficial nutritional association called ***symbiosis.*** *They secret the enzyme cellulase that catalyzes the digestion of cellulose in the guts of these animals.*

Digestion in ruminants

Ruminants are mammals which chew cud. Cud is imperfectly/incompletely chewed grass or plant materials that are taken into the stomach (rumen) and later returned back to the mouth for further chewing through a process called ***regurgitation.*** Ruminants have a stomach made up of four chambers namely; ***Rumen, Reticulum, Omasum and Abomasum***.

The alimentary canal of a ruminant e.g. a goat



In the mouth, the saliva does not contain any enzyme. So only mastication (chewing) and softening of food takes place. The food moves through the oesophagus by peristalsis (wave like motion) to the rumen.

In the rumen, the cud is mixed with the bacteria which secrets cellulase enzyme that catalyzes the breakdown of cellulose to glucose, which in turn is fermented to organic acids. These fatty acids are absorbed into the blood through the rumen wall and are the major source of energy for ruminants. The fermentation produces carbon dioxide and methane, which are belched out.

The fermented grass passes to the **reticulum** and is formed into balls ('cud'), which are regurgitated to the mouth for further chewing. The reticulum also sieves out the hard materials and either retains them or sends them back to the mouth for further chewing. The fine 'cud' is then swallowed and passed to the Omasum.

In the Omasum much water is re-absorbed from the cud. The cud is then passed to the abomasum.

In the abomasum, normal gastric secretions begin to digest the proteins of grass. The abomasum is the true stomach. The chyme then passes to the duodenum and then to the small intestines, where digestion is completed and the products of digestion are absorbed.

Comparisons between ruminant and non-ruminant digestion

Similarities:

i) In both, young animals have a single stomach where digestion takes place.

ii) The final digestion of proteins and carbohydrates takes place in the small intestines.

Differences:

Ruminant	Non-Ruminant
Chew cud.	Do not chew cud.
Have a four chambered stomach.	Have a single stomach.

Ptyalin (salivary amylase is absent in saliva.	Ptyalin is present in saliva.
Most digestion and absorption takes place in the stomach.	Most digestion and absorption takes place in the ileum.
Water absorption takes place in the stomach.	Water absorption takes place in the colon.

Digestion of cellulose in termites

Termites eat wood, dry leaves and other plant materials which contain cellulose. The digestion of cellulose also takes place in the gut (stomach) with the help of protozoans which live symbiotically in the termite's gut. These protozoa have the ability to produce the enzyme cellulase which catalyzes the digestion of cellulose to glucose.

NUTRITION IN PLANTS

Nutrition in plants is by a process called **photosynthesis**. Photosynthesis is the formation of complex organic substances inside the cell containing chlorophyll from carbon dioxide and water using sunlight energy.

The process of photosynthesis occurs in all green plants in organelles called **chloroplasts** most of which are found in leaves. Chloroplasts contain chlorophyll which traps sunlight energy.

The process of photosynthesis is very complicated but it can be summarized by the equations below.

Carbon dioxide + water $\xrightarrow[Chlorophyll]{Sunlight\ energy}$ starch (Glucose) + oxygen

$6\ CO_{2(g)} + H_2O_{(l)} \xrightarrow[Sunlight\ energy]{Chlorophyll} C_6H_{12}O_{6(s)} + 6O_{2(g)}$

Conditions necessary for photosynthesis to take place

1) Light:

This is the source of energy necessary for the process of photosynthesis to take place. The rate of photosynthesis increases with increasing light intensity up to a maximum where it remains constant. The energy of light is used for the following purposes:

i) Used to split water molecules into hydrogen atoms and oxygen. The oxygen is given off by the photosynthesizing plants. The hydrogen atoms combine with CO_2 to form carbohydrates.
$H_2O \xrightarrow{split\ by\ light\ energy} 2H^+ + O_2$

ii) Provides energy for photosynthesis. The process by which light energy splits water into H^+ and oxygen is called photolysis of water.

2) Temperature:

Temperature influences the rate of chemical reactions which are controlled by enzymes which are protein in nature.

The rate of photosynthesis doubles for every ten degrees centigrade (10^0C) rise in temperature up to about 40^0C where the rate of photosynthesis drops drastically because the enzymes are denatured.

Adaptation of leaves to carry out photosynthesis

The leaf is the major organ of photosynthesis in a plant.

The leaf is adapted to carry out the photosynthesis process in a number of ways namely

External adaptations:

i) **Leaves are broad and flat:** This provides a large surface area for trapping sunlight and taking in of Carbon dioxide.

ii) **Leaf arrangement / leaf mosaic:** Leaves are usually arranged in such a way that they rarely shade or block each other thus ensuring that each leaf obtains maximum sunlight for photosynthesis. This is termed as a leaf mosaic.

iii) **Thinness:** Most leaves are just a few cells thick thus providing a small diffusion distance for carbon dioxide to easily reach all the photosynthesizing cells.

Internal adaptation of a leaf:

iv) **Palisade mesophyll layer contains numerous chloroplasts** especially the palisade thus it is the best position to receive sunlight.

v) **The spongy mesophyll** layer has many **air spaces** thus allowing gases to easily diffuse to all photosynthesising cells.

vi) **Network of veins (vascular tissues) which** contains the phloem and the xylem where by the phloem conducts food made by the leaf and the xylem conducts dissolved mineral salts up to the stem.

vii) **Presence of stoma which** controls passage of gases and water vapour between air and the leaf. There are more stomata on the lower side of the leaf compared to the upper side to reduce water loss by transpiration.

viii) **Has cuticle** which is a water proof layer and so it helps to prevent desiccation (water loss) by the photosynthesizing tissues.

Factors that affect the rate of photosynthesis

1) **Amount of chlorophyll:** Chlorophyll is a green pigment that absorbs light energy from the sun.
The more chlorophyll, the more the light energy absorbed leading to increased rate of photosynthesis. The less the chlorophyll, the less light energy absorbed leading to decreased rate of photosynthesis

2) **Amount of CO_2 in the atmosphere:** It is required as a raw material for photosynthesis thus the rate of photosynthesis increases in CO_2 concentration and it decreases with the lowering of CO_2 concentration. Carbon dioxide is absorbed from the atmosphere by terrestrial plants through their stomata. For aquatic plants like algae, they absorb the carbon dioxide as hydrogen carbonates which diffuse directly from the water into plant tissues. The use of carbon dioxide is to combine or react with hydrogen atoms to form carbohydrates. Thus CO_2 is used as a raw material.

3) **Light intensity:** The rate of photosynthesis increases with increase in light intensity. And it lowers with decrease in light intensity.

4) **Temperature:** It is required for the activity of enzymes that control the rate of photosynthesis. Thus the rate of photosynthesis increases with increase in temperature till the optimum temperature for enzyme action. Beyond which the enzymes are denatured leading to a decrease in the rate of photosynthesis.

5) **Number of stomata:** The more the stomata, the more the gaseous exchange. This avails more CO_2 to the plant leading to high rate of photosynthesis.

6) **Surface area for photosynthesis:** The larger the area for photosynthesis (more leaves) the more light energy is absorbed which causes increased rate of photosynthesis.

7) **Availability of water:** Water is a raw material for the process of photosynthesis. It is absorbed by the root hairs from the soil and transported up the rot by the xylem vessels. A decrease in the quantity of water in the soil lowers the rate of photosynthesis.

Importance of photosynthesis

- It is the means by which the sun's energy is captured by plants for use by all organisms.
- It provides a source of complex organic molecules for heterotrophic organisms as food.
- It releases oxygen for use by aerobic organisms.
- It reduces on gaseous carbon dioxide, which would accumulate in the atmosphere to cause pollution.

Revision questions

1. *A scientist grew some cereal plants in a field. During the course of one day he took several plants every 4 hours and measured the amount of sugar in the leaves.*

Time of day	*4am*	*8am*	*12noon*	*4pm*	*8pm*	*12mid night*	*4am*
Sugar concentration (arbitrary units)	*0.45*	*0.60*	*1.75*	*2.00*	*1.4*	*0.5*	*0.45*

a) Plot the data on a graph paper
b) What is the probable concentration of sugar in the leaves at 10am and 2am?
c) At what time of the day is sugar probably at a maximum in the leaf and why?
d) Explain why the sugar concentration changes over the 24hr period.

(Source: Roberts, M., Biology (Nelson science)

AN EXPERIMENT TO TEST A LEAF FOR STARCH

The presence of starch is evidence that photosynthesis has been taking place.

Apparatus: A green leaf, water bath, Iodine solution, Water**,** absolute alcohol (99%-OH), beaker, white surface or tile

Procedure:

1) A leaf from a health plant which has been receiving sunlight is removed and placed in boiling water (water bath) for about 5 minutes. This softens the leaf cell wall protoplasm and makes it permeable to Iodine.
2) The leaf is then placed in a beaker containing 99% alcohol and boiled using a water bath until all the chlorophyll is dissolved out. This decolorizes the leaf and makes detection of any colour changes possible and easier.
3) The leaf is then washed in hot water which softens it.
4) The leaf is now spread on a white surface tile and drops of iodine added on it.

Observation:

A blue black colour shows that starch is present.

NOTE: If the brown colour of iodine remains, this shows that the leaf lacks starch or the starch is absent.

Conclusion: The presence of starch in a leaf shows that photosynthesis was taking place.

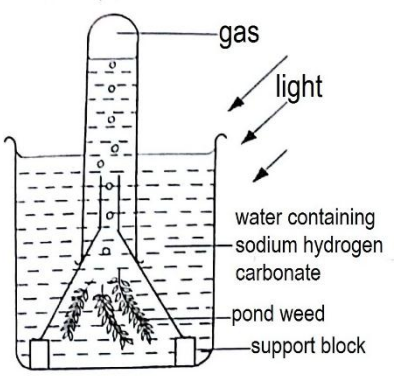
AN EXPERIEMENT TO SHOW THAT OXYGEN IS GIVEN OFF DURING PHOTOSYNTHESIS

Apparatus: Afresh water weed, Funnel and wooden blocks, Test tube, beaker, Water, Sodium hydrogen carbonate.

Procedure:

a) The funnel is inverted in the beaker over the plant.
b) Sodium hydrogen carbonate is added to the water to provide CO_2
c) The funnel is raised slightly above the bottom of the beaker using small wooden blocks to allow water to circulate freely under it.
d) The apparatus is then placed in the bright sunlight.
e) Another similar set up is made and placed in darkness. This acts as the control experiment.

The apparatus is arranged as shown below:



Observation:

Gas bubbles are evolved and sufficient gas is collected at the top of the test tube. In the control experiment, no bubbles are evolved.

Conclusion:

The gas collected relights the glowing split proving that it is oxygen. The evolution of oxygen by the water plant in the presence of sunlight is an indication that photosynthesis is taking place.

NOTE: This experiment can also be carried out to estimate the rate of photosynthesis (speed) by counting the number of bubbles produced per unit time

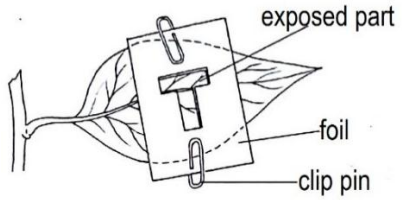
AN EXPERIMENT TO SHOW THAT LIGHT IS NECESSARY FOR PHOTOSYNTHESIS

Apparatus/materials: Potted plant, Aluminum foil, Water, Ethanol, White tile, Source of heat, Wire gauze, Dropper, Boiling tube and a razor blade.

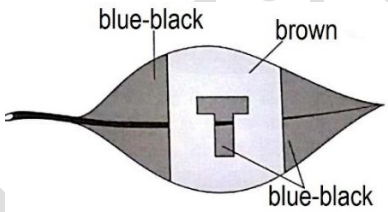
Procedure:

1) Get a potted plant and place it in darkness for 24 hours to de-starch it.
2) Make a shape in an aluminum foil and make a stencil
3) Place the stencil around the leaf with the cut shape facing upwards where light strikes.
4) Place the plant in sunlight for 3 hours.
5) Remove the leaf with a stencil from the plant using a razor blade
6) Remove the stencil and carry out the test for starch.

Before testing for starch



After testing for starch



Observation:

The parts, which were covered by the stencil, turned brown while the parts exposed to light turned blue-black.

Conclusion: Light is necessary for photosynthesis to take place.

Explanation:

Putting the leaf in darkness removes starch in the leaf by all the starch being converted into simple sugars. Putting the plant in light is to allow photosynthesis to take place. Covering the leaf with a stencil is to prevent light from reaching certain parts of the leaf. During exposure to light, the parts covered do not access sunlight and do not photosynthesize while the un-covered parts access sunlight and photosynthesize. Testing for starch helps to find out whether photosynthesis took place or not.

Revision questions

1. *In an experiment, a leaf from a plant which had been kept in darkness overnight was boiled in water for 10 minutes, boiled in alcohol and then washed in warm water, iodine solution was lastly added onto the leaf.*
   a) *Why was the leaf boiled in: (i) water and (ii) alcohol?*
   b) *What observation was made after adding iodine to the leaf? Give a reason for your answer.*
   c) *What is the aim of the experiment?*

AN EXPERIMENT TO SHOW THAT CARBONDIOXIDE IS NECESSARY FOR THE PROCESS OF PHOTOSYNTHESIS

Apparatus: Sodium hydroxide**,** conical flasks fitted with corks with a hole, a well-watered de-starched potted plant, Iodine, 99% alcohol**,** water beaker, white tile and test tubes.

