STANDARD HIGH SCHOOL ZZANA
S.2 BIOLOGY NOTES

INSTRUCTIONS

READ AND WRITE THE NOTES IN YOUR BOOKS AND ATTEMPT ALL EXERCISE PLEASE

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.

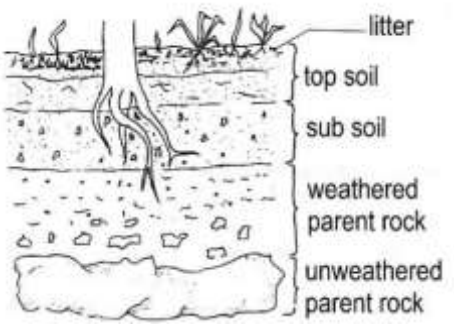
Man contributes to biological weathering through direct splitting of rocks during road and house construction and indirectly through cultivation.

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

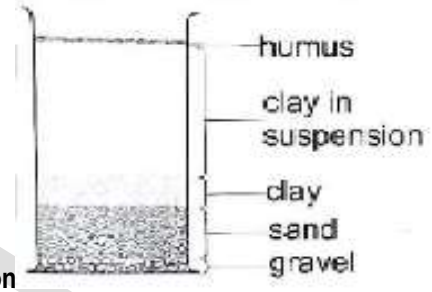
i) They provide a surface for anchoring plant roots hence providing support to the plants.
ii) Soil particles give a rigid frame work to the soil.
iii) They provide mineral elements to the soil which are the absorbed by plants using roots.

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

Percentage of air

Percentage of air

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

Percentage of water

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 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 105^0C = *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 =
Percentage of humus =

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*

Percentage of humus

= 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

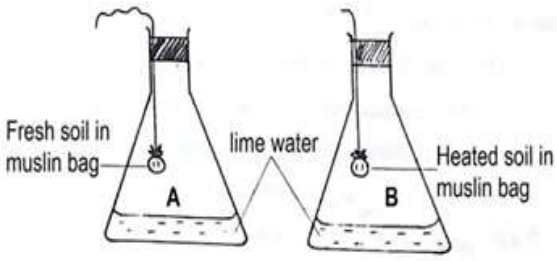
Apparatus

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***.

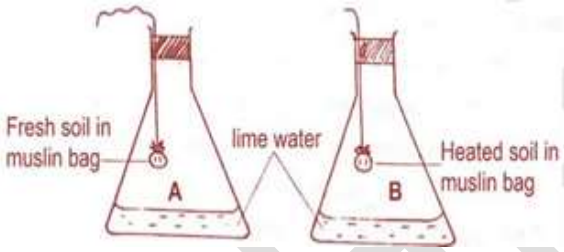
Conclusion

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.

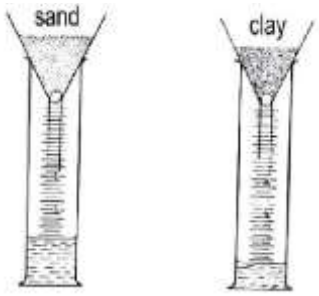
Experiment to compare the drainage and retention of water in sand and clay soils

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.

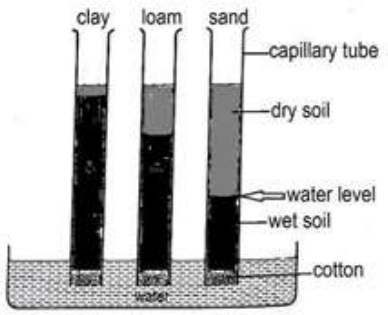
Experiment to demonstrate and compare capillarity through sand, clay and loam soils

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.

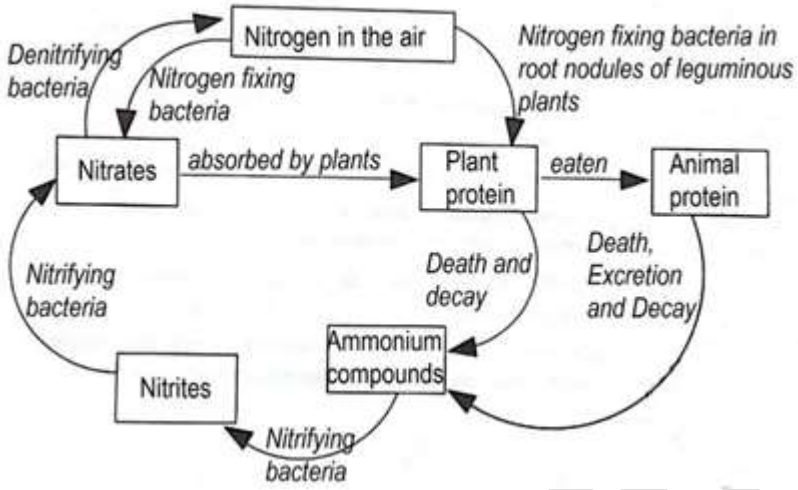
Animals obtain nitrogen they need by eating plants or other animals that have eaten plants.