Procedure:

i) The leaves of a potted plant are de-starched by keeping the plant in darkness for two days.

ii) The petiole of the leaf (stalk) is passed through the hole in the cork so that the leaf is completely enclosed in a flask containing soda lime (Sodium Hydroxide) ***The Sodium Hydroxide absorbs all Carbon dioxide in the air enclosed in the flask.***

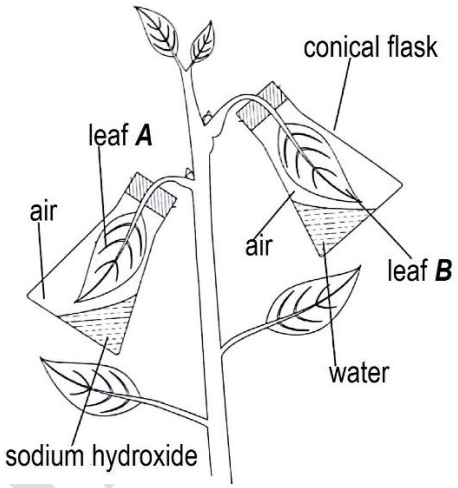
iii) The flask is then made air tight by smearing Vaseline at the neck of the flask to prevent any air from entering.

iv) A control experiment is also set up with the conical flask containing water instead of sodium hydroxide.

v) The plant and the flasks are then placed in sunlight for 6 hours.

vi) The enclosed leaves are then removed from the plant and then tested for starch using Iodine solution.

Setup:



Observation:

The leaf in the flask containing Sodium Hydroxide solution remains brown (the colour of Iodine persisted) when tested for starch while the leaf in the empty flask / control experiment turned blue black.

Conclusion:

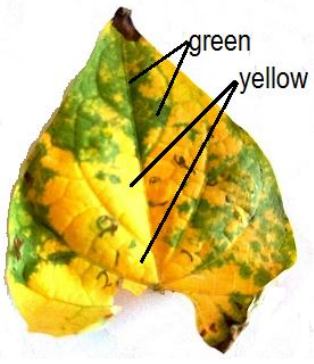
The leaf in the flask containing Sodium Hydroxide didn't contain starch since it lacked Carbon dioxide which was absorbed from the flask by the Sodium Hydroxide solution thus Carbon dioxide is necessary for photosynthesis.

AN EXPERIMENT TO SHOW THAT CHLOROPHYLL IS NECESSARY FOR PHOTOSYNTHESIS

Apparatus: A beaker, alcohol, white tile**,** Iodine, test tube, and Plant with variegated leaves.

A variegated leaf *is one which has chlorophyll in some parts of the leaf lamina and not in other parts of the same leaf. It has green and yellow parches on the same leaf.*

Variegated leaf



Procedure:

After a period of de-starching (removing starch) by placing a plant in a dark cupboard for two days, the variegated plant is then exposed to sunlight for about two (2) hours.

The parts of the leaf that are not green are used as the control experiment.

At the end of the two hours, the leaf is removed and then tested for starch.

Observation:

The parts that were green are stained blue black with iodine solution while the yellow patches stained brown with iodine (brown is the colour of iodine).

Conclusion:

The green parts of leaf contained starch because they contained chlorophyll and thus turned blue black while the yellow patches (non-green parts) did not contain starch because they lacked chlorophyll.

Chlorophyll is thus necessary for photosynthesis.

Gaseous exchange and compensation point

Both respiration and photosynthesis take place in a green plant. In darkness, Green plants do not photosynthesize, however they continue to respire. Here oxygen is used up (through respiration) and carbon dioxide is given off and there is an overall net consumption of sugars and glucose during respiration.

At low light intensity, some photosynthesis occurs and some carbon dioxide produced in respiration by plants is used up in photosynthesis. However, there is a net loss of Carbon dioxide.

As the light intensity increases, the rate of photosynthesis also increases until a point is reached when all the Carbon dioxide produced during the process of respiration is reused in the process of photosynthesis. This point is called the **compensation point**.

The compensation point *is that point of light intensity at which the amount of Carbon dioxide produced during respiration is equal to the amount of Carbon dioxide consumed during photosynthesis.*

At the compensation point, the rate of photosynthesis is equal to the rate of respiration i.e. the rate at which food (glucose) is manufactured is equal to the rate at which it is used up in the process of respiration and this means that there is no net gain nor loss in the mass of the plant.

Revision questions

1. *At an agricultural research station, a group of scientists measured the amount of carbon dioxide in the middle of a wheat field every 3 hours for 24 hours. The results are shown below:*

Time	*24 (mid night)*	*3*	*6*	*9*	*12 (noon)*	*15*	*18*	*21*	*24 (mid night)*
%age of carbon dioxide in the air	*0.042*	*0.037*	*0.031*	*0.029*	*0.028*	*0.030*	*0.032*	*0.035*	*0.042*

   a) *Plot a graph representing the results above.*
   b) *Explain the results as shown by the graph you have plotted.*
   c) *How would you expect oxygen to change during the same period?*

Source: *Roberts, M., Biology (Nelson science)*

Mineral nutrition in plants

Pants need mineral elements for proper growth. Mineral elements are divided into two categories depending on the relative amounts of element needed.

i) **Essential elements:** These are elements needed in large quantities for proper plant growth, e.g. nitrogen, phosphorus, magnesium, potassium, calcium, sulphur, carbon, hydrogen, oxygen, etc.
ii) **Trace elements:** These are elements need in small quantities for proper plant growth they include manganese zinc boron silicon aluminum copper, molybdenum, and iron.

Plants obtain minerals from mineral salts present in the soil; Mineral salts are absorbed in form of soluble salts e.g. nitrogen as nitrate, phosphorus as phosphates, sulphur as sulphate. When a particular element is missing in the soil, a plant shows deficiency signs. For instance, a deficiency of magnesium causes yellowing of the leaves since it is required for the formation of the green coloring pigment, chlorophyll. Therefore the leaves turn yellow due to lose of the green colour.

TRANSPORT OF MATERIALS IN ORGANISMS

This refers to the movement of materials from one part of the organism to another.

Requirements of transport system

- The materials to be transported
- The medium of transport
- The channels of transport
- Energy

Materials to be transported:

In animals, they include respiratory gases oxygen and carbon dioxide, nitrogenous excretory products e.g. uric acid, nutrients e.g. glucose, amino acid, etc. In plants, they include oxygen and carbon dioxide.

The medium of transport:

The medium of transport in plants and lower animals is water and it is blood in vertebrates and in a few invertebrates like arthropods, annelids (earth worm).

The channels of transport:

In most animals, these are blood vessels, in others like earth worms, it is the body cavity (coelom). In higher plants, there is a vascular system or system of xylem and phloem.

Energy:

Circulation of blood in animals requires energy supplied from respiration used in pumping of the heart and muscle contractions.

MOVEMENT OF MATERIALS IN AND OUT OF CELLS

Substances like nutrients and excretions move in and out of the cell by active transport, Phagocytosis, Pinocytosis, Diffusion and Osmosis.

Pinocytosis:

This is the process by which animal cells take in liquid materials into their bodies. Thus it is said to be cell-drinking.

Phagocytosis:

This is the process by which animal cells take in solid materials. The cell engulfs/invaginates or takes in solid materials and form a food vacuole where the food is digested.

Importance of phagocytosis

1) Used by amoeba during feeding
2) White blood cells destroy pathogens by phagocytosis
3) Unicellular animals egest undigested material by phagocytosis

Active transport

This is the *movement of molecules from the region of* ***low concentration*** *to the region of* ***higher concentration*** **against concentration gradient using energy**.

Importance of active transport

1) Used by plant roots or root hairs to absorb mineral ions from the soil.
2) Used in the absorption of food materials from the ileum into the blood stream
3) Used in the reabsorption of minerals in the kidney during urine formation
4) Used in the secretion and active uptake of ions in the fish gills from fresh water

DIFFUSION

This is the ***movement of molecules of gases and liquids from a region of high concentration to a region of low concentration***. Diffusion occurs because small molecules are in constant random motion. Diffusion only takes place where there is a difference in concentration i.e. where there is a concentration gradient and continues until there is even distribution of molecules.

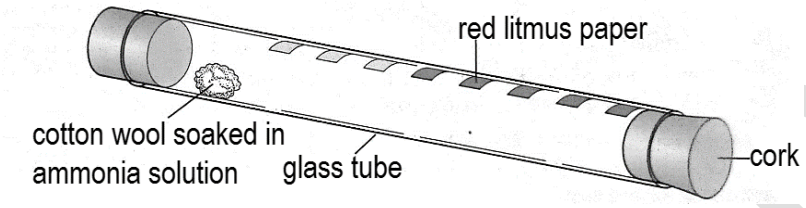
Experiment to demonstrate diffusion in gasses

Apparatus/materials: glass tube, red litmus papers, distilled water, cotton wool and ammonia solution.

Procedure:

- Wet red litmus papers are put inside the glass tube at different points in a line using a glass rod.
- Cotton wool soaked in ammonia solution is put at the open end of the glass tube and the other end is corked.
- The setup is left to stand for some time while observing the time taken for the litmus papers to turn blue.

Setup:



Observation:

The red litmus papers will turn blue in series from the one closest to the cotton wool to the one far away from the cotton wool.

Conclusion:

Diffusion occurs in gases.

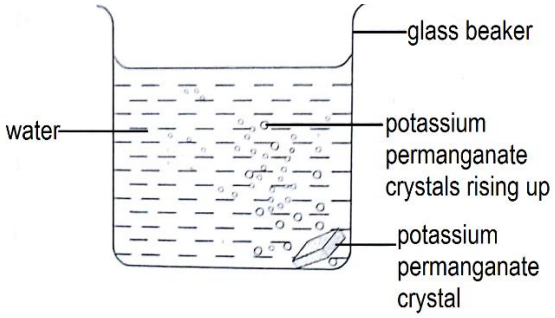
Note: The cotton wool soaked in ammonia gives off ammonia vapour which then diffuses away from the cotton wool throughout the glass tube turning the red litmus papers blue.

Experiment to demonstrate diffusion in liquids

Materials: Glass beaker**,** Potassium permanganate crystals**, w**ater and a glass tube

Procedure:

- Insert a glass tube inside the beaker and hold it upright.
- Pour water into the beaker until it is three quarters full.
- Drop a small crystal of potassium permanganate through the glass tube to the bottom of the beaker.
- Slowly lift the glass tube out of the water.
- Leave the set up for about 30 minutes.
- Observe the gradual spreading of the dark purple colour.



Observation:

After 20-30 minutes, a 'shading off' in the colouring will be noticed, with the darkest colour at the bottom, and the top of the mixture almost colourless. Eventually, the potassium permanganate color will have spread first at the bottom and later upward to color all the water in the beaker.

Conclusion:

Diffusion occurs in liquids.

The particles of potassium permanganate diffuse evenly through the liquid on their own. The particles dissolved in a liquid spread out or diffuse from areas of higher concentration to areas of lower concentration. They continue to do so until their concentration throughout the liquid is equal.

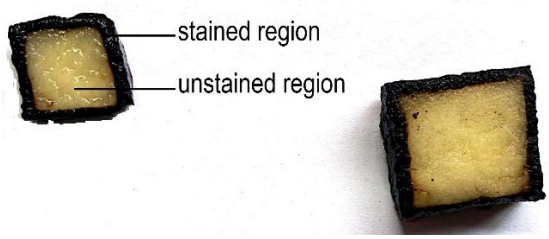
Question: *what difference would you observe if warm water is used instead of cold water? Give a reason for the difference.*

Experiment to demonstrate diffusion

Materials: Razor blade, Irish potato, potassium permanganate and beaker

Procedure:

- Peel the Irish potato and cut out cubes of dimensions 1cm by 1cm by 1cm.
- Immerse the cubes in potassium permanganate solution in a small beaker for 15 minutes, after which, remove them and dry them with a blotting paper.
- Using a razor blade, cut the cube transversely into two equal halves.



Observation: The outer portion of the cube is stained with the potassium permanganate and the center of the cube is left unstained.

Conclusion:

Diffusion occurs by movement of molecules from a region of high concentration to a region of low concentration.

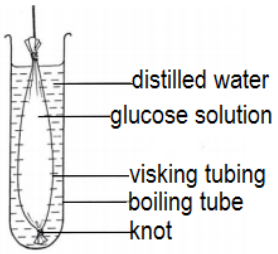
An experiment to show diffusion through an artificial membrane

Apparatus/materials: boiling tube, visking tubing (about 10cm–15cm), thread, glucose solution, distilled water, Benedicts solution and heat source**.**

Procedure:

- Soak the visking tubing in water and open it.
- Tie one end of the visking tubing using a thread to make a very tight knot.
- Put about 10cm of glucose solution into the visking tubing through the open end.
- Tie the open end tightly with a thread and wash the surface of the visking tubing with water.
- Place the visking tubing containing the glucose solution into the boiling tube containing distilled water.
- Allow the experiment to stand for about 15 minutes.
- After 15 minutes, carry out the Benedicts test on the distilled water in the boiling tube.

Set up:



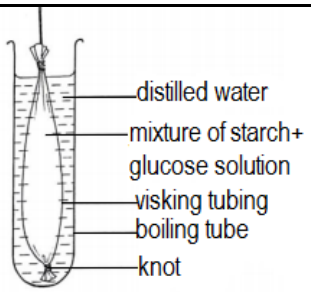
Observation:

The distilled water turns to an orange precipitate on boiling with Benedict's solution.

Conclusion: Glucose molecules moved from the visking tubing into the distilled water in the boiling tube by **diffusion**.

Note:

- When a mixture of ***starch and glucose solution*** is put into the visking tubing and placed in distilled water, only glucose molecules pass through the visking tubing membrane but not starch molecules. This is because ***glucose molecules are small*** thus can pass through the semipermeable membrane but ***starch molecules are large*** hence can't pass through a semipermeable membrane.
- Sucrose and maltose molecules don't cross semi permeable membranes because their molecules are also large since they are disaccharides.



Factors affecting the rate of diffusion

1) Concentration gradient

Concentration gradient is the difference in concentration between the 2 regions where diffusion takes place. The higher the concentration gradient between the two regions, the faster is the rate of diffusion.

2) Temperature

The higher the temperature of the substances (molecules), the faster the rate of diffusion, because temperature increases the kinetic energy of molecules.

3) Size and density of molecules

The smaller the molecules, the faster the rate of diffusion. The denser the particle, the lower the rate of diffusion.

4) Distance over which diffusion occurs

The shorter the distance between the two regions of different concentration, the greater is the rate of diffusion like the alveoli of lungs or the epithelial linings of the ileum are thin to provide a short distance for diffusion thus increasing the rate of diffusion.

5) Surface area over which diffusion occurs

The larger the surface over which diffusion is to take place, the faster is the rate of diffusion e.g. diffusion surfaces like the ileum have numerous villi (finger-like projections) which increase surface area to increase the rate of diffusion.

Types of diffusion

Simple diffusion: This is the type of diffusion where molecules or ions move freely across the cell membrane without being aided.

Facilitated diffusion: This is where molecules or ions move across the cell membrane being aided by protein carriers.

Significance of diffusion to organisms

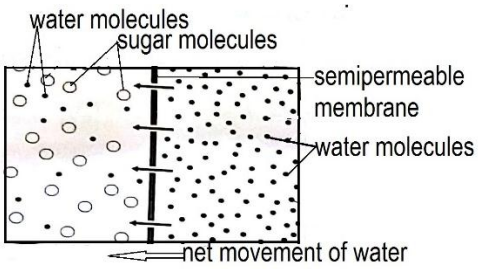
- Plant root hairs take up some salts by diffusion
- Unicellular organisms like amoeba take in oxygen and pass out carbon dioxide through the cell membrane by diffusion.
- Digested food e.g. simple sugars, amino acids, enter the blood from the gut by diffusion.
- Once dissolved in blood, the food substances diffuse out of the blood into the cells where they are needed.
- Oxygen diffuses into blood and CO_2 out of blood in the lungs of mammals and gills of fish by diffusion.
- Waste products of metabolisms like urea diffuse out of the animal cells into blood.

OSMOSIS

This is the *movement of water/solvent molecules from a dilute solution to a concentrated solution across a semi permeable membrane.*

It is the *movement water/solvent molecules from a solution of low solute concentration to a solution of high solute concentration across a semi permeable membrane.*

Diagram showing details of osmosis



A semi/partially/selectively permeable membrane is one which can allow the passage of some materials to occur and prevent other materials from passing across it.

When 2 solutions are separated by a semi permeable membrane having small pores, water molecules continue to move from a dilute solution to a concentrated solution through it.

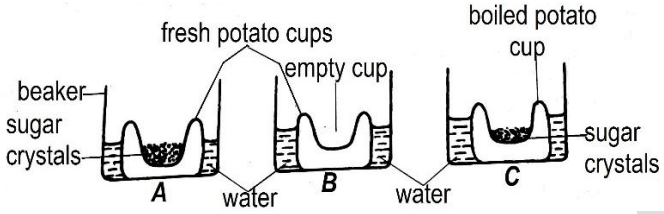
Experiment to demonstrate osmosis in a living tissue

Materials:

Fresh Irish potatoes, knife, Petri dishes, sugar or salt and water.

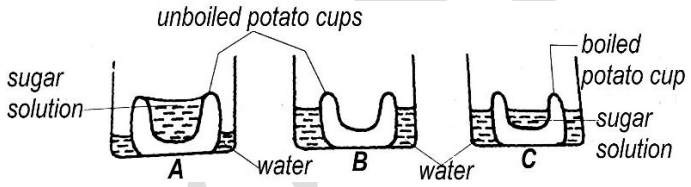
Procedure

a) 3 fresh Irish potatoes are peeled and their ends sliced flat. The interiors are scooped out to form a 'cup' with walls of uniform thickness. The potato cups are labelled ***A***, ***B*** and ***C*** respectively.
b) In ***A***, some crystals of sugar are placed in the cup, while the other potato ***B*** is left empty as a control.
c) The third potato 'cup' ***C*** is boiled to kill or destroy the tissues and also some sugar crystals are put in it.
d) All the potato cups are placed in water in Petri dishes. The experiment is let to run for 2-6 hours.



End of experiment (2-6 hours)

The liquid in the cup potato ***A*** had risen to form a sugar solution and in the Petri dish, the level of water had fallen.
In potato ***B***, the cup was still empty and the water level in the Petri dishes remained the same.
In the boiled potato cup, the solution in the cup rises to the same level with the water in the petri dish.



Conclusion

Osmosis takes place in living tissues and does not take place in boiled tissues because boiling the tissues destroys membrane semi permeability and then it becomes freely permeable.

Explanation

Living tissues have cell membrane or cell walls acting as semi permeable membrane and allow water to move through by osmosis while boiling a living tissue makes it freely permeable.

Experiment to demonstrate osmosis in an artificial membrane

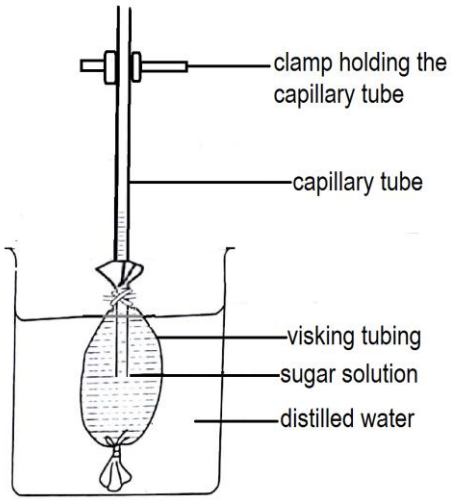
Materials:

Cellophane/visking tubing (about 10-15cm length), boiling tube, sugar solution, water and thread.

Procedure:

i) Tie one end of the visking tubing using a thread to make a very tight knot.
ii) Make a sugar solution and pour it into the tubing.
iii) Take a capillary tube about 30cm in length and place it in the tubing so that the end dips into the sugar solution.
iv) Tie the open end of the tubing tightly around the capillary tube using a strong thread.
v) Fix the capillary tube to the clamp and suspend the tubing with the solution in a beaker of water.
vi) Mark the level of the solution in the capillary tube and that of water in the beaker and leave the set up to stand for 30 minutes. Record the observation and deduction.

Set up:



Observation:

The level of the sugar solution in the capillary tube increases.

The level of the water in the beaker decreases.

Conclusion: Osmosis has taken place.

Interpretation

- Water molecules passed through the cellophane tubing into the sugar solution by osmosis, thus increasing its volume and forcing it up the capillary tube.
- Water acts as a dilute solution
- Sugar solution acts as a concentrated solution
- Membrane of the visking tubing acts as the semi permeable membrane.

Terms used in osmosis

1) **Water potential of a cell:** This is the ability of a solution to lose water. A dilute solution has a higher water potential than a concentrated one.
2) **Solute potential:** It is the degree of lowering the water potential due to presence of a solute in a solution. Therefore, the higher the concentration of the solute in a solution, the lower its solute potential.
3) **Hypotonic solution:** This is a solution which is dilute ***compared to another*** solution. It is generally termed as less concentrated.
4) **Isotonic solutions:** These are solutions with the same solute concentration.
5) **Hypertonic solution:** This is a solution which is more concentrated ***than the other***. It is generally termed as a more concentrated solution.

Osmosis in red blood cells

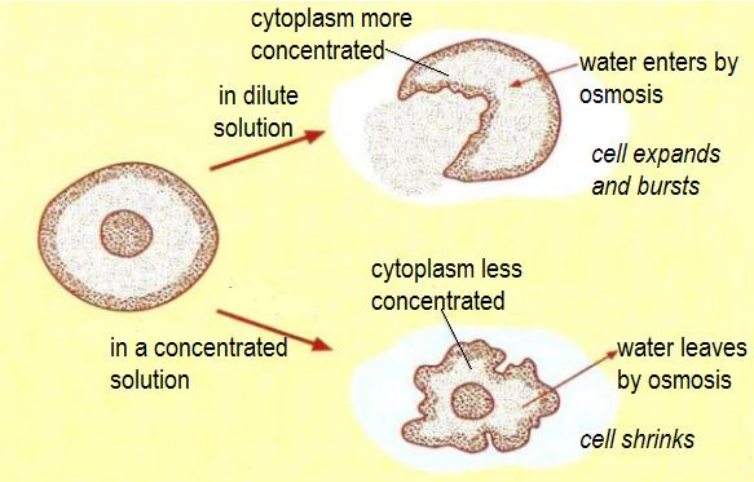
Unlike plant cells, animal cells like red blood cells lack a cell wall and only have a cell membrane which is delicate and cannot resist stretching.

When red blood cells are placed in a dilute solution (hypotonic solution) i.e. distilled water, the cells will take in water through osmosis, the volume increases and the membrane eventually *bursts* ***(haemolysis***).

When the red blood cells are placed in a more concentrated solution (hypertonic solution) e.g. a strong sugar solution, water moves out of the cells to the surrounding solution by osmosis. The cell volume decreases. The cell encloses less contents and it appears wrinkled. This is known as **crenation**.

However, when red blood cells are placed in isotonic solution they neither gain nor lose water.

Hemolysis and crenation in a red blood cell



Revision question

Red blood cells are sensitive to changes in the ion concentration of an external solution. The cells shrink when immersed in a highly concentrated salt solution. They burst or haemolyse when immersed in a low concentrated salt solution. The table below shows the percentage of red blood cells that haemolyse at different salt concentrations. Use the information to answer the questions that follow.

% salt concentration	*0.30*	*0.35*	*0.40*	*0.45*	*0.50*	*0.55*
% red blood cells haemolysed	*100*	*95*	*85*	*50*	*20*	*0*

a) Plot a graph to represent the data above with the percentage of salt concentration on the horizontal axis and the percentage of the haemolysed red blood cells on the vertical axis.

b) At what percentage of salt concentration are all red blood cells haemolysed?

c) At what percentage of salt concentration are the number of haemolysed cells equal to non-haemolysed cells?

d) Briefly explain the process of haemolysis.

e) What would you expect to happen to the red blood cells if they are placed in 0.6% salt solution?

f) From the figures given in the table, suggest the safest percentage of salt concentration for human blood. Give reasons for your answer.

Source: Maina, A., Kelemba, J. & Majani, D. Comprehensive Secondary Biology Form 2 (Oxford, 2004)

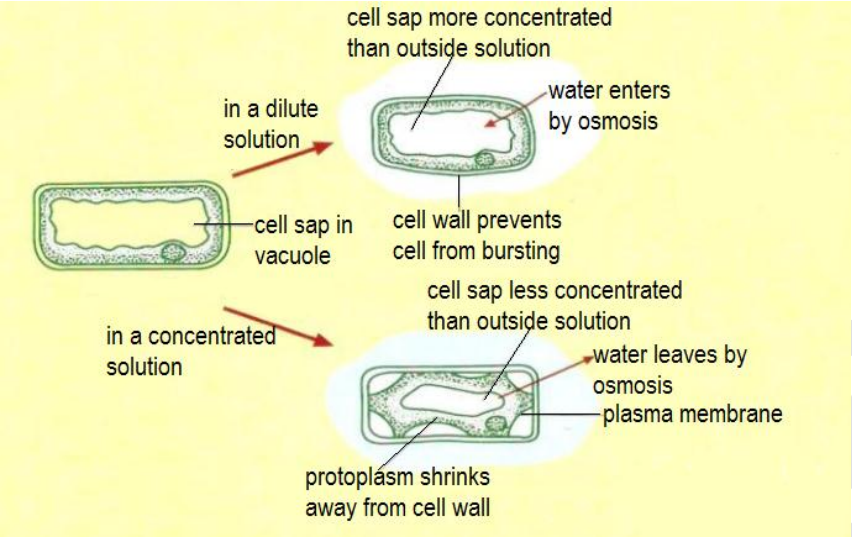
Osmosis in plant cells

Plant cells possess a rigid cell wall which prevents the cell from bursting.

When a plant cell is placed in a dilute solution (water) than the cell sap, water enters by osmosis through the semi permeable cell wall and cell membrane into the cell sap. The volume of cell sap increases and it makes the sap vacuole expand. This causes the protoplasm move towards the cell wall thus gaining ***turgidity***. Time comes when the protoplasm is pressing against the cell wall and no more water can be absorbed. At this state, the cell is said to have gained ***full turgidity*** and the force on the cell wall is called ***turgor pressure***.

When the cell is placed in a more concentrated solution than its cell sap, water moves from the cell sap through the cytoplasm then the cell wall, to the surrounding solution. This causes the vacuole to shrink and the protoplasm to lose contact with the cell wall and the cell is said to have become flaccid or plasmolysed. Therefore, a flaccid cell is one whose protoplasm has lost contact with the cell wall due to loss of water from the cell sap of the vacuole by osmosis.