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.***

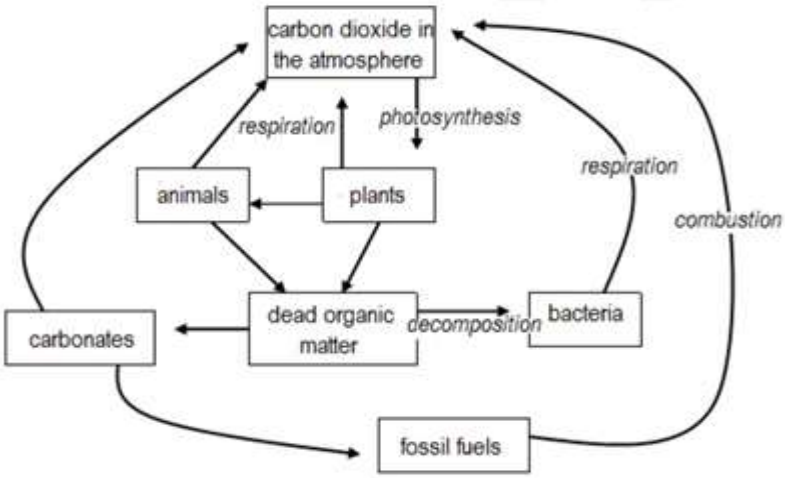
Deficiency of nitrogen in plants causes small sized plants and yellow underdeveloped leaves.

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:

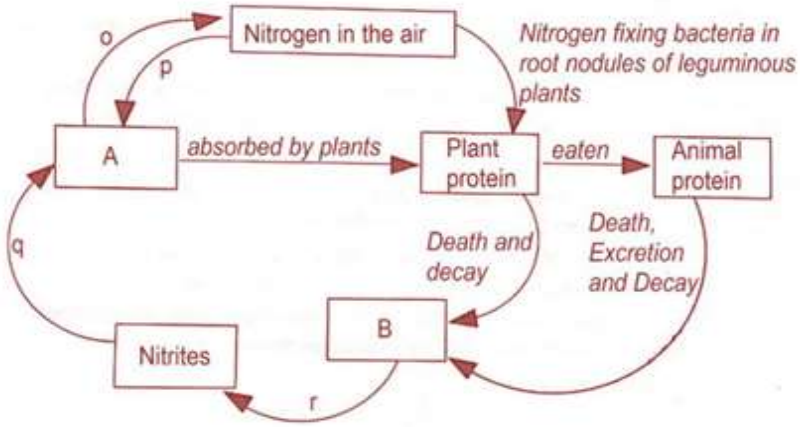
Combustion (burning): When carbon containing fuels e.g. petroleum, coal, natural gas, fire wood are burnt, CO_2 is released into the atmosphere. Formation of such fuels over millions of years is referred to as ***fossilization***.

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:

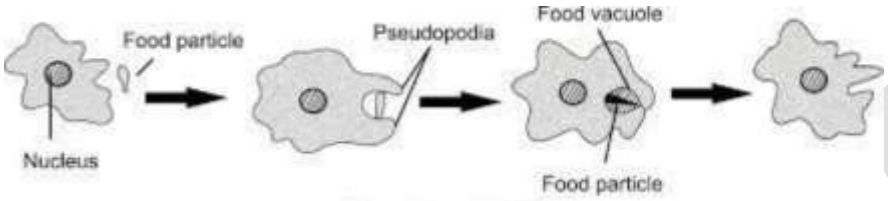
This is a nutritional relationship between two organisms of different species where both organisms benefit. However, only one organism benefits nutritionally.