Diagram showing plasmolysis in a plant cell



Experiment to demonstrate turgor and plasmolysis in a plant tissue

Materials: Cock borer, test tubes, water**,** Irish potato**,** razor blade and sucrose.

Procedure

- Get four test tubes and pour ¾ of water in 3 of them and leave one empty.
- Mix the sucrose in one test tube to make 5% sucrose solution.
- Mix sucrose in another test tube to make 50% sucrose solution.
- Leave one test tube with pure water and the forth test tube empty.
- Using a cock borer, make 4 potato cylinders of the same length e.g. 3.0 cm. Name this the initial length.
- Deep the potato cylinders in each test tube.
- Leave the setup to stand for about one hour.
- Remove the cylinder from each test tube and measure each length. Also feel the texture. Tabulate your results as shown in the table below.

Beaker	Initial length/cm	Final length/cm	Change in length/cm	% change in length	Texture (soft/tough)
Pure water	3.0	3.3	+0.3	+10.0%	Tough
5% sugar solution	3.0	3.0	0	0	Tough
50% sugar solution	3.0	2.8	-0.2	-0.67%	Soft/flaccid
Empty beaker	3.0	2.9	-0.1	-0.33%	Soft

Observation:

The cylinder in water had increased in length and became tougher.

The cylinder in 5% sucrose solution didn't change in length and the texture remained the same

The cylinder in 50% sucrose solution had decreased in length and become soft, flaccid and curved.

The potato in the empty beaker decreased in length.

Conclusion: Turgor and plasmolysis occur in plant cells.

Explanation

- The cylinder in water increased in length because water molecules moved into it from the surrounding water by osmosis because the cell sap had a higher concentration than the surrounding water.
- There was no change in length for the cylinder in 5% sucrose solution because the solution had the same concentration as the cell sap of a potato cylinder hence no net osmosis.

- There was a decrease in length for the cylinder in 50% sucrose solution because water molecules moved out of the cylinder which had a lower concentration by osmosis.
- There was a decrease in length for the cylinder in the empty beaker because water was lost to the surrounding by evaporation.

Significance of osmosis in plants

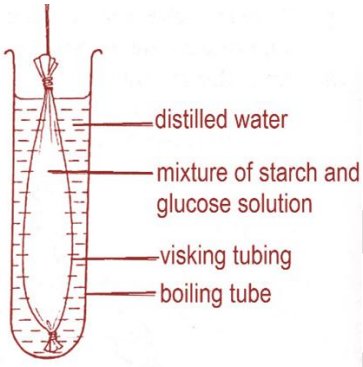
i) Absorption of water by root hairs from soil
ii) It enhances movement of water from root hairs via the cortex to the xylem.
iii) For support in non- woody plants.
iv) It facilitates opening and closing of stomata.

Significance of osmosis in other organisms including animals

i) Movement of water in to unicellular organisms.
ii) Movement of water from tissue fluid to the cell.
iii) It enables reabsorption of water into the blood stream via the kidney tubules.

Revision questions

1. *Define cell physiology?*
2. *State factors that affect diffusion.*
3. *In the experimental set up shown below, a student took samples of water from the boiling tube. This was done at the beginning of the experiment and after twenty minutes.*



The student tested the samples from the boiling tube for starch and glucose, and recorded the results as shown in the table below.

Time (mins)	***Test for starch***	***Test for glucose***
Start (0 mins)	*Absent*	*Absent*
After 20 mins	*Absent*	*Present*

a) Give an explanation for the:
i) Presence of glucose in the water
ii) Absence of starch in the water sample

b) During the experiment it was noted that the levels of the distilled water in the boiling tube and the liquid inside the visking tube had changed. What changes occurred in the: (i) Boiling tube? And (ii) Visking tube?

c) Briefly explain the changes observed above.

Source: Maina, A., Kelemba, J. & Majani, D. Comprehensive Secondary Biology Form 2 (Oxford, 2004)

4. *Six identical potato cylinders measuring 2.0 cm in length were each placed in a different concentration of sugar solution. After two hours, the potato cylinders were removed from the solutions and re measured. The table below shows the results.*

Concentrations of sugar solutions in mol l^{-1}	*0.1*	*0.2*	*0.3*	*0.4*	*0.5*	*0.6*
Length of potato cylinders after 2 hours (cm)	*2.40*	*2.25*	*2.15*	*2.05*	*1.98*	*1.02*
Difference in length of potato cylinders after 2 hours (cm)						

(a) Complete the table by filling in the difference in length of each potato cylinder after two hours.
(b) Plot a graph of the difference in length after 2 hours against concentration of sugar solutions.

(c) What was the effect of the concentration of the sugar solutions on the length of the potato cylinders?

(d) Explain why the concentration of the sugar solutions affected the length of the potato cylinders as stated above.

(e) (i) From your graph, determine the concentration of the sugar solution that would give no difference in length of a potato cylinder.

(ii)Explain what happens in a potato cylinder when no change in length occurs.

(f) Suggest one other observation other than change in size that would be made on the potato cylinders.

Source: Unknown

TRANSPORT IN PLANTS

Transporting tissue in plant is ***xylem and phloem***. It involves movement of water, salts and organic molecules (manufactured food).

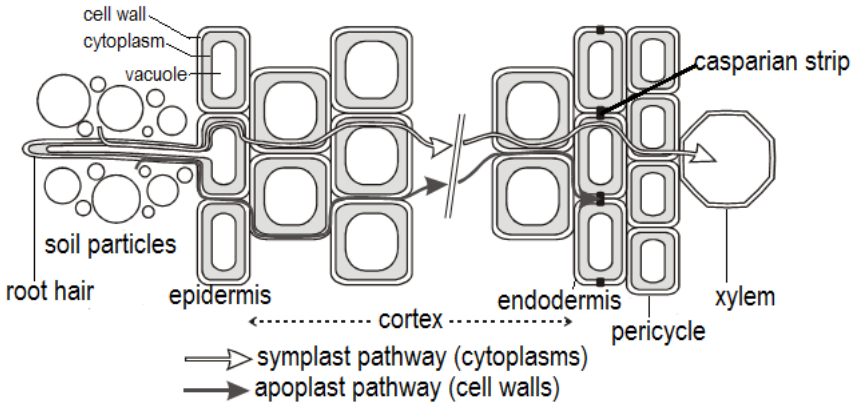
Water absorption by the root hairs to the xylem

Up take of water also called absorption is a continuous stream through the plant. Root hairs in the soil are surrounded by a film of water containing mineral salts/soil solution.

The soil solution once inside the root hair vacuole is called cell sap and has a lower osmotic potential than the soil solution. **Osmotic potential** is the pressure which must be applied to prevent osmosis into a solution when separated from pure water by a semi-permeable membrane. The cell membrane of the root hair is semi permeable.

The above conditions enable water to move from the soil, pass through the cell membrane into the vacuole by osmosis.

Root hair vacuoles contain a high concentration of solute than the surrounding water. Water is absorbed by root hairs by osmosis. This causes the root hair vacuoles to become less concentrated than those of the adjacent cortex cells. Water is then passed into the cortex cells by osmosis and it then enters the xylem tissue.



Water moves through the root cortex from cell to cell by 3 path ways:

i) Some of the water flows along the cell walls (Apoplast).

ii) Some water travels in the cytoplasm (Symplast).

iii) Most of the water moves from vacuole to vacuole.

The inner most region of cortex (endodermis) is made up of an impermeable casparian strip which controls the entry of water from the cortex into the xylem.

Adaptations of the root hair to water absorption

i) The root hair is slender and flexible and can therefore flow between the soils particles.

ii) They are numerous which increase the surface area available for water absorption.

iii) They lack the cuticle which would restrict water absorption.
iv) They are long and narrow which increases surface area to volume ratio that increases the rate of water absorption.
v) The cytoplasm of the root hair contains numerous mitochondria where respiration occurs to release ATP needed for active transport of mineral salts from the soil solution to the cytoplasm of the root hairs.
vi) At the centre of the root hair is a vascular tissue which transports water and mineral salts to the rest of the plant.
vii) The cell sap of the root hair contains sugars, amino acids and salts, and so it's concentrated than the soil solution and this low osmotic potential enables water to enter it by osmosis.

Movement of water through the stem to the leaves

Once the water reaches the xylem vessels, it rises up the stem xylem by the following forces:

1. Capillarity:

This is the ability of water to move up a tiny tube. It is usually caused by the surface tension but because the capillary tube is narrow, the water rise is limited.

2. Cohesion – tension forces:

This is a force of attraction between the molecules of the same substance. Cohesion between water molecules allows water in a continuous column without breaking. This occurs because as water is lost by transpiration from the leaves, the water potential at the top of xylem vessels falls below that at the bottom of the xylem in the root. Water is now pulled by this potential difference because of the cohesion of the water molecules.

3. Adhesion:

This is the force of attraction between molecules of different substances. Adhesion forces between walls of xylem and water molecules support a considerable weight of water within the xylem tissue and prevent the water in the xylem vessels from collapsing.

4. Root pressure:

This is regarded as the pressuring force of the water up the stem from the roots.

It is affected by the same factors that affect respiration in living cells like oxygen supply, temperature, starch supply and the presence of respiratory poison like cyanides.

The root pressure theory has been suggested as a result of a common observation that water tends to exude from the cut stem indicating that some pressure in a root is actually pushing the water up. However, like capillary, root pressure is not sufficient on its own to push water to the leaves of the plant at the top of the tree and can slowly cause guttation in transpiring herbaceous plants.

5. Transpiration pull:

This is the pulling force generated by the evaporation of water from the leaves. This is caused when the cells of the spongy mesophyll layer in the leaf lose water by evaporation into the air spaces causing their cell sap to become more concentrated and as a result they draw the water from the surrounding cells by osmosis. These cells in turn get water from the xylem in the veins and then water from the xylem moves to replace the lost water by evaporation. This evaporation sets up the passing action on water in the xylem called transpiration pull.

Importance of water to the plant

- Raw material for photosynthesis.
- Solvent for mineral salts and oxygen that enable them to diffuse into the roots.
- It is a constituent of the cytoplasm and all sap of the growing plants.
- Provides turgidity which provides support in non woody plants.
- Cools the leaves of the plants during transpiration.

Absorption of mineral salts by the root hairs

Mineral salts are moved in the plant in the xylem in solution with water. Roots absorb mineral salts in form of ions by diffusion and active transport. Active transport is the movement of the materials against the concentration gradient by the use of energy released from respiration.

Revision questions

1. *A student did an experiment to find the effect of oxygen on the uptake of bromide ions by the roots of barley plants. The temperature was kept at 17^0C.*

	Uptake (relative units)
Oxygen present	*100*
Oxygen absent	*10*

   a) *Why was the temperature kept at 17^0C?*
   b) *What effect does oxygen have on the uptake of ions by the roots?*
   c) *What do the results suggest about the way ions are taken up by the roots?*

2. *A scientist investigated the uptake of mineral salts by the roots of young barley plants. What conclusion can be drawn from these findings and how might they help farmers?*
   a) *Salts were taken up even when they were more dilute in the soil water than inside the root.*
   b) *The rate of uptake was increased by raising the temperature, so long as it did not exceed 40^0C*
   c) *Uptake stopped if the roots were treated with a poison that stopped respiration.*
   d) *Uptake was much slower if the soil was water logged.*

Source: *Roberts, M., Biology (Nelson science)*

TRANSPORT OF THE PRODUCTS OF PHOTOSYNTHESIS

The process by which the soluble products of photosynthesis are carried in plants is called **translocation.** Translocation is the movement of manufactured food from the side of photosynthesis. Throughout the plant, sugars and amino acids are transported in the phloem from the leaves to the growing parts of the plant or storage organs. Food substances may also move from the storage organs to the growing regions of the plants. In the phloem, food substances can move upwards or down wards.

The translocation process

The process of photosynthesis leads to accumulation of food substances in leaves. This causes a high turgor pressure within the leaves.

Food substances in the roots are used for respiration or they are stored in the storage organs and these results in the low turgor pressure in the root cells. The difference between turgor pressure in the roots and leaves enables the food substances to move from leaves to other parts of the plant by a process called ***mass flow*** which is the major process of translocation.

There is also a minor process i.e. active transport where the sugars e.g. sucrose are actively transported from leaves to the storage organs.

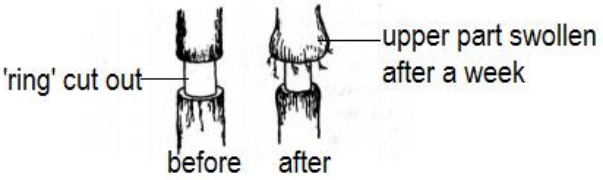
Evidence to show that food made in leaves is translocated by the phloem

1) The Ring Experiment:

Remove a ring of the bark from the stem at a point between the ground and the upper leaves. Leave another plant with the ring on. The plants are left to stand for one week after which the observation is made.

Observation

The upper part of the ring on the stem swells immediately above the ring while the lower part of the ring remains unswollen. The unringed plant remains unchanged.



Conclusion: The phloem transports manufactured food.

Explanation

When a ring is cut through the bark of the stem, the phloem tissue is removed along with it since it's found within the bark.

This cuts off the supply of manufactured food to the lower parts of the plant, as a result, the phloem in the upper part of the stem will transport the food to the part just above the ring.

The food will then accumulate in this part hence it will swell. When the ring is removed, the tree or plant also dries because the food supply to the root is cut off therefore the stored food in the roots gets exhausted and the roots die.

2) Feeding Aphids:

When the proboscis of the sucking aphid is cut, it is found to have penetrated into the phloem tube and when its contents of the proboscis are analyzed, it is found to contain products of photosynthesis (sucrose) which are transported to the bark through the phloem.

3) Radio Active Tracers:

If a plant is exposed to CO_2 labeled with radioactive C-14, the C-14 becomes incorporated into the end products of photosynthesis which are subsequently detected in the stem. That these substances are confined to the phloem and can be shown by cutting sections of the stem, placing the sections in contact with photographic film and making auto radiographing it is found that the sites of radioactivity correspond precisely to the positions of the phloem.

TRANSPIRATION

This is a process by which plants lose water in form of water vapour mainly through leaves to the atmosphere. Transpiration can also occur from flowers.

Types of transpiration

1. **Stomatal transpiration:** This is the transpiration through the stomatal opening. This contributes up to 80-90% of water lost.
2. **Cuticular transpiration:** This occurs through the leaf cuticle which amounts for about 20% of the water lost.
3. **Lenticular transpiration:** This occurs through the stem pores called lenticels and accounts for about 0.1% of the water lost.

Water can also be lost from the plants as water droplets in a process called guttation through special structures found on leaf margins.

An experiment to show that water is lost mainly from leaves during transpiration

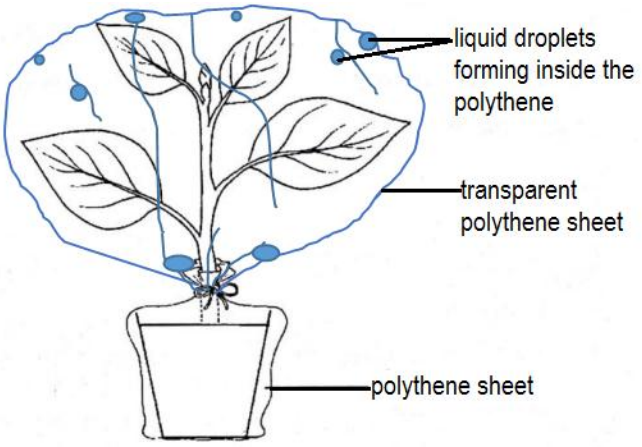
Apparatus:

Potted plant, transparent polythene sheet, thread and Cobalt (II) chloride paper or anhydrous copper (II) sulphate.

Procedure

i) Tie polythene sheet around the tin of the potted plant. Using a string to avoid evaporation of water from the soil surface.
ii) Tie a transparent polythene sheet around the leafy shoot of the plant.
iii) Set up another similar control experiment but with leaves removed and dry plant.
iv) Leave the experiment to settle for 3 hours in bright sunlight.
v) Remove the polythene sheet around the leafy shoot and test the drops of liquid inside the polythene using anhydrous copper (ii) sulphate / cobalt (ii) chloride paper.

Potted plant wrapped in polythene sheet



Observation

Vapour forms inside the polythene and condenses to liquid droplets that turn anhydrous copper (II) sulphate from white to blue or blue cobalt (II) chloride paper to pink.

No vapour is observed in the set up with no leaves / dry plant.

Conclusion: Transpiration occurs mainly through the leaves.

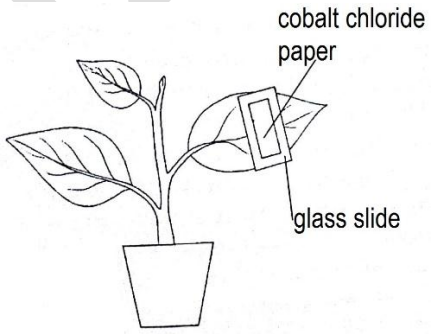
Note: A control experiment may also be a covered pot where the plant shoot has been cut off.

Experiment to compare transpiration rates on both surfaces of a leaf

Apparatus: Potted plant, glass slide**, c**obalt (II) chloride paper

Procedure

i) Fix pieces of Cobalt (II) chloride paper on the upper and lower surfaces of a leaf still attached onto the plant with glass slides.
ii) Tie the slides using the rubber bands.
iii) Note the time taken for the Cobalt (II) chloride paper on each slide to change colour from blue to pink.



Observation

The lower surface cobalt (II) chloride paper turns pink faster than that on the upper surface.

Conclusion

The lower surface has a higher transpiration rate than the upper surface because the lower surface has many stomata whereas the upper surface has fewer stomata.

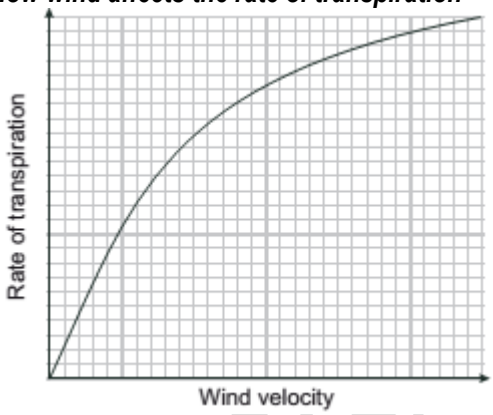
Factors that affect the rate of transpiration

Anything that increases the water potential gradient between the air spaces in the leaf and air outside, or that speeds up the movement of the water molecules, will increase the rate of transpiration.

i) **Humidity:** humidity is a measure of how much water vapour is held in the air. In conditions of low humidity – that is, when the air is dry – there is a steep water potential gradient between the leaf and the air. Transpiration rates are therefore greater in low humidity than in high humidity.
ii) **Temperature:** an increase in temperature causes an increase in the kinetic energy of water molecules. This increases the rate of evaporation of water from the cell walls into the air spaces, and also the rate of diffusion of the water vapour out of the leaf. An increase in temperature therefore increases the rate of transpiration.
iii) **Light intensity:** light does not normally have any direct effect on the rate of transpiration during the daytime. However, many plants close their stomata at night, when it is dark and they are unable to photosynthesis and so do not need to use carbon dioxide from the air.

iv) **Air movements:** the more the air around the plant's leaves is moving, the faster the humid air surrounding them is carried away. This helps to prevent the leaf becoming surrounded by air that is saturated with water vapour, and maintains a water potential gradient from the air spaces inside the leaf to the air outside. Transpiration therefore happens faster on a windy day than on a still day.

How wind affects the rate of transpiration



v) **Plant structure:** transpiration occurs from the surface of leaves and green stems. For plants that need to conserve water, reducing the area of these surfaces will limit the rate of transpiration. This can be done by ***dropping*** leaves in dry seasons, having small leaves or having no leaves (relying on green stems for photosynthesis).

vi) **Leaf anatomy:** a number of structural features can reduce the rate of transpiration, even when stomata are open. All of these features act by trapping still air outside the stoma. This increases the distance water has to diffuse before it can be carried away in the mass flow of air in the wind. The further the distance water has to diffuse, the slower the rate of transpiration.

This is achieved by one of the following;

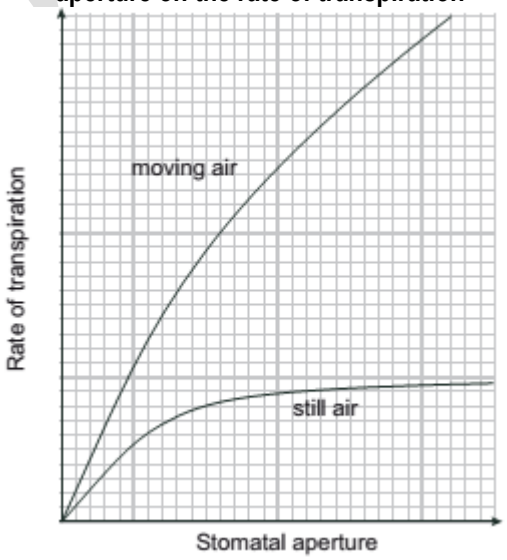
- Having stomata set in pits.
- Having more stomata on a leaf surface that is on the inside of a rolled leaf than the upper surface.
- Having dense hairs on the leaf surface.
- Having a thick layer of waxy cuticle on the leaf.

vii) **Stomatal aperture:** in many plants, stomata close at night.

In especially dry conditions, the plant may close its stomata even when light levels are ideal for photosynthesis, to avoid losing too much water from its leaves. There is often a compromise to be reached between allowing in enough carbon dioxide for photosynthesis, and not letting out too much water vapour. The rate of transpiration is higher at larger aperture.

However, if you look at the graph, you will see that in still air, the increase in the rate of transpiration is very little at larger apertures, whereas in windy conditions, the rate continues to increase even with larger apertures.

The effects of wind velocity and stomatal aperture on the rate of transpiration



viii) Surface area for transpiration: Plants with wide/broad leaves have a larger surface for transpiration thus they experience a higher rate of transpiration.

Experiments to measure the rate of transpiration

1. The weighing method:

This is where a potted plant is weighed on the weighing balance to determine the difference in weight before and after transpiration. The difference in weight shows the amount of water lost by the plant in a given period of time.

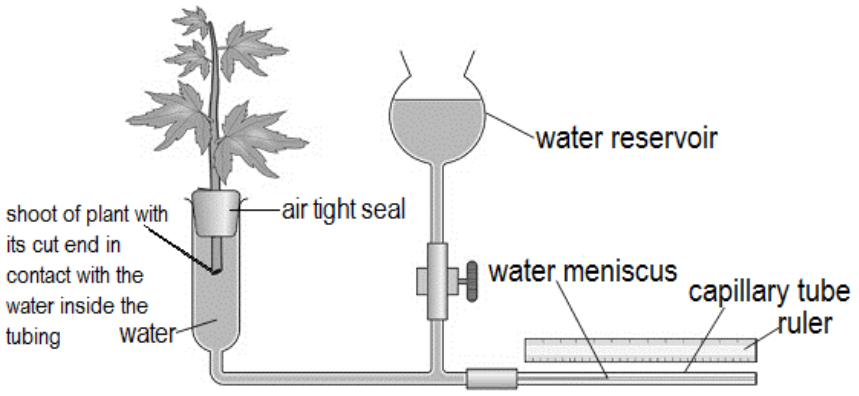
2. Potometer method:

This is done using an instrument called a potometer. The potometer works on assumption that water lost from the leaves during transpiration equals water absorbed by the plant.

Therefore the potometer:

- ✓ Directly measures the rate of water uptake/ absorption of the shoot and
- ✓ Indirectly measures rate of water loss / evaporation of water/ transpiration from the leaves.

Set up of a potometer



Procedure:

i) A leafy shoot of a plant is cut under water to prevent air bubbles from entering as these would block the xylem vessels.
ii) The leafy shoot is fixed into the air-tight seal (cork) and then fitted into the mouth of the potometer vessel full of water.
iii) Vaseline is smeared at the interface of the shoot and the cock to prevent entry of air into the apparatus.
iv) A meniscus is set inside the capillary tube and its cm level with the ruler is noted and recorded. V_1
v) At a given mark V_1, reached by the meniscus, a stop clock is started and after a given time t, the new position of the meniscus, V_2, is noted and recorded.

Rate of transpiration= $\frac{distance\ moved\ by\ the\ air\ bubble}{time\ taken}$

$= \frac{V2-V1}{t}$

vi) In any given set of environmental conditions, about 3 experiments can be performed, resetting the meniscus after each experiment by opening the tap and then closing it.
vii) Average rate is then calculated and taken as the rate of transpiration in that environment.

Precautions taken when using a potometer in order to ensure that accurate results are obtained

- A leafy shoot should be used to ensure significant water loss.
- The shoot must be cut under water to prevent air from entering and blocking the xylem vessels.
- The whole apparatus must be full of water.
- There should be no air bubbles in the capillary tube.
- The meniscus should not be allowed to go past the ruler calibrations.

Adaptations of plants to reduce transpiration rate

i) Shedding off of leaves in deciduous plants to reduce transpiration since most of it occur from the leaves
ii) Reducing the number, size and distribution of the stomata and only on lower epidermis
iii) Structural adjustments in stomata i.e. some plants have sunken stomata and others have hairy stomata which reduces evaporation from them.
iv) Reduction in leaf structure i.e. some plant leaf are reduced to narrow or thorny / spines structures that reduce surface area over which transpiration occurs.
v) Rolling of leaves to create a humid atmosphere around the stomata in order to reduce water loss.
vi) Possession to thick cuticle of the leaves to prevent water loss through it.
vii) Thick leaves that store water
viii) Changes in the rhythm of stomata opening i.e. they close during day and open at night when temperatures are very low.
ix) They shed off their leaves in extremely hot environment to cut down water loss.

Importance of transpiration (functions/advantages)

i) Results in the absorption of water and its movement up the plant to aid processes like photosynthesis.
ii) Contribution to maintenance of continuous stream of water throughout the plant.
iii) Transported water keeps the plant cells turgid and cools the plant.
iv) Results in the movement of mineral salts up the plants to where they are needed.

Disadvantages / dangers of transpiration

i) Excessive water loss from the plant may lead to wilting, drying and even death of the plant.
ii) Water may lead to over cooling which affect metabolic activities
iii) Over absorption of mineral salts with water lead to soil exhaustion.