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 Benedict's solution and ***boil***. of	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.*** Colourless or turbid solution turned to a ***brown solution***.	*Starch* ***present.*** 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 Cobalamine	Meat, eggs, dairy foods.	Formation of red blood cells	Anemia
C^{12} 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_{43-} (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.
F (Fluorine)	Drinking water	Strong bones and teeth.	• Muscle cramp (sharp pains in muscles). 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:

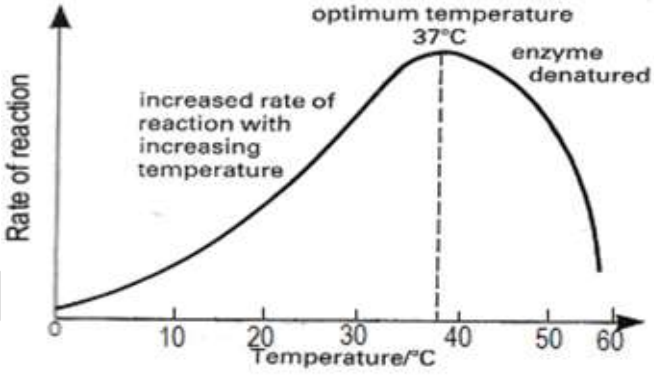
A substrate is a substance (food) acted upon by the enzyme to form simpler products.

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 37^0C). *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) 30^0C 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

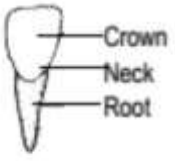
There are 4 types of teeth in mammals and these include;

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.

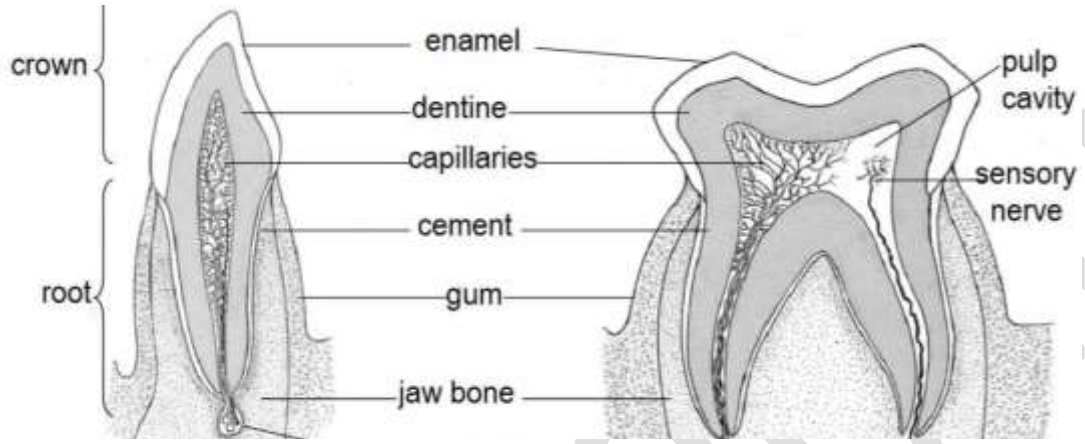
Revision questions

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

Vertical section through an incisor **Vertical section through molar**



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	$I\frac{3}{3}; C\frac{1}{1}; PM\frac{4}{4}, M\frac{2}{3}$	42
Rat	$I\frac{1}{1}; C\frac{0}{0}; PM\frac{0}{0}, M\frac{3}{3}$	16
Cow	$I\frac{0}{3}; C\frac{0}{1}; PM\frac{3}{3}, M\frac{3}{3}$	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