Revision questions

1. *A freshly cut leafy shoot was set up in a simple potometer made of a capillary tube. The number of minutes taken for the bubble to run over 15cm in the tube was recorded with the potometer set under different environmental conditions, as in the table below:*

	Environmental conditions			
	A	*B*	*C*	*D*
Time taken to run over 15 cms (in mins)	*60*	*50*	*25*	*75*
Rate of bubble movement cm/min				

   a) *Calculate the rate of bubble movements in conditions A, B, C, D and fill in the table above.*
   b) *What does the rate of bubble movement under each conditions represent in this experiment?*
   c) *Give at least 2 important precautions you would take when setting up the shoot in the potometer, to ensure that the apparatus works well.*

2. *Suggest a reason for the following:*
   a) *It is better to water plants in the evening than in the middle of the day.*
   b) *Before transplanting a plant it is a good idea to remove some of its leaves.*
   c) *Water moves up a stem more quickly on a day than on a humid day*
   d) *In very humid conditions water may drip from leaves.*
   e) *When a greenfly feeds on a plant it sticks its proboscis into the phloem.*
   f) *If a tree is felled, a watery liquid may ooze out of the stump for a while.*

3. *Explain how the following features helps plants that live in hot, dry places to cope with the shortage of water in their environment.*
   a) *Thick cuticle covering the leaves*
   b) *Small leaves*
   c) *Stomata sunk down into pits in the epidermis*
   d) *Very deep roots.*
   e) *Roots just beneath the surface of the soil.*

Source: Roberts, M., Biology (Nelson science)

TRANSPORT OF MATERIALS IN ANIMALS

Smaller organisms (protozoa) that have large surface area to volume ratio carry out transport by simple diffusion.
Transport system is important in large organisms (multicellular) because the increased size of the organisms and the great distance over which materials are supposed to move makes diffusion rate slow which in turn make it inadequate for the distribution of these materials.
To overcome the physical limitation on size placed by diffusion, multicellular animals have the major adaptations. They have organs that provide a large surface area for absorption of nutrients such as small intestines and exchange of gases such as lungs/ gills, without a great increase in total body volume. They have a transport (circular) system within the body, so that substances can be carried to cells that need them and waste products removed more quickly than in diffusion.

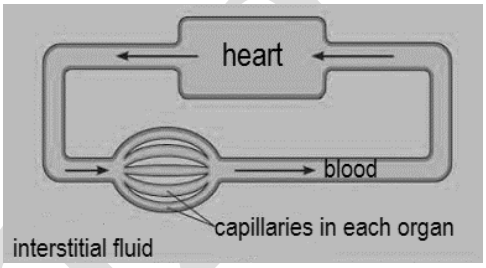
Plants do not need a circulatory system because:

- The oxygen requirement of the plant is very low as compared to mammals.
- Plants have a continuous series of airspaces throughout the body opening to the atmosphere by the stomata and lenticels.
- Oxygen from the air diffuses through the stomata opening in to the airspaces and from the air spaces in to the cells by diffusion. The oxygen dissolved in the soil water also diffuses through the root hairs in to the cell sap.
- The carbon dioxide produced during respiration is used up during photosynthesis.

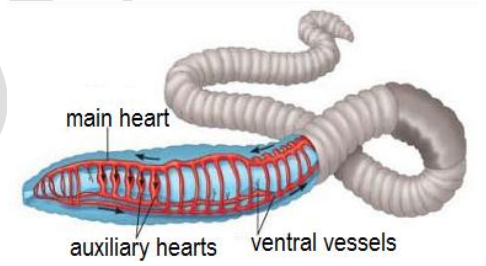
CIRCULATORY SYSTEMS IN ANIMALS

1. Closed circulatory system:

Closed circulatory system e.g. in earthworm, fish and mammals have blood confined in tubes. Here blood is pumped by the heart to tissues through the arteries and return to the heart through the veins. The arteries and veins are connected by capillaries which are thin walled. The body cells do not come in to direct contact with blood but are bathed in the tissue fluids. Substances diffuse out of the blood which is confined to blood vessels into the tissue fluid and then across to cell membrane into the cell.



Closed circulation



Closed circulation in an earth worm

Advantages of closed circulatory system

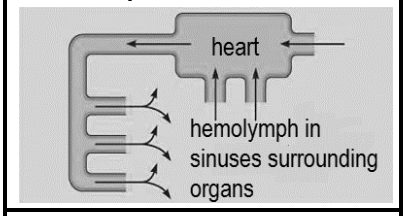
- ✓ Distribution of blood/materials is easily controlled.
- ✓ Blood flows very fast leading to quick supply of materials.
- ✓ Blood flows at a high pressure leading to an effective system.

Demerits of closed circulatory system

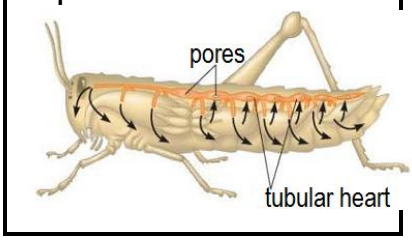
- ✓ It requires a special heart whose pumping action provides pressure for movement of blood. Blood movement meets a high resistance within vessels.

2. Open circulatory system e.g. in mollusks and arthropods

Here, the circulatory fluid is pumped into open spaces and it bathes the organs directly. The circulatory fluid, called ***hemolymph*** is also the interstitial fluid. Contraction of one or more hearts pumps the hemolymph through the circulatory vessels into interconnected ***sinuses*** (spaces surrounding the organs). Within the sinuses, exchange of materials occurs between the hemolymph and body cells. Relaxation of the heart draws hemolymph back in through pores, and body movements help circulate the hemolymph by periodically squeezing the sinuses



Open circulation



Open circulation in an insect

Advantages of open circulatory system

- ✓ Easy diffusion of materials due to absence of vessel barriers.
- ✓ It does not require special pumping hearts since blood is flowing through cavities with less resistance.

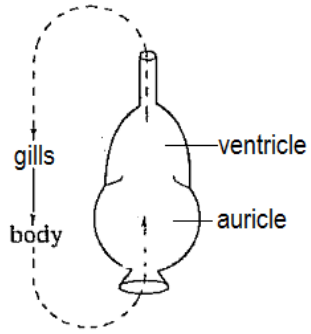
Disadvantages of open circulatory system

- ✓ There is little control over distribution of materials or blood.
- ✓ Blood flows sluggishly/slowly at a low pressure leading to slow supply of materials.

TYPES OF CLOSED CIRCULATORY SYSTEM

1. Single circulatory system:

Single circulation in fish



This is the type of circulation where deoxygenated blood from the body tissues is pumped to the gills from where it flows to various parts of the body and then returns to the heart. It has a heart with only two chambers i.e. one auricle/atrium and one ventricle e.g. in fish. Blood flows only once through the heart for every complete circuit of the body.

2. Double circulatory system

In a double circulatory system, blood is pushed out in the heart in to a series of capillaries and the blood passes through the heart twice in each circulation. It involves two separate circulation i.e.

- Pulmonary circulation to the lungs
- Systemic circulation to the rest of the body

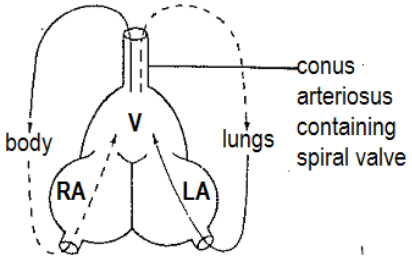
That is, blood from the right ventricle is pumped into the lungs through the pulmonary artery and return to the left atrium via the pulmonary vein and this is called **pulmonary circulation.**

Blood from the left ventricle is pumped through the aorta to the rest of the body and returns to the right atrium through the vena cava and this is called **systemic circulation**

Double circulation is further divided into 2;

- Incomplete double circulation
- Complete double circulation

Incomplete double circulation



Incomplete double circulation: This is a system in which blood flows through the heart twice for every complete cycle through a partially divide heart with three-chambers. The heart has one ventricle through which both oxygenated and deoxygenated blood from the two atria flow.

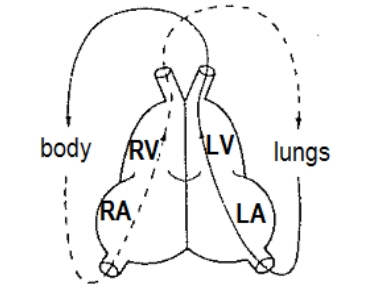
Mixing of oxygenated and deoxygenated bloody is prevented by ridges present in the ventricle. This system of blood circulation is found in amphibians like frogs.

Complete double circulation: blood flows through the heart twice within a four-chambered heart for every complete cycle of circulation.

Mixing of oxygenated and deoxygenated blood is prevented by a wall called septum.

It is found in birds, reptiles and mammals.

Complete double circulation



Advantages of double circulatory system

- ✓ Blood is pumped directly to where it's needed.
- ✓ There is complete separation of oxygenated and deoxygenated blood which improves efficiency of oxygen distribution and can therefore sustain the high metabolic rate required by such animals that possess it.
- ✓ Pumps blood at a high pressure.

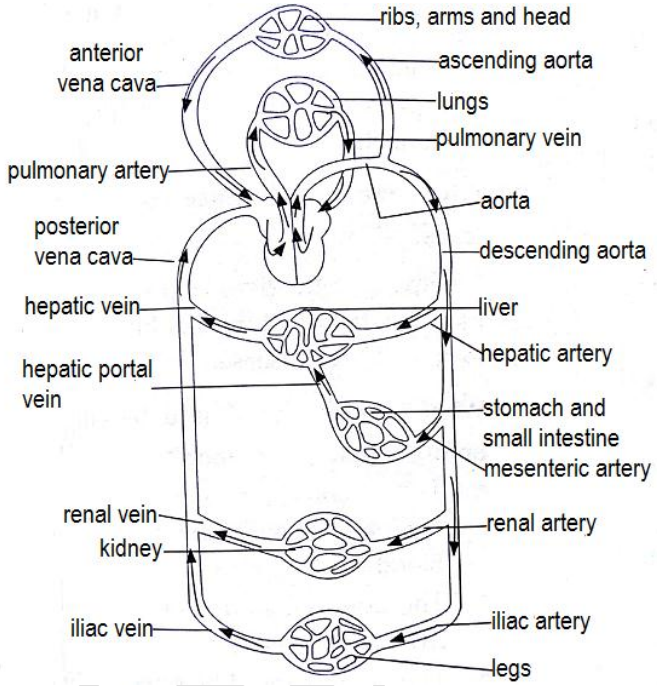
Note: The amount of blood flowing to a certain organ can be regulated by changing the diameter of the blood vessel.

THE MAMMALIAN CIRCULATORY SYSTEM

The continual circulation of blood in mammals is due to the pumping action of the heart. The circulation of blood in mammals is divided into two. That is;

1. **The pulmonary circulation**; this is the circulation of blood from the heart to the lungs and from the lungs back to the heart. This type of circulation involves the pulmonary artery and pulmonary vein.
2. **The systemic circulation**; this is the circulation of blood from the heart to the rest of the body apart from the lungs and from the rest of the body back to the heart.

Diagram showing the flow of blood in a mammal



BLOOD VESSELS

These are the tubes that carry blood throughout the body and they include: arteries, veins, and capillaries

Arteries and veins both have three layers in their walls but the layer of the muscles (elastic tissue).is much greater in arteries than in the veins.

1. ARTERIES:

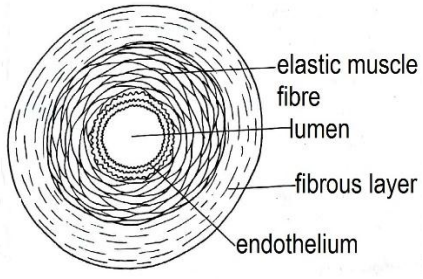
These carry blood from the heart to the body capillaries. Arteries divide into smaller vessels called arterioles which then divide repeatedly to form capillaries.

They have no valves except at the base of the pulmonary artery and aorta.

They carry oxygenated blood except the pulmonary artery and umbilical artery.

They all carry blood from the heart to other parts of the body.

Transverse section of an artery

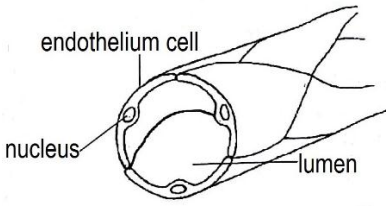


Adaptations of arteries to their functions

- Has three layered wall which is strong to withstand the high pressure resulting from pumping action of the heart.
- They have fibrous outer wall so as to withstand high pressure
- Their walls are elastic to allow stretching due to high blood pressure.
- They have narrow lumen than veins which maintains blood flow at high pressure.

2. CAPILLARIES

Transverse section of a blood capillary



These are the smallest blood vessels with thin walls to allow diffusion of materials between blood and the tissue fluid. They connect arterioles to venules.

They pass very close to the cells taking to the cells food, oxygen, and mineral salts etc. as well as taking a way carbon dioxide, urea and other waste products from the cells.

They are responsible for the exchange of materials between blood and cells, because their walls are permeable allowing water, dissolved food substances to pass through except proteins because they have large molecules.

Blood pressure reduces in them as a result of their resistance, and blood flows in them slowly without pulse. The capillaries network is so dense and the capillaries unite to form large vessels called venules which join to form veins.

Adaptations of capillaries to its functions

- They have a large surface area for exchange of materials.
- They have very thin walls for faster diffusion of materials.
- Slow movement of blood in capillaries makes exchange of materials efficient.

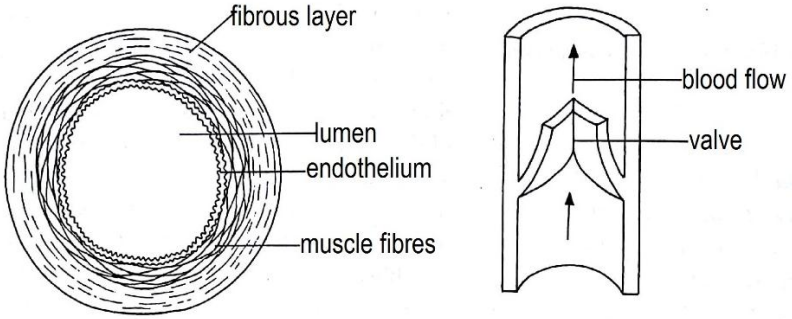
3. VEINS

These carry blood from tissues to the heart. The pressure in them is steady and less than in arteries. All veins carry de-oxygenated blood except pulmonary vein. They have less elastic muscles.

Blood in the veins flows slowly after losing pressure in the capillaries; however the sluggish flow of blood is maintained by:

- Possession of valves which prevent back flow.
- Having a wide lumen that offers a low resistance to blood flow.
- Action of skeletal muscles against veins as they contract during movement increases blood pressure in veins.
- Inhaling lowers the pressure in thoracic cavity leading to flow of blood towards the heart.

Transverse section of a vein **transverse section of a vein**



Characteristics of veins (Adaptations)

- They have wide lumen to encourage flow of blood at low pressure.
- They have thinner walls than arteries which are adequate to withstand low pressure.
- They have valves at intervals along their length which prevent blood from flowing backwards or maintain flow of blood in one direction

Structural differences between arteries, veins and capillaries

Artery	Veins	Capillaries
Have thick muscular walls	Veins have thin and less muscular walls	Have thinner walls
have more elastic fibres	Have few elastic fibres	Do not have elastic fibres
Have smaller lumen relative to diameter	Have a wider lumen relative to diameter	Have largest lumen relative diameter
Have no valves except at the base of aorta	Have valves throughout their length	Have no valves
Can constrict	Can't constrict	Can't constrict
Walls not permeable	Walls not permeable	Walls permeable

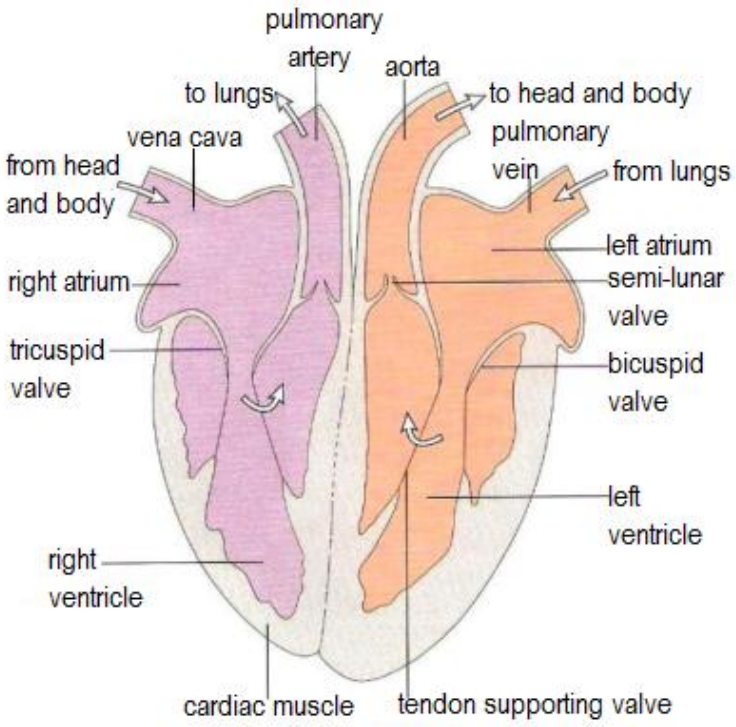
Functional differences between arteries, veins and capillaries

Artery	Vein	Capillaries
Transport blood away from the heart to organs and body tissues.	Transport blood from body tissues and organs to the heart.	They connect arteries to veins.
Transport oxygenated blood except pulmonary artery and umbilical artery	Transport deoxygenated blood except pulmonary vein and umbilical vein	Transport both oxygenated and deoxygenated blood
Blood flows rapidly at high pressure.	Blood flows slowly at low pressure	Blood flows slowly at low pressure
Blood flows in pulse	Blood flows smoothly.	Blood flows smoothly.

Revision questions

1. *Describe the movement of blood from the alimentary canal to the lungs in mammals.*
2. *Describe the route taken by urea made in the liver to where it is excreted.*
3. *Give ways in which the content of blood carried by the hepatic artery is different from that in hepatic portal vein.*
4. *How are veins and arteries suited to their functions?*
5. *How is blood flow in veins maintained?*

THE MAMMALIAN HEART



Its function is to pump blood around the body. The whole heart is surrounded by the pericardium which has two layers between which is the pericardial fluid that reduce friction between them.

The heart is made of tissues called cardiac muscles which have the potential to contract rapidly.

It's divided in to four chambers. The upper chambers are called atrium/auricle and the lower chambers are each called ventricle.

The heart is divided in to sections i.e. left and right by a muscular septum whose function is to prevent mixing of oxygenated and deoxygenated blood.

Blood flow in one direction in the heart is maintained by the presence of valves.

The auricles receive blood from all parts of the body while the ventricles pump blood to the body e.g. the left atrium receives oxygenated blood from the pulmonary vein and pump it to the left ventricle through the bicuspid valve.

The right atrium receives deoxygenated blood from the rest of the body from the vena cava and pumps it to the right ventricle via the tricuspid valve.

The ventricle walls are more muscular (have thicker walls) to generate a high pressure than those of the auricles because the auricle pump blood to shorter distance i.e. to the ventricle while the ventricles pump blood longer distances to body parts and lungs.

The walls of the ***left ventricle*** that pump blood in to the systemic circulation are thicker than those of the right ventricle which pump blood to pulmonary circulation.

Flow of blood through the heart:

Blood flows in to the heart from the rest of the body via the vena cava to the right atrium which pumps it to the right ventricle via the tricuspid valve.

The right ventricle pumps blood to the pulmonary artery to the lungs and blood flows back to the left atrium via the pulmonary vein which pumps it to the left ventricle via the bicuspid valve and then finally pumped to the rest of the body via the aorta.

THE CARDIAC CYCLE

This refers to the sequence of events by which the heart pumps and is refilled with blood. The cardiac cycle involves two phases:

- Re-filling of the heart with blood
- Pumping of blood

The pumping action of the heart consists of alternate contraction and relaxation of cardiac muscles in the walls of the heart. Contraction of cardiac muscles is called ***systole*** while relaxation is called ***diastole***.

During diastole, the cardiac muscles in the walls of the atria relax and expand; blood from the vena cava and pulmonary vein enter the atria and becomes filled with blood. The walls of the ventricles relax and expand while those of the atria contract, forcing blood from the atria into ventricles via bicuspid and tricuspid valves as semilunar valves remain closed.

During systole, cardiac muscles of the ventricles contract, forcing blood out of the heart via the semi lunar valves into the aorta and pulmonary artery. At this time, the atria relax and expand in order to be re-filled with blood. The cuspid valves close against high blood pressure to prevent the back flow of blood into the auricles. The closure of the valves produces the heart sound termed as '***lub'.***

After expelling blood, ventricles relax and their pressure lowers compared to aorta and pulmonary artery pressure.

This would cause back flow of blood to the heart but is prevented by sudden closure of the semi lunar valves. The closure of the semi lunar valves causes a second heart sound called '***dub'.***

The 2 sounds '***lub' and 'dub'*** are so close and often described as *'lub-dub'* and they form a single heartbeat.

Factors affecting the heart beat rate

- Exercise.
- Hormones in the body e.g. adrenaline
- State of health and diseases e.g. malaria
- Age i.e. it's faster in infants than adults.
- Body size i.e. it is faster in small organisms than large
- Sex i.e. faster in female than in male.

NB: In normal adults at rest, heart contracts about 70 to 72 times per minute.

BLOOD

Blood is a connective tissue made up of cells suspended in a fluid matrix called ***plasma.*** There are two types of cells in blood i.e. **White blood cells (leucocytes) and red blood cells (erythrocytes)**. The **platelets (thrombocytes)** are **fragments of cells.**

In an adult human being, there are five to six liters of blood with blood making up approximately 10% of the body weight.

Main components of blood

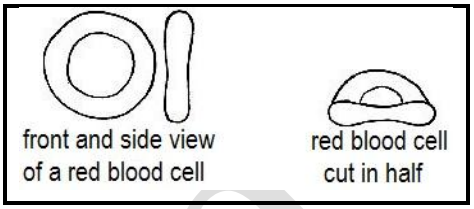
1. Red blood cells/erythrocytes
2. White blood cells/leucocytes
3. Platelets/thrombocytes
4. Plasma

General importance of blood in the bodies of animals

i) It transports oxygen from the lungs to all parts of the body.
ii) It transports digested food from the ileum to other parts of the body for use.
iii) It transports Carbon dioxide from the tissues to the lungs.
iv) It transports nitrogenous wastes from the liver to the kidney where they are excreted.

v) It transports hormones from their site of production to where they perform their functions.
vi) It distributes heat and aids in temperature control.
vii) It prevents infection by transportation of white blood cells.

THE RED BLOOD CELLS (ERYTHROCYTES)



They are manufactured from the red bone marrow.
. They have a biconcave disk shape and contain a red pigment, haemoglobin.

Importance of Red Blood Cells

They transport oxygen from gaseous exchange surfaces to the tissues
They transport carbon dioxide from tissues to the gaseous exchange surfaces.

Adaptations of Red Blood Cells to carry out their function

- They are biconcave in shape so as to avail a large surface area to volume ratio for absorption of oxygen.
- They have hemoglobin molecules that bind to oxygen and transport it from the lungs to the tissues.
- They have a thin membrane which reduces the diffusion distance for the respiratory gases in and out of the cells.
- They lack nuclei which provides enough space for packaging of haemoglobin
- They lack mitochondria and generate their ATP exclusively by anaerobic respiration to prevent them from using the oxygen they are carrying.
- They are numerous per mm^3 to increase surface area for transportation of oxygen
- They have flexible membranes which make them able to squeeze through capillary networks as they exchange materials they transport with the surrounding tissues.

NB: The concentration of red blood cells increases as one climbs up a mountain because the partial pressure of oxygen in the air reduces with increase in height above sea level. So the body adopts by producing more red cells to increase the available total surface area to bind and carry oxygen to the tissues regardless the reducing oxygen partial pressure.

Red blood cells are made from the red bone marrow of short bones in adults and in the fetus, red blood cells are made in the liver. On average, red blood cells last for four months after which they are destroyed in the liver to form bile pigment and the iron in haemoglobin is stored in the liver They are more numerous than any other cells in the blood.

THE WHITE BLOOD CELLS (LEUCOCYTES)

These are blood cells made from the white bone marrow of long bones. They are also made in the spleen and lymphatic system. They are responsible for defense of the body against infection. They are fewer in blood than the red blood cells.

Characteristics of white blood cells

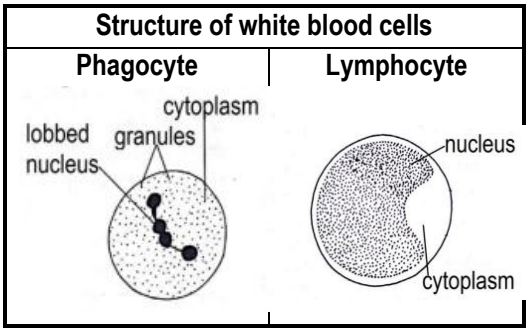
- They have no definite shape (they are amoeboid
- They have a nucleus even at maturity.
- They are relatively few in blood but their number increases when the body is attached by an infection.

White blood cells are divided into two major categories. These are;

Phagocytes: These are white blood cells with a lobed nucleus. They ingest and destroy germs/pathogens by phagocytes.

Lymphocytes: These are white blood cells, which defend the body by producing antibodies.

Structure of white blood cells



Action of white blood cells (phagocytes) on the foreign bodies

Some white blood cells attack and destroy the foreign particles directly by themselves. These are called ***phagocytes*** and they destroy the foreign particles by Phagocytosis. In this process the white blood cells form pseudopodia, which they use to engulf the foreign particle by Phagocytosis.

After engulfing the foreign particle, a food vacuole is formed into which digestive enzymes are produced. The enzymes break down the particle and the important materials are absorbed by the white blood cell while the wastes are excreted out of the cell through the contractile vacuole.

Some white blood cells destroy foreign particles by releasing antibodies, which destroy the particles. White blood cells, which produce antibodies, are called lymphocytes. There are four types of antibodies produced.

1) **Opsonins**; these attach to the outer surface of the foreign particle and make it easier for phagocytic white blood cells to engulf them.
2) **Agglutinins**; these cause the foreign particles to stick together. In this condition the foreign particles cannot invade the tissues.
3) **Lysins**; these destroy bacteria by dissolving their outer coats.
4) **Anti-toxins**; these combine with and so neutralize the toxins produced by foreign particles.

THE PLATELETS (THROMBOCYTES)

These are blood cells formed as fragments in the bone marrows during the formation of red blood cells. They don't have a nucleus. They are responsible for blood clotting.