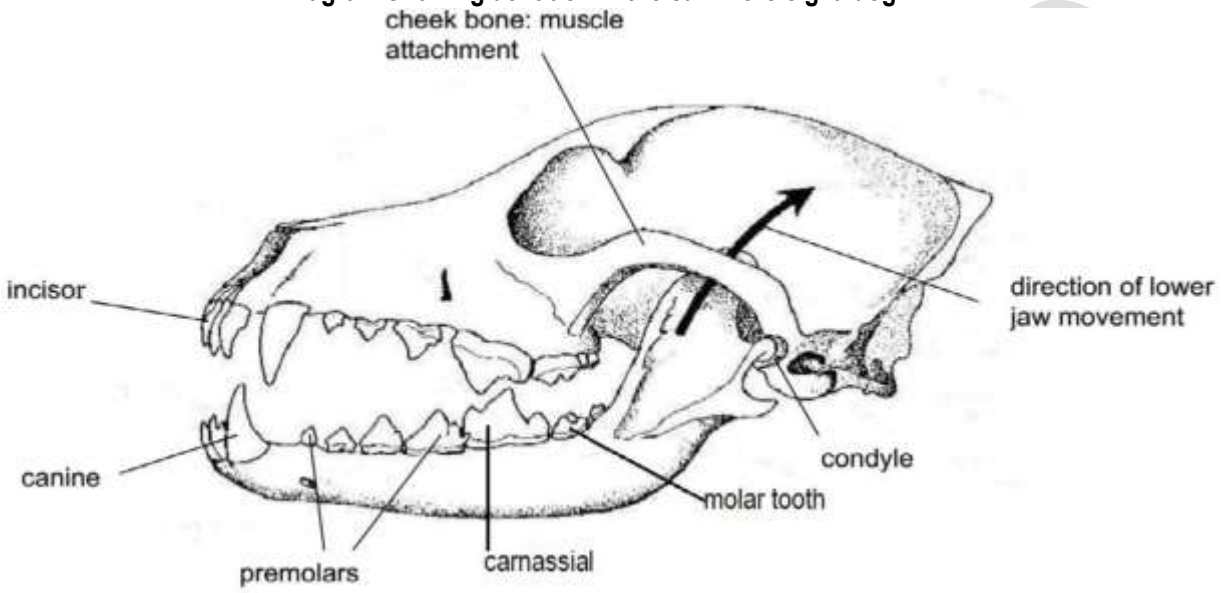
- Visit a dentist regularly for checkup.
- Proper cleaning of teeth (brushing after meals).
- Avoid sweet sugary foods like sweets which encourage bacterial growth.
- Avoid opening bottles using teeth.
- Avoid eating very hot and very cold foods especially at a go since they result into alternate expansion 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.

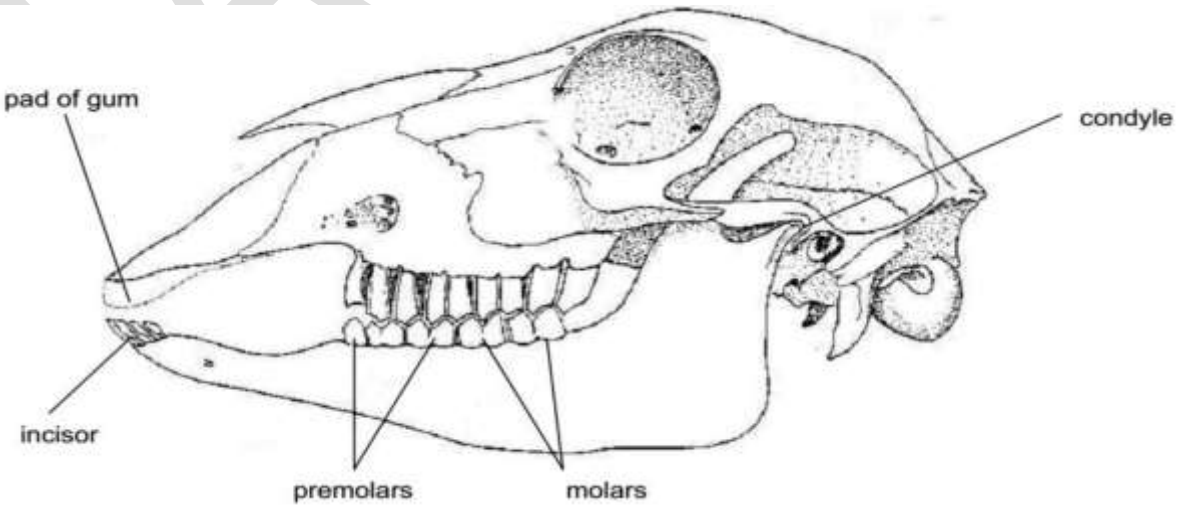
Diagram showing dentition in the carnivore e.g. a dog