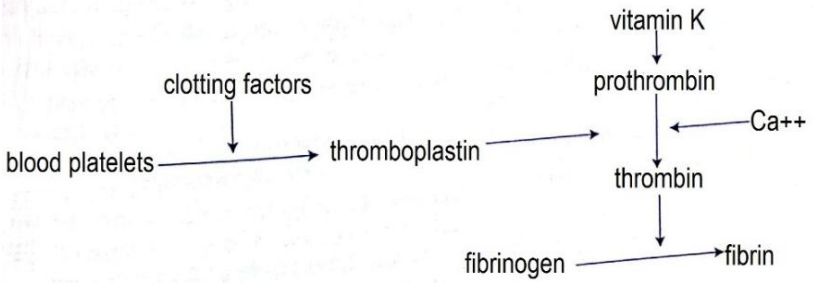
Functions

They play a role in blood clotting which protects the body against excessive loss of blood and entry of pathogens through the injured part. ***Blood clotting is the process by which blood stops oozing out of a cut or wound***. It is important because of the following reasons.

1. It prevents excessive loss of blood from the body.
2. It is a step towards healing of cuts and wounds.
3. The blood clot creates a barrier to prevent entry of bacteria and other pathogens in the body.

The Process of Blood Clotting:

When blood is exposed to air as a result of a cut or wound, the platelets in the blood at the damaged tissue stimulate the release of a chemical called **Thromboplastin (thrombokinase)**. In the presence of **calcium ions** and **vitamin K**, **thromboplastin** stimulates the conversion of **prothrombin** to thrombin enzyme. **Thrombin** then catalyzes the conversion of soluble blood protein **fibrinogen** to the insoluble form **fibrin.** Fibrin forms fibers, which form a mesh and trap blood cells and proteins. This mesh dries to form a scab, which is called the blood clot.



BLOOD PLASMA

This is the fluid part of blood. It is made up of;

i) A soluble protein called **fibrinogen** that plays a role in blood clotting.
ii) **Serum**, a watery fluid containing a variety of substances transported from one part of the body to another e.g. hormones, lipids, enzymes, urea, carbon dioxide, plasma, proteins, amino acids etc.

Functions of blood plasma

- To transport hormones from gland producing them to the target sites.
- To transport food nutrients from the gut to the other parts of the body.
- To transport antibodies to the infected parts of the body.
- To transport Urea from the liver to the Kidneys for excretion.
- To transport carbon dioxide from the body muscles to gaseous exchange system.
- To transport heat from the liver and body muscles to other body parts hence maintaining a constant body temperature range.
- To transport platelets to injured sites on the body so as to initiate blood clotting.
- To distribute salts around the body so as to maintain the body's electrolytes balance.

THE LYMPHATIC SYSTEM

This is part of the vascular system. It forms the second type of circulation. Most of the tissue fluid as explained above goes back into the blood capillaries and the remainder enters the lymphatic system and becomes lymph fluid. The lymph fluid is transported through lymph vessels. The lymph vessels are similar to veins but they have more valves than the veins. The movement of the lymph fluid through the lymph vessels is due to the contractions of the surrounding muscles. As they contract and relax, they squeeze the lymph vessels to gain the force by which lymph moves. The walls of the lymphatic vessels have pores, which allow the entry of cell, wastes and bacteria. Before reaching the blood, lymph passes through the lymph nodes where the wastes and bacteria are removed.

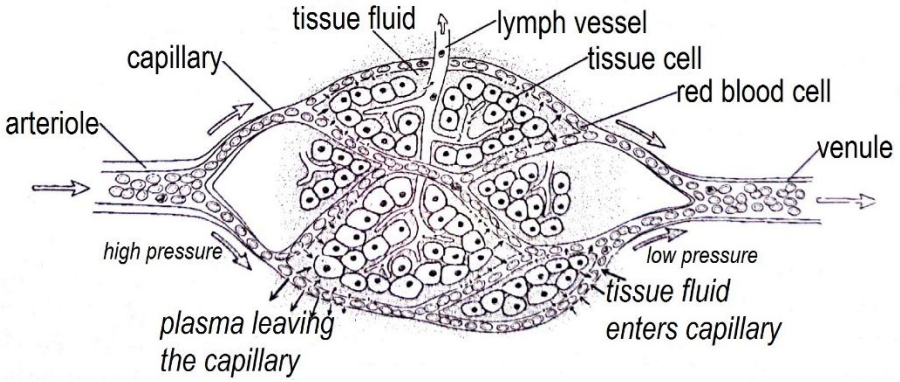
Exchange at the capillaries, formation of tissue fluid and later lymph.

As blood flows from arterioles into blood capillaries. Pressure builds up in the capillaries forcing small molecules like food materials and the fluid part of blood to leave the capillaries and enter the intercellular spaces, leaving behind large molecules like proteins in plasma and cells.

Once the fluid is in the intercellular spaces of tissues, it is no longer called blood but tissue fluid.

Once formed, the tissue fluid surrounds the cells. Body cells then get their requirements e.g. glucose, oxygen, etc. from the tissue fluid and they add excretory materials to the fluid.

Some of the fluid returns in to the capillaries and the other is drained in to a system of narrow channels called lymph vessels. The fluid in these vessels is now called lymph. Lymph is therefore, tissue fluid in the lymph vessels.



Functions of the lymphatic system

1. It transports fatty acids and glycerol from the ileum to the heart where they join the blood system.
2. It carries excretory substances from tissues to the blood stream.
3. It produces white blood cells, which assist in defense of the body.
4. It filters out bacteria before they reach the blood stream.
5. Transports hormones from glands to other body parts.

Differences between the lymphatic and blood system

Blood circulatory system	Lymphatic system
Has a heart which acts as a pump	Has no pump
Blood flow is two way, i.e. from heart to body and back to the heart.	Lymph flow is one way, i.e. from body tissues to the heart.
Blood travels at high speed.	Lymph travels at a very slow speed
Valves are only found in veins	Have valves in all its vessels
Contains blood cells and proteins	Only white blood cells present.
Does not contain fatty acids and glycerol	Contains and transports fatty acids and glycerol.
Have no nodes	Have nodes that produce lymphocytes

Similarities between blood system and lymphatic system

1. Both have valves in their vessels.
2. Both are means of transporting materials in the body
3. In both a selected muscle provides a force by which substances are moved.
4. Both have vessels through which materials are transported.

IMMUNITY AND THE IMMUNE SYSTEM

Immunity is the ability of an organism to resist infection. The immune response is based upon recognition of a foreign particle and the release of substances that destroy it. The foreign particle may be an antigen, bacteria, virus or any other ***pathogen***. (A pathogen is a disease-causing organism) The substance that destroys these particles can be a white blood cell or antibodies produced by white blood cells.

Types of immunity

Immunity may be inborn, may follow infection by disease, may by induced by vaccination or may be acquired from another organism. There are four main types of immunity; natural active, natural passive, artificial (or acquired) active and artificial passive.

1. **Natural active immunity:**
   There are many disease-producing organisms to which man is immune. This is because the human body produces antibodies easily and quickly which repel the invasion of these germs so successfully that no disease symptoms ever occurs. Once the body has started to manufacture antibodies in response to a disease-causing agent, it may continue to do so for a long time after, sometimes permanently. It is for this reason that most people suffer diseases such as mumps and measles only once in their lifetime.
2. **Natural passive immunity:**
   Pre-formed antibodies from one individual are passed to another individual of the same species. This provides temporary immunity. For example, many babies are immune to many diseases because certain antibodies are passed through the placenta or the milk produced first, called ***colostrum***. The protection slowly disappears.

3. **Artificial (acquired) active immunity:**
   This is acquired through vaccination or immunization whereby small doses of antigen, dead or weakened germs are injected into the body. The doses are usually safe. The entry of the germs or their antigens stimulate the defense 'force' of the body to manufacture antibodies against the antigens.
4. **Artificial (active) passive immunity:**
   This involves the injection of antibodies from another individual or animal usually of another species. Serum containing antibodies is injected into a person to provide him with a short-lived immunity. The antibodies are acquired from other mammals like horses, rats and rabbits. This occurs in the treatment of tetanus and diphtheria in humans.

Summary:

	Active	**Passive**
	Antibodies made by the body's immune system.	Antibodies are acquired and not made by the body's immune system.
Natural	• Response to disease. • Rejecting transplant.	Acquired antibodies via placenta and breast milk.
Artificial	Vaccination (Injection of the antigen in a weakened form)	Injection of antibodies from another individual. e.g. anti-venom against snake
Differences	• Antibodies are made in response to antigen • Production of memory cells • Long lasting	• Antibodies provided • No memory cells • Short lasting

ACQUIRED IMMUNE DEFICIENCY SYNDROME (AIDS)

AIDS is caused by the Human Immunodeficiency Virus (HIV). When the HIV enters the body, the immune system recognizes it as a foreign antigen and responds by releasing antibodies and natural white blood cells to destroy the HIV. However, the HIV attacks and destroys the body's natural killer cells. The white blood cells reduce in number, the immune system is weakened and the body is not able to fight against infections effectively. Therefore AIDS victims frequently die due to opportunist pathogens which take advantage of the impaired resistance.

There is, as yet, no cure for AIDS. Much effort is being put in developing a vaccine but progress is hampered by the rapid rate at which HIV mutates and the fact that it hides inside the white blood cell membrane. Furthermore, AIDS affects almost exclusively humans, there are no suitable animals on which to test new drugs.

Current approaches to trying to find a suitable treatment for AIDS:

i) Development of drugs which inhibit HIV. For example, Post Exposure Prophylaxis (PEP) drugs which should be taken within 72 hours after unprotected sex with an HIV positive person. The medicines can have unpleasant side effects.
ii) Development of a vaccine to prevent AIDS.
iii) Development of medicines which boost the immune system of AIDS sufferers. For example, Antiretroviral drugs (ARVs).
iv) Treatment for the other infections which develop in AIDS sufferers.

Preventive measures:

- Educating the mass of the risks and how to minimize them.
- Avoid sharing needles and syringes
- Avoid having unprotected sexual intercourse. Use condoms!
- Avoid contact with the blood of another person especially sharing pins, needles, safety pins, etc

Symptoms of AIDS:

- Oral thrush.

- Tuberculosis or pneumonia.
- Loss of weight.
- Skin cancer called Kaposi's sarcoma ('*kisipi*'- in Luganda, Runyakitara languages)
- Loss of memory and coordination may also occur in the late stages of the diseases.

BLOOD GROUPS

There are 4 main blood groups i.e.

1) Blood group A
2) Blood group B
3) Blood group AB
4) Blood group O

When one has got less blood than necessary, blood transfusion is carried out. The one who gives blood to a patient is called a **donor** and the one receiving is known as a **recipient**. Doctors have to match the blood of the donor to that of the recipient because when incompatibles blood is mixed, the red blood cells stick together (agglutinate) and blood clots. This is a fatal situation.

Agglutination is caused by the presence of proteins called **antigens** on the surface of cells being mixed with specific **antibodies**, which work against them. Blood groups are determined by the type of antigens one has in blood. This means that one having antigen ***A*** belongs to blood group ***A.*** Those with antigen ***B*** belong to blood group ***B***. Those with antigens ***A*** and ***B*** belong to blood group ***AB*** while those without antigens belong to blood group ***O.*** Each blood produces particular antibodies, which work against particular antigens when introduced into the body. For example, blood group ***A*** produces antibody ***b*** (anti ***B***). This means that blood group ***A*** is anti (against) blood containing antigen ***B*** (blood group ***B***).

The table below shows the blood groups, the antigens they carry and the antibodies they produce.

Blood group	Antigen present	Antibody produced
A	A	b or (anti B)
B	B	a (anti A)
AB	A and B	None
O	No antigen	a and b or (anti A and B)

Note:

Antibodies are represented by small letters while antigens are represented by capital letters. Before doctors can carry out transfusion, they carry out tests to make sure that the patient's and donor's blood are compatible (the recipient's blood must not contain antibodies that act on the antigens in the donor's blood. For example antigen ***A*** would agglutinate if mixed with blood containing antibody a. i.e. blood group ***B.***

Table of compatibility

Recipient

Donor	A	B	AB	O
A	√	X	√	X
B	X	√	√	X
AB	X	X	√	X
O	√	√	√	√

Key

X --------- Incompatible

√ --------- Compatible

Blood group ***AB*** can receive blood from all other blood groups because it has no antibodies and it is therefore called a **universal recipient**.

Blood group ***O*** can donate blood to all blood groups because it has no antigens and it is therefore called a **universal donor**.

Revision questions

1. *State the transport functions of blood in mammals.*
2. *What is the importance of clot formation? Name an inherited disease which affects blood clotting.*
3. *One of the functions of blood is the formation of a clot. Briefly explain how a clot is formed.*
4. *Describe and explain the effect of increase in altitude on the number of red blood cells in organisms.*
5. *Name the mineral element present in red blood cell pigment.*
6. *Name two foods that would provide this mineral element.*
7. *Name the tissue in the body in which red blood cells are produced.*
8. *With the help of diagrams show how a white blood cell engulfs a bacterium.*
9. *State two factors which assist in producing a directional flow of fluid in lymph vessels.*
10. *What does immunity mean to you?*
11. *What are antibodies and how do they function?*
12. *Describe the main types of immunity in the human body?*
13. *How does the HIV weaken the body's immunity?*
14. *A person of blood group **A** needs blood transfusion. He is taken to a hospital which lacks his type of blood group, but has other types. What other type of blood could be used for the transfusion?*

END OF S.2 WORK, CONGRADULATIONS

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"You will experience a painful sharpening from time to time, but this is required if you are to become a better pencil."