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

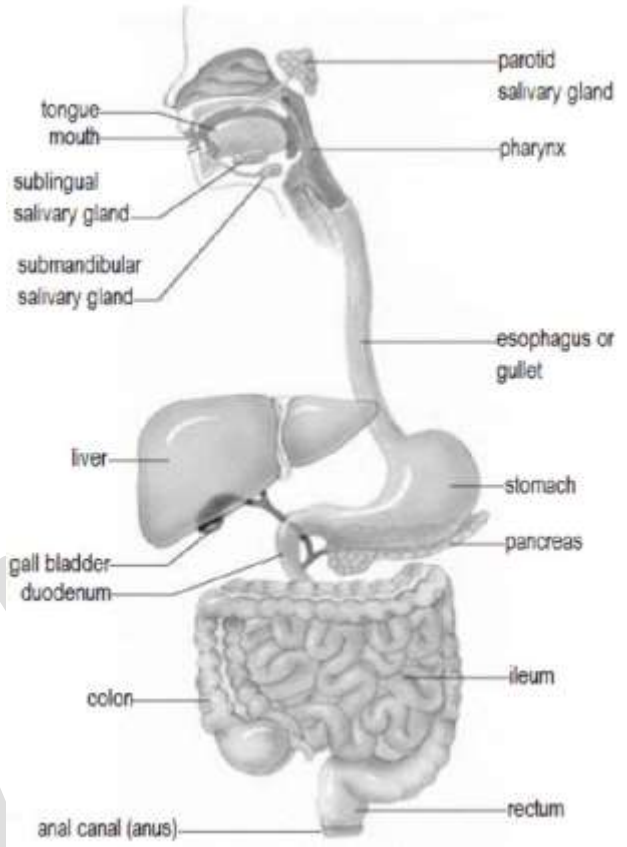
Ingestion Digestion Egestion

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.

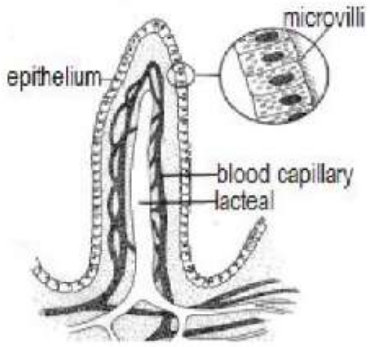
The ileum shows various adaptions to suit the process of absorption which includes:

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.

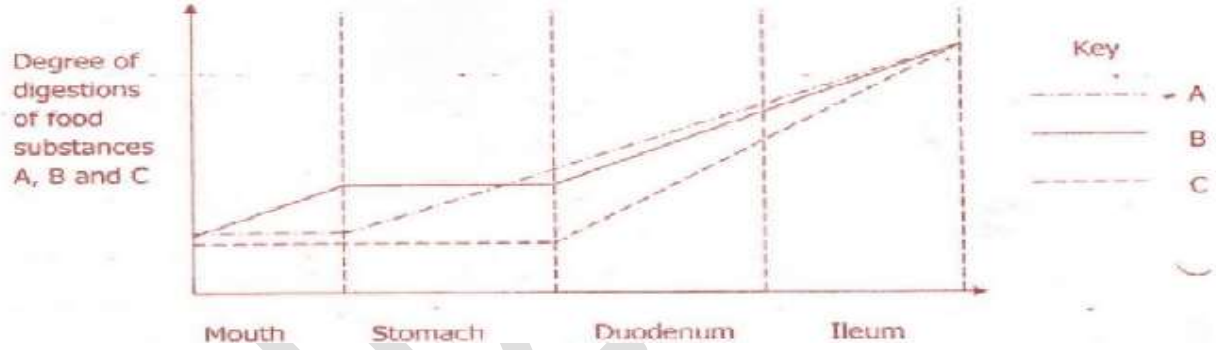
Glucose, Amino acids and Fructose pass into the blood capillaries of the villus which join up to form the Hepatic portal vein which transport these nutrients to the liver.

Assimilation

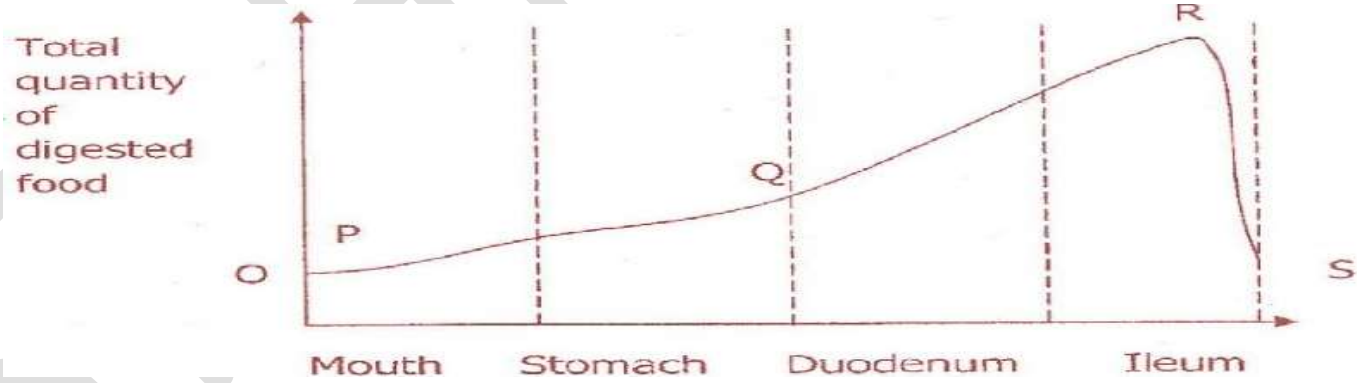
Assimilation is the incorporation/utilization of the products of digestion into the body's metabolism for life processes e.g. respiration, growth and repair and digestion.

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.

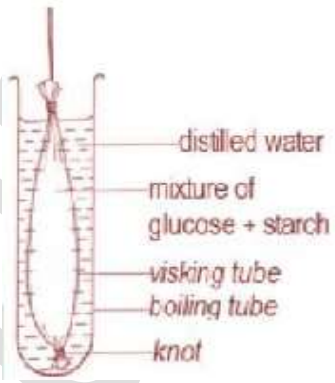
x) ***Storage of blood.*** Blood vessels in the liver can expand and contract such that the amount of blood in the liver can vary from $300cm_3$ – $1500cm_3$, an increase of five times thus the liver can be a blood reservoir.

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.*

Temperature	***37^{0}C***	***37^{0}C***	***37^{0}C***	***37^{0}C***
Material present	***Test tube 1***	***Test tube 2***	***Test tube 3***	***Test tube 4***
	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

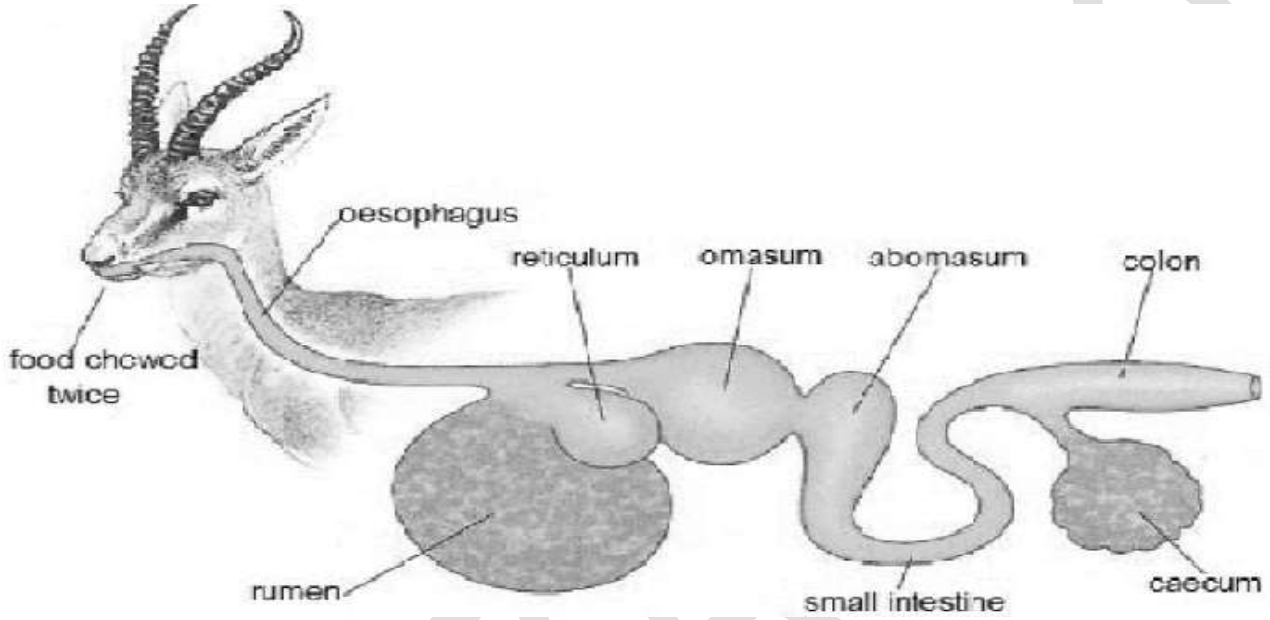
Animals that depend on plant materials (herbivores) like leaves, wood, grass are faced with a problem of digesting the cellulose that make up the plant walls. It is necessary to break down cellulose into glucose and also break through the cellulose to release the inside cell nutrients which are required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